STATION EVALUATION
NATION RIVER NEAR FORT ST. JAMES
(07ED001)

A.G. Smith
G. Vallières

Planning and Studies Section
Water Resources Branch
Vancouver, B.C.

October, 1987

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River near Fort St. James.

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ABSTRACT

The streamflow data collected at this station has been analyzed in this report. Rating curve extensions, both high and low, have been inspected. Streamflow characteristics have been compared to those of neighbouring streams and methods of computation have been noted. The effect of various physical conditions on the development of data have been related to the quality of the records.

Nearly half (47%) of the streamflow record has been estimated which includes ice periods and periods during open water where stage record has not been obtained because of equipment malfunction. The early definition of the high end of the rating curve is considered to be over-estimated by 11% but well within accuracy limits. The present control appears to be very stable, while the earlier one at the bridge either shifted at low stage or was insensitive.

The control is stable enough that a mean curve could be developed for the open water period and updated only when required.

This appears to be a station where discharge under ice could be computed by a flow model.

Quality of the data would be classified as being good except for estimated and ice periods.

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1. INTRODUCTION

Streamflow records are among the most valuable of all hydrologic factors used in basin planning. The flow of streams is a sensitive indicator of climatic variations as runoff is the residual of precipitation after requirements for evapotranspiration have been satisfied. Streamflow records to be used in any analysis involving the record as a whole should be checked for quality. The primary purpose of station evaluation, therefore, is to assess the quality of data being gathered at hydrometric stations. This report was undertaken to provide a quality assessment of the streamflow data collected at this station.

1.1 Purpose of Station

The station was established on June 13, 1938, as part of Water Power Resources inventory of Northern British Columbia.

1.2 Basin Description

The Nation River rises in the Hogem Range on the northeastern edge of the Interior Plateau. It flows through two large lakes, Tchentlo and Chuchi, before joining what used to be the Parsnip River (now the Williston Reservoir). See location map in Figure 1.

The gauging station is located downstream of the Fort St. James-Manson Creek Road bridge six miles below the outlet of Chuchi Lake. The basin at the stream gauging station has a drainage area of 4,350 km^2. A stream profile and area elevation curve are shown on Figures 2 and 3, respectively.

Climate

The climate of the basin is dominated by continental air masses. It has long cold winters and short cool summers with moderate precipitation spread fairly evenly throughout the year as shown in Figures 4 and 5. Although Polar continental air dominates for most of the year, Polar Pacific air moves across the Coast Ranges at times bringing some amelioration. Summer temperatures are among the lowest recorded in the province. Frost-free periods are very short in this area.

Precipitation amounts are low as shown in Figure 5 for Fort St. James. The summer maximums in the area are in June and July which are the wettest months.

1.3 Station Description

This station was established June 13, 1938 with a staff gauge and measurements were made from the highway bridge. An automatic recorder was installed in a California shelter on a box culvert in September 1940 as shown in Figure 7. The recorder was moved 400 metres below the bridge (new station) on October 18, 1954, shown in Figure 8. The cableway was built 600 yards downstream of the recorder in 1957. The flood of June 11, 1964 destroyed the cableway as shown in Figure 9a. The cableway was re-established in September of 1964 as shown in Figure 9b.

Measurements were made from the bridge and later from the cableway. Some sample cross sections are shown for both locations in Figures 10 and 11 respectively.

It will be noted that the bridge measurement site presented many problems with piers, pilings, backwater and handlining around bridge braces as shown in Figure 12.

Some difficulty was experienced in maintaining the recorder along the river bank as there was a continual problem with river ice.

Flow Computations

Gauge heights were obtained from a staff gauge and later from a chain gauge read sporadically during open water periods until 1967.

Open water discharge values are obtained from a rating curve established or verified each year with from one to six measurements. Flow under ice has been estimated by the use of from one to three measurements per season, air temperatures and hydrographing with other streams in the area.

2. QUALITY OF DATA

2.1 Derivation of Maximum Flows

An inspection of past rating curves indicates that the control is slightly unstable throughout the range of stage as shown in Figures 13 and 13a, where selected discharges are plotted against stage for the period each rating curve has been used. The latter record, 1954 to 1985, indicates a greater change in the high range of the rating curve. This is possibly due to lack of upper curve definition. Very little scatter shows on the logarithmic plot of stage versus discharge shown in Figures 14a and 14b although the early period, 1938 to 1954 (Figure 13a), shows considerable scatter at the low end. This is possibly due to the poor measuring conditions and an insensitive control at the highway bridge. These graphs also indicate the changes in control throughout the range of stage. At the bridge, the control change occurs at or near the gauge height of 0.9 metres. It will also be observed in Figure 10, a cross-section of the stream channel, that the configuration of the channel changes in the same range. At the cableway, the control changes twice. The two controls are located at or near 1.25 and 2.0 metres respectively. These two channel conditions will be seen in Figure 11 where the bank configurations change abruptly. These changes in control have been recognized but not properly accounted for in drawing the various rating curves. As the rating curves were not kept constant at the top end, adherence has not been maintained with the criterion that when the channel controls the flow a major change to the channel must occur before the rating can be changed.

The highest discharge measurement taken at the first location was obtained on May 31, 1946 with a flow of 368 cubic metres per second (m^3/s) . The maximum recorded gauge height of 3.335 metres was obtained on May 29, 1946. The discharge at this gauge height was 510 m^3/s, estimated by extending the rating curve above a measured flow of 368 m^3/s.

The highest discharge measurement at the present location was obtained on June 16, 1964 by boat near the outlet of Chuchi Lake with a flow of 564 m^3/s. The maximum recorded gauge height of 4.389 metres was obtained on June 11, 1964. The discharge at this gauge height was 708 m^3/s, estimated by extending the rating curve above a measured flow of 564 m^3/s. The highest measured flow and estimated peaks are shown in Figure 15.

Figure 16 shows the relationship of Curves #3 and #4 when extended to the maximum gauge height of 4.389 metres. The difference between the peak estimated flows is approximately 11%.

Double-Mass Curve Analysis

The streamflow records are assumed to be free of any influence of man made storage or diversion. No changes in basin runoff characteristics due to logging, forest fires or mining are expected. Under the assumption that a constant ratio of cumulative annual peak runoff exists between a given station and a group of stations, each record was tested for homogeneity by a double-mass curve analysis. The runoff characteristics for the area were established by using three gauging stations with ten years of record. Data for constructing the double-mass curves were concurrent only from 1977 to 1986. The cumulative annual maximum discharge per square kilometre of drainage area at each gauging station was plotted against the cumulative average annual maximum daily discharge per square kilometre of drainage area for all three stations as shown in Figure 17. A decided break in slope is noted at the 1982 point. The latter period had somewhat higher peaks than the earlier period, but the increase is less marked on the Nation River than on the streams comprising the pattern. The change does not test statistically significant at the 5% level on the basis of a variance ratio test.

The relationship of the maximum instantaneous to the maxium daily discharge is 1.01 which indicates that this stream is well regulated by upstream lake storage.

Table 1 lists the hydrometric and meteorologic stations in the area which were used in this study.

Assessment of the Quality of Maximum Flow

The top ends of the rating curves have been adequately defined after the high water measurement of June 8, 1972. It appears that an earlier boat measurement on June 16, 1964, was too high and plotted to the right of the present curve by 11%. However, it is still within the considered accuracy of high water measurements. The multiple controls in the rating curve have been recognized although the breaks were not adequately defined. When the control is stable, as with this station, a mean curve would be acceptable. Minor deviations are no doubt due to inaccuracies of measurement, stage and an insensitive control. At this particular station a composite curve could be developed as shown in Figures 18 to 21 for the three controls.

The uncertainty function program was used to calculate the accuracy of the stage-discharge relationship. The parameters used in the study were the number and accuracy of measurements and the accuracy of the stage-discharge relationship during the open water period. No loss of record was considered. The standard error is shown in Table 2 and Figure 23 corresponding to the number of measurements required to obtain that standard error. The variation in standard error is also shown for selected measurement error. The standard error represents the maximum error in the instantaneous discharge two-thirds of the time.

The number of open water discharge measurements used in the analysis over the 32 year period was 99 which averages to 3.2 per season. The standard error as indicated in Table 2 for 3.2 measurements is about 4.3%. The latter period of record of the Tulameen River (1974 to 1984) had a standard error of approximately 14% for the same number of measurements. Measurements at this station are required only to confirm the validity of the rating curve.

2.2 Derivation of Minimum Flows

Minimum flows have occurred from freeze-up to early spring. All of the annual minimum flows have been obtained under ice cover. Forty percent of the year this stream is frozen over as shown in Figure 23 and Table 3. Records for the period affected by ice are estimated by the use of one to three measurements, hydrographing with other stations, and temperature records at Germansen Landing, Fort St. James, Prince George or Fort St. John. A more reliable means of estimating flow under ice is by the use of recession analysis or by use of a flow model. In order to make maximum use of the above methods the timing of ice measurements would require some refinement.

The lowest discharge measurement to date was on September 4, 1942 for a flow of 8.8 m^3/s. The minimum flow on record is 5.49 m^3/s, estimated for the period of April 5 to 11, 1944.

Assessment of the Quality of Minimum Flows

There was some shifting of the section control during the time the station was located at the road bridge. This apparent shifting may have been due to the awkward metering facility and the imprecise control. Figures 13a and 13b indicate the amount of shifting taking place. The shifts in control are adjusted from season to season, depending on the suspected cause. When there are long periods between measurements, adjustments are not always reliable. There have been ten rating curves developed for thirteen years of record which is almost one per year.

During the time the station has been in its present location only twelve rating curves have been used over thirty-two years.

The standard error as shown by the uncertainty function program is a means to assess the quality of data as shown in Table 2. The record produced for the ice periods is an educated guess guided by one or more measurements, temperature data (sometimes located miles from the basin), and hydrographs from neighbouring stations. The ice period each year as shown in Table 3 averages five months per year. The ice period, together with the missing data periods which have been estimated, make up 47% of the record produced from this station. This is shown graphically in Figure 23.

2.3 Derivation of Average Flow

The mean annual discharge for the period of record is 57.3 m^3/s (18 years). The shifting of control does not appear to have any effect on the average flow.

The estimated open water record has amounted to 6.4% of the total record produced. Lost stage record was due to clock stoppage.

The volume of runoff (May to August) is over 75% of the annual runoff from this basin. Figures 24 and 25 show the distribution of annual and monthly runoff for this station. The volume of runoff for the ice period averages approximately 10% of the annual runoff.

Double-Mass Curve Analysis - Annual Discharge

Under the assumption that a constant ratio of cumulative annual runoff exists between a given station and a group of stations, each record was tested for homogeneity by a double-mass curve analysis. The runoff characteristics for the area were established by using three gauging stations with ten years of record. Data for constructing the double-mass curve was concurrent only from 1977 to 1986. The cumulative mean annual runoff in millimetres was plotted against the cumulative average annual runoff for all three stations. The results are shown in Figure 26. A break in slope occurs at the 1979 point. The latter period has somewhat higher runoff per km^2 than the earlier period, but the increase is less marked on the Nation River than on the streams comprising the pattern.

Assessment of the Quality of Average Flow

The quality of the mean annual discharge is not adversely affected by the minor shifting of control at the lower stages or the change in rating curves at the top end.

2.4 SUMMARY

The reliability of the present stage-discharge relationship is good. There is some shifting taking place throughout the range of stage. The estimation of low flow data could be improved by use of the model for estimating flow rate under ice.

2.5 RECOMMENDATIONS

A mean rating curve should be developed from the historic data obtained from the present site. One or two open water measurements should be taken each year to ensure the rating has not changed. The mean curve could be adjusted every five years or as required.

Recession curve analysis and the application of a flow model should be initiated as soon as possible in order to improve the estimation of flow rates during ice periods. A measurement program would be used to set up the model.

3. STATISTICS OF DATA

3.1 Statistical Structure of Selected Streamflow Characteristics

The following streamflow characteristics are considered: mean annual, mean monthly, 1, 7 and 14 day lows, maximum daily mean and maximum instantaneous discharges.

Population Statistics

The best estimates of the population are given by:

Mean $\bar{x} = (1/N)\ \Sigma x$

Standard Deviation $\bar{s} = \{[1/(N-1)]\ \Sigma(x-\bar{x})^2\}^{1/2}$

Skew Coefficient $\bar{g} = \{N^2/[(N-1)(N-2)]\}\ (m_3/\bar{s}^3)$

Coefficient of Kurtosis $\bar{g}_2 = \{[N^2(N+1)]/[(N-1)(N-2)(N-3)]\}(m_4/\bar{s}^4)$

The third and fourth central moments are defined by:

$m_3 = (1/N)\ \Sigma\ (x-\bar{x})^3$

$m_4 = (1/N)\ \Sigma\ (x-\bar{x})^4$

The values are listed in Table 4.

3.2 Non-Parametric Statistical Tests

The streamflow characteristics of 1 and 7 day lows, and the maximum daily mean and maximum instantaneous discharges have been tested by non-parametric tests for independence, stationarity, homogeneity and general randomness. The data and tests results are listed in Table 5 to 10.

3.3 Flood Frequency Distribution

The magnitude and frequency of peak discharges are shown in table form for the annual maximum daily and annual maximum instantaneous discharges. The period of record used is from 1974 to 1984. The flood frequency estimates are given for four distributions: Generalized Extreme Value, Three Parameter Lognormal, Log Pearson Type III, and Wakeby. The Weibull distribution is used only if the untransformed data has a high negative skew. The distributions are fitted to the data and shown in Figures 27 to 30. The discharge data, sample statistics and flood frequency regime data are listed in Tables 11 to 14 for the maximum daily discharge. The same distributions fitted to the maximum instantaneous discharge are shown in Figures 31 to 34. The discharge data, sample statistics and flood frequency regime data are listed in Tables 15 to 18.

Figure 35 shows the monthly maximum discharge for the period 1974 to 1984.

3.4 Low Flow Frequency Distribution

Low flow frequency curves show the magnitude and frequency of low flows for various periods of consecutive days. The periods selected are the 1, 7 and 14 days. The climatic year (which begins May 1st and ends April 30th) was used for each period. The Gumbel III probability distribution has been fitted to the data and is shown in Figures 36 to 38. Tables 19 to 23 list the low flow data, sample statistics and frequency regime data. For comparison purposes Figure 39 shows the family of low flow frequency curves for the periods of 1, 7 and 14 consecutive days.

The distribution of monthly minimum discharges for the period of record are shown in Figure 40.

3.5 Hydrographs

The time distribution of runoff is influenced by climatic factors and by the topographic and geologic features of the basin; thus the final hydrograph is affected by all three factors. Climatic factors predominate in producing the rising limb while the recession limb is largely independent of storm characteristics producing the runoff. The maximum, minimum, and mean hydrographs and the standard deviations are illustrated in Figure 41 for this basin. The runoff characteristics are illustrated in the comparison of hydrographs shown in Figure 42 for the Nation and the Omineca Rivers for 1985.

3.6 Base-Flow Index

Geologic conditions are generally considered to have a major influence on low flow yields. To isolate the geologic effect on low flows a value called the base-flow index statistic is computed. It is defined as the ratio of the runoff under the base-flow separation line to the total runoff for the same period. Differences in this value can be attributed to differences in basin hydrogeology with very little influence from climate. The index indicates the amount of storage available in the basin as groundwater. The average value of the index for Nation River basin is NOT AVAILABLE.

3.7 Flow Duration Curves

The flow duration curve is used for the purpose of determining water supply potential for run of river hydro projects, municipal and domestic water supplies and irrigation purposes. The amount of flow available for any selected percent of time can be obtained from the curve. The chronological sequence of events is completely masked in a duration curve which greatly restricts its use. Figure 43 shows the flow duration curve for daily mean flows.

3.8 Basin Physiographic Parameters

Stream basins have been outlined on the U.T.M. projection maps of the National Topographic System. These maps, at a scale of 1:50,000, have a rectangular system of grid lines spaced at one kilometre. The computation of basin parameters is based on four of these squares, making a grid system of two km by two km. The parameters extracted per square are: the value of the elevation at the centre of the two by two square, area of lakes and swamps, stream lengths and the number of contour lines crossing both the horizontal and vertical lines passing through the centre of the square. The average basin parameters are computed from the sum of the values of all squares within the basin boundary. A short description of the parameters follows.

Basin Area:

Summation of 1 km squares included in the basin multiplied by four which is the area of each square in km^2.

Average Basin Elevation:

Arithmetic mean of the elevation in metres of all squares. The elevation of each two by two square is measured at its geometric centre.

Percentage of Lakes and Swamps:

Summation of the area of lakes and swamps of each square divided by the area of the basin and multiplied by 100%.

Stream Density:

Summation of the stream lengths of each square divided by the basin area.

Average Basin Slope:

Proportional to the summation of all the contour lines crossing either the horizontal or the vertical line passing through the centre of each square.

4. CONCLUSIONS

4.1 Quality of Data

The quality of the data from this station at its present location is considered to be good. There is very little shifting of control and thus one average rating curve could be developed for the latter period of record.

Peak discharge characteristics should not be used in correlation studies as the basin is not homogeneous with others in the region.

Estimation of low flow under ice could be improved with the use of a model.

This station could be operated with one measurement during the open water period.

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TABLES 1 - 23

TABLE 1

SELECTED HYDROMETRIC AND METEOROLOGIC STATIONS USED IN STUDY

HYDROMETRIC STATIONS

Station Number	Station Name	Drainage Area (km^2)
07EA004	Ingenika River above Swannell River	4200
07EC003	Mesilinka River above Gopherhole Creek	2980
07EC002	Omineca River above Osilinka River	5490
07ED001	Nation River near Fort St. James	4350

METEOROLOGIC STATIONS

Station Number	Station Name
1092970	Fort St. James
1133090	Germanson Landing
1073347	Hazelton Temlahan
1097970	Takla Landing

TABLE 2

UNCERTAINTY FUNCTION STUDY

RELATION OF STANDARD ERROR OF DATA TO NUMBER AND PERCENT ERROR OF MEASUREMENTS 1954 TO 1985

	STANDARD ERROR IN PERCENT			
Number of Measurements	Measurement Error 2.5%	Measurement Error 4.0%	Measurement Error 5.0%	Measurement Error 6.0%
0	6.201	5.355	4.435	2.948
1	6.158	5.319	4.405	2.928
2	6.115	5.282	4.374	2.908
3	6.072	5.244	4.343	2.887
4	6.029	5.207	4.312	2.867
5	5.985	5.169	4.281	2.846
6	5.940	5.131	4.249	2.825
7	5.896	5.092	4.217	2.804
8	5.851	5.053	4.185	2.782
9	5.806	5.014	4.153	2.761
10	5.760	4.975	4.120	2.739
11	5.714	4.935	4.088	2.717
12	5.668	4.895	4.054	2.695
13	5.621	4.855	4.021	2.673
14	5.588	4.826	3.997	2.657
15	5.549	4.824	3.997	2.657
Variance of Process	0.000724	0.000540	0.000371	0.000164
Measurement Variance	0.000118	0.000302	0.000471	0.000678

One Day Autocorrelation	0.74244
Variance of Residuals	0.000850
Sample Size	99

TABLE 3

PORTION OF DATA ESTIMATED EACH YEAR

Calendar Year	Ice Periods Estimated Record (months)	Open Water Periods Actual Record (months)	Open Water Periods Estimated Record (months)
1985	6	6	0
1984	5 1/2	4 1/2	2
1983	4 1/2	7 1/2	0
1982	5 1/2	6 1/2	0
1981	4 3/4	7 1/4	0
1980	5	7	0
1979	5 1/2	6	1/2
1978	4 3/4	7 1/4	0
1977	5	7	0
1976	5	7	0
1975	5	6 1/2	1/2
1974	3 1/2	4	1 (Recorder Vandalized)
1973	5	6	1
1972	4 1/2	5	2 1/2
1971	4 1/2	4 3/4	2 3/4
1970	4 1/2	5	2 1/2
1969	3 1/2	7 1/2	1
1968	4	8	0

TABLE 4

STATISTICS FOR SELECTED STREAMFLOW CHARACTERISTICS
FOR PERIOD 1967 to 1985

Streamflow Characteristics	MEAN	SD	CV	CS	CK	Percent of Annual Runoff
<u>Mean Monthly</u>						
JAN	16.0263	3.916	24.43	0.7465	4.314	2.23
FEB	12.4426	2.320	18.65	0.3835	2.408	1.76
MAR	11.2916	2.228	19.73	0.9340	4.740	1.59
APR	14.9147	3.792	25.42	0.0394	2.352	2.15
MAY	145.5263	44.700	30.72	0.5540	2.770	22.20
JUN	248.6632	77.920	31.33	-0.0049	3.810	34.16
JUL	99.0211	38.910	39.30	0.3479	2.918	13.17
AUG	36.9211	16.430	44.49	0.8579	3.674	5.31
SEP	26.3947	11.320	42.88	0.9826	4.124	3.63
OCT	31.0947	14.440	46.43	1.1430	4.653	4.81
NOV	30.7474	13.780	44.83	1.1460	5.125	5.64
DEC	21.9211	8.353	38.10	1.0550	4.141	3.34
<u>Mean Annual</u>	57.3790	12.400	21.60	0.3432	3.738	
<u>Low Flow</u>						
1 Day	10.08	2.0446	0.2029	-0.1659		
1 Day	10.21	2.1425	0.2099	-0.0217		
14 Days	10.34	2.0938	0.2026	0.0871		
<u>High Flow</u>						
Maximum Daily	340.867	114.929	0.3370	1.1450	5.8330	
Instantaneous	341.857	119.501	0.3500	1.1650	5.6580	

Table 5 Minimum Daily Flow Series

WSC STATION NO.=07ED001 VERSION=1 N-DAY MEAN DURATION= 1
WSC STATION NAME=NATION R NR FT ST JAMES
WATER SEASON (MONTH/DAY) FROM JUN 1 TO MAY 31

SEQ.NO.	YEAR	MON	FLOW
1	1944	4	5.490
2	1967	3	9.630
3	1967	9	13.900
4	1969	3	8.470
5	1970	4	12.700
6	1971	2	9.000
7	1972	3	11.200
8	1973	4	11.500
9	1974	4	10.800
10	1975	4	8.210
11	1976	3	10.600
12	1977	3	11.200
13	1978	3	10.200
14	1979	2	8.270
15	1980	4	7.350
16	1981	3	11.900
17	1981	9	9.320
18	1983	3	13.000
19	1984	2	9.420
20	1985	3	9.350

Table 6 Non-parametric Statistical Tests - Minimum Daily Flow Series

```
      --- SPEARMAN TEST FOR INDEPENDENCE ---

07ED0011 1        NATION R NR FT ST JAMES
ANNUAL MAXIMUM DAILY FLOW SERIES  1944 TO 1985  DRAINAGE AREA =  4350.000


SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =-0.427   D.F.= 17
                   CORRESPONDS TO STUDENTS T =-1.945
                CRITICAL T VALUE AT 5% LEVEL = 1.740    NOT SIGNIFICANT
                    -    -    -    -  1%   -  = 2.567    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant serial dependence.

```
      --- SPEARMAN TEST FOR TREND ---

07ED0011 1        NATION R NR FT ST JAMES
ANNUAL MAXIMUM DAILY FLOW SERIES  1944 TO 1985  DRAINAGE AREA =  4350.000


SPEARMAN RANK ORDER CORRELATION COEFF = 0.004   D.F.= 18
            CORRESPONDS TO STUDENTS T = 0.016
         CRITICAL T VALUE AT 5% LEVEL = 2.101    NOT SIGNIFICANT
             -    -    -    -  1%   -  = 2.878    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the serial(lag-one) correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant trend.

```
      --- RUN TEST FOR GENERAL RANDOMNESS ---

07ED0011 1        NATION R NR FT ST JAMES
ANNUAL MAXIMUM DAILY FLOW SERIES  1944 TO 1985  DRAINAGE AREA =  4350.000


THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN(RUNAB) = 13
             THE NUMBER OF RUNS ABOVE THE MEDIAN(N1) = 10
             THE NUMBER OF RUNS BELOW THE MEDIAN(N2) = 10

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)
```

For this test, Z = 0.000

Critical Z value at the 5% level = 1.960 NOT SIGNIFICANT

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis cannot be rejected. That is, the sample is significantly random.

```
   --- MANN-WHITNEY SPLIT SAMPLE TEST FOR HOMOGENEITY ---

07ED0011 1        NATION R NR FT ST JAMES
ANNUAL MAXIMUM FLOW SERIES  1944 TO 1985   DRAINAGE AREA=  4350.000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE= 10
                    SUBSAMPLE 2 SAMPLE SIZE= 10

                                 MANN-WHITNEY U =  47.5
     CRITICAL U VALUE AT 5% SIGNIFICANT LEVEL =  27.0    NOT SIGNIFICANT
         -     -     -     -  1%       -      -  =  19.0    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that there is no location difference between the two samples.

At the 5% level of significance, there is no significant location difference between the two samples. That is, they appear to be from the same population.

Table 7 Maximum Daily Discharge

WSC STATION NO=07ed001
WSC STATION NAME=NATION RIVER NEAR FORT ST JAMES

MONTH (1)	YEAR (2)	DATA (3) (CMS)	ORDERED (4) (CMS)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
5	1941	246.000	702.000	1	1.99	50.333
5	1942	368.000	583.000	2	5.30	18.875
6	1944	196.000	470.000	3	8.61	11.615
5	1945	294.000	462.000	4	11.92	8.389
5	1946	418.000	418.000	5	15.23	6.565
6	1950	328.000	416.000	6	18.54	5.393
5	1958	470.000	405.000	7	21.85	4.576
5	1959	351.000	385.000	8	25.17	3.974
6	1960	292.000	381.000	9	28.48	3.512
5	1962	239.000	368.000	10	31.79	3.146
6	1964	702.000	360.000	11	35.10	2.849
6	1967	462.000	351.000	12	38.41	2.603
5	1968	416.000	351.000	13	41.72	2.397
5	1969	343.000	345.000	14	45.03	2.221
6	1970	385.000	343.000	15	48.34	2.068
6	1971	268.000	328.000	16	51.66	1.936
6	1972	583.000	328.000	17	54.97	1.819
5	1973	294.000	321.000	18	58.28	1.716
6	1974	360.000	294.000	19	61.59	1.624
6	1975	253.000	294.000	20	64.90	1.541
6	1976	351.000	292.000	21	68.21	1.466
5	1977	281.000	281.000	22	71.52	1.398
6	1978	203.000	268.000	23	74.83	1.336
6	1979	321.000	253.000	24	78.15	1.280
5	1980	147.000	246.000	25	81.46	1.228
5	1981	405.000	239.000	26	84.77	1.180
6	1982	381.000	203.000	27	88.08	1.135
5	1983	196.000	196.000	28	91.39	1.094
6	1984	345.000	196.000	29	94.70	1.056
6	1985	328.000	147.000	30	98.01	1.020

Table 8 Non-parametric Statistical Tests - Maximum Daily Flow Series

--- SPEARMAN TEST FOR INDEPENDENCE ---

07ed001 NATION RIVER NEAR FORT ST JAMES
ANNUAL MAXIMUM DAILY FLOW SERIES 1941 TO 1985 DRAINAGE AREA = 4350.000

```
SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =-0.219   D.F.= 27
                CORRESPONDS TO STUDENTS T =-1.165
             CRITICAL T VALUE AT 5% LEVEL = 1.703    NOT SIGNIFICANT
                -    -    -    -  1%   -  = 2.473    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant serial dependence.

