Station Evaluation

More Creek near the Mouth

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STATION EVALUATION
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ABSTRACT

The streamflow data collected at this station has been analyzed in this report. Rating curves, both high and low ranges have been inspected for appropriate extensions. The high and mean flow 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.

Over one half of the record has been estimated which includes the ice period (39%) and periods during open water (12%) where no stage data has been obtained. One third of the peak flow record has been estimated from rating curves extended more than two and a half times the value of the highest measured flow.

Further analysis of peak flow data will not be done until the rating curves have been adequately defined.

Accuracy of the data is limited by site conditions. Streamflow data for the characteristics of minimum and means will not be improved unless a stable control is found or the frequency of measurements is increased.

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 the 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 July 20, 1971 for hydroelectric power studies at the request of G.E. Crippen and Associates acting for B.C. Hydro.

1.2 Basin Description

The creek rises in the Boundary Range of the Coast Mountains between the Iskut and Stikine Rivers. It is a tributary to the Iskut River. See location map in Figure 1.

The gauging station is located 4 kilometres (km) above the confluence of More Creek and the Iskut River. The basin at the stream gauging station has a drainage area of 844 square kilometres (km^2). A stream profile and area-elevation curve are shown on Figures 2a and 2b respectively. There are many glaciers of various sizes in the basin and there is the problem of "jokulhlaups" (the Icelandic term for glacier outburst floods) occurring at times.

Climate

The climate of the basin is dominated by continental influences. The mean temperature for the four winter months is below freezing as shown in Figure 3. The winter continental Arctic air masses move down from the north producing some extremely low temperatures as shown for Telegraph Creek in Figure 4. In the spring and summer these cold air masses are pushed back and the climate warms up reaching temperatures in the mid-thirties. As a contrast, the relatively even climatic regime for Stewart is shown in Figure 5.

Precipitation is generally light in the valley bottoms as shown in the histogram of precipitation in Figure 6. The basin is located in the lee slopes of the Coast Mountains which accounts for the lower precipitation. Precipitation is considerably heavier in the mountains as evidenced by the abundant snow and ice fields. Figure 7 shows a cross section of the Province (Lat. 53° 30' 00" north) relating precipitation to altitude and distance from the sea.

Pacific storms find their way through the mountain to produce October floods. The Nass, Bell-Irving, and Unuk River valleys to the south provide access for these storms.

1.3 Station Description

This station was established July 20, 1971 with a cableway and manometer shown in Figure 8a. The recorder was moved 500 ft. downstream June 15, 1972. A metal Brytex shelter was built on September 11, 1979 to house the recorder. Figure 8b shows a panoramic view of river channel at recorder.

Highwater measurements are made from the cableway. Some cross sections under the cableway are shown in Figure 9 which indicate the stream bed is very unstable and subject to scouring during high flow. Low water measurements are made by wading at various locations above and below the gauge. Wading cross sections are shown in Figure 10. These sections also scour during high flows.

Flow Computations

Gauge heights are computed from an automatic chart trace. Open water discharge values are obtained from a rating curve established each year by an average of five measurements. Flow under ice has been estimated from the use of an average of two measurements per season, air temperatures, and hydrographing with other streams. The recession analysis, as shown in Figure 11, is also a method of estimating flow under ice but has not been used in the B.C.-Yukon District.

2. QUALITY OF DATA

2.1 Derivation of Maximum Flows

An inspection of past rating curves indicates that the control is unstable at the low end as shown in Figure 12, where selected discharges are plotted against stage for the period for which each rating curve has been used. A large scatter shows at low stage on the logarithmic plot of stage versus discharge shown in Figure 13. This graph also indicates that there is a change in control from section to channel at or near the stage of 1.8 metres (m). This change in control has not been recognized or accounted for in the various rating curves. The rating curves have been kept constant at the top end which agrees with the concept that the downstream channel controls the flow and requires a major bank erosion before the rating changes.

The highest discharge measurement taken during the operation of the station was obtained on October 2, 1980 with a flow of 180 cubic metres per second (m^3/s). The maximum recorded gauge height of 6.03 m was obtained on October 8, 1974. A histogram of precipitation which caused the high stage of October 1974 is shown in Figure 14 for Bob Quinn Lake and Telegraph Creek. The discharge at this gauge height was 603 m^3/s estimated by extending the rating curve above a measured discharge of 169 m^3/s which is a long extension of the rating curve. The highest measured flow and estimated peaks are shown for each year in Figure 15.

The rule of thumb for estimating high flow is that the estimated flow should not exceed double the highest measured flow that was used to establish the rating curve. Figure 16 indicates the relationship of the extended rating curve #5, computer extension of curve #5, and the extended composite curve at all open water measurements. The composite curve is to the right of the extended rating curve #5 giving a peak flow over 30% higher than originally estimated, as shown in Table 1. There are four estimated high flows during the period of record that could possibly range from 20 to 30% lower than the actual flow.

Double-Mass Curve Analysis

The streamflow records are free of any influence of storage or diversion. There are no changes in basin runoff characteristics due to logging, forest fires or mining. Assuming 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 five gauging stations with fourteen years of concurrent record from 1972 to 1984. These stations are listed in Table 2 and their locations are shown in Figure 17.

The cumulative annual maximum discharge per square kilometre of drainage area for the station More Creek near the Mouth was plotted against the cumulative average annual maximum daily discharge per square kilometre of drainage area for all five stations as shown in Figure 18. More Creek shows some changes in slope but they are not significant on the basis of a variance-ratio test (F-test).

The relationship of the published annual maximum instantaneous discharge to the published annual maximum daily discharge is shown in Figure 19 and the ratio of the two is: for snowmelt peaks 1.17; for rainstorm peaks 1.44.

Table 2 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 not been adequately defined leaving some question as to the validity of at least four of the twelve estimated peaks.