--- SPEARMAN TEST FOR TREND ---

07ed001 NATION RIVER NEAR FORT ST JAMES
ANNUAL MAXIMUM DAILY FLOW SERIES 1941 TO 1985

```
SPEARMAN RANK ORDER CORRELATION COEFF = 0.124   D.F.= 28
         CORRESPONDS TO STUDENTS T = 0.659
      CRITICAL T VALUE AT 5% LEVEL = 2.048    NOT SIGNIFICANT
         -    -    -    -  1%   -  = 2.763    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the serial(lag-one) correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant trend.

--- RUN TEST FOR GENERAL RANDOMNESS ---

ANNUAL MAXIMUM DAILY FLOW SERIES 0 TO 0

```
THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN(RUNAB) =  0
     THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) =  0
     THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) =  0
Range at 5% level of significance: -1. to 12.        SIGNIFICANT
```

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis can be rejected. That is, the sample is not significantly random.

--- RUN TEST FOR GENERAL RANDOMNESS ---

07ed001 NATION RIVER NEAR FORT ST JAMES
ANNUAL MAXIMUM DAILY FLOW SERIES 1941 TO 1985

```
THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN(RUNAB) = 19
     THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 15
     THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 15
Range at 5% level of significance: 11. to 21.    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis cannot be rejected. That is, the sample is significantly random.

Table 9 Maximum Instantaneous Discharge

WSC STATION NO=07ED001
WSC STATION NAME=NATION RIVER NR FORT ST JAMES -

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3) (CMS)	(4) (CMS)	(5)	(6) (%)	(7) (YEARS)
5	1941	249.000	708.000	1	2.13	47.000
5	1942	368.000	586.000	2	5.67	17.625
6	1944	197.000	470.000	3	9.22	10.846
5	1946	425.000	462.000	4	12.77	7.833
5	1958	470.000	425.000	5	16.31	6.130
6	1959	371.000	416.000	6	19.86	5.036
6	1960	292.000	405.000	7	23.40	4.273
5	1962	240.000	385.000	8	26.95	3.711
5	1963	275.000	371.000	9	30.50	3.279
6	1964	708.000	368.000	10	34.04	2.937
6	1967	462.000	365.000	11	37.59	2.660
5	1968	416.000	351.000	12	41.13	2.431
5	1969	345.000	345.000	13	44.68	2.238
6	1971	268.000	345.000	14	48.23	2.074
6	1972	586.000	331.000	15	51.77	1.932
5	1973	297.000	323.000	16	55.32	1.808
6	1974	365.000	297.000	17	58.87	1.699
6	1975	260.000	292.000	18	62.41	1.602
6	1976	351.000	283.000	19	65.96	1.516
5	1977	283.000	275.000	20	69.50	1.439
6	1978	206.000	268.000	21	73.05	1.369
6	1979	323.000	260.000	22	76.60	1.306
5	1980	151.000	249.000	23	80.14	1.248
5	1981	405.000	240.000	24	83.69	1.195
6	1982	385.000	206.000	25	87.23	1.146
5	1983	198.000	198.000	26	90.78	1.102
6	1984	345.000	197.000	27	94.33	1.060
5	1985	331.000	151.000	28	97.87	1.022

Table 10 Non-parametric Statistical Tests - Maximum Daily Discharge

--- SPEARMAN TEST FOR INDEPENDENCE ---

```
07ED001             NATION RIVER NR FORT ST JAMES - MAX
ANNUAL MAXIMUM DAILY FLOW SERIES  1941 TO 1985  DRAINAGE AREA =  4350.000

SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =-0.123   D.F.= 25
                   CORRESPONDS TO STUDENTS T =-0.622
                CRITICAL T VALUE AT 5% LEVEL = 1.708    NOT SIGNIFICANT
                    -    -    -    -  1%   - = 2.485    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the serial(lag-one) correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant serial dependence.

--- SPEARMAN TEST FOR TREND ---

```
07ED001             NATION RIVER NR FORT ST JAMES - MAX
ANNUAL MAXIMUM DAILY FLOW SERIES  1941 TO 1985  DRAINAGE AREA =  4350.000

SPEARMAN RANK ORDER CORRELATION COEFF = 0.143   D.F.= 26
            CORRESPONDS TO STUDENTS T = 0.739
         CRITICAL T VALUE AT 5% LEVEL = 2.056    NOT SIGNIFICANT
             -    -    -    -  1%   - = 2.779    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant trend.

--- RUN TEST FOR GENERAL RANDOMNESS ---

```
07ED001             NATION RIVER NR FORT ST JAMES - MAX
ANNUAL MAXIMUM DAILY FLOW SERIES  1941 TO 1985  DRAINAGE AREA =  4350.000

THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN(RUNAB) = 17
     THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 14
     THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 14
Range at 5% level of significance: 10. to 20.    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis cannot be rejected. That is, the sample is significantly random.

--- MANN-WHITNEY SPLIT SAMPLE TEST FOR HOMOGENEITY ---

```
07ED001             NATION RIVER NR FORT ST JAMES - MAX
ANNUAL MAXIMUM FLOW SERIES  1941 TO 1985   DRAINAGE AREA=  4350.000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE= 14
                    SUBSAMPLE 2 SAMPLE SIZE= 14

                              MANN-WHITNEY U =  79.5
     CRITICAL U VALUE AT 5% SIGNIFICANT LEVEL =  61.0    NOT SIGNIFICANT
        -     -    -    -  1%       -       - =  47.0    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that there is no location difference between the two samples.

At the 5% level of significance, there is no significant location difference between the two samples. That is, they appear to be from the same population.

Table 11 Sample Statistics and Frequency Regime Data for Generalized Extreme Value Distribution - Maximum Daily Discharge

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
07ed001 NATION RIVER NEAR FORT ST JAMES

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	340.867	114.929	0.337	1.145	5.833
LN X SERIES	5.779	0.330	0.057	-0.098	3.983

X(MIN)= 147.000
X(MAX)= 702.000
LOWER OUTLIER LIMIT OF X= 138.980

TOTAL SAMPLE SIZE= 30
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= 0.2806E+04
GEV PARAMETERS: U= 291.57 A= 91.650 K= 0.036

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	125.00
1.050	0.952	187.00
1.250	0.800	248.00
2.000	0.500	325.00
5.000	0.200	425.00
10.000	0.100	490.00
20.000	0.050	550.00
50.000	0.020	625.00
100.000	0.010	680.00
200.000	0.005	733.00
500.000	0.002	801.00

Table 12 Sample Statistics and Frequency Regime Data for Three Parameter Lognormal Distribution - Maximum Daily Discharge

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
07ed001 NATION RIVER NEAR FORT ST JAMES

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	340.867	114.929	0.337	1.145	5.833
LN X SERIES	5.779	0.330	0.057	-0.098	3.983
LN(X-A) SERIES	5.894	0.294	0.050	0.030	3.977

X(MIN)= 147.000
X(MAX)= 702.000
LOWER OUTLIER LIMIT OF X= 138.980

TOTAL SAMPLE SIZE= 30
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= -37.602 M= 5.894 S= 0.294

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	124.00
1.050	0.952	185.00
1.250	0.800	246.00
2.000	0.500	325.00
5.000	0.200	427.00
10.000	0.100	491.00
20.000	0.050	551.00
50.000	0.020	626.00
100.000	0.010	681.00
200.000	0.005	736.00
500.000	0.002	807.00

Table 13 Sample Statistics and Frequency Regime Data for Log Pearson Type III Distribution - Maximum Daily Discharge

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
07ed001 NATION RIVER NEAR FORT ST JAMES

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	340.867	114.929	0.337	1.145	5.833
LN X SERIES	5.779	0.330	0.057	-0.098	3.983

X(MIN)= 147.000
X(MAX)= 702.000
LOWER OUTLIER LIMIT OF X= 138.980

TOTAL SAMPLE SIZE= 30
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT M= 0.2373E+07
LP3 PARAMETERS: A=-0.1180E-01 B= 754.1 LOG(M)= 14.68
M = 0.2373E+07

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	129.00
1.050	0.952	187.00
1.250	0.800	247.00
2.000	0.500	325.00
5.000	0.200	425.00
10.000	0.100	489.00
20.000	0.050	548.00
50.000	0.020	622.00
100.000	0.010	676.00
200.000	0.005	729.00
500.000	0.002	799.00

Table 14 Sample Statistics and Frequency Regime Data for Wakeby Distribution - Maximum Daily Discharge

FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
07ed001 NATION RIVER NEAR FORT ST JAMES

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	340.867	114.929	0.337	1.145	5.833
LN X SERIES	5.779	0.330	0.057	-0.098	3.983

X(MIN)= 147.000
X(MAX)= 702.000
LOWER OUTLIER LIMIT OF X= 138.980

TOTAL SAMPLE SIZE= 30
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED BY ASSUMING M TO BE NON-ZERO. THE ITERATION ALGORITHM WAS NOT REQUIRED.

M= 125.068 A= 167.905 B= 5.04 C= 213.424 D= 0.262

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	128.00
1.050	0.952	164.00
1.250	0.800	251.00
2.000	0.500	330.00
5.000	0.200	405.00
10.000	0.100	470.00
20.000	0.050	547.00
50.000	0.020	674.00
100.000	0.010	792.00
200.000	0.005	934.00
500.000	0.002	1170.00

Table 15 Sample Statistics and Frequency Regime Data for Generalized Extreme Value Distribution - Maximum Instantaneous Discharge

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
07ED001 NATION RIVER NR FORT ST JAMES

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	341.857	119.501	0.350	1.165	5.658
LN X SERIES	5.779	0.338	0.059	0.004	3.759

X(MIN)= 151.000
X(MAX)= 708.000
LOWER OUTLIER LIMIT OF X= 137.238

TOTAL SAMPLE SIZE= 28
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= 0.9313E+04
GEV PARAMETERS: U= 289.57 A= 92.391 K= 0.010

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	125.00
1.050	0.952	186.00
1.250	0.800	246.00
2.000	0.500	323.00
5.000	0.200	427.00
10.000	0.100	495.00
20.000	0.050	560.00
50.000	0.020	643.00
100.000	0.010	705.00
200.000	0.005	766.00
500.000	0.002	846.00

Table 16 Sample Statisitics and Frequency Regime Data for Three Parameter Lognormal Distribution - Maximum Instantaneous Discharge

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
07ED001 NATION RIVER NR FORT ST JAMES

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	341.857	119.501	0.350	1.165	5.658
LN X SERIES	5.779	0.338	0.059	0.004	3.759
LN(X-A) SERIES	5.783	0.337	0.058	0.009	3.759

X(MIN)= 151.000
X(MAX)= 708.000
LOWER OUTLIER LIMIT OF X= 137.238

TOTAL SAMPLE SIZE= 28
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= -1.235 M= 5.783 S= 0.337

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	127.00
1.050	0.952	184.00
1.250	0.800	243.00
2.000	0.500	324.00
5.000	0.200	430.00
10.000	0.100	499.00
20.000	0.050	564.00
50.000	0.020	648.00
100.000	0.010	710.00
200.000	0.005	773.00
500.000	0.002	856.00

Table 17 Sample Statistics and Frequency Regime Data for Log Pearson Type III Distribution - Maximum Instantaneous Discharge

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
07ED001 NATION RIVER NR FORT ST JAMES

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	341.857	119.501	0.350	1.165	5.658
LN X SERIES	5.779	0.338	0.059	0.004	3.759

X(MIN)= 151.000
X(MAX)= 708.000
LOWER OUTLIER LIMIT OF X= 137.238

TOTAL SAMPLE SIZE= 28
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MOMENTS

LP3 PARAMETERS: A= 0.7441E-03 B= 0.2068E+06 LOG(M)= -148.1
M = ZERO

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	128.00
1.050	0.952	184.00
1.250	0.800	243.00
2.000	0.500	323.00
5.000	0.200	430.00
10.000	0.100	499.00
20.000	0.050	565.00
50.000	0.020	649.00
100.000	0.010	712.00
200.000	0.005	775.00
500.000	0.002	858.00

Table 18 Sample Statistics and Frequency Regime Data for Wakeby Distribution - Maximum Instantaneous Discharge

FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
07ED001 NATION RIVER NR FORT ST JAMES

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	341.857	119.501	0.350	1.165	5.658
LN X SERIES	5.779	0.338	0.059	0.004	3.759

X(MIN)= 151.000
X(MAX)= 708.000
LOWER OUTLIER LIMIT OF X= 137.238

TOTAL SAMPLE SIZE= 28
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED BY ASSUMING M TO BE NON-ZERO. THE ITERATION ALGORITHM WAS NOT REQUIRED.

M= 130.136 A= 154.782 B= 4.71 C= 293.874 D= 0.222

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	132.00
1.050	0.952	165.00
1.250	0.800	246.00
2.000	0.500	328.00
5.000	0.200	411.00
10.000	0.100	481.00
20.000	0.050	563.00
50.000	0.020	693.00
100.000	0.010	810.00
200.000	0.005	946.00
500.000	0.002	1160.00

Table 19 Sample Statistics and Frequency Regime Data for Gumbel III Distribution

07ED001 NATION R NR FT ST JAMES
1 DAY LOW FLOW MEAN DISCH. IN PERIOD JUN 1 TO MAY 31

STARTING MONTH	YEAR	1 DAY MEAN FLOW	ASCENDING ORDER	RANK	CUMULAT. PROBABIL.	RETURN PERIOD
					(%)	(YEARS)
4	1944	5.4900	5.4900	1	2.97	33.67
3	1967	9.6300	7.3500	2	7.92	12.63
9	1967	13.9000	8.2100	3	12.87	7.77
3	1969	8.4700	8.2700	4	17.82	5.61
4	1970	12.7000	8.4700	5	22.77	4.39
2	1971	9.0000	9.0000	6	27.72	3.61
3	1972	11.2000	9.3200	7	32.67	3.06
4	1973	11.5000	9.3500	8	37.62	2.66
4	1974	10.8000	9.4200	9	42.57	2.35
4	1975	8.2100	9.6300	10	47.52	2.10
3	1976	10.6000	10.2000	11	52.48	1.91
3	1977	11.2000	10.6000	12	57.43	1.74
3	1978	10.2000	10.8000	13	62.38	1.60
2	1979	8.2700	11.2000	14	67.33	1.49
4	1980	7.3500	11.2000	15	72.28	1.38
3	1981	11.9000	11.5000	16	77.23	1.29
9	1981	9.3200	11.9000	17	82.18	1.22
3	1983	13.0000	12.7000	18	87.13	1.15
2	1984	9.4200	13.0000	19	92.08	1.09
3	1985	9.3500	13.9000	20	97.03	1.03

MEAN= 10.08 S.D.= 2.0446 SKEW= -0.1659 C.V.= 0.2029
GUMBEL III DISTRIBUTION - PARAMETERS BY MAXIMUM LIKELIHOOD
N= 20 XMIN= 5.490 A= 4.29473 E= 2.5116 U= 10.8235

RETURN PERIOD (YRS)	DROUGHT ESTIMATE
1.005	14.77
1.010	14.38
1.110	12.61
1.250	11.80
2.000	10.14
5.000	8.373
10.000	7.434
20.000	6.674
50.000	5.862
100.000	5.359
200.000	4.934
500.000	4.468

Table 20 Low Flow Frequency - 7 Day Minimum Discharge

WSC STATION NO.=07ED001 VERSION=1 N-DAY MEAN DURATION= 7
WSC STATION NAME=NATION R NR FT ST JAMES
WATER SEASON (MONTH/DAY) FROM JUN 1 TO MAY 31

SEQ.NO.	YEAR	MON	FLOW
1	1944	4	5.490
2	1967	3	9.780
3	1967	9	14.600
4	1969	3	8.500
5	1970	4	13.100
6	1971	2	9.080
7	1972	3	11.300
8	1973	4	11.600
9	1974	4	10.800
10	1975	4	8.390
11	1976	3	10.600
12	1977	3	11.300
13	1978	3	10.300
14	1979	2	8.330
15	1980	4	7.350
16	1981	3	12.000
17	1981	9	9.570
18	1983	3	13.100
19	1984	2	9.540
20	1985	3	9.390

Table 21 Sample Statistics and Frequency Regime Data for Gumbel III Distribution - 7 Day Minimum Discharge

```
  07ED001  NATION R NR FT ST JAMES
        7 DAY LOW FLOW MEAN DISCH. IN PERIOD JUN  1 TO MAY 31
MEAN=  10.21  S.D.=   2.1425  SKEW=  -0.0217  C.V.=   0.2099
   GUMBEL III DISTRIBUTION   -   PARAMETERS BY MAXIMUM LIKELIHOOD
   N= 20        XMIN=     5.490      A=  3.73452      E=   3.1664  U= 10.9572
```

RETURN PERIOD (YRS)	DROUGHT ESTIMATE
1.005	15.34
1.010	14.90
1.110	12.92
1.250	12.02
2.000	10.23
5.000	8.380
10.000	7.431
20.000	6.683
50.000	5.907
100.000	5.440
200.000	5.053
500.000	4.642

07ED001 NATION R NR FT ST JAMES
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD

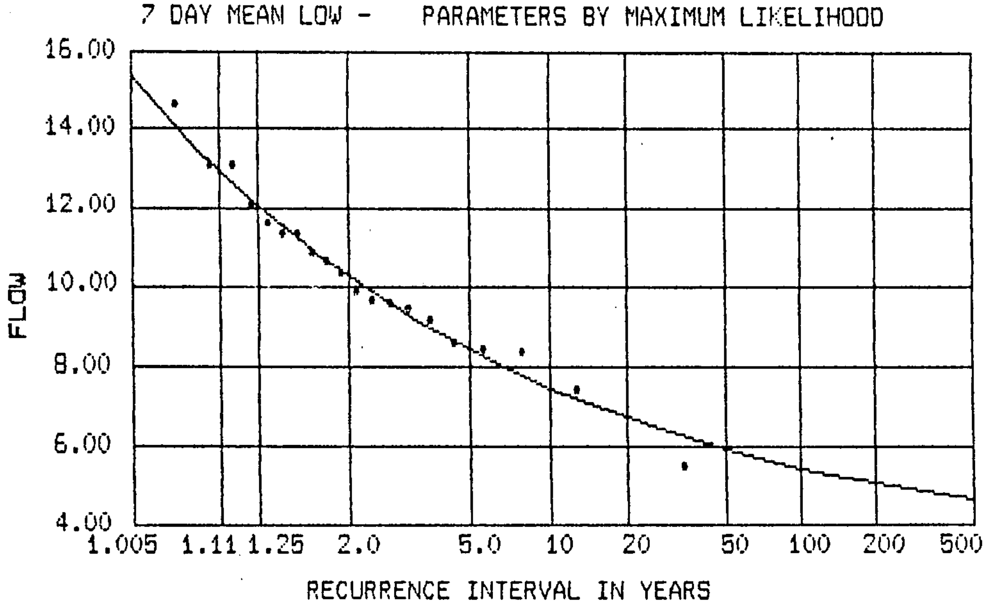


Table 22 Low Flow Frequency - 14 Day Minimum Discharge

WSC STATION NO.=07ED001 VERSION=1 N-DAY MEAN DURATION=14
WSC STATION NAME=NATION RIVER NEAR FORT ST. JAMES
WATER SEASON (MONTH/DAY) FROM JUN 1 TO MAY 31

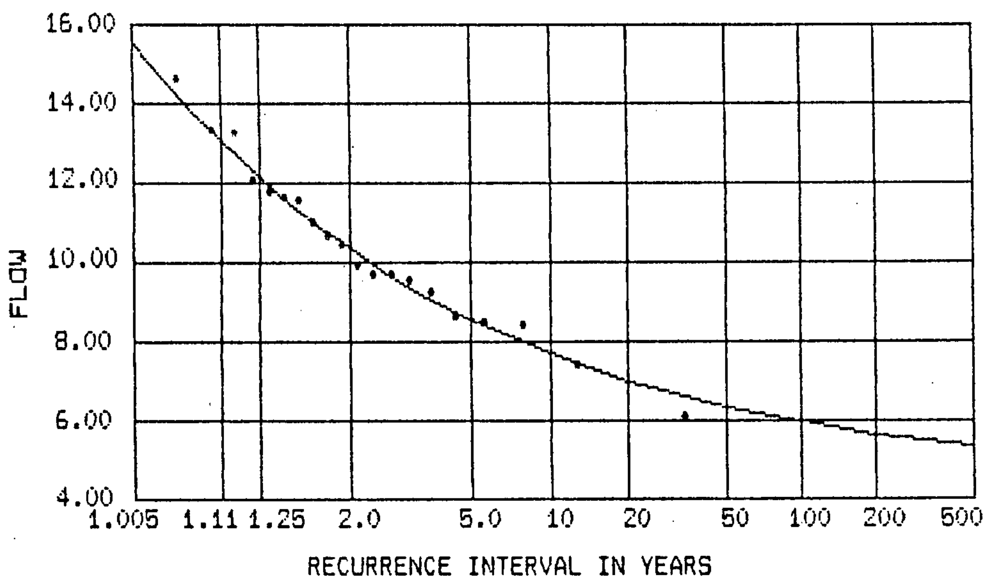
SEQ.NO.	YEAR	MON	FLOW
1	1944	4	6.090
2	1967	3	9.900
3	1967	9	14.600
4	1969	3	8.570
5	1970	4	13.300
6	1971	2	9.260
7	1972	3	11.600
8	1973	4	11.700
9	1974	4	10.900
10	1975	4	8.460
11	1976	3	10.600
12	1977	3	11.500
13	1978	3	10.400
14	1979	2	8.390
15	1980	4	7.370
16	1981	3	12.000
17	1981	9	9.650
18	1983	3	13.200
19	1984	2	9.680
20	1985	3	9.530

Table 23 Sample Statistics and Frequency Regime Data for Gumbel III Distribution - 14 Day Miniumum Discharge

07ED001 NATION RIVER NEAR FORT ST. JAMES
14 DAY LOW FLOW MEAN DISCH. IN PERIOD JUN 1 TO MAY 31
MEAN= 10.34 S.D.= 2.0938 SKEW= 0.0871 C.V.= 0.2026
GUMBEL III DISTRIBUTION - PARAMETERS BY MAXIMUM LIKELIHOOD
N= 20 XMIN= 6.090 A= 3.19303 E= 4.4062 U= 11.0261

RETURN PERIOD (YRS)	DROUGHT ESTIMATE
1.005	15.57
1.010	15.09
1.110	13.01
1.250	12.09
2.000	10.31
5.000	8.545
10.000	7.678
20.000	7.018
50.000	6.357
100.000	5.974
200.000	5.667
500.000	5.352

07ED001 NATION RIVER NEAR FORT ST. JAMES
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
14 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD



FIGURES 1 - 42

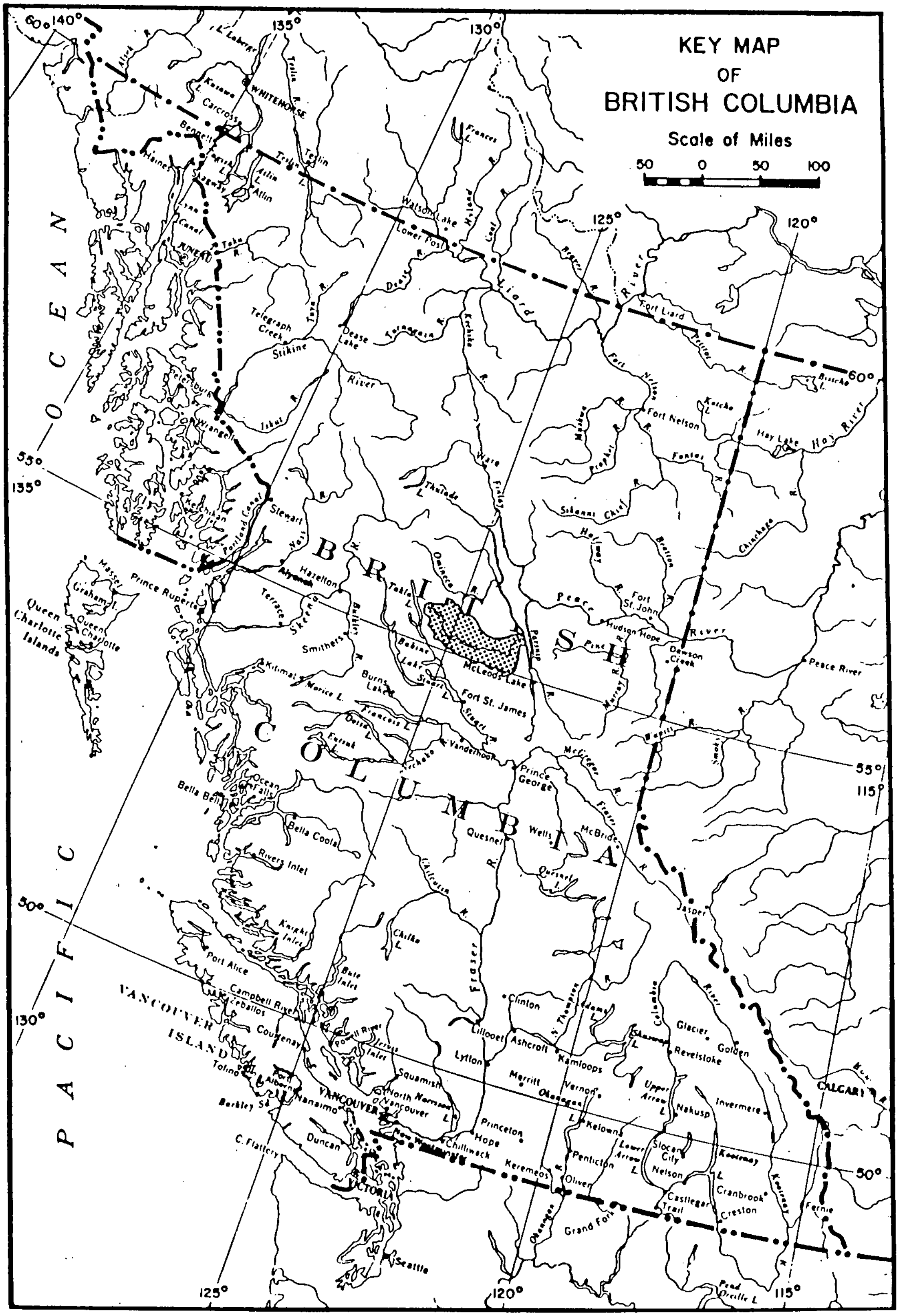


Figure 1 Key Map of British Columbia with Basin Outline

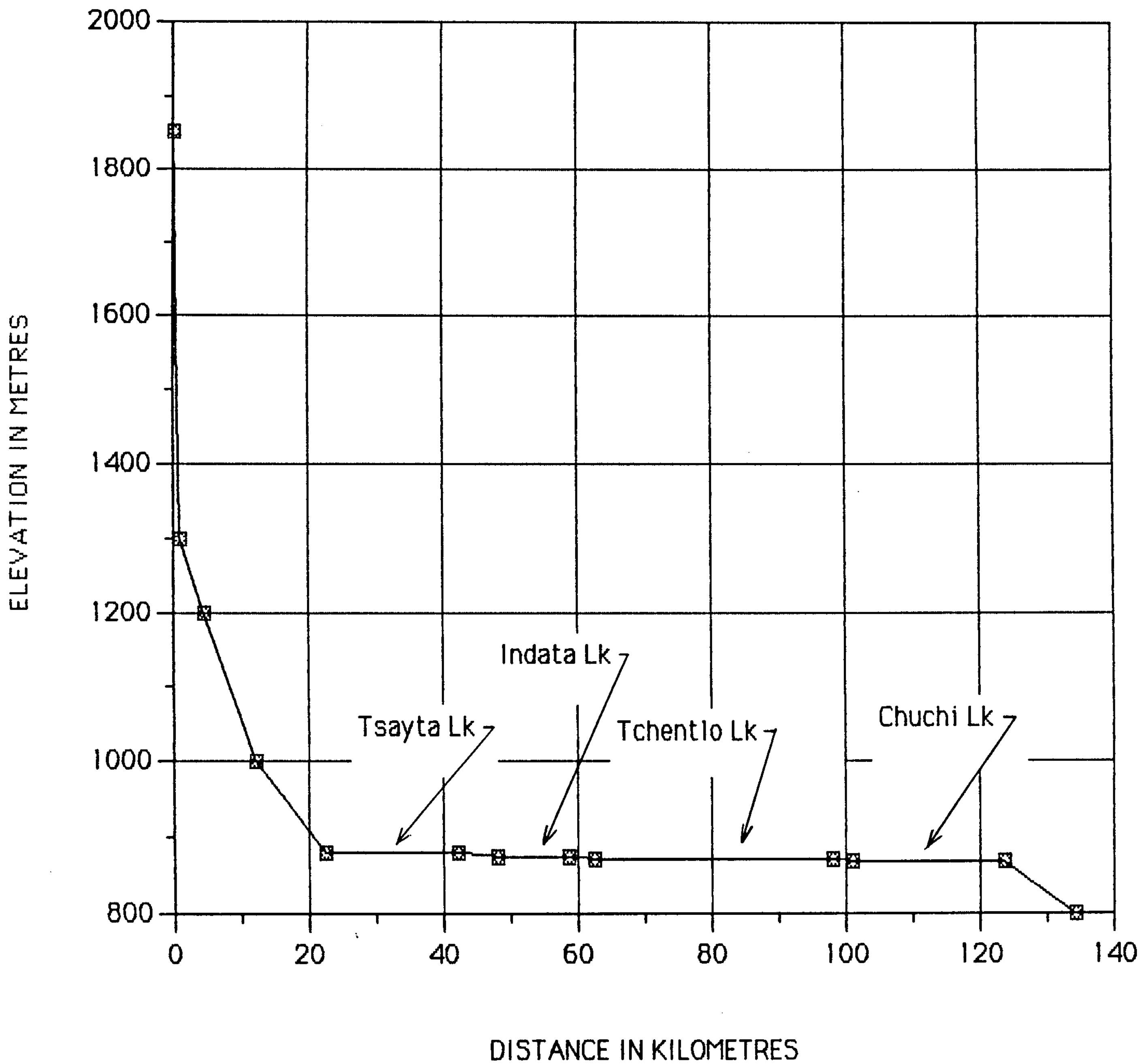


Figure 2 Profile of Nation River

FIGURE 3 - HYPSOMETRIC CURVE

NOT AVAILABLE

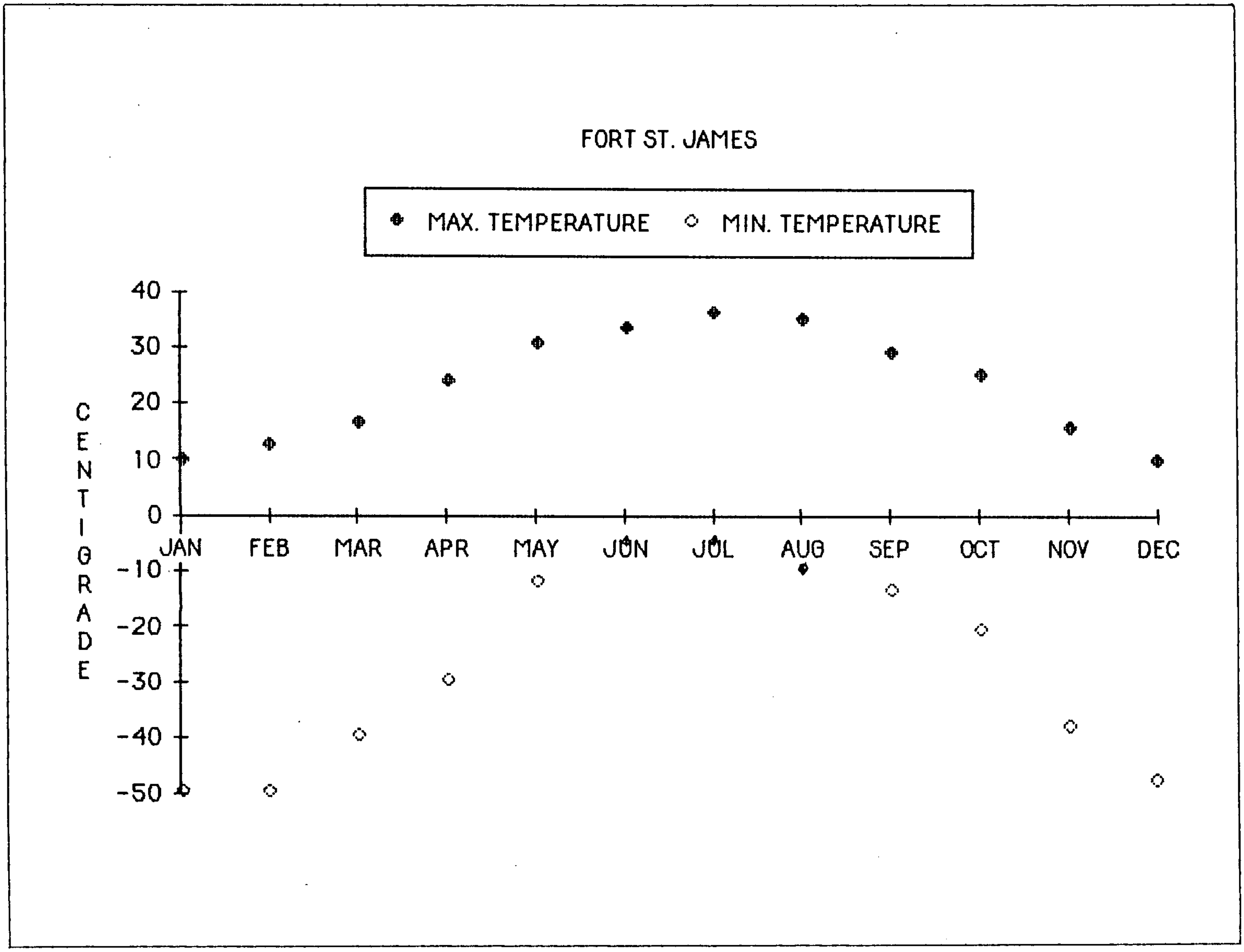


Figure 4 Monthly Maximum and Minimum Temperature Extremes at Fort St. James

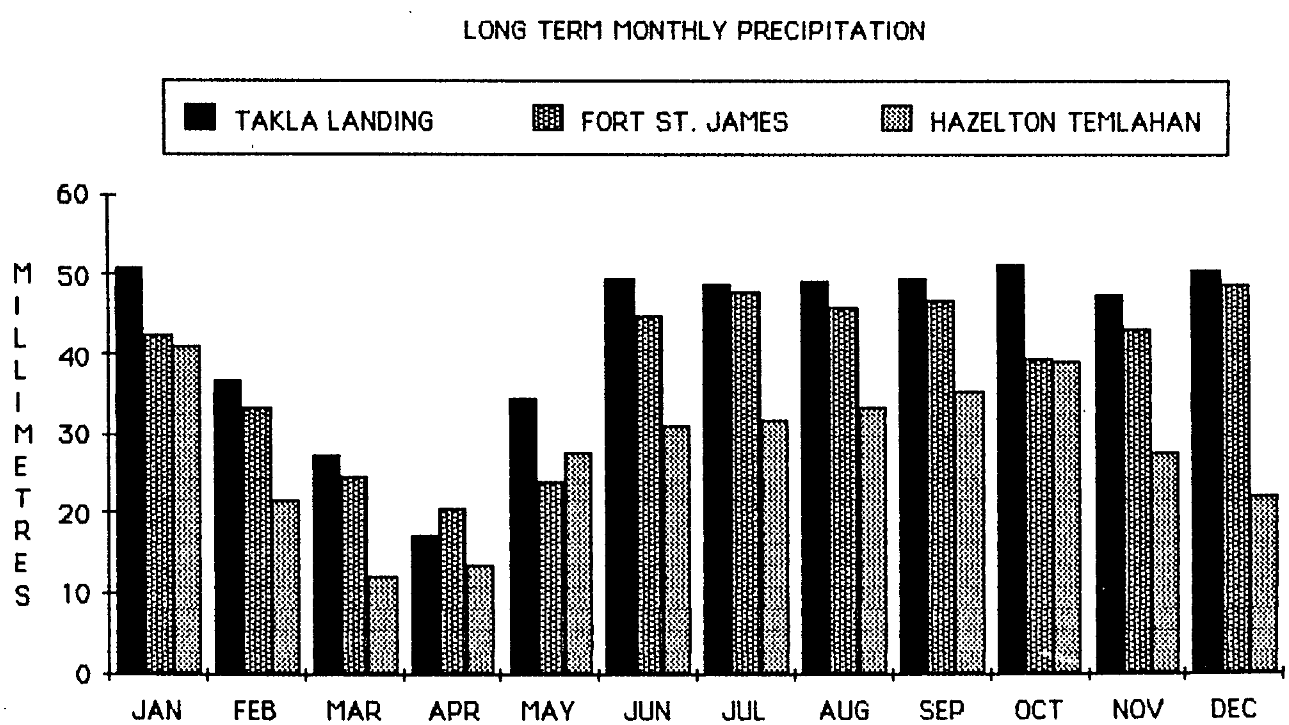


Figure 5 Histogram of Monthly Precipitation at Fort St. James, Takla Landing and Hazelton Temlahan