The uncertainty function program was used to calculate the accuracy of the stage-discharge relationship. The parameters used in the study are the number and accuracy of measurements and the accuracy of the stage-discharge relationship during the open water period. The standard error for the discharge measurements is set at 5% to account for any unusual measuring conditions. No loss of record was considered. The standard error is shown in Table 3 and Figure 20, corresponding to the number of measurements required to obtain that standard 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 eleven year period was 61, which averages to 5.5 per season. The standard error as indicated in Table 3 for 5.5 measurement is about 16.5%. The latter period of record for the gauging station Tulameen River near Princeton (1974-1984) had a standard error of approximately 14% for the same number of measurements. To obtain the same standard error as the Tulameen River data, a mimimum of eight measurements would be required each year during the open water period.

2.2 Derivation of Minimum Flows

Minimum flows have occurred from freeze-up in fall to early spring. Nearly all of the annual minimum flows have been obtained under ice cover. For two-fifths of the year this stream is under ice as shown in Table 4. Records for the period affected by ice are estimated by the use of two measurements, comparing hydrographs of other stations, and temperatures recorded at Bob Quinn Lake. A more reliable means of estimating flow under ice is by the use of recession analysis or by use of a flow model. The ice measurements would need to be timed better in order to make maximum use of the above methods.

The lowest discharge measurement to date was made January 12, 1972 for a flow of 3.48 m^3/s. The minimum flow on record is 2.58 m^3/s estimated for the period of March 8, 1972.

Assessment of the Quality of Minimum Flows

The section control is subject to considerable shifting as indicated in Figure 12. The shifts in control are adjusted from measurement to measurement. When there are long periods between measurements, adjustments are not always reliable. There have been thirteen rating curves developed for twelve years of record which means at least one shift per year.

A shifting control does not always mean poor record. It is a matter of how well the measurement program is planned. The standard error as shown by the uncertainty function program is a means to assess the quality of data as shown in Table 3.

The ice period record is an educated guess guided by, at most, two measurements, temperature data and hydrographs from neighbouring stations. The ice period each year as shown in Table 4 averages 5.5 months per year. The ice period together with the missing data periods which have been estimated make up 50% of the record produced from this station. This is shown graphically in Figure 21.

2.3 Derivation of Average Flow

The mean annual discharge for the period of record is 47.7 m^3/s (10 years). The shifting control is not expected to have a significant effect on the average flow.

Open water record estimation has amounted to 12% of the total record produced. For example, in the calendar year of 1984, which is the worst year, 73 days of record were actually recorded; 182 days of ice period and 111 days of open water flow were estimated. Lost records are due to equipment malfunction such as dead batteries, faulty motors, loose jewel bearings and jammed gears.

The volume of runoff (June to September) is approximately 75% of annual runoff. Figure 22 shows the annual and monthly distribution of runoff for this station. Volume of runoff for the ice period averages approximately 8% of the annual runoff.

Double-Mass Curve Analysis

Assuming that a constant ratio of cumulative annual runoff (in millimetres) 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 the five gauging stations, listed in Table 2, with thirteen years of concurrent record from 1973 to 1985. The cumulative mean annual runoff in millimetres for More Creek was plotted against the cumulative average annual runoff for all five stations. The results are shown in Figure 23. More Creek shows some minor changes in slope but they are not significant on the basis of a variance ratio test (F-test).

Assessment of the Quality of Average Flow

The quality of the mean annual discharge would not be adversely affected by the shifting control at the lower stages or the undefined upper end of the rating curves because the volume of the extreme high and low flows amounts to a small percentage of the average discharge.

2.4 Summary

The reliability of the stage-discharge relationship for the lower stages is poor. The control is in a continual process of shifting caused either by high water or ice. The top end of the rating curve, although held fairly constant, has never been defined by measurements. Some estimated high flows have been obtained from extending the rating curve by over three times the highest measured discharge. Until the high flow data has been verified it should not be used for further analysis.

Low flow data will not be improved until a stable control is found although some improvement will be obtained by use of a model for estimating flow rates under ice.

2.5 Recommendations

If possible the station should be relocated to a section with a stable control. A stable control would reduce the number of measurements required to produce good records. Since this is a fly-in station, operational costs could be significantly reduced.

The high end of the rating curves must be defined as soon as possible in order to verify the peak flow data. The slope-area method could possibly be used on this stream. The low end of the rating curves requires more measurements to define the shifts in control and to reduce the standard error.

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 during ice periods. A measurement should be obtained as soon as possible after freeze-up occurs to aid in the use of either of the above analyses.

3. STATISTICS OF DATA

3.1 Statistical Structure of Selected Streamflow Characteristics

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

Population Statistics

The best estimates of 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:

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

The values are listed in Table 5.

3.2 Non-Parametric Statistical Tests

The streamflow characteristics of 1 and 7 day low flows have been tested by non-parametric tests for independence, stationarity, homogeneity and general randomness. The data and results are listed in Tables 6 and 7.

3.3 Flood Frequency Distribution

Annual peak discharges from this basin are caused by two types of runoff: snowmelt and rainstorms, or rain on snow.

Floods from snowmelt generally occur from June to August, and those occurring from rainstorms from September through October. The type of flood was determined from an examination of mean daily discharge hydrographs. It was assumed that a fairly steady rise and recession should indicate snowmelt runoff, and that a sharp rise would indicate runoff from rainstorms. Two arrays of annual peak discharges were defined and frequency distributions were fitted. The frequency curve for the two event analysis is obtained by combining the frequencies of the events.

For this station, the magnitude and frequency of peak discharges will not be computed until the data has been verified.

The distributions of the monthly maximum daily discharge for the period of record 1972 to 1985 are shown in Figure 24.

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 for this study are the 1, 7 and 14 day. The climatic year was used for each period which begins May 1 and ends April 30. The Gumbel III probability distribution has been fitted to the data and is shown in Figures 25 to 27. Tables 8 to 10 list the low flow data, sample statistics and frequency regime data. For comparison purposes Figure 28 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 is shown in Figure 29.

3.5 Hydrograph Characteristics

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 30 for this basin.