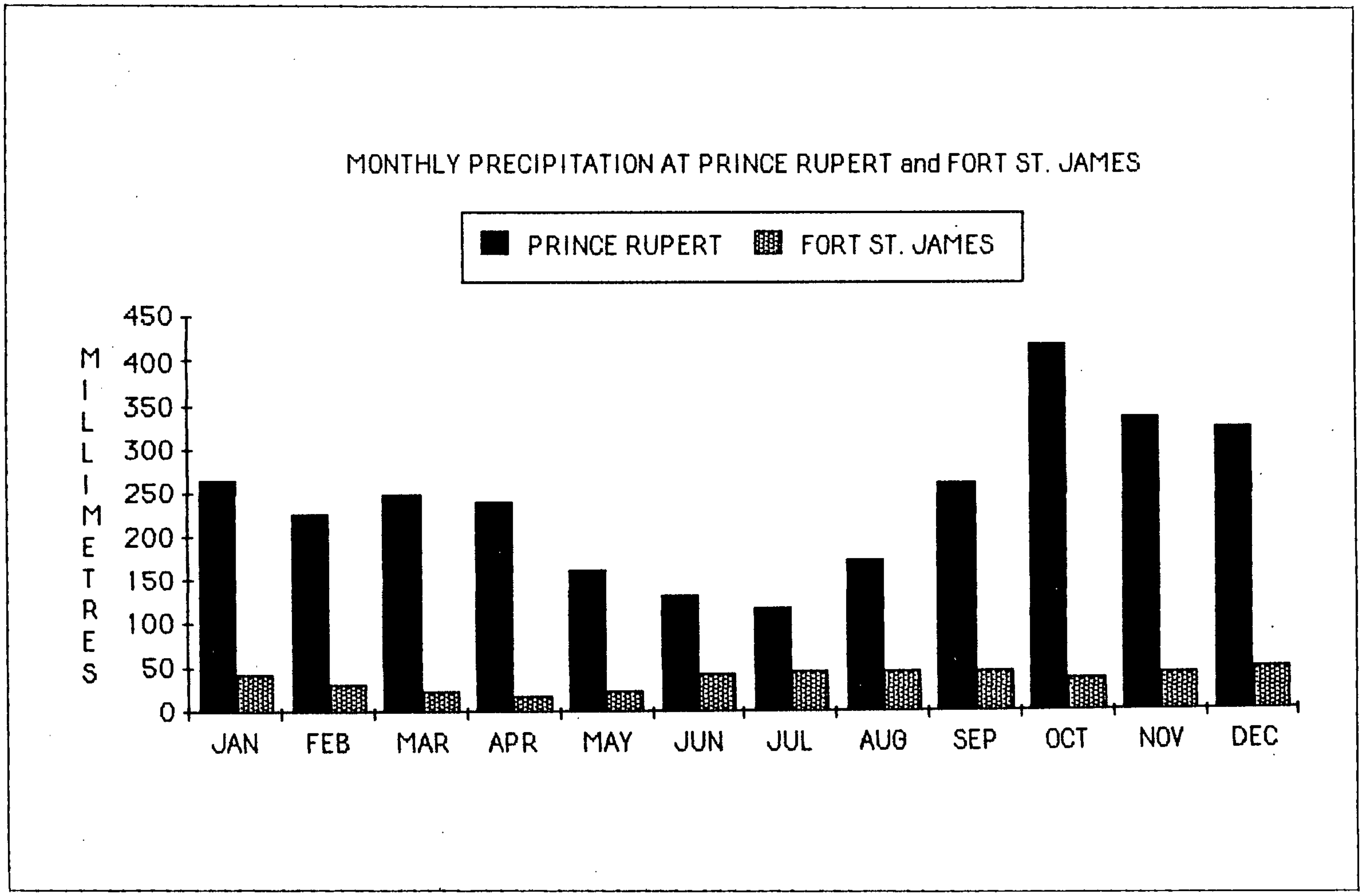


Figure 6 Histogram of Monthly Precipitation at Fort St. James and Prince Rupert

Nation River gauge shelter

partially completed shelter

Nation River

rock loaded platform

Figure 7 Photographs of Bridge and Recorder

Figure 8 Photographs of California Shelter and Well

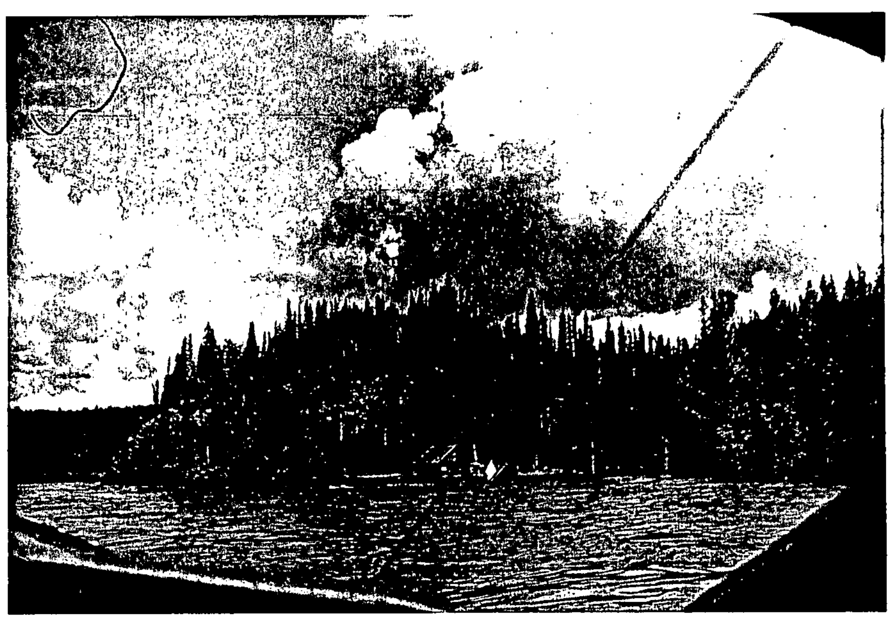


Figure 9a Photographs of the High Water of June 16, 1964

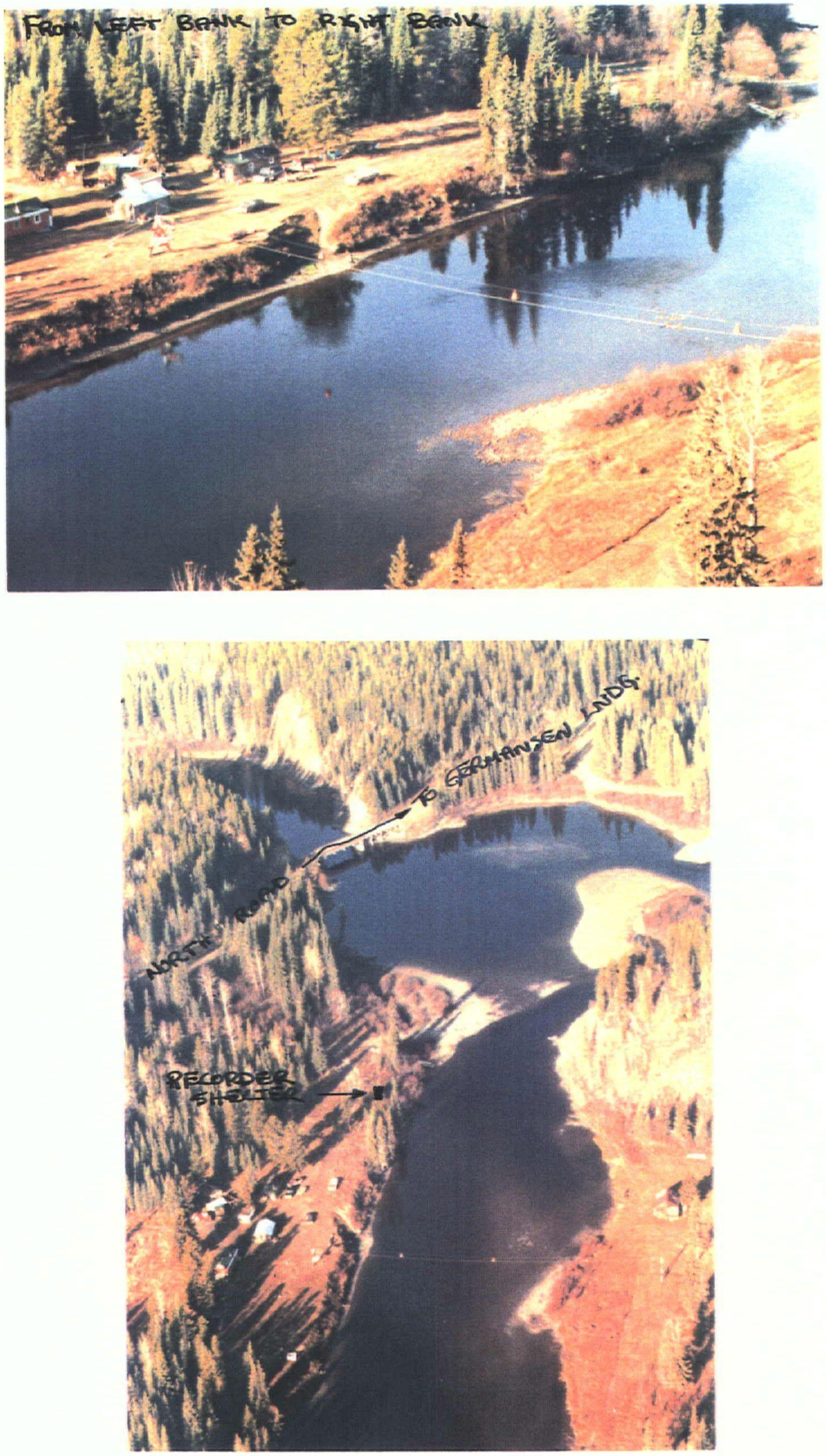


Figure 9b Photographs of Present Cableway and Recorder Site

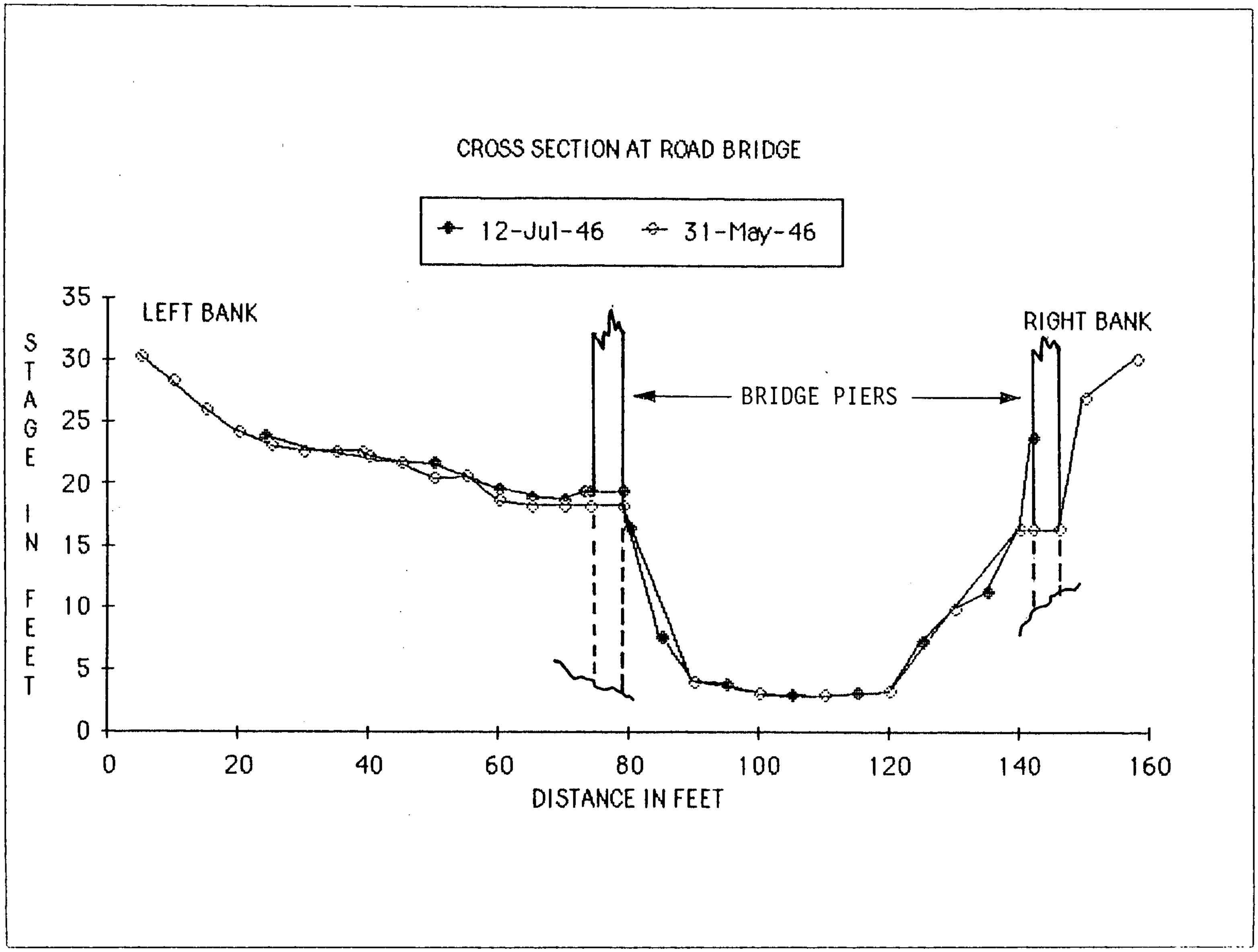


Figure 10 Cross Section of Metering Site on Road Bridge

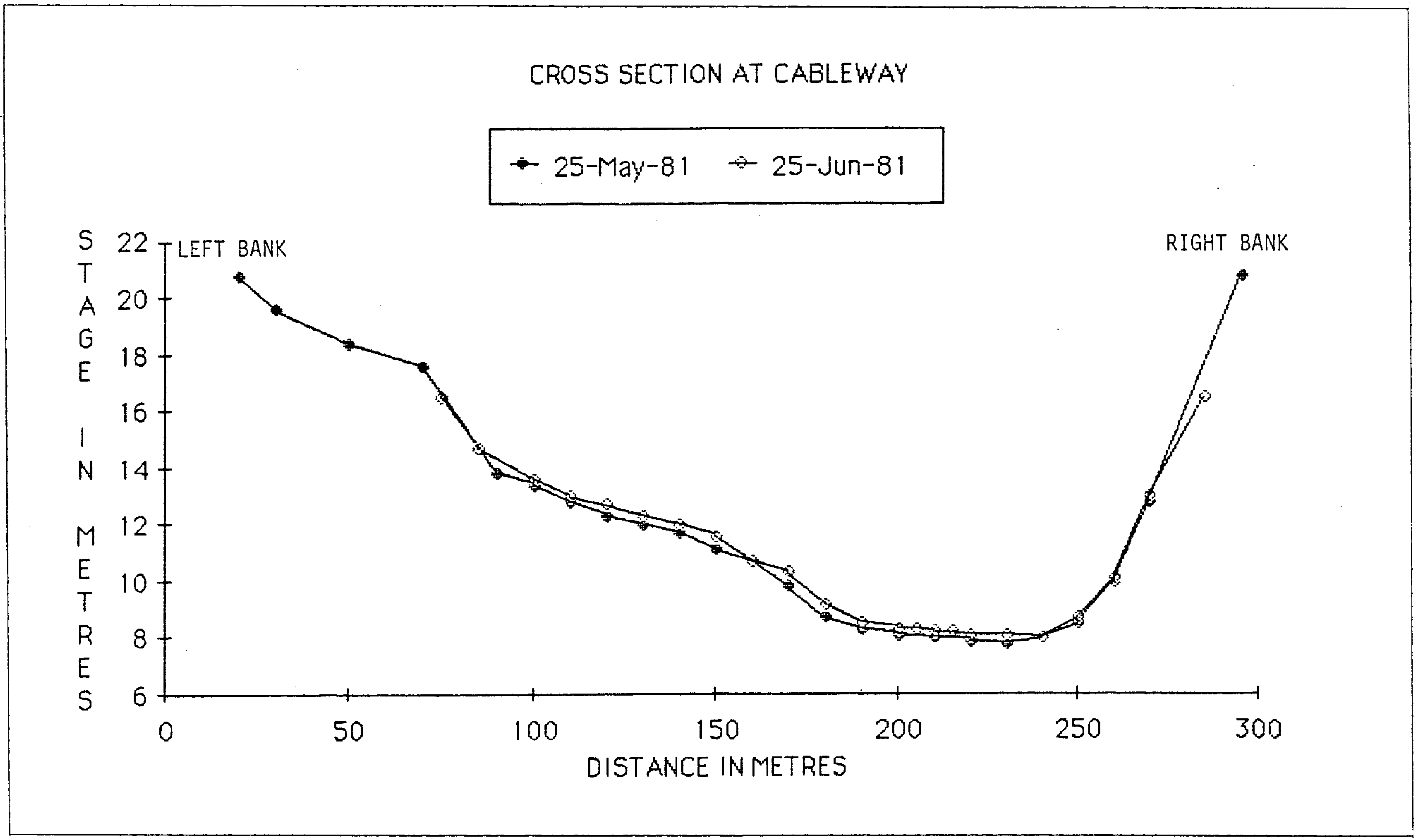
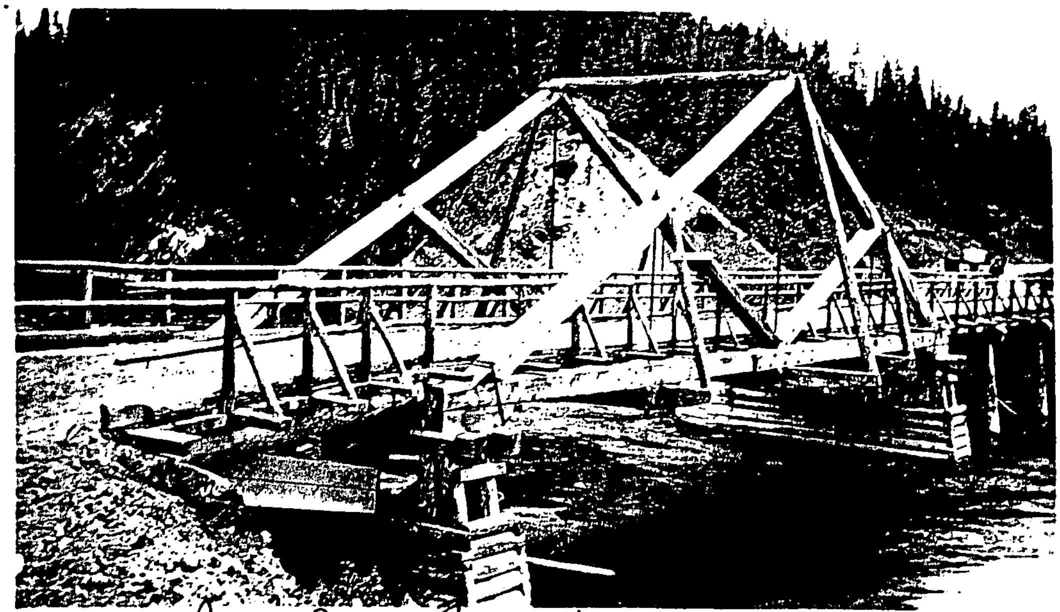


Figure 11 Cross Section at Cableway



Hatton River Suggested auto gauge site

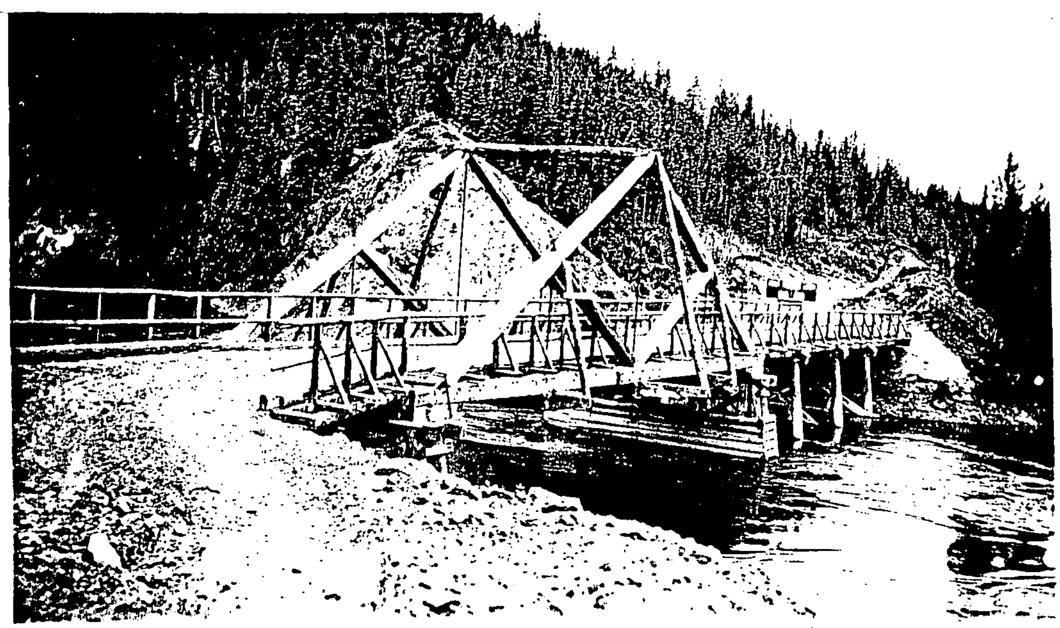


Figure 12 Photographs of Road Bridge Original Metering Site

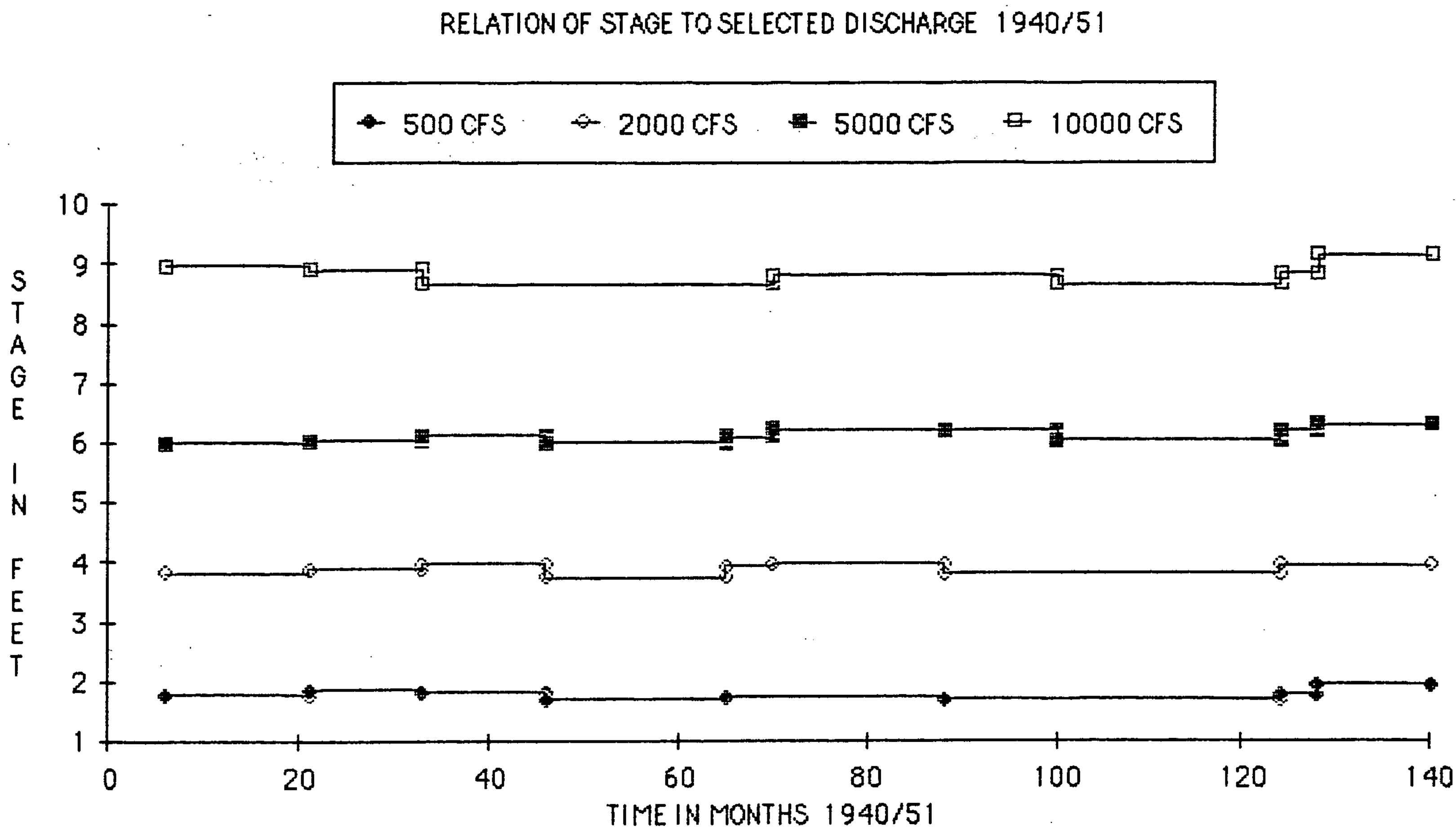


Figure 13a Stage Relationship with Selected Discharges 1940 to 1951

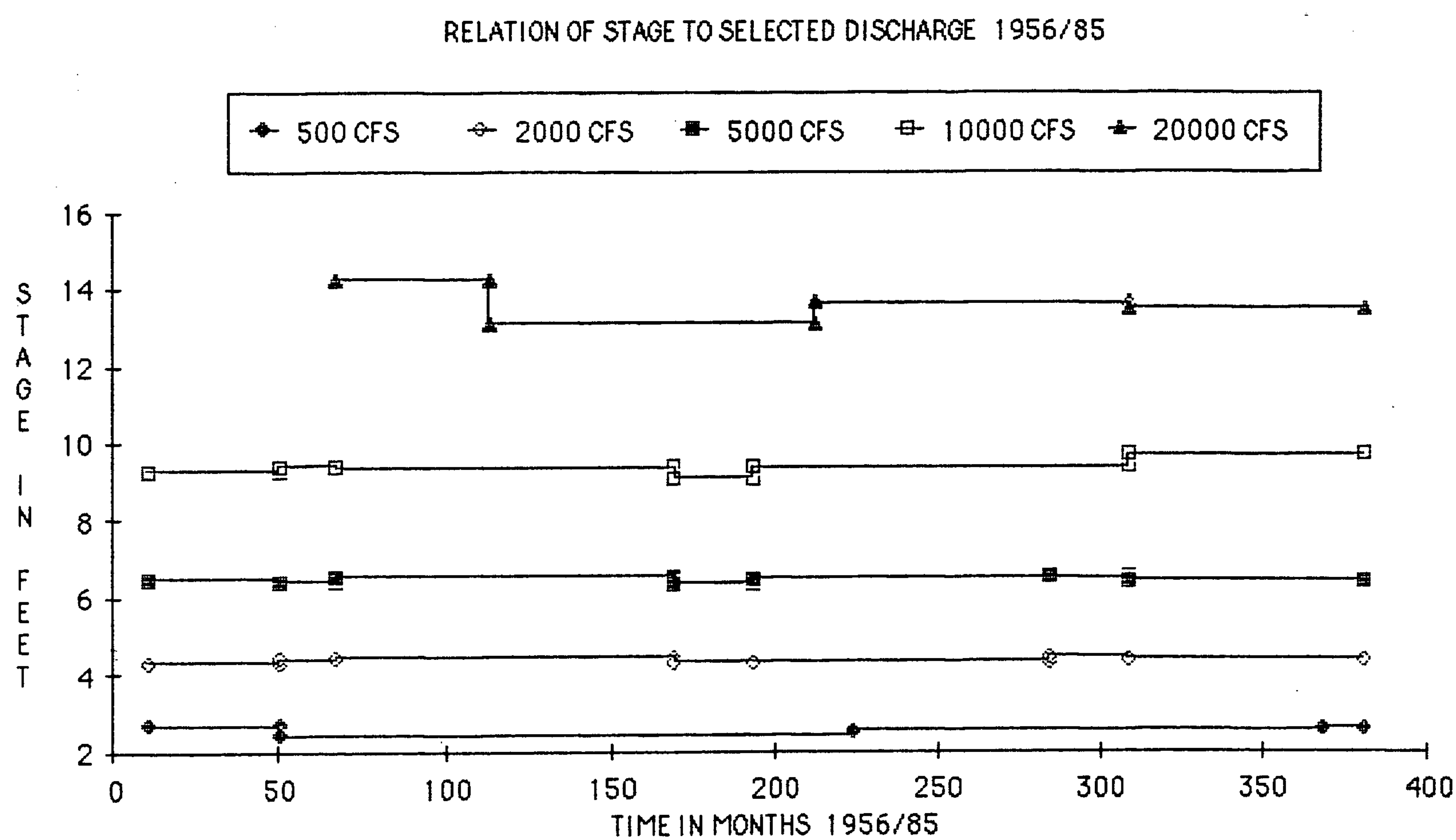


Figure 13b Stage Relationship with Selected Discharges 1956 to 1985

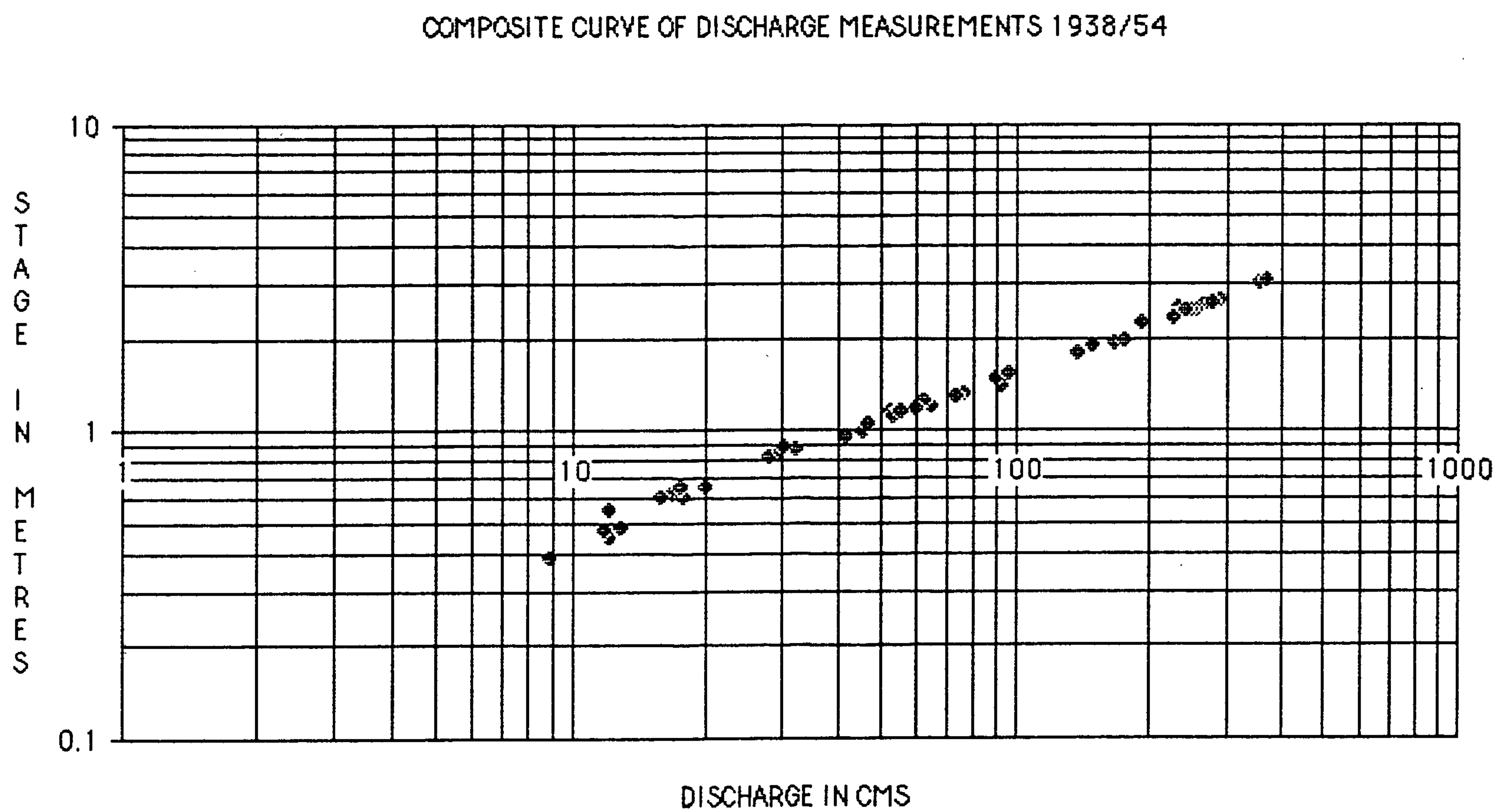


Figure 14a Composite Curve of all Open Water Measurements for the Period 1938 to 1954

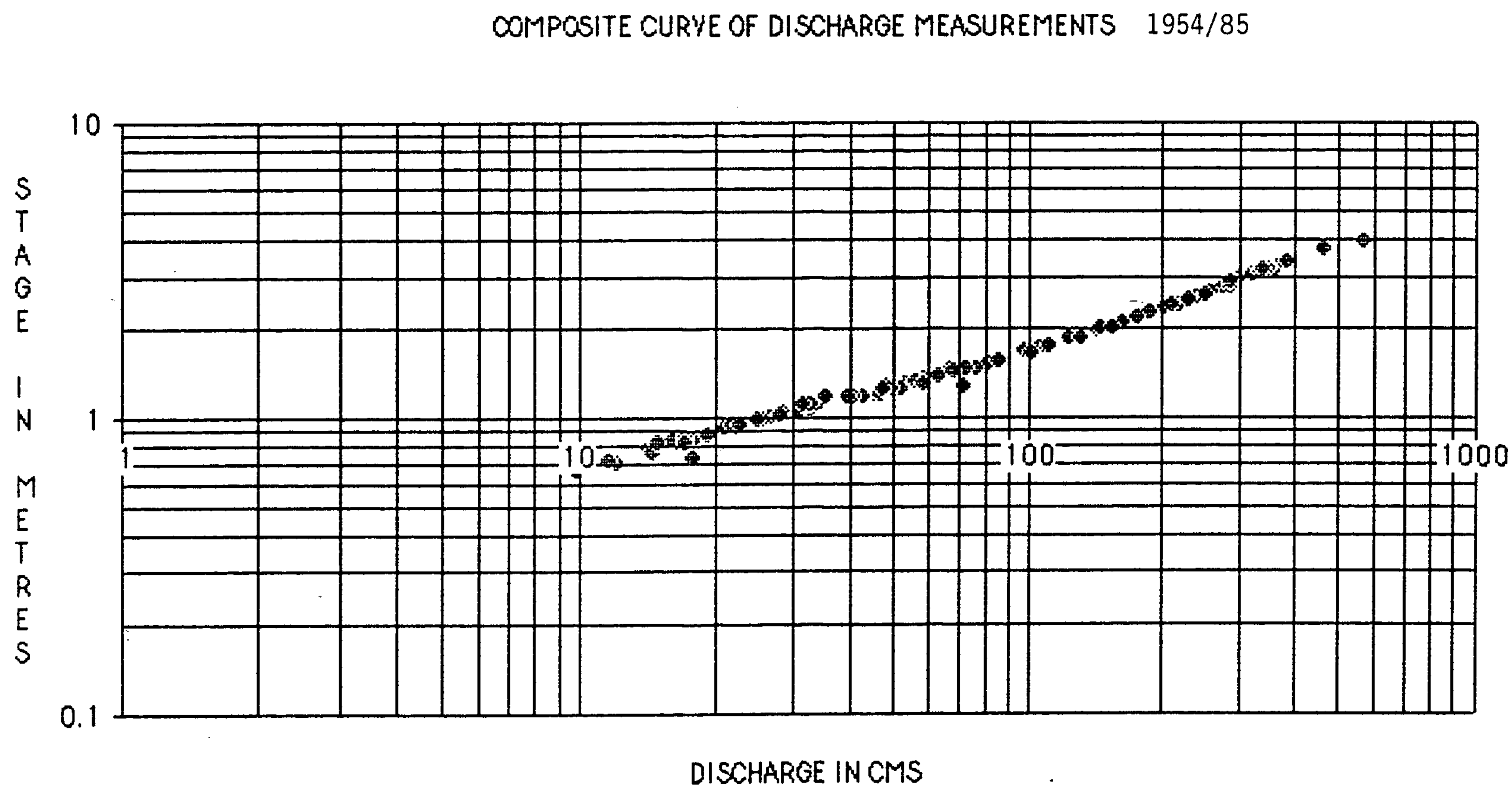


Figure 14b Composite Curve of all Open Water Measurements for the Period 1954 to 1985

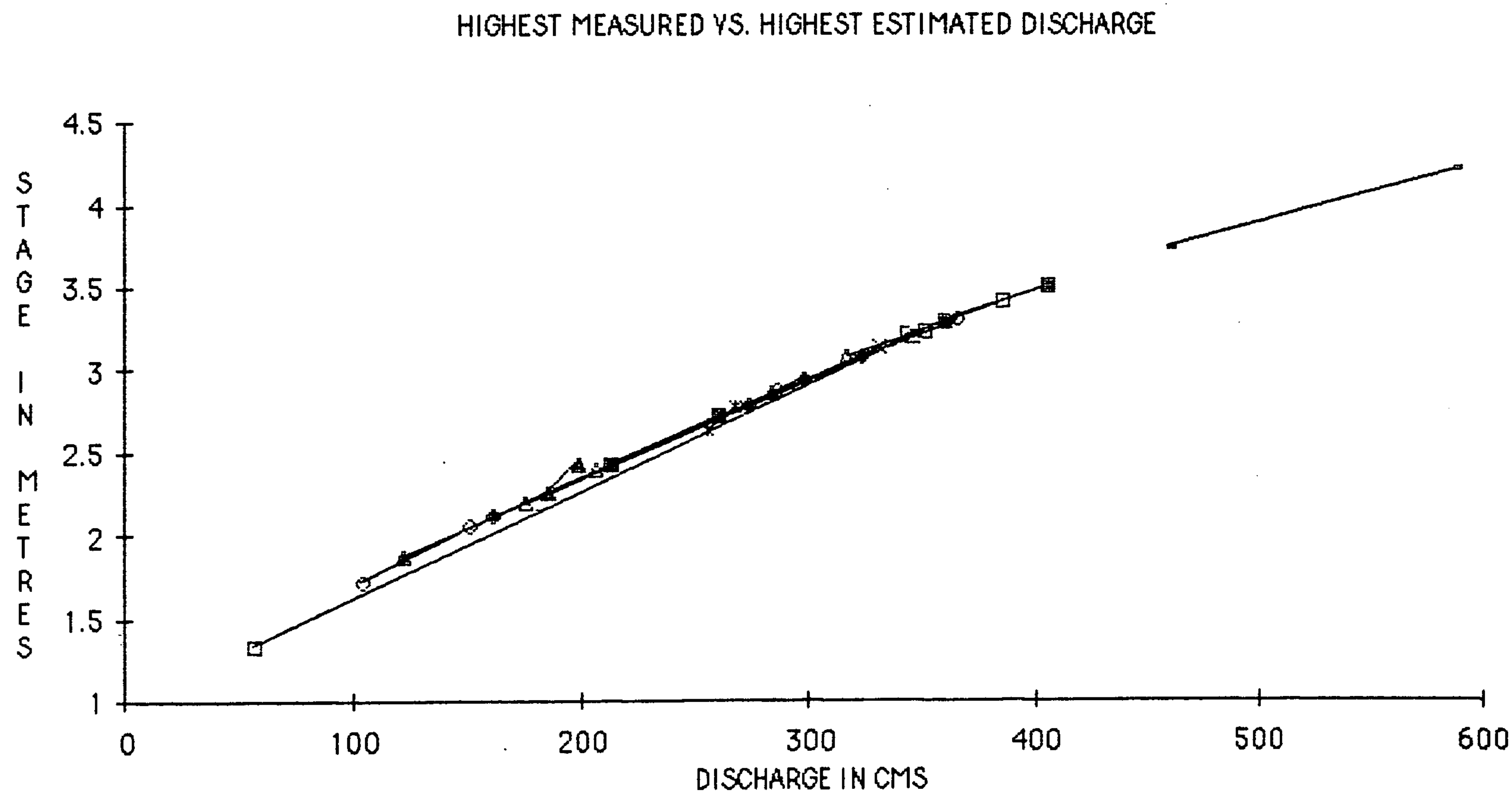


Figure 15 Measured vs. Estimated Discharges for Period of Record

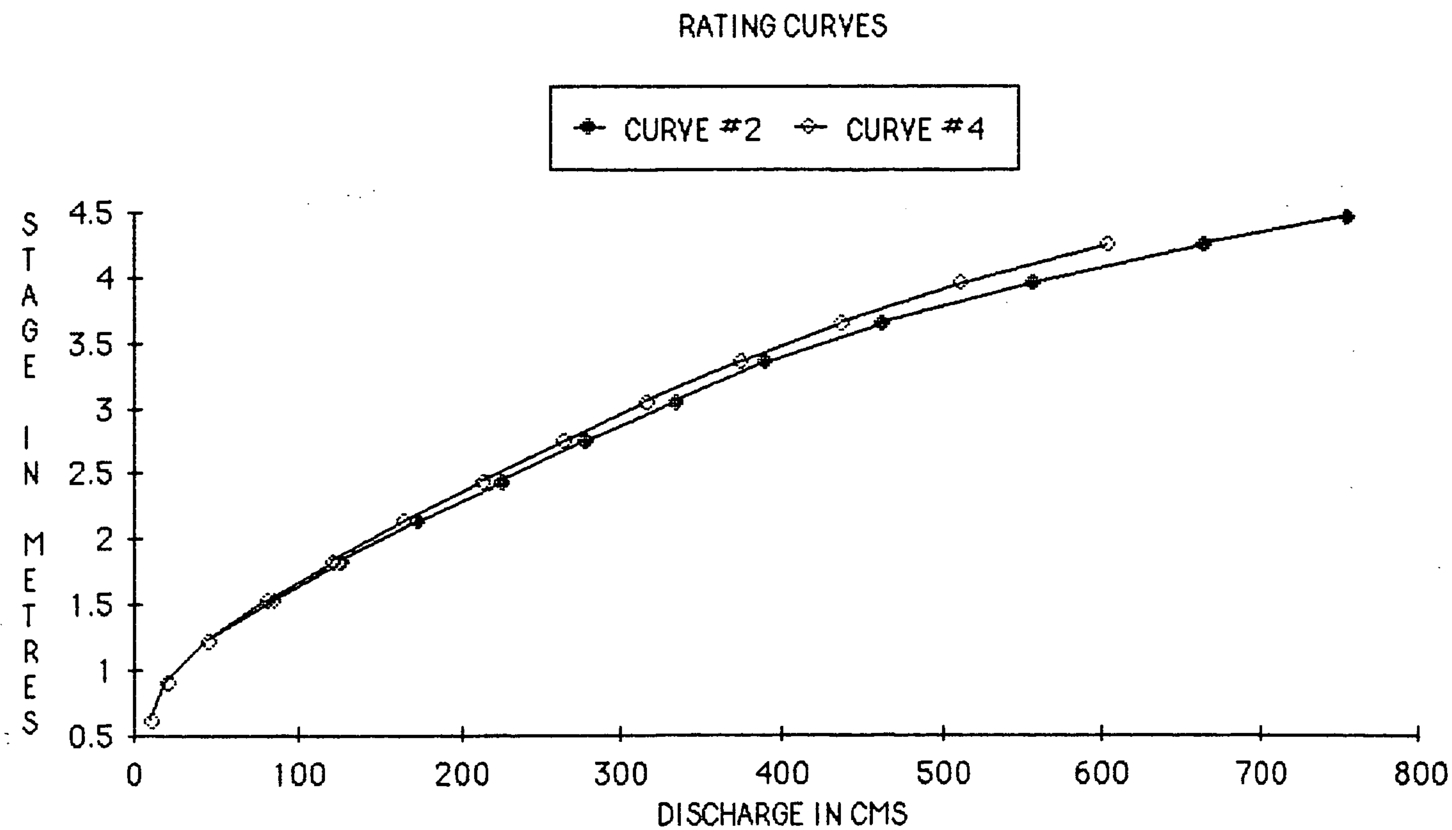


Figure 16 Relationship of Extended Rating Curves #2 and #4

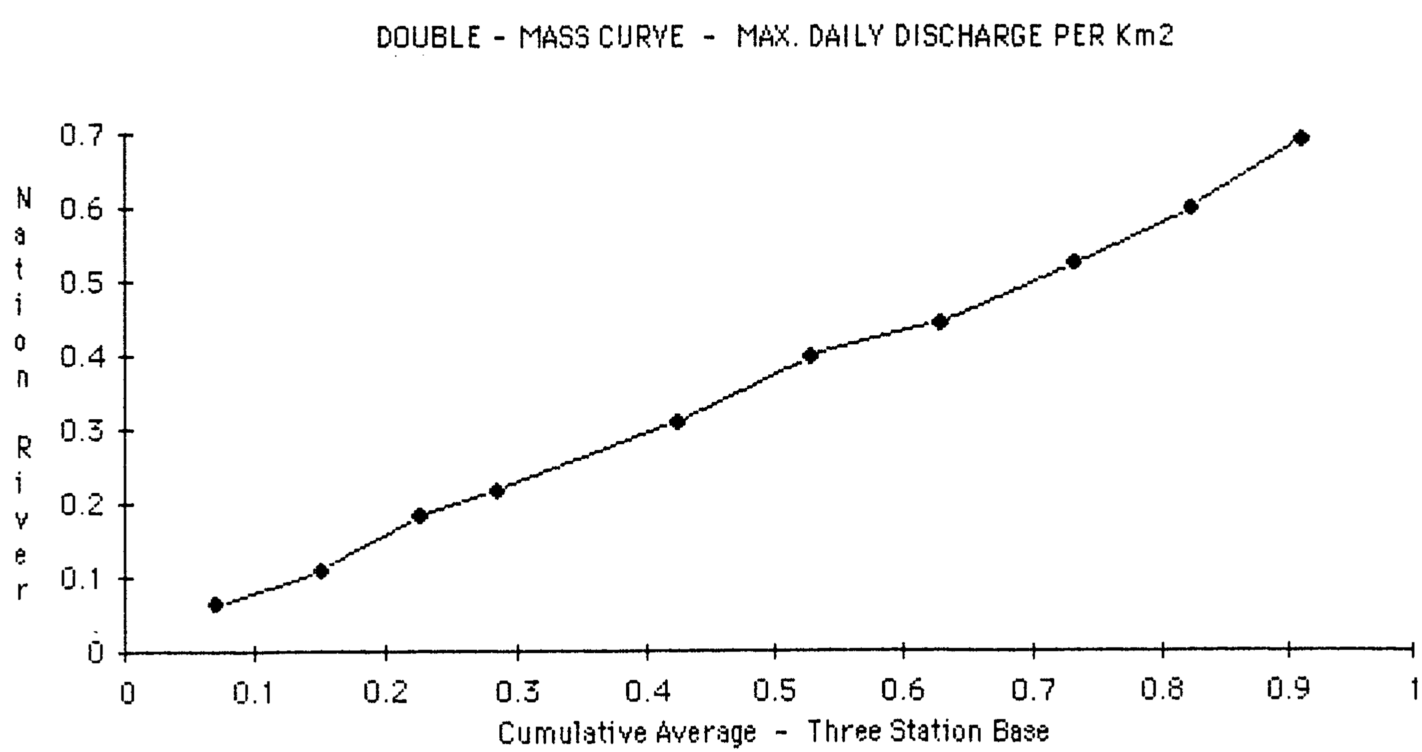


Figure 17 Double-Mass Curve Analysis of Maximum Daily Discharge per Square Kilometre

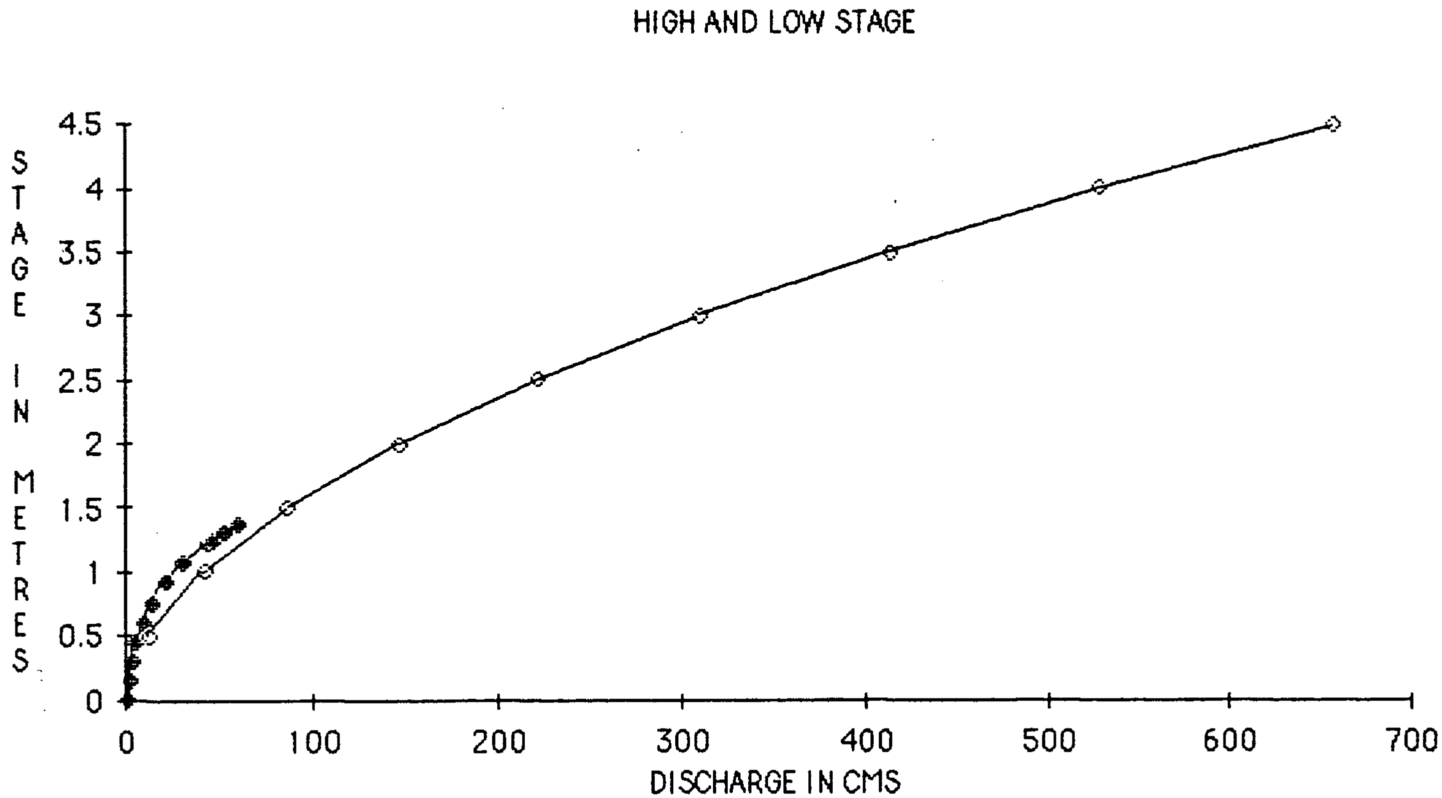


Figure 18 Relationship of the High and Low Controls of the Rating Curves

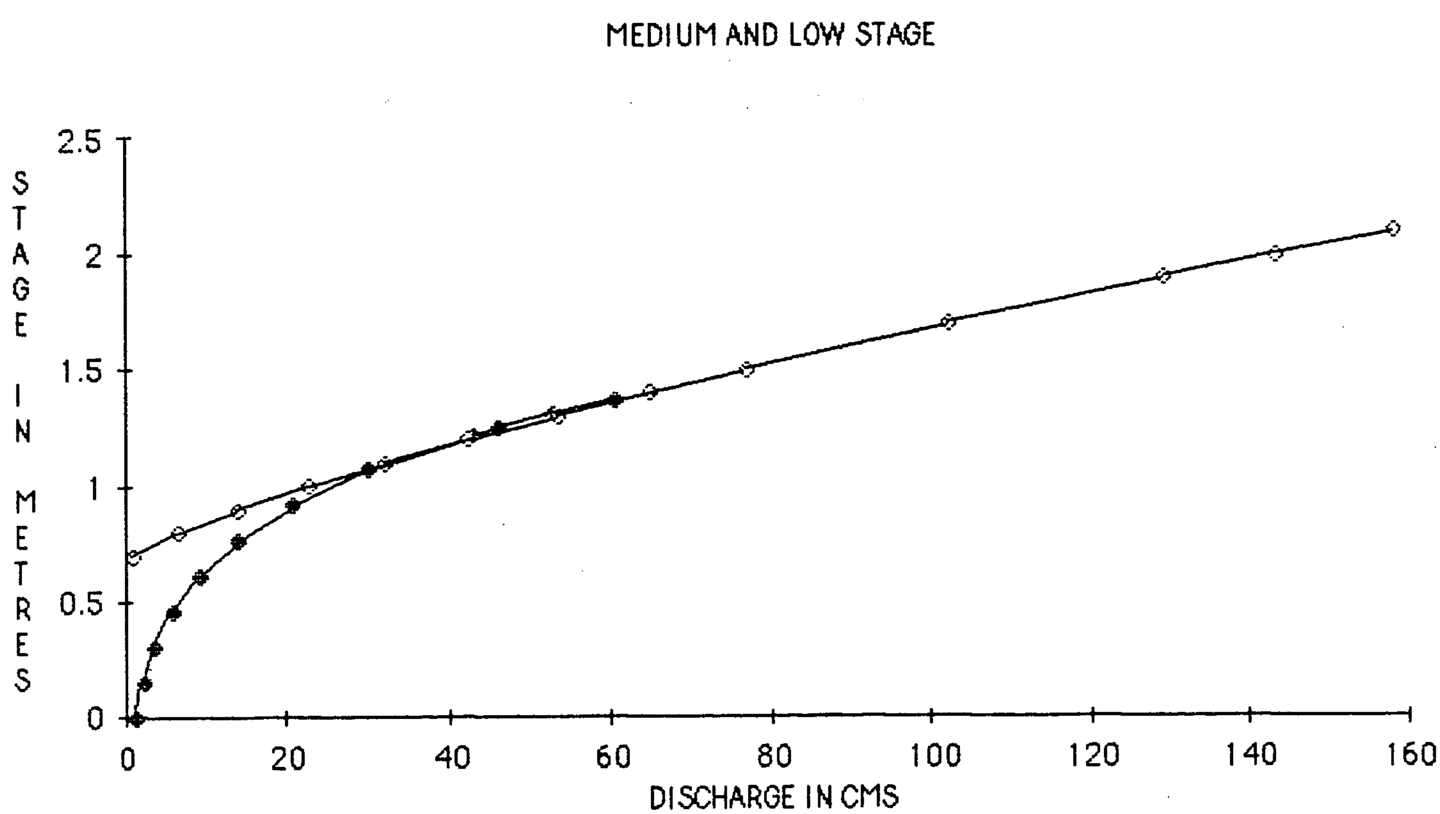


Figure 19 Relationship Between the Medium and Low Controls of the Rating Curves

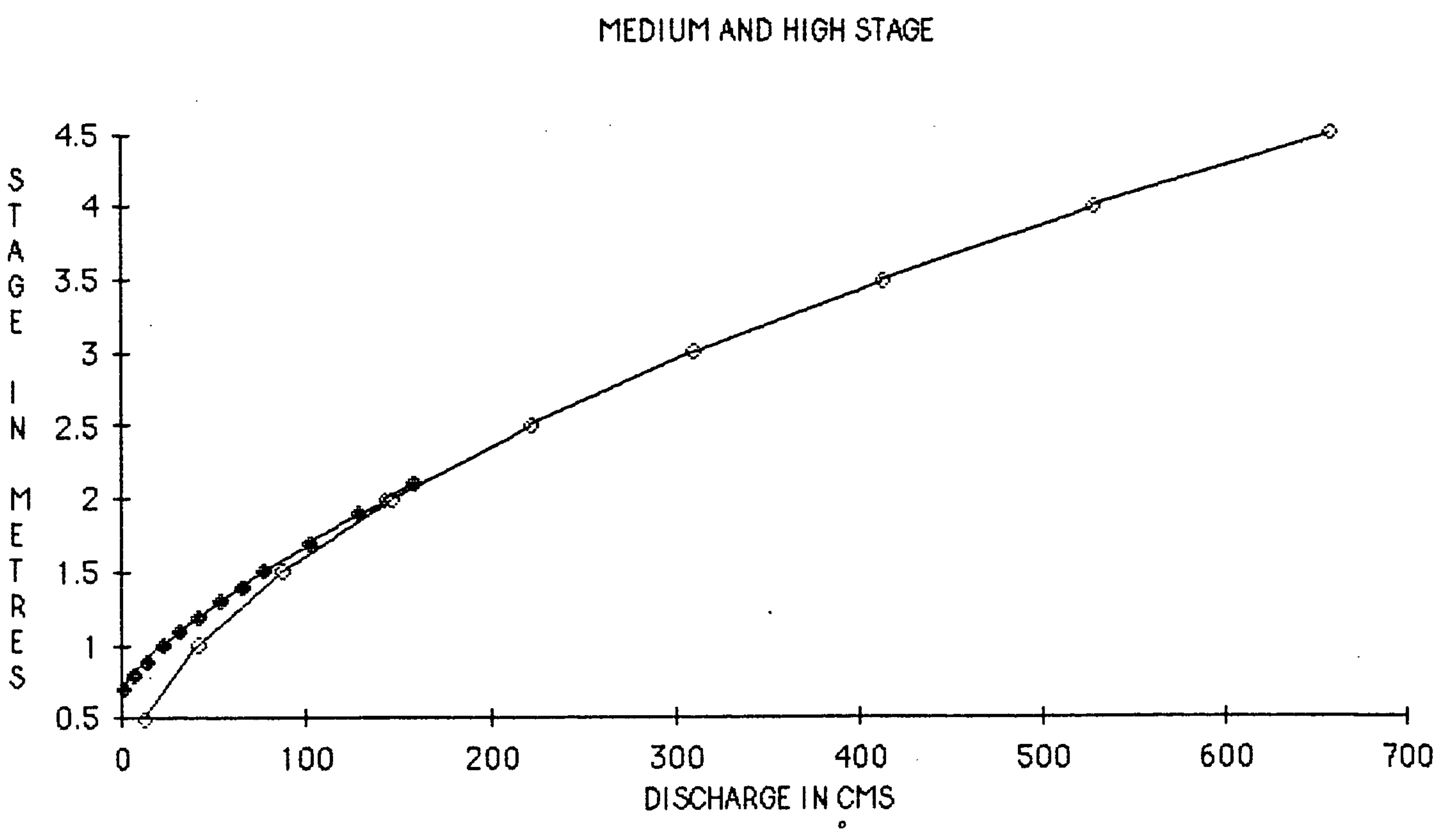


Figure 20 Relationship between the High and Medium Controls of the Rating Curves

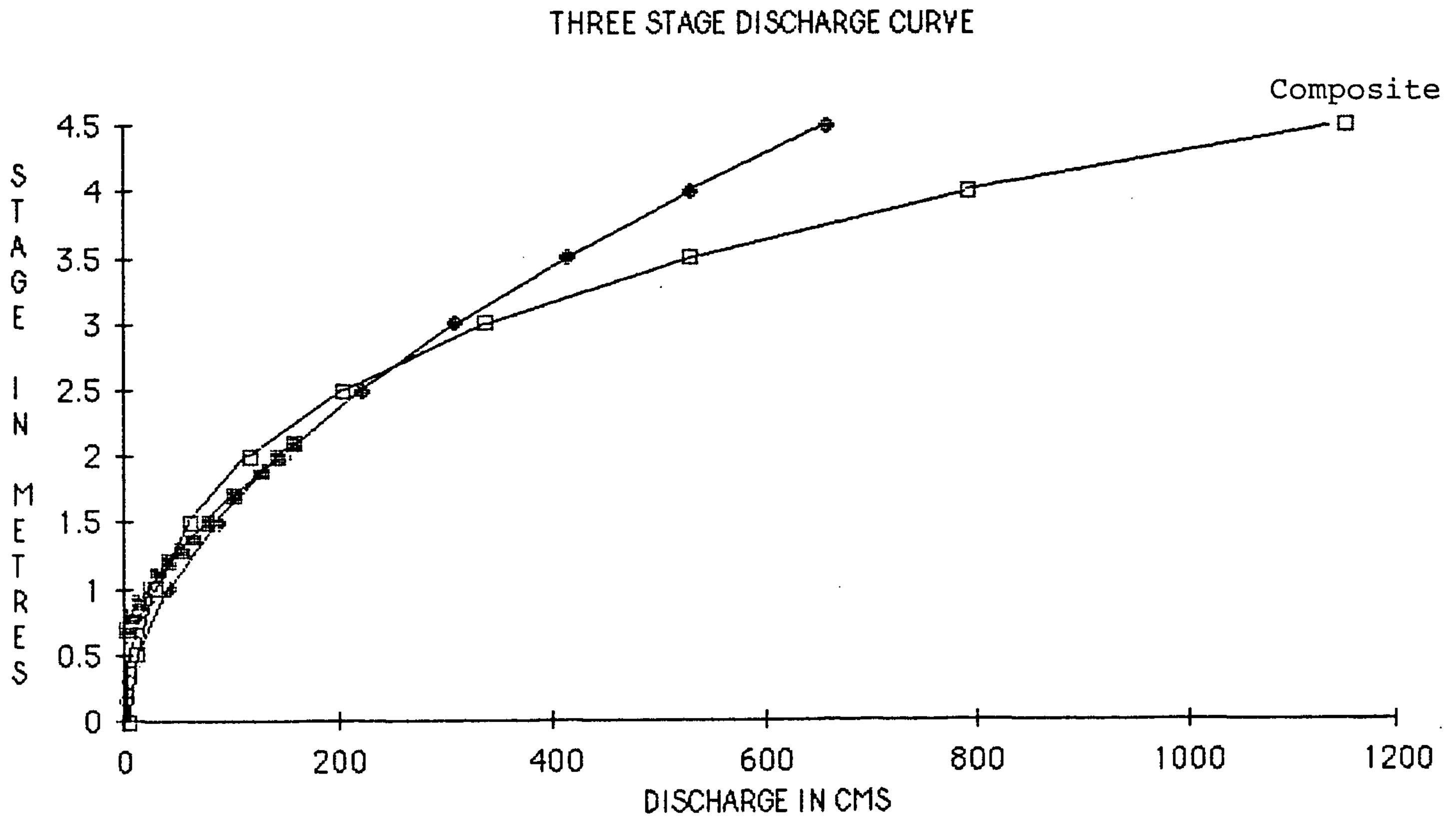


Figure 21 Relationship between the Three Controls and the Composite Curve

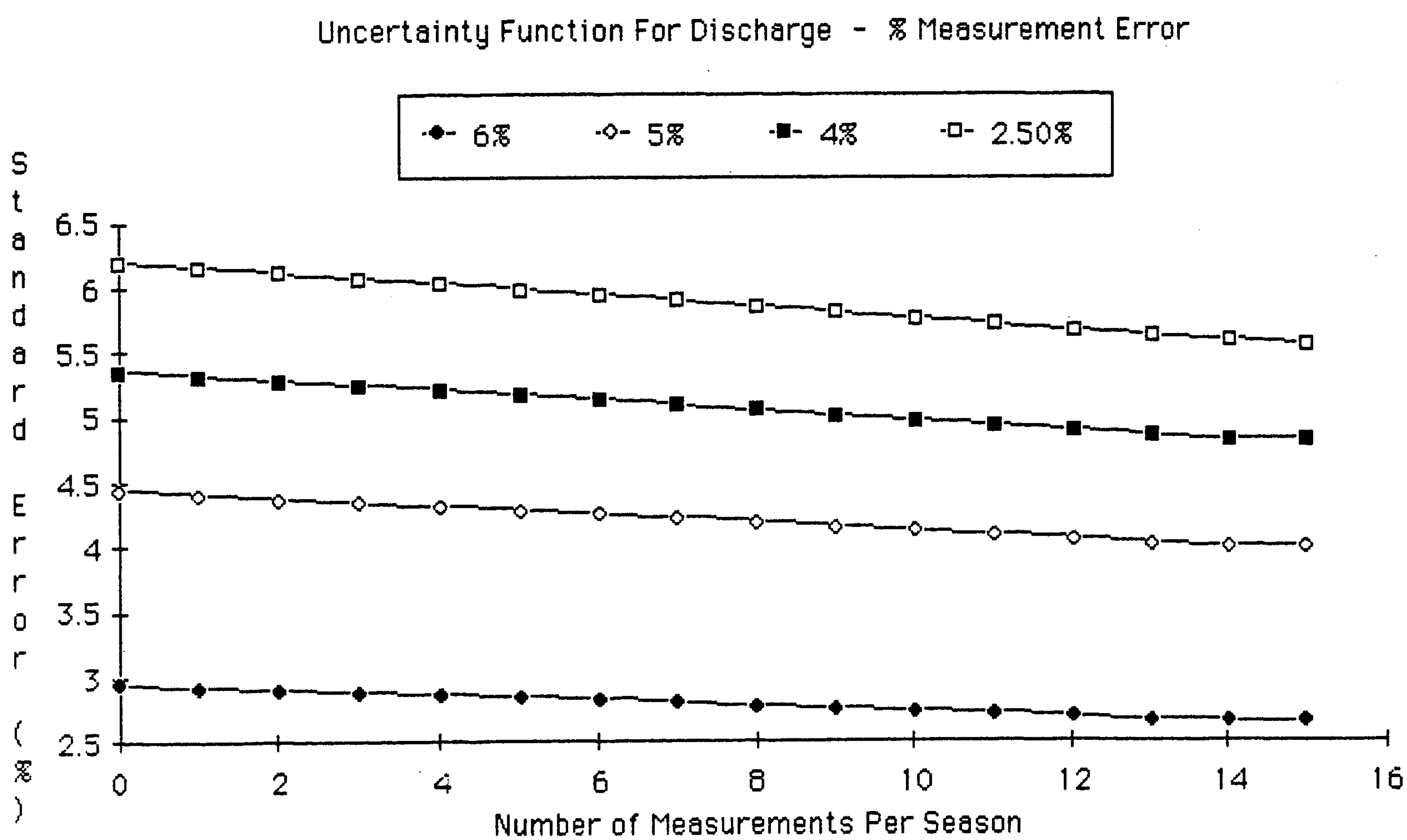


Figure 22 Relation of Standard Error of Data to Number and Percent Error of Measurements