3.6 Base-Flow Index Statistic

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 More Creek basin is 0.742. The yearly values are given in Table 11.

3.7 Flow Duration Curve

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 31 shows the flow duration curve for daily mean flows.

3.8 Basin Physiographic Parameters

Stream basins have been defined on the Universal Transverse Mercator 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 a unit of four of these squares, making a grid system of 2 km x 2 km squares. The parameters extracted are: the elevation at the centre of the 2 km x 2 km square, area of lakes and swamps, stream length and the number of contour lines crossing either the horizontal or vertical line passing through the centre of the 2 km x 2 km square. The average values of basin parameters are computed from the sum of the 2 km x 2 km squares within the basin boundary. A short description of the parameters follows.

Basin Area:

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

Average Basin Elevation:

Arithmetic mean of the elevation in metres of all squares. The elevation of each 2 x 2 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.

The values are listed in Table 12.

4. CONCLUSIONS

4.1 Quality of Data

The quality of the data from this station is considered to be poor because of the continuous shifting of the control with insufficient measurements to follow the shifting accurately and the undefined top end of the rating curves.

Peak discharge data should not be used for statistical analysis or correlation studies until the top end of the rating curve has been adequately defined.

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TABLES 1 - 12

TABLE 1

COMPARISON OF ESTIMATED PEAK FLOW FROM EXTENDED RATING CURVES

DATE	STAGE Metres	EXTENDED RATING CURVE #5 (m^3/s)	COMPUTER EXTENSION OF CURVE #5 (m^3/s)	EXTENDED COMPOSITE CURVE (m^3/s)
October 8, 1974	6.030	603	730	804
October 18, 1978	5.61	552	646	705
October 5, 1980	4.824	453	501	536
September 8, 1981	5.153	484	560	604

TABLE 2

SELECTED HYDROMETRIC AND METEOROLOGIC STATIONS
USED IN STUDY

HYDROMETRIC STATIONS

STATION NUMBER	STATION NAME	DRAINAGE AREA (Km^2)
08DC006	Bear River above Bitter Creek	350
08DD001	Unuk River near Stewart	1480
08CG004	Iskut River above Snippaker Creek	7230
08CG001	Iskut River below Johnson River	9350
08CG005	More Creek near the Mouth	844
08CG006	Forrest Kerr Creek above 460 M Contour	311

METEOROLOGIC STATIONS

STATION NUMBER	STATION NAME
1200R0J	Bob Quinn Lake
1204215	Kinaskan Lake
1208202	Todagin Ranch
1208041	Telegraph Creek
1067742	Stewart A

TABLE 3

UNCERTAINTY FUNCTION STUDY

RELATION OF STANDARD ERROR OF DATA TO NUMBER OF MEASUREMENTS

1973 TO 1983

NUMBER OF MEASUREMENTS	STANDARD ERROR IN PERCENT OF THE INSTANTANEOUS DISCHARGE (TWO-THIRDS OF THE TIME)
0	24.75
1	23.02
2	21.26
3	19.62
4	18.18
5	16.91
6	15.81
7	14.90
8	14.10
9	13.44
10	12.81
15	10.63
20	9.29
25	8.33
30	7.62
35	7.06

STATISTICS

One Day Autocorrelation	0.95956
Variance of Process	0.01121
Mean of Residuals	-0.01347
Measurement Variance	0.000471
Variance of Residuals	0.01168
Sample Size	61.0

TABLE 4

PORTION OF ANNUAL RECORD ESTIMATED

CALENDAR YEAR	ICE PERIOD ESTIMATED RECORD (MONTHS)	OPEN WATER PERIODS ACTUAL RECORD (MONTHS)	OPEN WATER PERIODS ESTIMATED RECORD (MONTHS)
1971	5	5.5	1.5
1972	5	4	3
1973	4.5	4	3.5
1974	5	7	0
1975	4	5.5	2.5
1976	3	5	4
1977	4.5	7.5	0
1978	5	7	0
1979	5	6	1
1980	3	6	3
1981	4	8	0
1982	5	6.5	0.5
1983	5.5	6.5	0
1984	6	2.5	3.5
1985	5	6.5	0.5

TABLE 5

STATISTICS FOR SELECTED STREAMFLOW CHARACTERISTICS
FOR PERIOD 1972 TO 1985

STREAMFLOW CHARACTERISTIC	MEAN	SD	CV	CS	CK	PERCENT OF ANNUAL RUNOFF
<u>MEAN MONTHLY</u>						
JAN	6.2664	2.233	35.63	1.585	7.258	1.09
FEB	5.6443	1.801	31.91	0.5204	3.086	1.00
MAR	5.0850	1.119	22.00	0.7041	3.975	0.89
APR	8.6600	2.937	33.91	0.5411	2.868	1.51
MAY	42.8231	12.88	30.09	0.5000	3.237	7.48
JUN	108.7231	21.12	19.43	0.2921	5.842	19.00
JUL	136.2000	22.56	16.56	-0.4724	4.409	23.79
AUG	113.7182	18.14	15.95	0.7813	4.043	19.87
SEP	66.3923	25.79	38.84	0.9896	5.139	11.60
OCT	50.1615	27.53	54.88	0.9680	3.974	8.76
NOV	17.5971	7.747	44.02	0.8762	3.032	3.07
DEC	8.1250	3.007	37.01	1.606	6.784	1.42
<u>MEAN ANNUAL</u>	47.7258	5.046	10.57	0.8795	4.166	
<u>LOW FLOW</u>						
1 DAY	4.2879	1.053	24.55	0.8608	5.345	
7 DAY	4.3615	1.094	25.08	0.8966	5.453	
14 DAY	4.4507	1.139	25.59	0.9023	5.409	
<u>HIGH FLOW</u>						
MAXIMUM DAILY	267.5385	80.68	30.16	1.197	4.704	
INSTANTANEOUS	352.0833	135.5	38.48	0.8228	3.272	