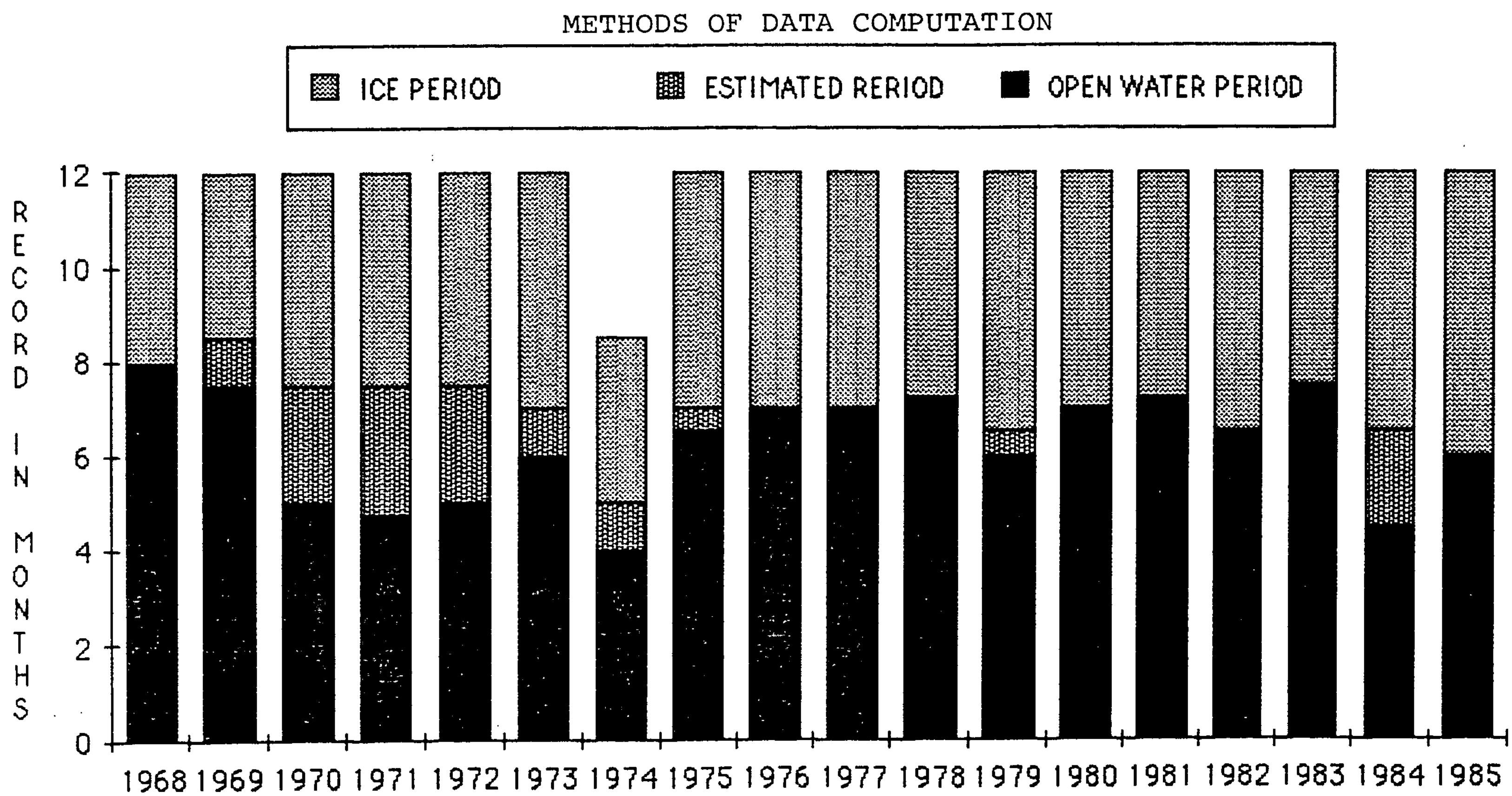


Figure 23 Methods of Data Computation

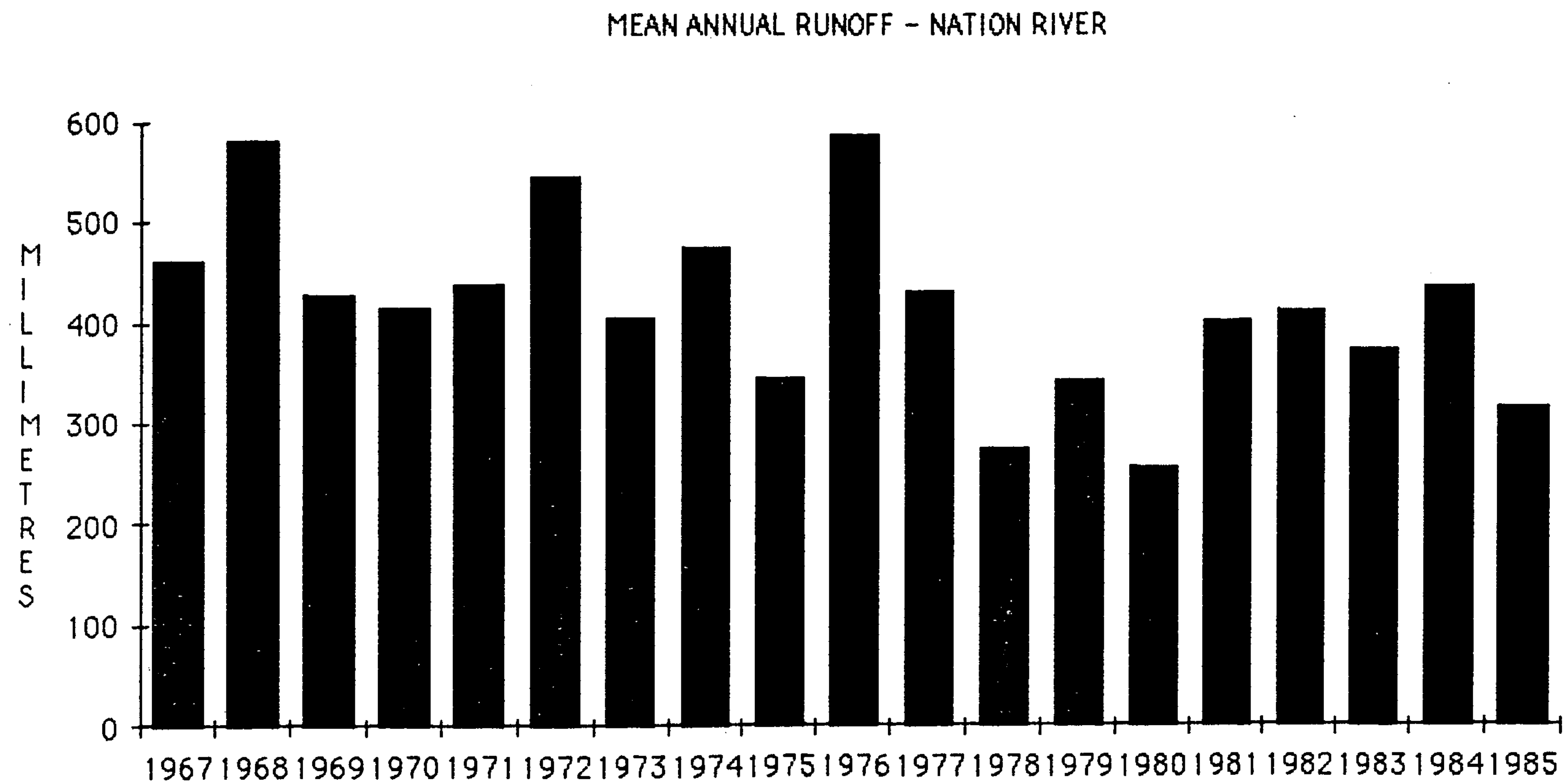


Figure 24 Mean Annual Runoff

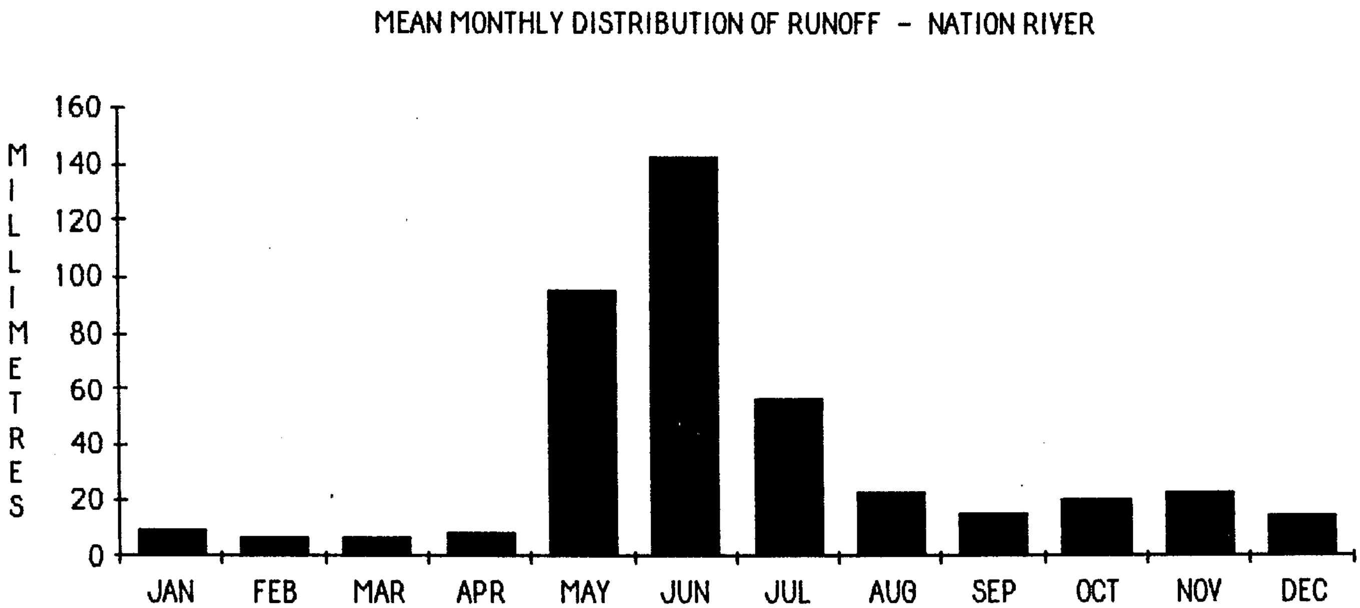


Figure 25 Mean Monthly Distribution of Runoff

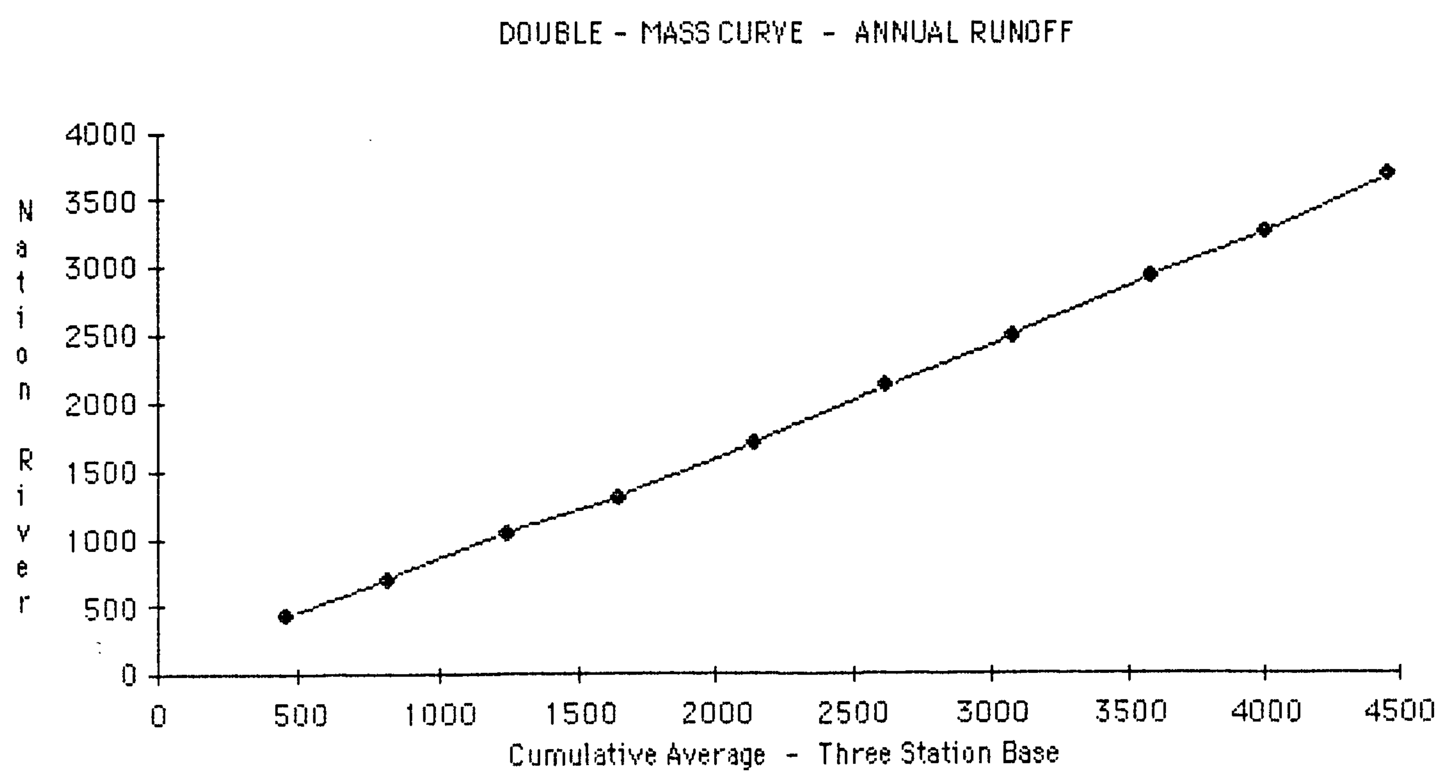


Figure 26 Double-Mass Curve Analysis of Annual Discharge

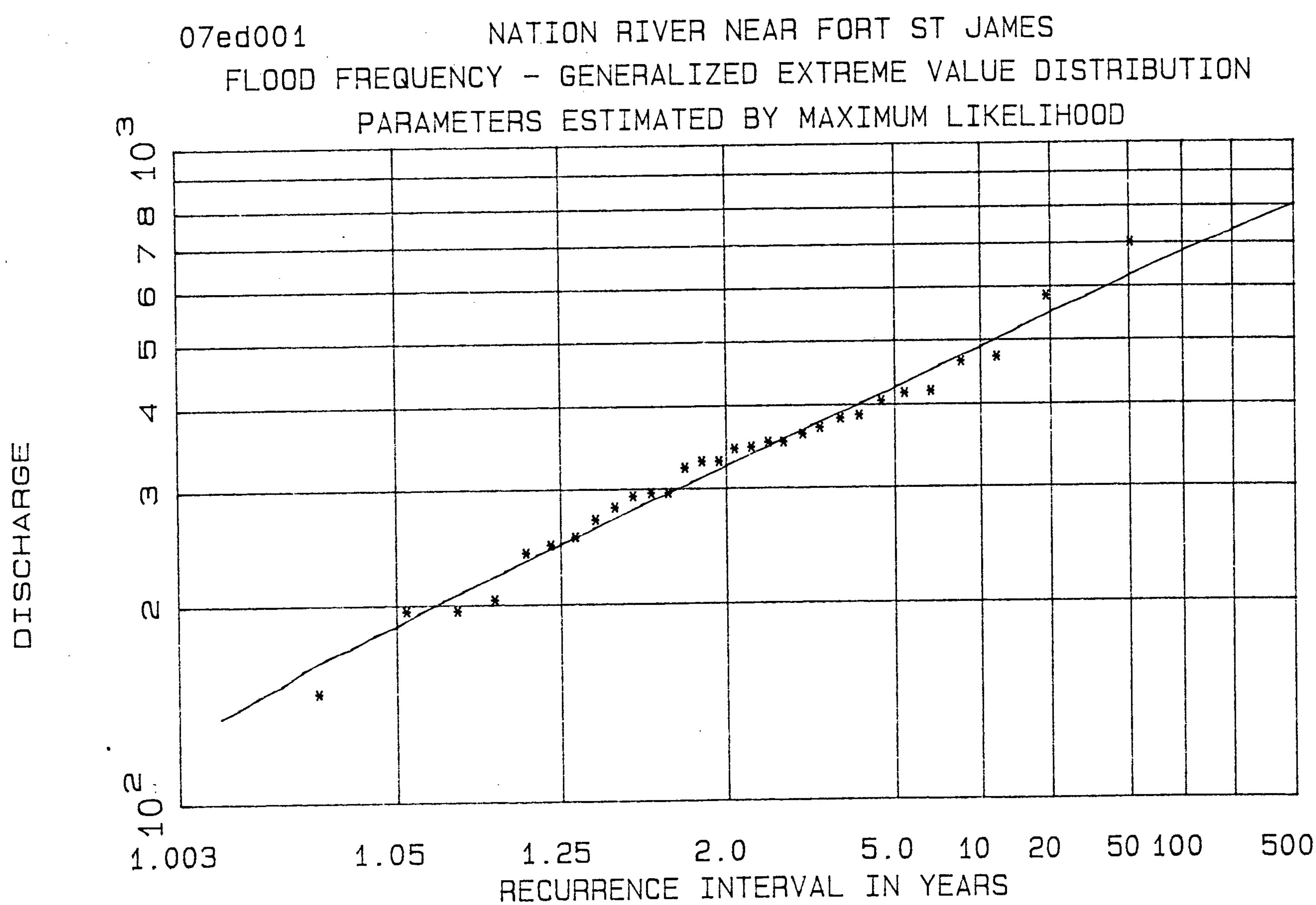


Figure 27 Flood Frequency Curve for Generalized Extreme Value - Maximum Daily Discharge

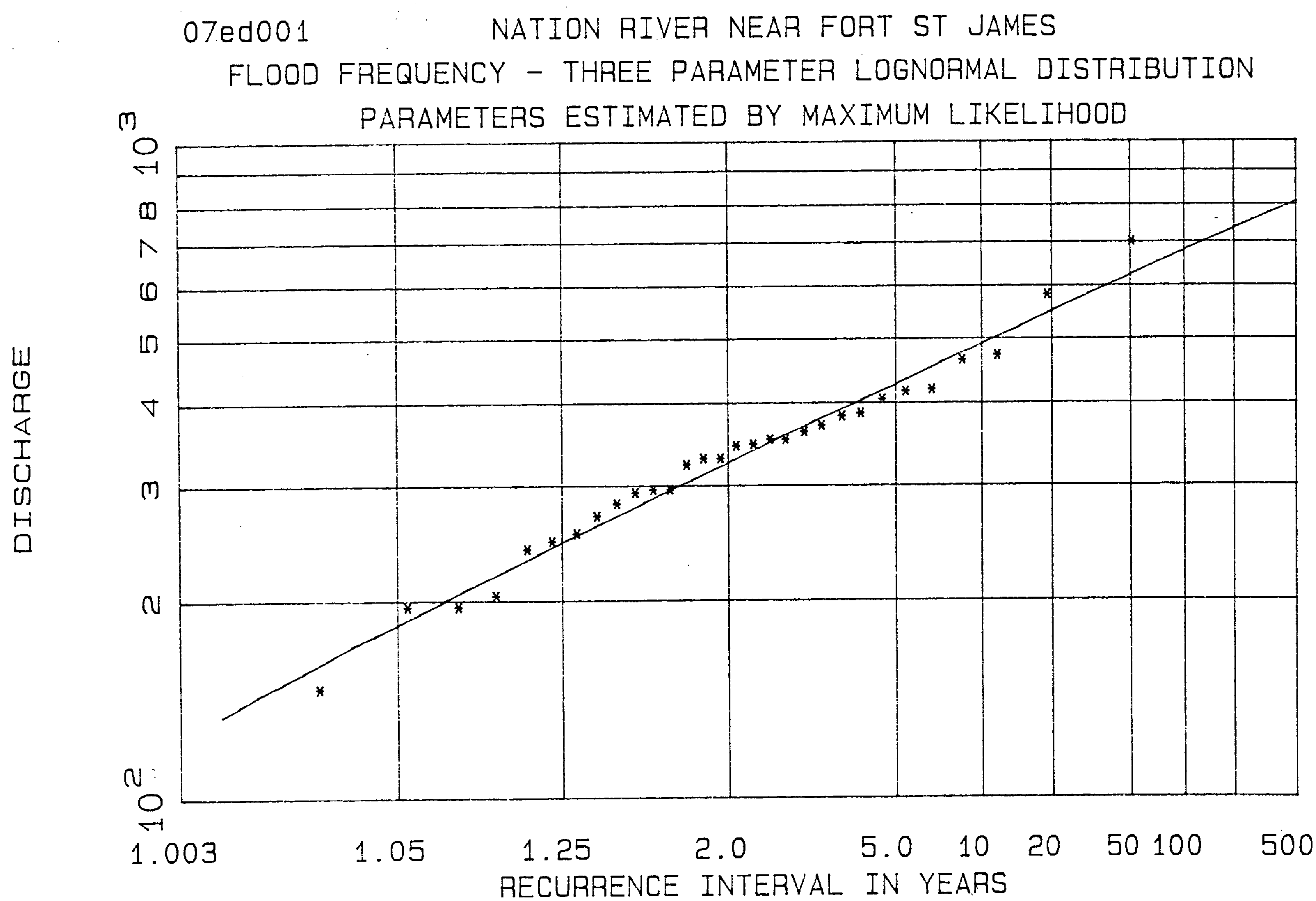


Figure 28 Flood Frequency Curve for Three Parameter Log Normal - Maximum Daily Discharge