Table 6 Minimum Flow Series: 1 day, 7 day, 14 day

N-DAY MEAN DURATION= 1

WATER SEASON (MONTH/DAY) FROM DEC 1 TO MAY 31

SEQ.NO.	YEAR	MON	FLOW
1	1972	3	2.580
2	1973	3	4.250
3	1974	3	4.110
4	1975	4	4.500
5	1976	3	3.140
6	1977	3	5.470
7	1978	3	3.600
8	1979	2	4.470
9	1980	3	5.300
10	1981	4	6.800
11	1982	4	3.780
12	1983	4	4.080
13	1984	2	3.550
14	1985	2	4.400

N-DAY MEAN DURATION= 7

WATER SEASON (MONTH/DAY) FROM DEC 1 TO MAY 31

SEQ.NO.	YEAR	MON	FLOW
1	1972	3	2.600
2	1973	3	4.460
3	1974	2	4.140
4	1975	4	4.650
5	1976	3	3.190
6	1977	3	5.570
7	1978	3	3.670
8	1979	2	4.470
9	1980	3	5.390
10	1981	3	7.000
11	1982	4	3.800
12	1983	3	4.110
13	1984	1	3.600
14	1985	2	4.420

N-DAY MEAN DURATION=14

WATER SEASON (MONTH/DAY) FROM DEC 1 TO MAY 31

SEQ.NO.	YEAR	MON	FLOW
1	1972	2	2.620
2	1973	3	4.500
3	1974	2	4.185
4	1975	3	4.920
5	1976	3	3.220
6	1977	3	5.710
7	1978	3	3.770
8	1979	2	4.480
9	1980	3	5.500
10	1981	3	7.190
11	1982	3	3.850
12	1983	3	4.150
13	1984	1	3.690
14	1985	2	4.510

Table 7 Non-parametric Statistical Tests: Minimum Daily Flow Series

--- SPEARMAN TEST FOR INDEPENDENCE ---

```
08CG0051 1        MORE CREEK NEAR THE MOUTH
ANNUAL MAXIMUM DAILY FLOW SERIES  1972 TO 1985  DRAINAGE AREA =  844.0000

SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =-0.429   D.F.= 11
                   CORRESPONDS TO STUDENTS T =-1.573
                CRITICAL T VALUE AT 5% LEVEL = 1.796    NOT SIGNIFICANT
                    -    -   -   -  1%    -  = 2.718    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 ---

```
08CG0051 1        MORE CREEK NEAR THE MOUTH
ANNUAL MAXIMUM DAILY FLOW SERIES  1972 TO 1985  DRAINAGE AREA =  844.0000

SPEARMAN RANK ORDER CORRELATION COEFF =-0.134   D.F.= 12
            CORRESPONDS TO STUDENTS T =-0.469
         CRITICAL T VALUE AT 5% LEVEL =-2.179    NOT SIGNIFICANT
             -    -   -   -  1%    -  =-3.055    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 ---

```
08CG0051 1        MORE CREEK NEAR THE MOUTH
ANNUAL MAXIMUM DAILY FLOW SERIES  1972 TO 1985  DRAINAGE AREA =  844.0000

THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN(RUNAB) = 10
             THE NUMBER OF RUNS ABOVE THE MEDIAN(N1) =  7
             THE NUMBER OF RUNS BELOW THE MEDIAN(N2) =  7
```

(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 ---

```
08CG0051 1        MORE CREEK NEAR THE MOUTH
ANNUAL MAXIMUM FLOW SERIES  1972 TO 1985   DRAINAGE AREA=  844.0000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE=  7
                    SUBSAMPLE 2 SAMPLE SIZE=  7

MANN-WHITNEY U =18.0   P= 0.228   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.

Minimum Daily Flow (1 Day)

08CG005 MORE CREEK NEAR THE MOUTH
1 DAY LOW FLOW MEAN DISCH. IN PERIOD DEC 1 TO MAY 31

STARTING MONTH	YEAR	1 DAY MEAN FLOW	ASCENDING ORDER	RANK	CUMULAT. PROBABIL. (%)	RETURN PERIOD (YEARS)
3	1972	2.5800	2.5800	1	4.23	23.67
3	1973	4.2500	3.1400	2	11.27	8.87
3	1974	4.1100	3.5500	3	18.31	5.46
4	1975	4.5000	3.6000	4	25.35	3.94
3	1976	3.1400	3.7800	5	32.39	3.09
3	1977	5.4700	4.0800	6	39.44	2.54
3	1978	3.6000	4.1100	7	46.48	2.15
2	1979	4.4700	4.2500	8	53.52	1.87
3	1980	5.3000	4.4000	9	60.56	1.65
4	1981	6.8000	4.4700	10	67.61	1.48
4	1982	3.7800	4.5000	11	74.65	1.34
4	1983	4.0800	5.3000	12	81.69	1.22
2	1984	3.5500	5.4700	13	88.73	1.13
2	1985	4.4000	6.8000	14	95.77	1.04

Sample Statistics with Frequency Regime Data for Gumbel III Distribution

08CG005 MORE CREEK NEAR THE MOUTH
1 DAY LOW FLOW MEAN DISCH. IN PERIOD DEC 1 TO MAY 31
MEAN= 4.29 S.D.= 1.0528 SKEW= 0.8608 C.V.= 0.2455
GUMBEL III DISTRIBUTION - PARAMETERS BY MAXIMUM LIKELIHOOD