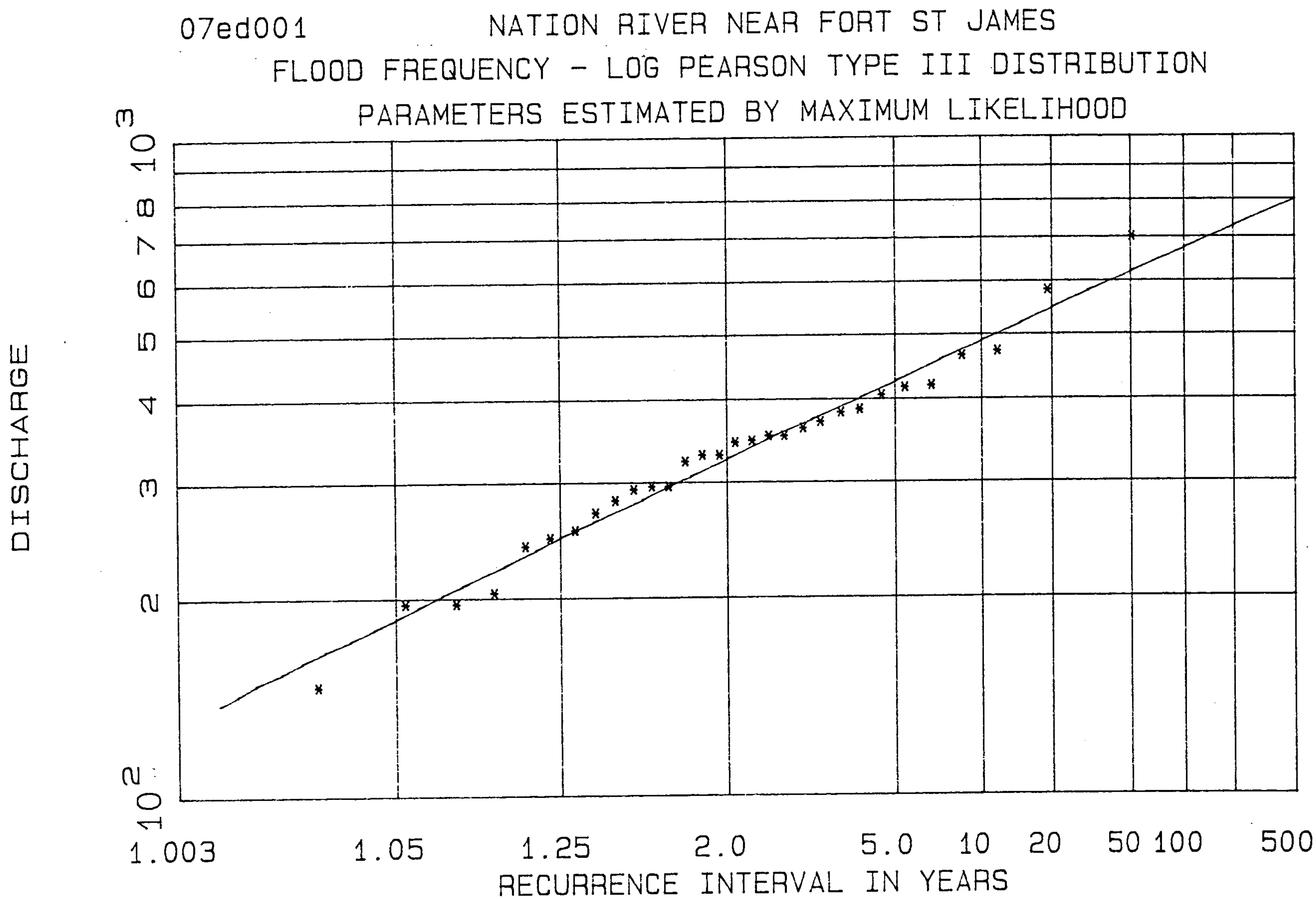


Figure 29 Flood Frequency Curve for Log Pearson III - Maximum Daily Discharge

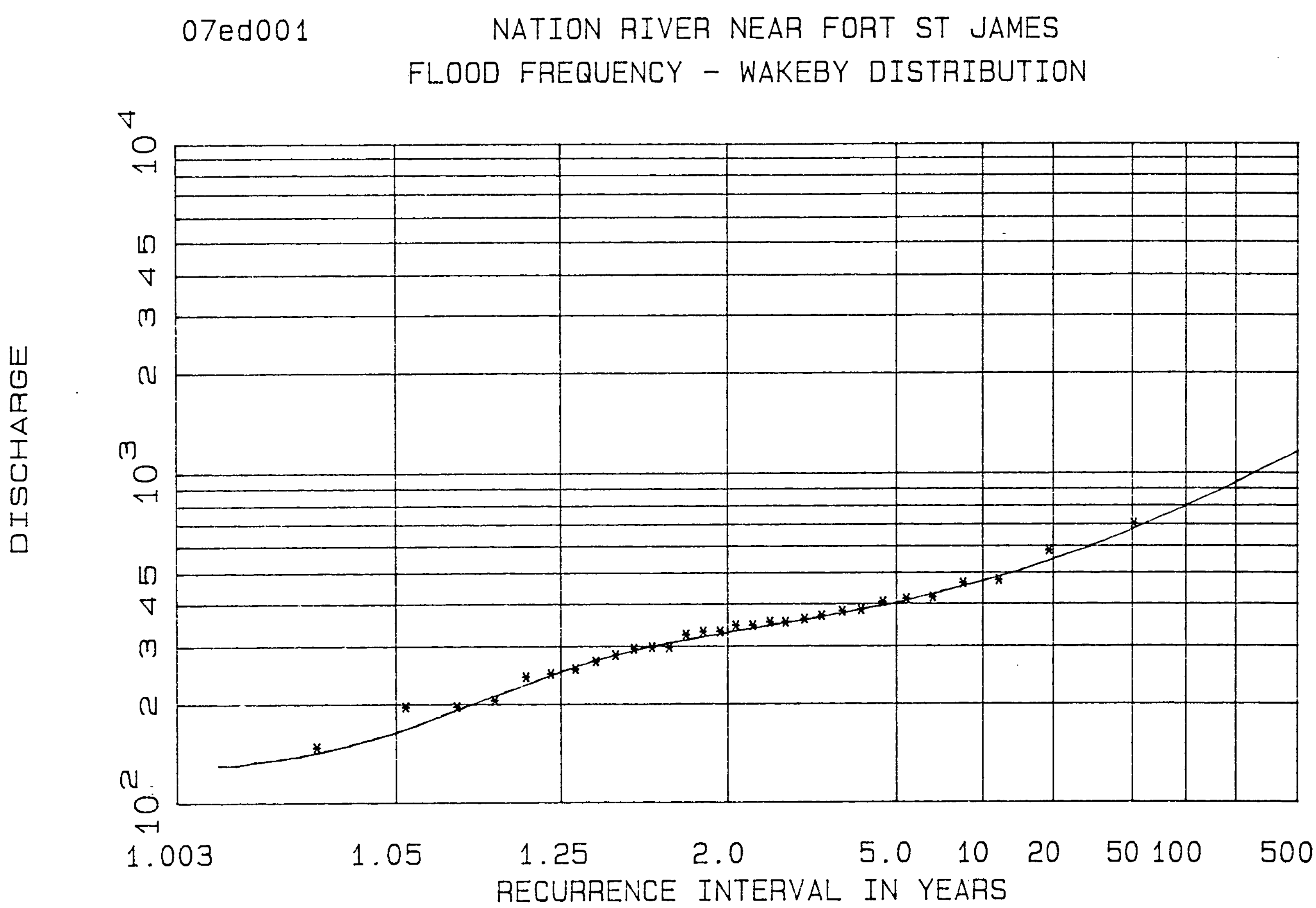


Figure 30 Flood Frequency Curve for Wakeby Distribution - Maximum Daily Discharge

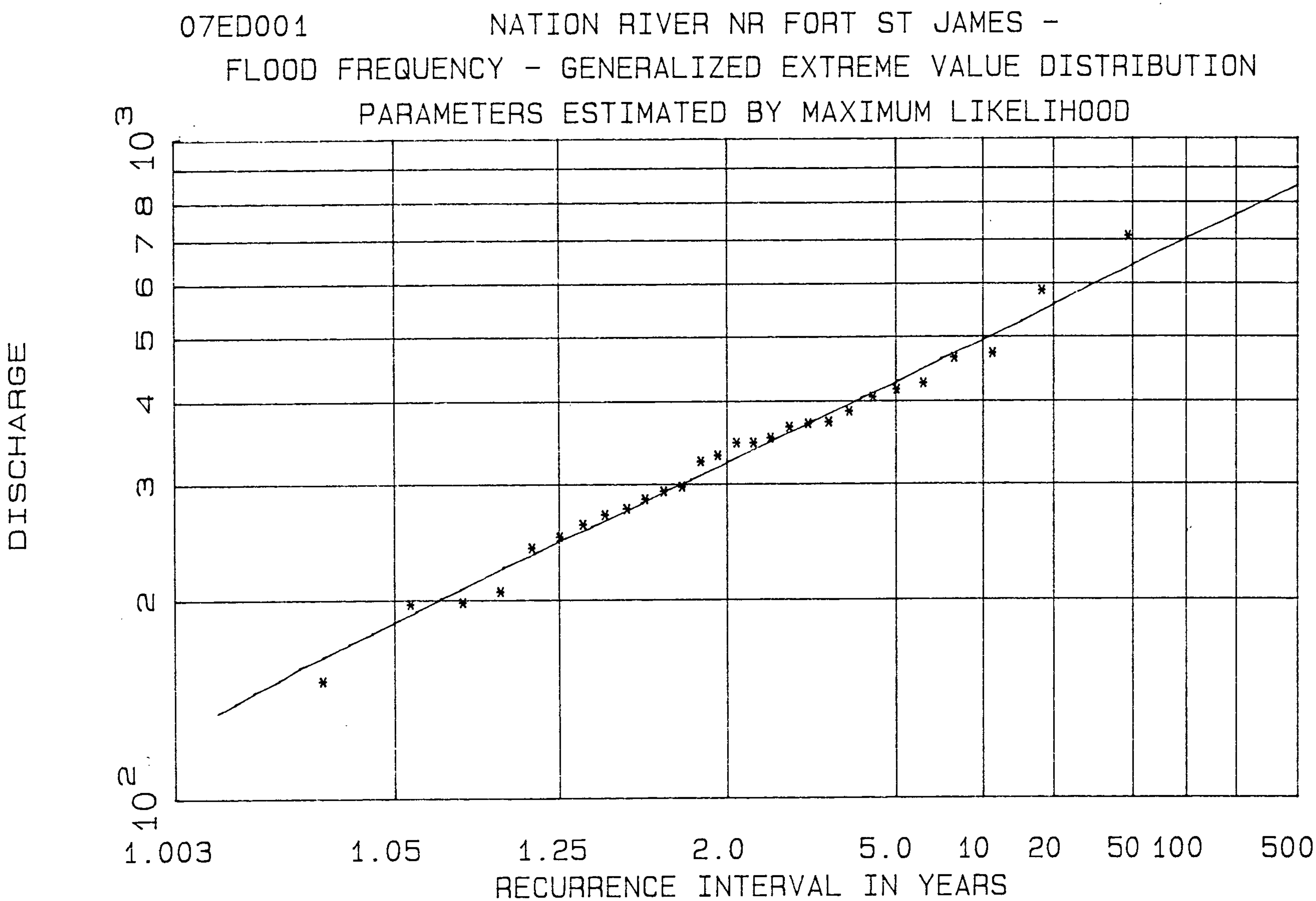


Figure 31 Flood Frequency Curve for Generalized Extreme Value Distribution - Maximum Instantaneous Discharge

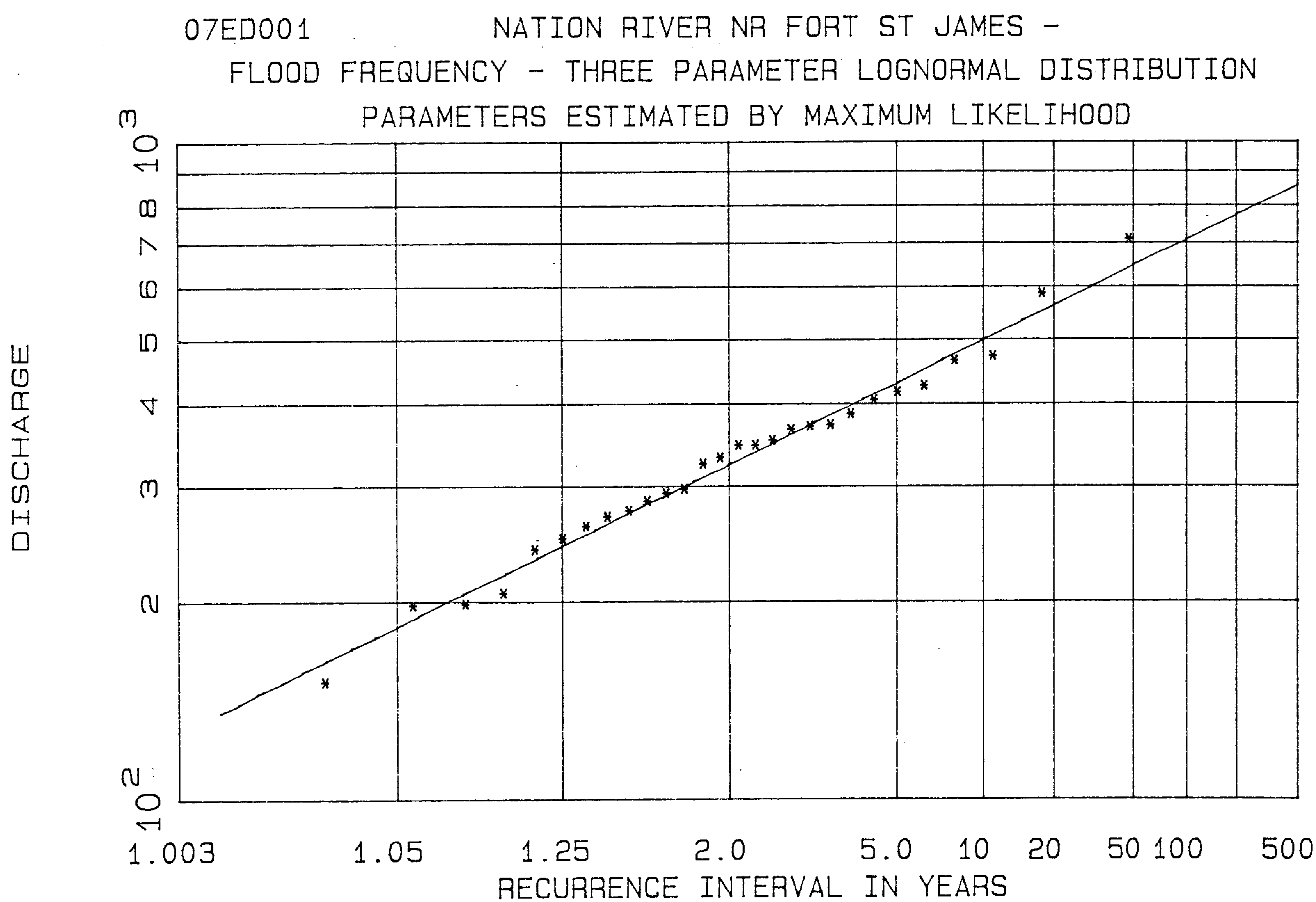


Figure 32 Flood Frequency Curve for Three Parameter Log Normal - Maximum Instantaneous Discharge

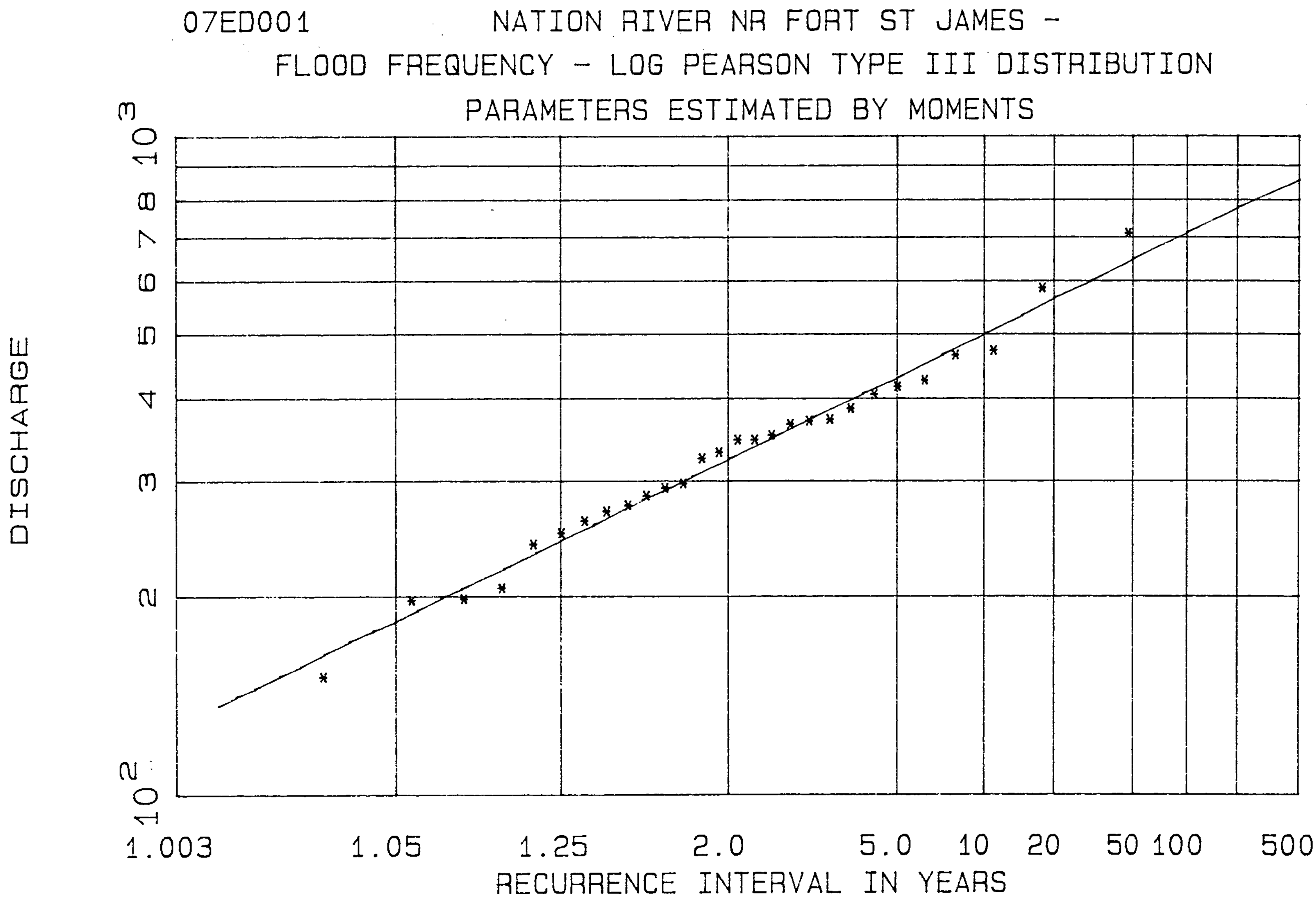


Figure 33 Flood Frequency Curve for Log Pearson III - Maximum Instantaneous Discharge

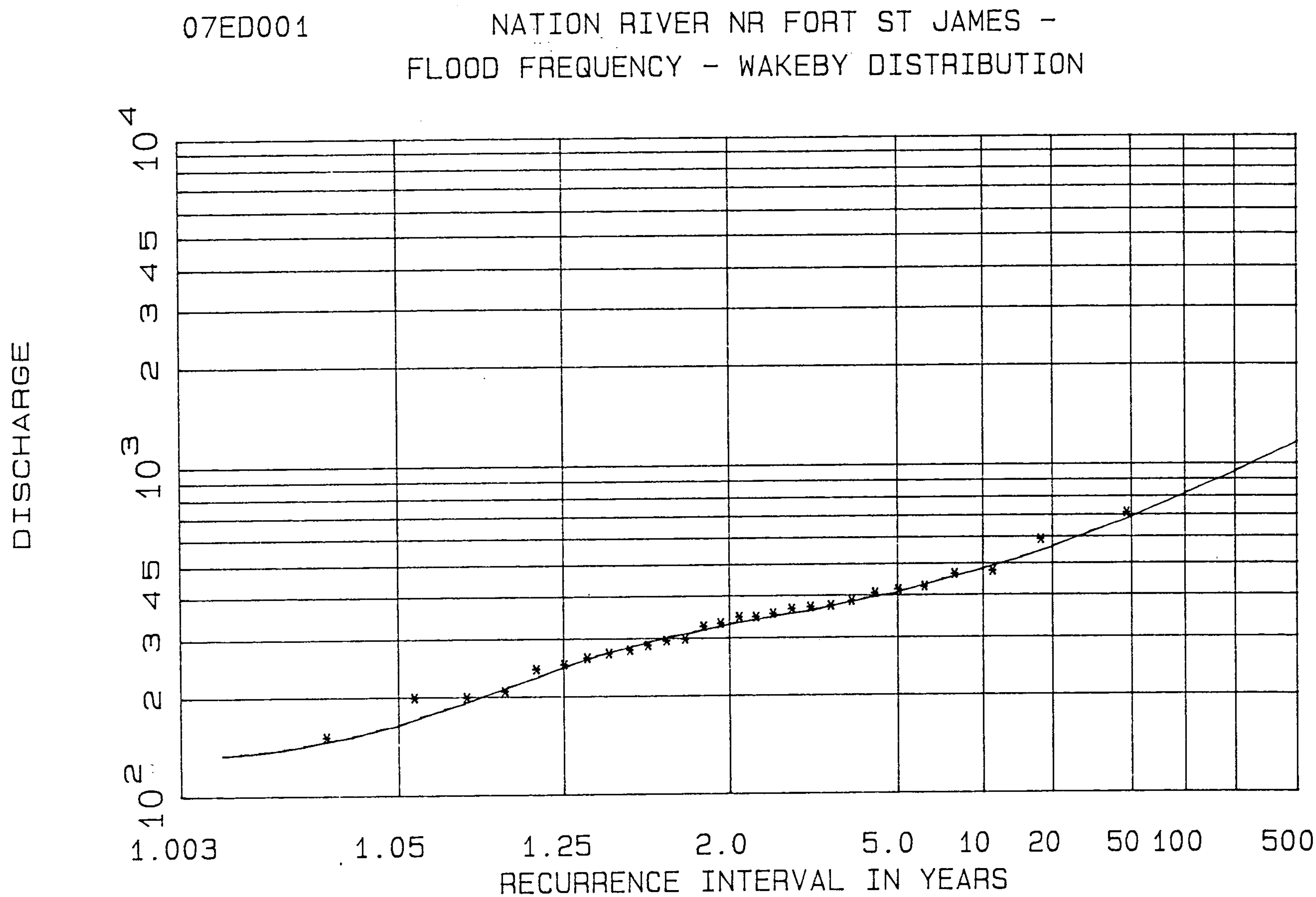


Figure 34 Flood Frequency Curve for Wakeby Distribution - Maximum Instantaneous Discharge