N= 14 XMIN= 2.580 A= 2.02718 E= 2.3050 U= 4.5386

RETURN PERIOD (YRS)	DROUGHT ESTIMATE
1.005	7.392
1.010	7.054
1.110	5.682
1.250	5.130
2.000	4.169
5.000	3.371
10.000	3.041
20.000	2.821
50.000	2.631
100.000	2.536
200.000	2.469
500.000	2.409

Table 8 Minimum Daily Flow (1 Day) and Sample Statistics with Frequency Regime Data for Gumbel III Distribution

Minimum Daily Flow (7 Day)

08CG005 MORE CREEK NEAR THE MOUTH
7 DAY LOW FLOW MEAN DISCH. IN PERIOD DEC 1 TO MAY 31

STARTING MONTH	YEAR	7 DAY MEAN FLOW	ASCENDING ORDER	RANK	CUMULAT. PROBABIL. (%)	RETURN PERIOD (YEARS)
3	1972	2.6000	2.6000	1	4.23	23.67
3	1973	4.4600	3.1900	2	11.27	8.87
2	1974	4.1400	3.6000	3	18.31	5.46
4	1975	4.6500	3.6700	4	25.35	3.94
3	1976	3.1900	3.8000	5	32.39	3.09
3	1977	5.5700	4.1100	6	39.44	2.54
3	1978	3.6700	4.1400	7	46.48	2.15
2	1979	4.4700	4.4200	8	53.52	1.87
3	1980	5.3900	4.4600	9	60.56	1.65
3	1981	7.0000	4.4700	10	67.61	1.48
4	1982	3.8000	4.6500	11	74.65	1.34
3	1983	4.1100	5.3900	12	81.69	1.22
1	1984	3.6000	5.5700	13	88.73	1.13
2	1985	4.4200	7.0000	14	95.77	1.04

Sample Statistics with Frequency Regime Data for Gumbel III Distribution

08CG005 MORE CREEK NEAR THE MOUTH
7 DAY LOW FLOW MEAN DISCH. IN PERIOD DEC 1 TO MAY 31
MEAN= 4.36 S.D.= 1.0937 SKEW= 0.9034 C.V.= 0.2507
GUMBEL III DISTRIBUTION - PARAMETERS BY MAXIMUM LIKELIHOOD
N= 14 XMIN= 2.600 A= 1.99924 E= 2.3283 U= 4.6188

RETURN PERIOD (YRS)	DROUGHT ESTIMATE
1.005	7.605
1.010	7.250
1.110	5.811
1.250	5.234
2.000	4.235
5.000	3.410
10.000	3.071
20.000	2.847
50.000	2.654
100.000	2.558
200.000	2.490
500.000	2.431

Table 9 Minimum Daily Flow (7 Day) and Sample Statistics with Frequency Regime Data for Gumbel III Distribution

Minimum Daily Flow (14 Day)

08CG005 MORE CREEK NEAR THE MOUTH
14 DAY LOW FLOW MEAN DISCH. IN PERIOD DEC 1 TO MAY 31

STARTING MONTH	YEAR	14 DAY MEAN FLOW	ASCENDING ORDER	RANK	CUMULAT. PROBABIL. (%)	RETURN PERIOD (YEARS)
2	1972	2.6200	2.6200	1	4.23	23.67
3	1973	4.5000	3.2200	2	11.27	8.87
2	1974	4.1850	3.6900	3	18.31	5.46
3	1975	4.9200	3.7700	4	25.35	3.94
3	1976	3.2200	3.8500	5	32.39	3.09
3	1977	5.7100	4.1500	6	39.44	2.54
3	1978	3.7700	4.1850	7	46.48	2.15
2	1979	4.4800	4.4800	8	53.52	1.87
3	1980	5.5000	4.5000	9	60.56	1.65
3	1981	7.1900	4.5100	10	67.61	1.48
3	1982	3.8500	4.9200	11	74.65	1.34
3	1983	4.1500	5.5000	12	81.69	1.22
1	1984	3.6900	5.7100	13	88.73	1.13
2	1985	4.5100	7.1900	14	95.77	1.04

Sample Statistics with Frequency Regime Data for Gumbel III Distribution

08CG005 MORE CREEK NEAR THE MOUTH
14 DAY LOW FLOW MEAN DISCH. IN PERIOD DEC 1 TO MAY 31
MEAN= 4.45 S.D.= 1.1384 SKEW= 0.9031 C.V.= 0.2558
GUMBEL III DISTRIBUTION - PARAMETERS BY MAXIMUM LIKELIHOOD
N= 14 XMIN= 2.620 A= 1.99106 E= 2.3407 U= 4.7156

RETURN PERIOD (YRS)	DROUGHT ESTIMATE