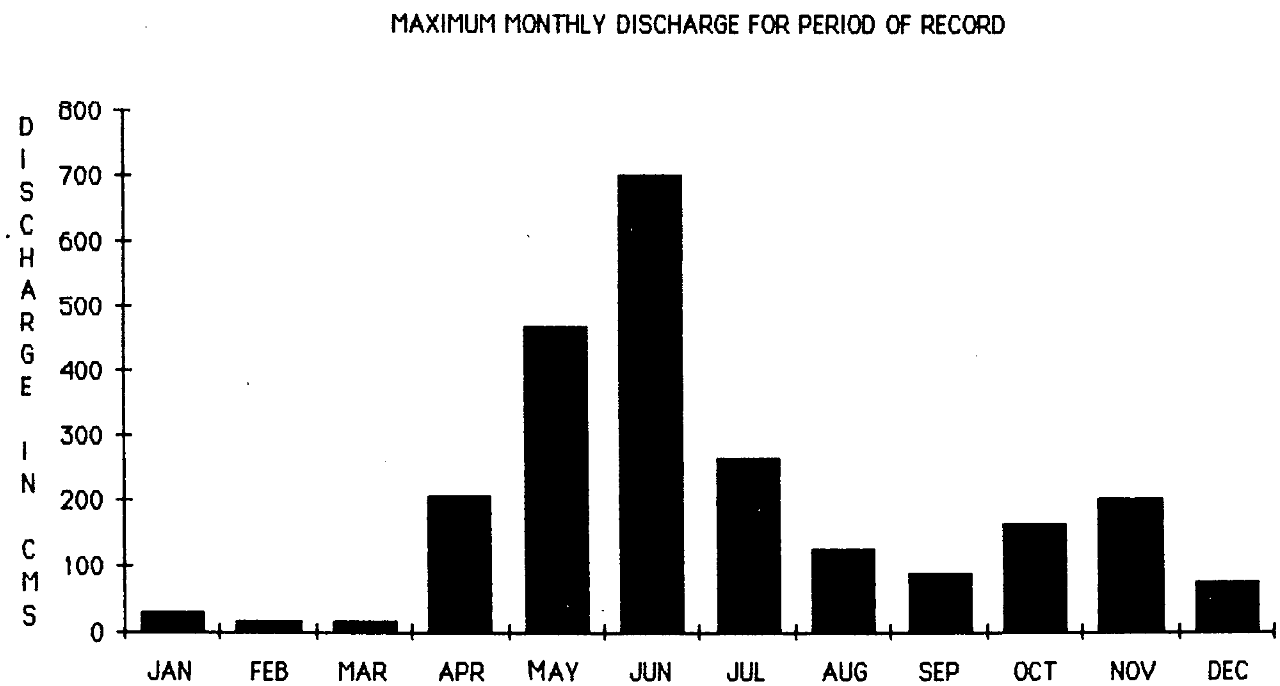


Figure 35 Distribution of Monthly Maximum Daily Discharge for Period of Record

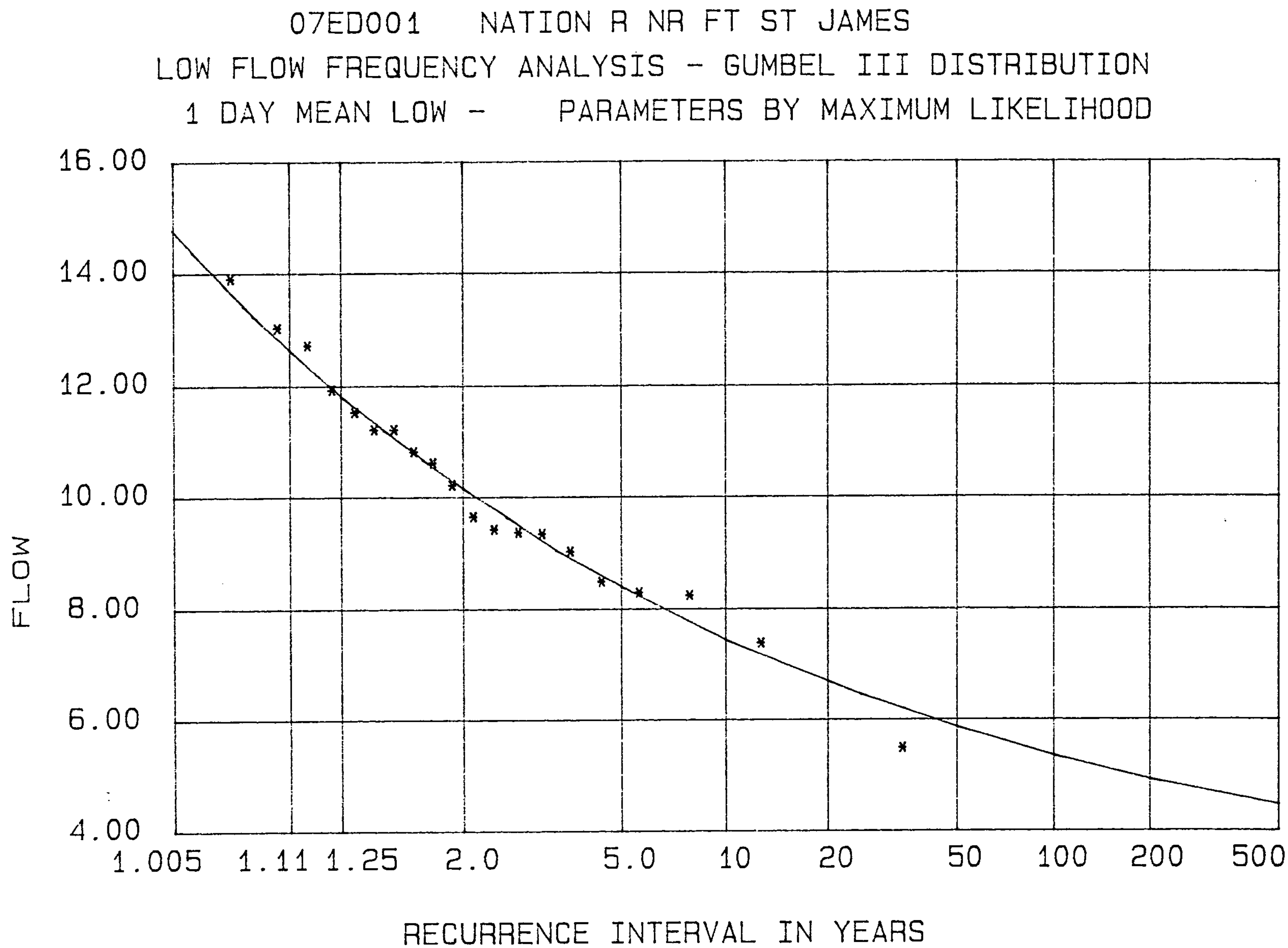


Figure 36 One Day Low Flow Frequency Curve for Gumbel III

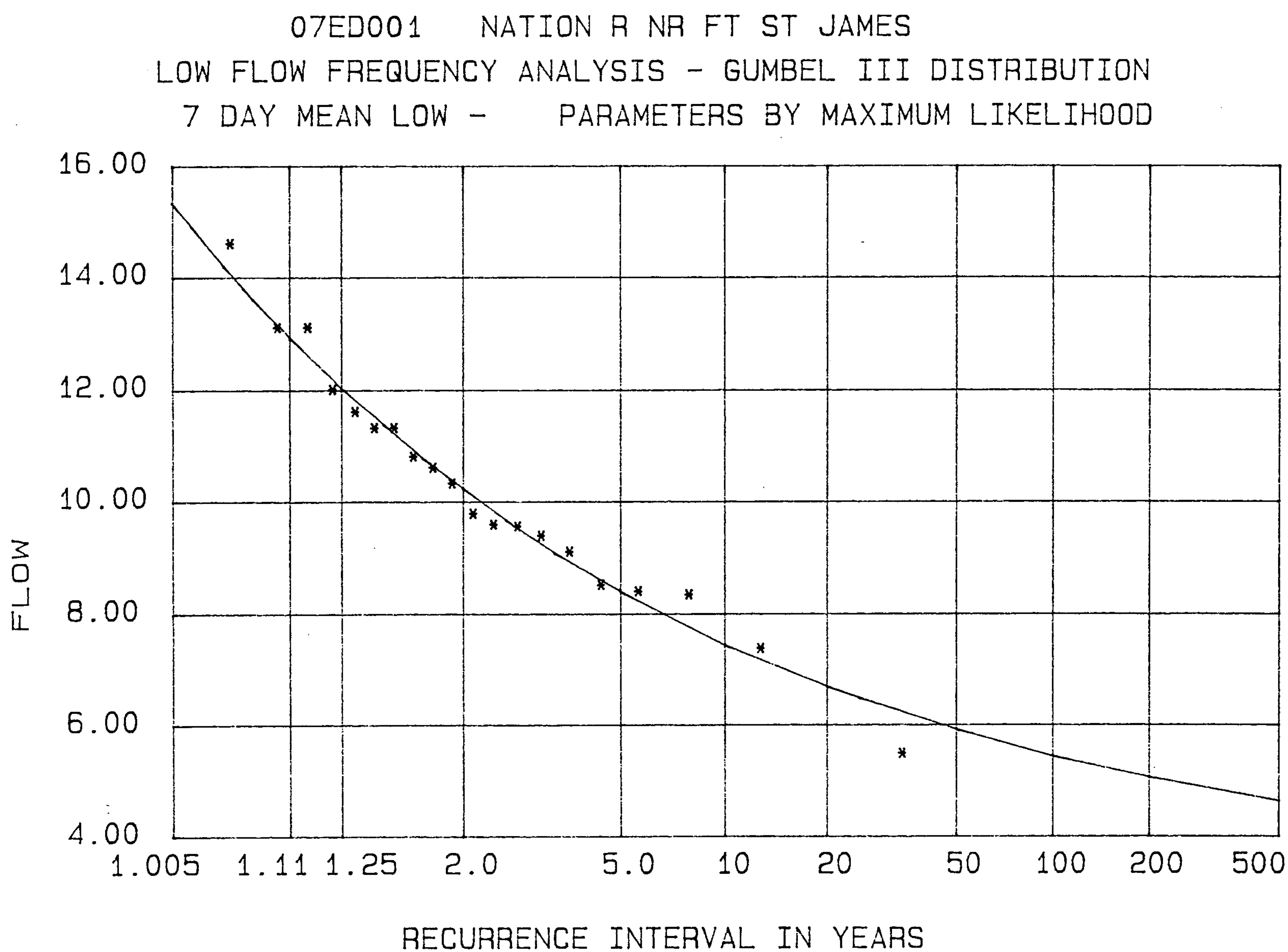


Figure 37 Seven Day Low Flow Frequency Curve for Gumbel III

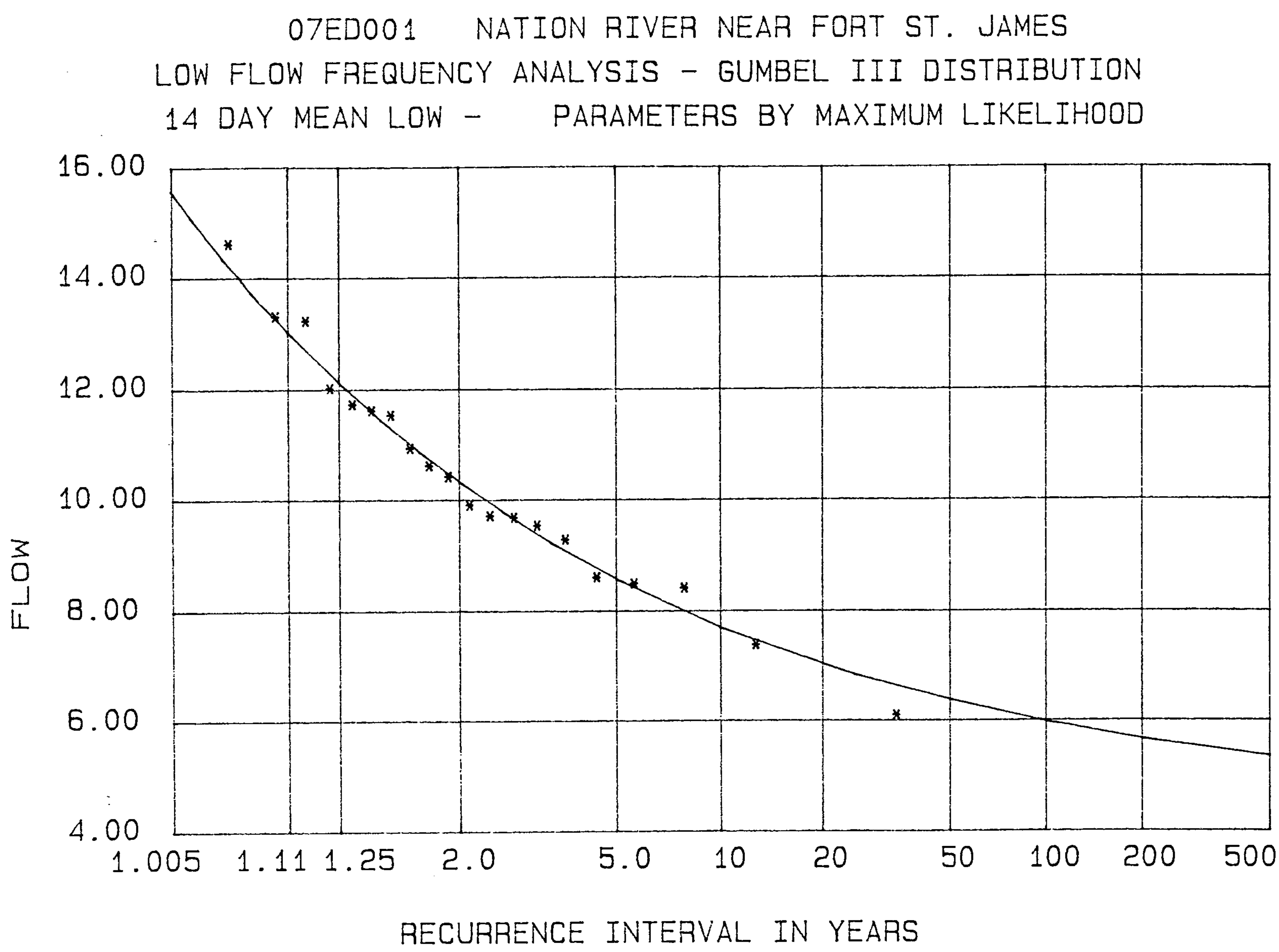


Figure 38 Fourteen Day Low Flow Frequency Curve for Gumbel III

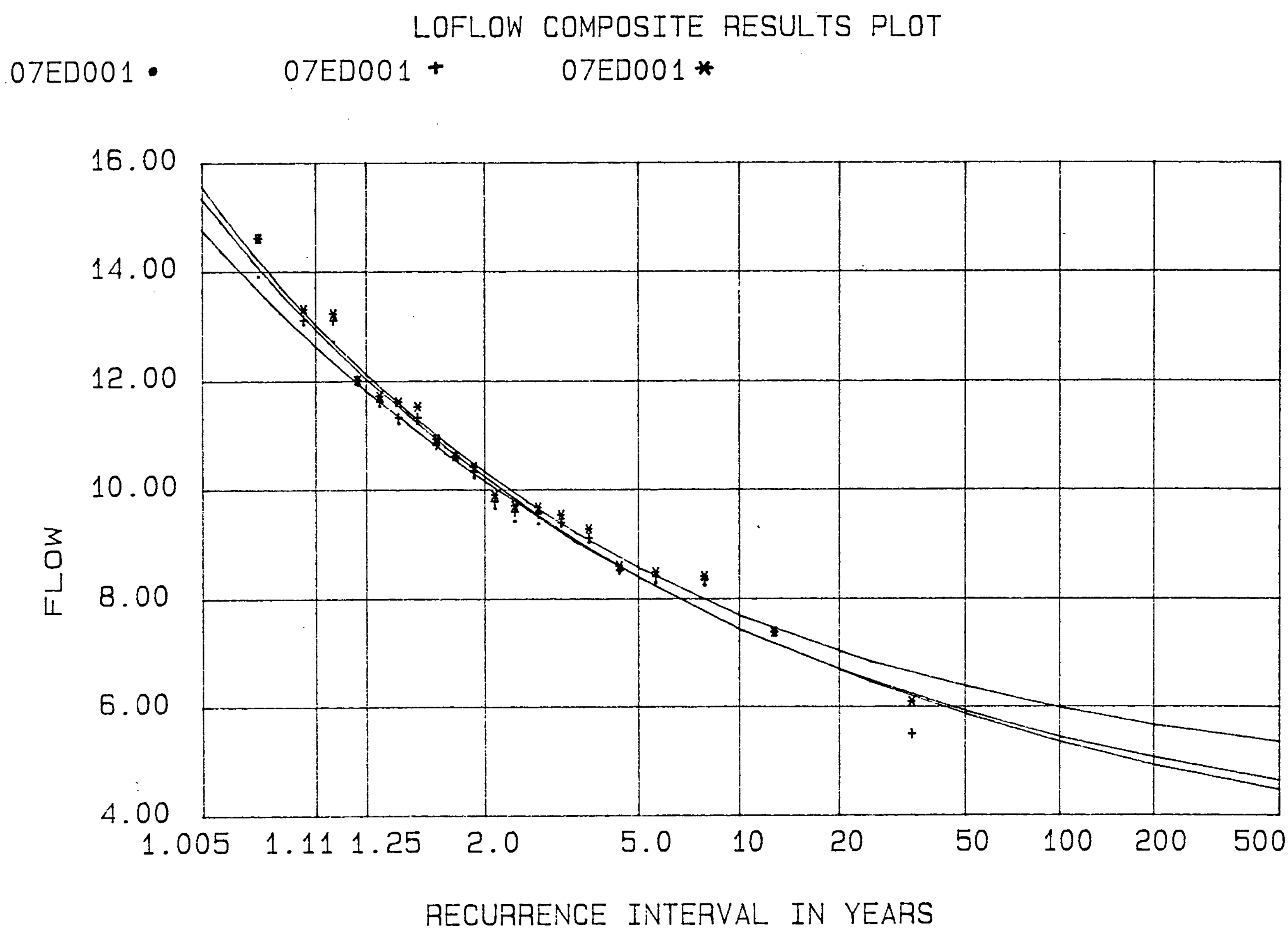


Figure 39 One, Seven, and Fourteen Day Low Flow Frequency Curves for Gumbel III

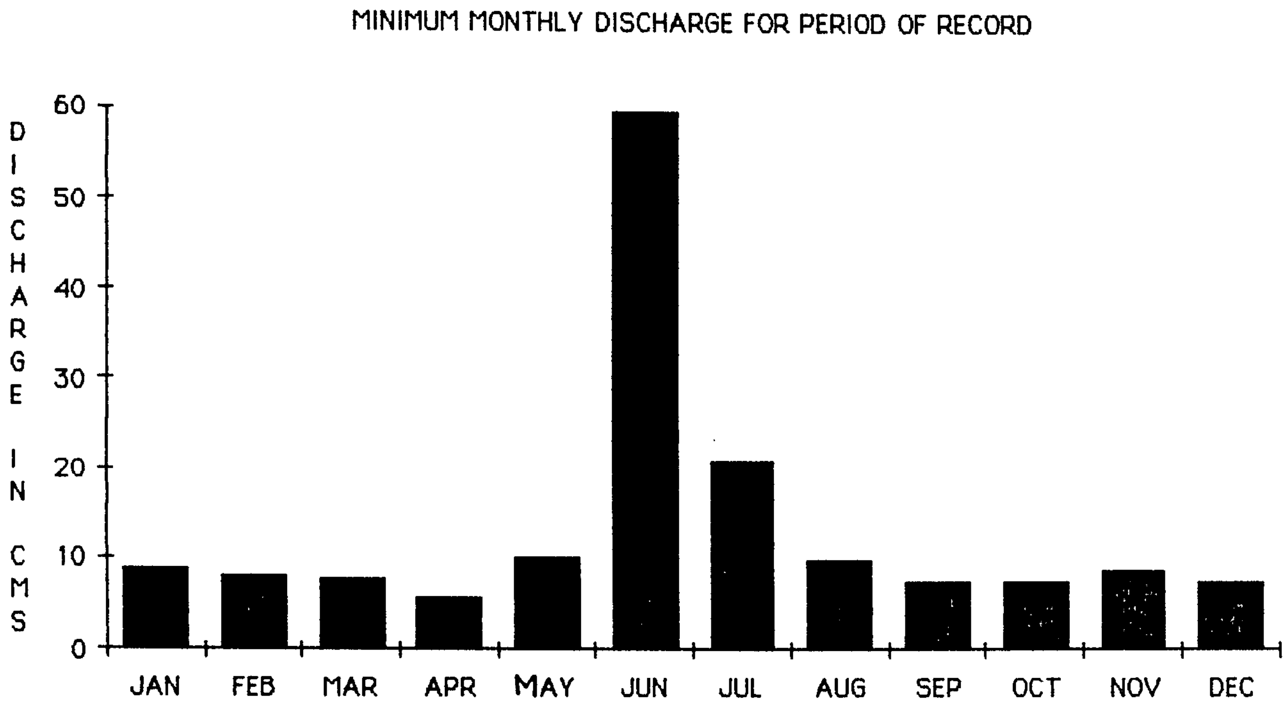


Figure 40 Distribution of Monthly Minimum Daily Discharge for Period of Record

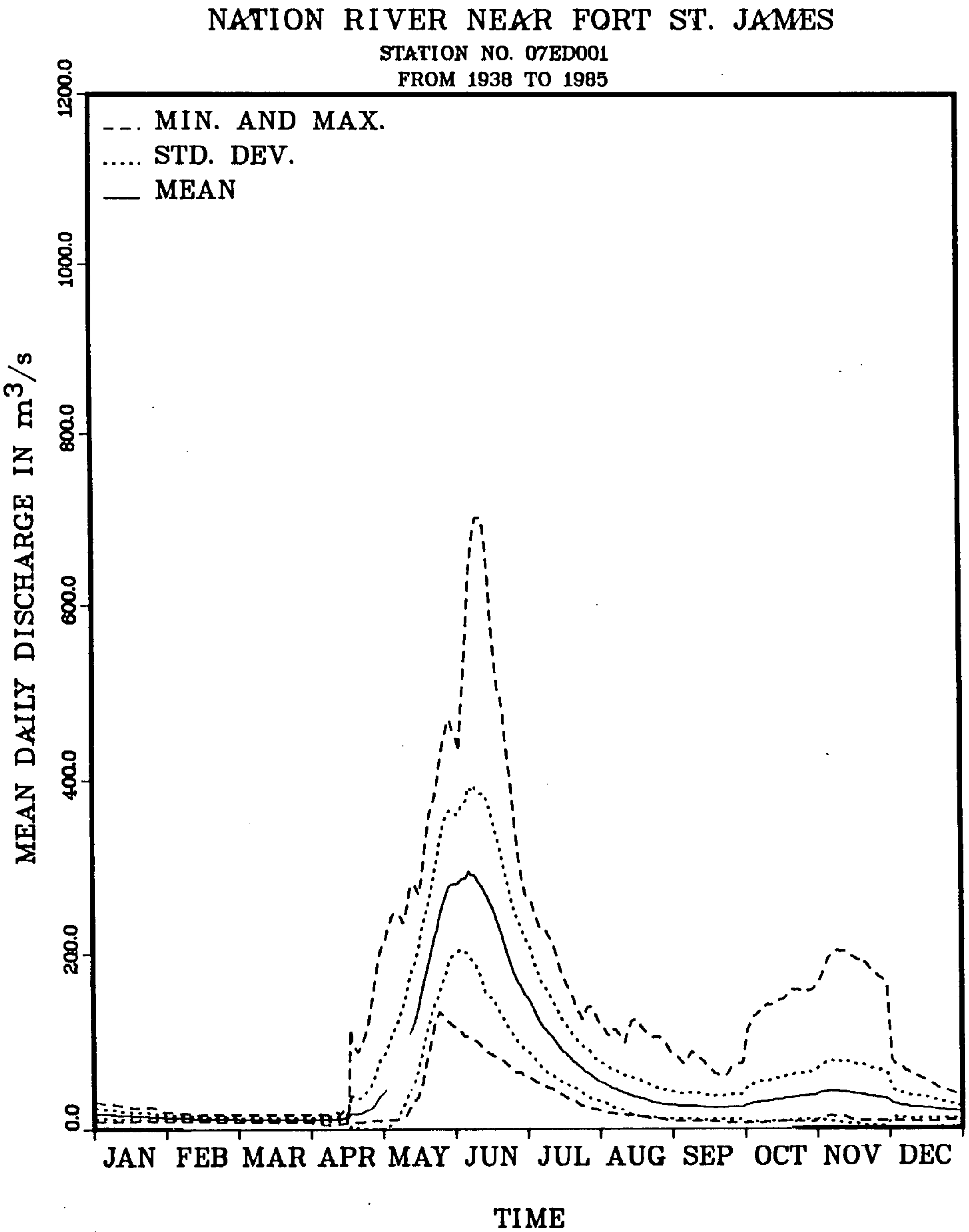


Figure 41 Hydrograph of the Maximum, Minimum, Mean and Standard Deviation of the Daily Discharge

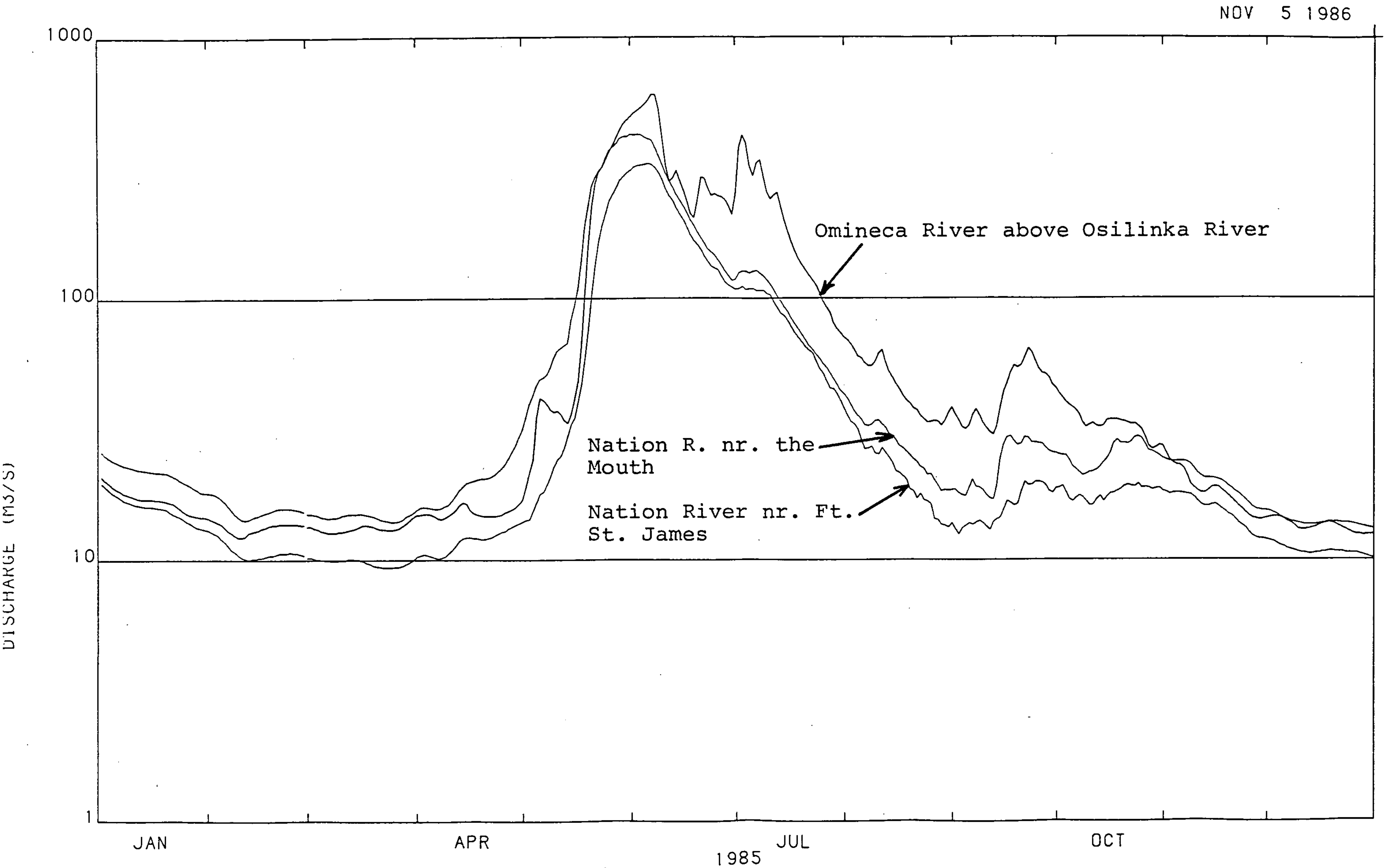


Figure 42 Hydrograph for Nation and Omineca Rivers for 1985

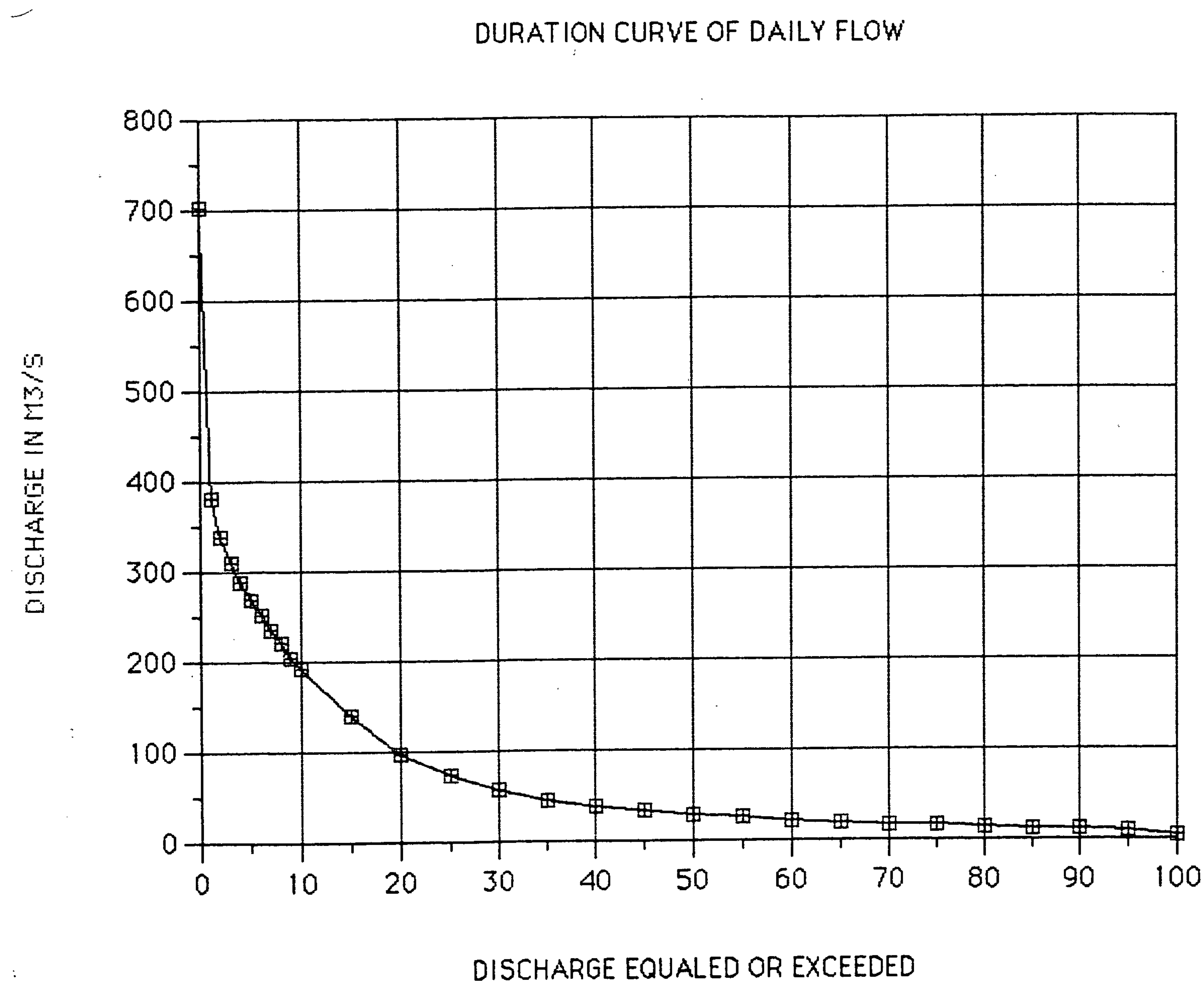


Figure 43 Duration Curve of Daily Flow