1.005	7.830
1.010	7.460
1.110	5.958
1.250	5.357
2.000	4.316
5.000	3.459
10.000	3.108
20.000	2.875
50.000	2.675
100.000	2.576
200.000	2.507
500.000	2.446

Table 10 Minimum Daily Flow (14 Day) and Sample Statistics with Frequency Regime Data for Gumbel III Distribution

TABLE 11

BASE FLOW INDEX

YEAR OF RECORD	BASE FLOW INDEX
1974	0.708
1975	0.744
1977	0.825
1978	0.699
1980	0.711
1981	0.695
1982	0.770
1983	0.754
1984	0.758
1985	0.752

Mean = 0.742
SD = 0.040
CV = 0.054

TABLE 12

BASIN PHYSIOGRAPHIC PARAMETERS

Station Name	Basin Area (km^2)	Average Elevation (m)	% of Lakes and Swamps	Stream Density (km/km^2)	Average Slope (m/km)	Main Channel Length (km)	Main Channel Slope (m/km)
More Cr. near the Mouth	888	4369	0.5394	0.5466	1954.4	33.6	14.0
Forrest Kerr Cr. ab. 460m Contour	311	4386	0.3183	0.2352	1407.9	32.3	55.8

FIGURES 1 - 31

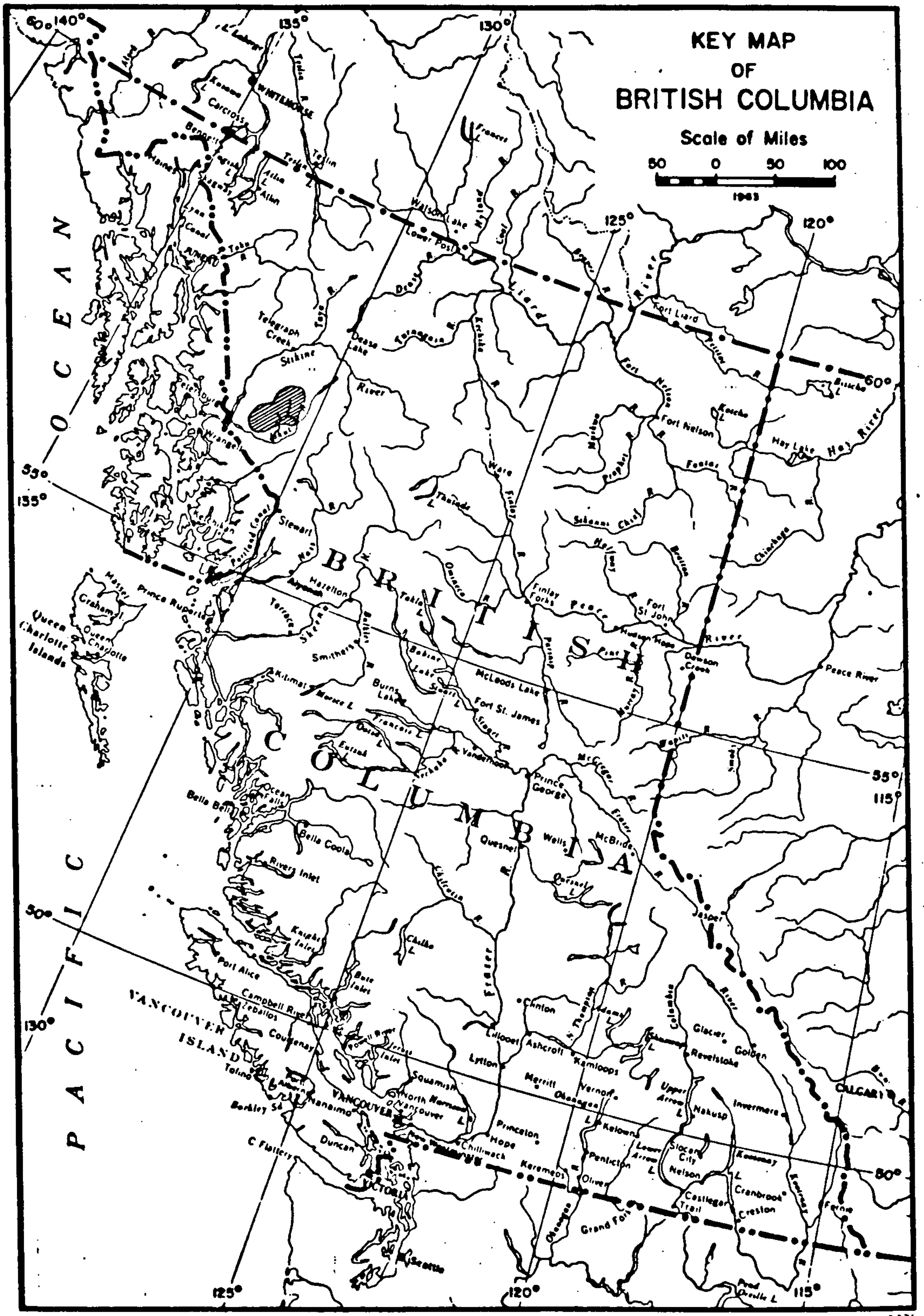


Figure 1 Key Map of B.C. Showing Location of Forrest Kerr Creek and More Creek Drainage Basins

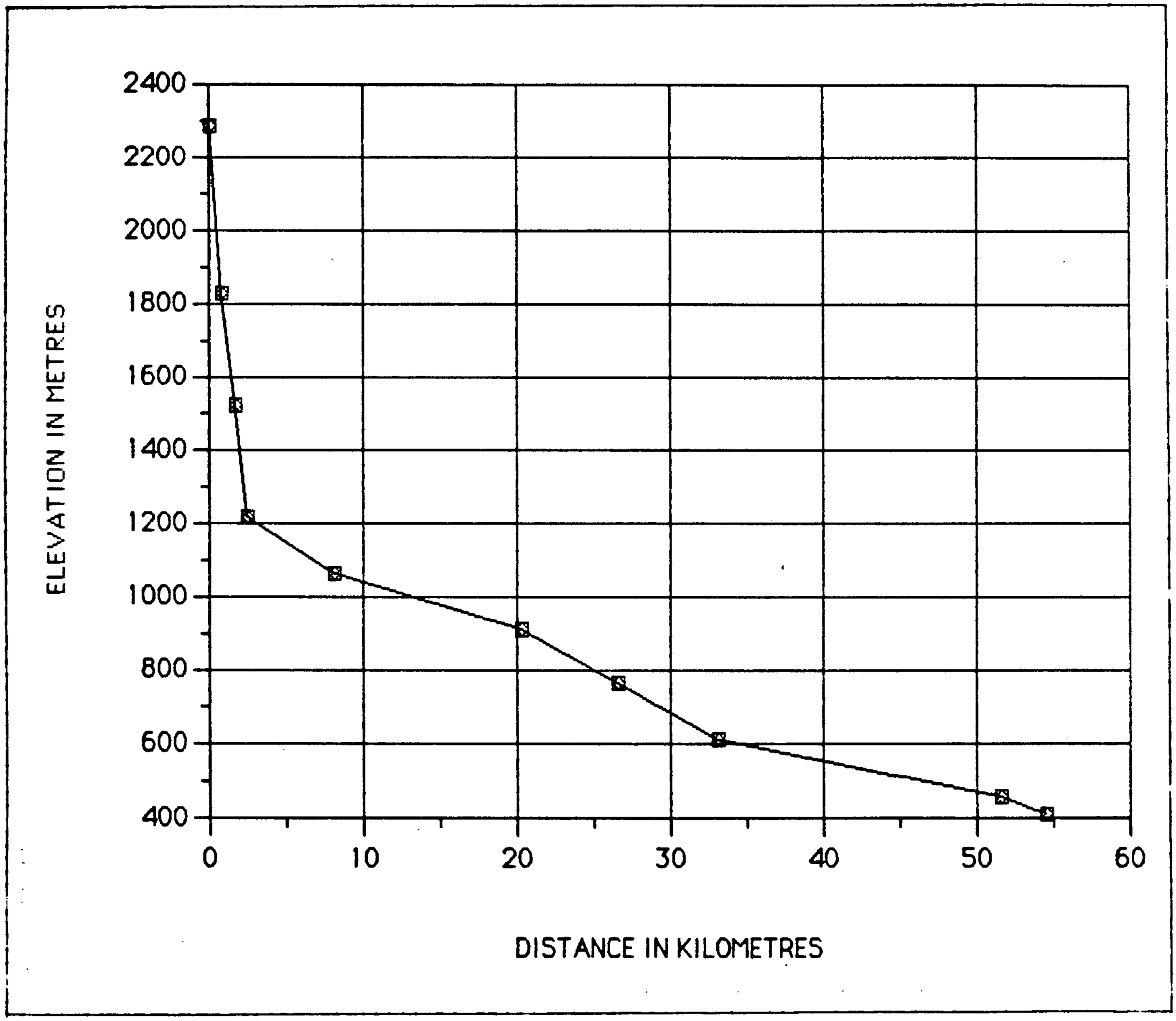


Figure 2a Profile of More Creek

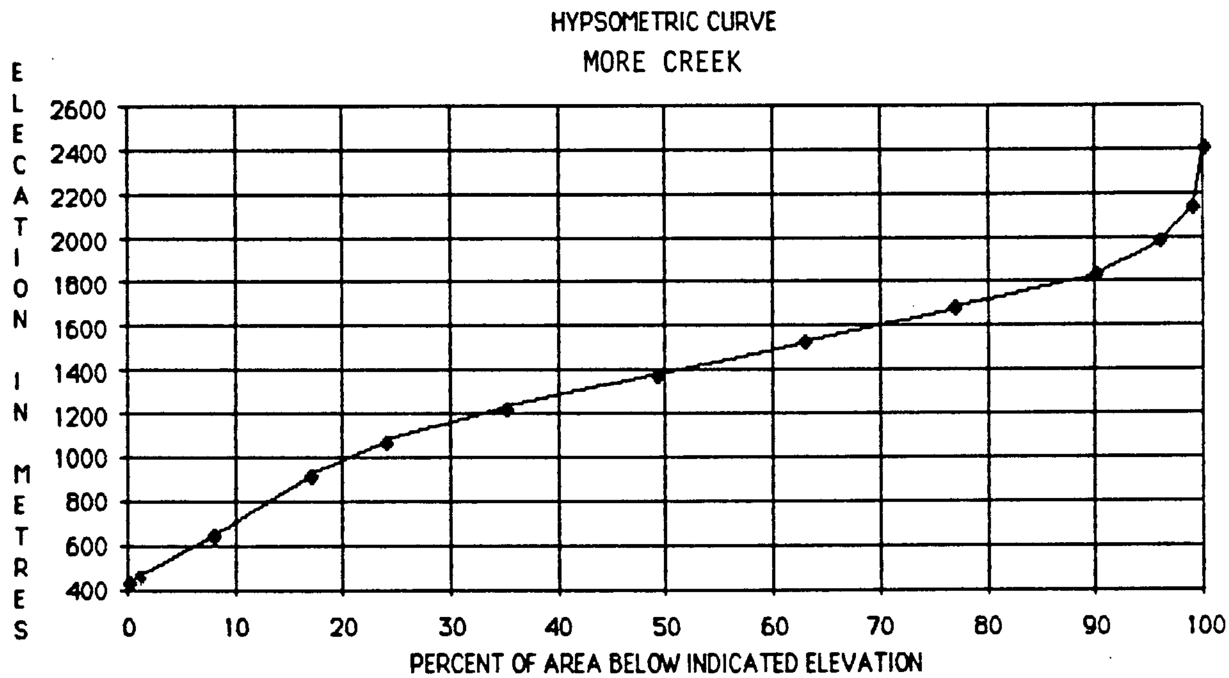


Figure 2b Area Elevation Graph

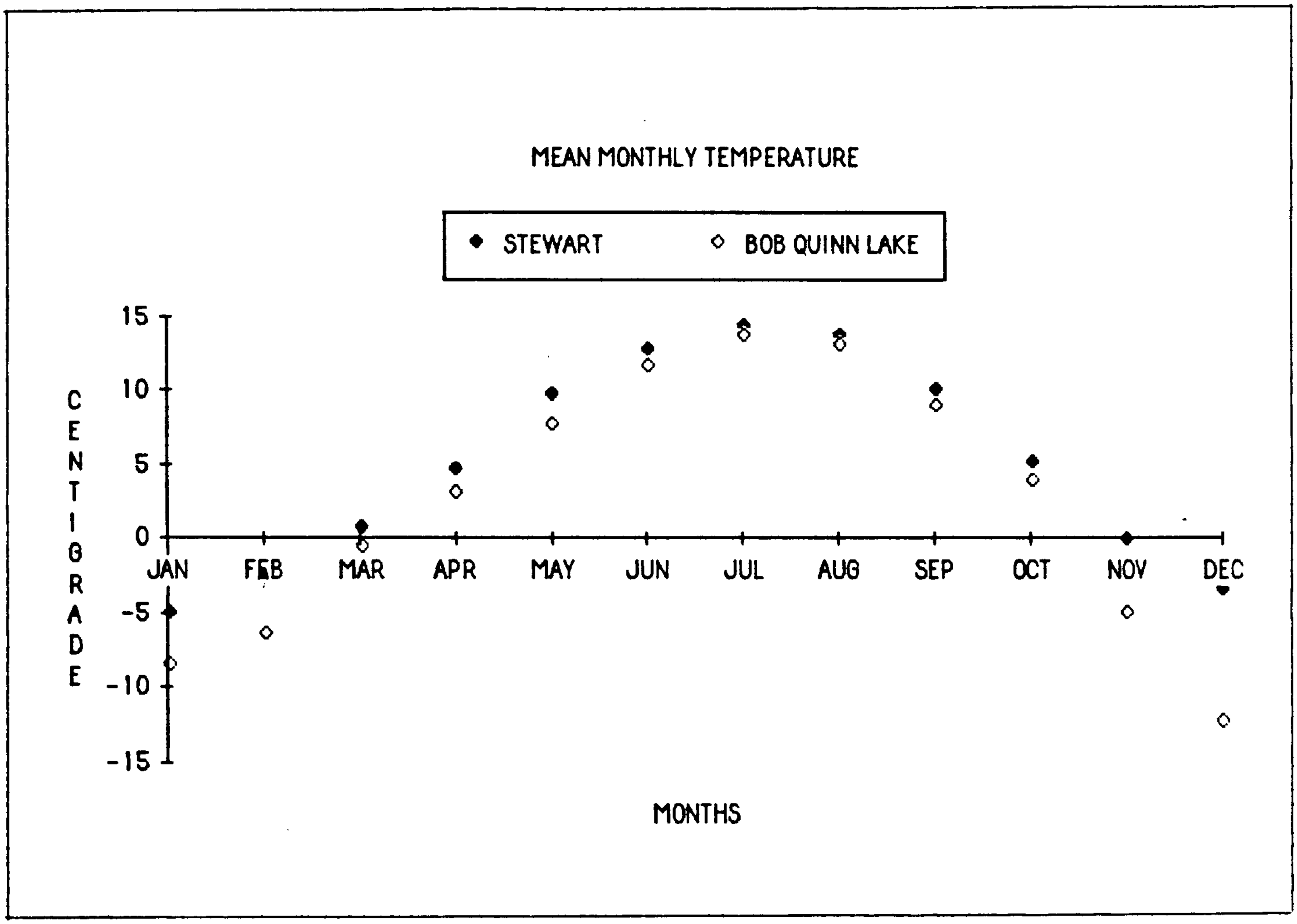


Figure 3 Monthly Mean Temperature - Stewart and Bob Quinn Lake

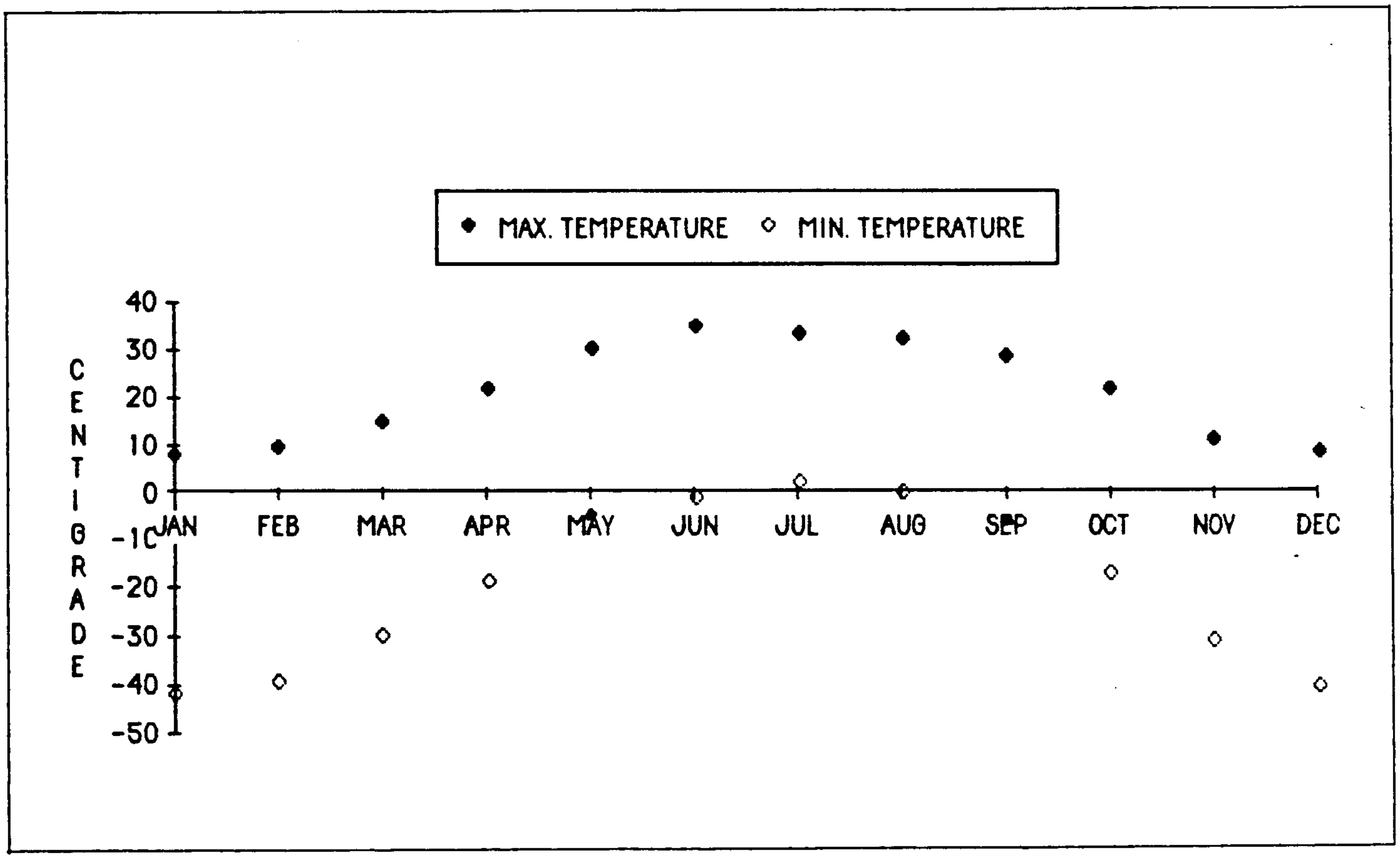


Figure 4 Maximum and Minimum Temperature Extremes - Telegraph Creek

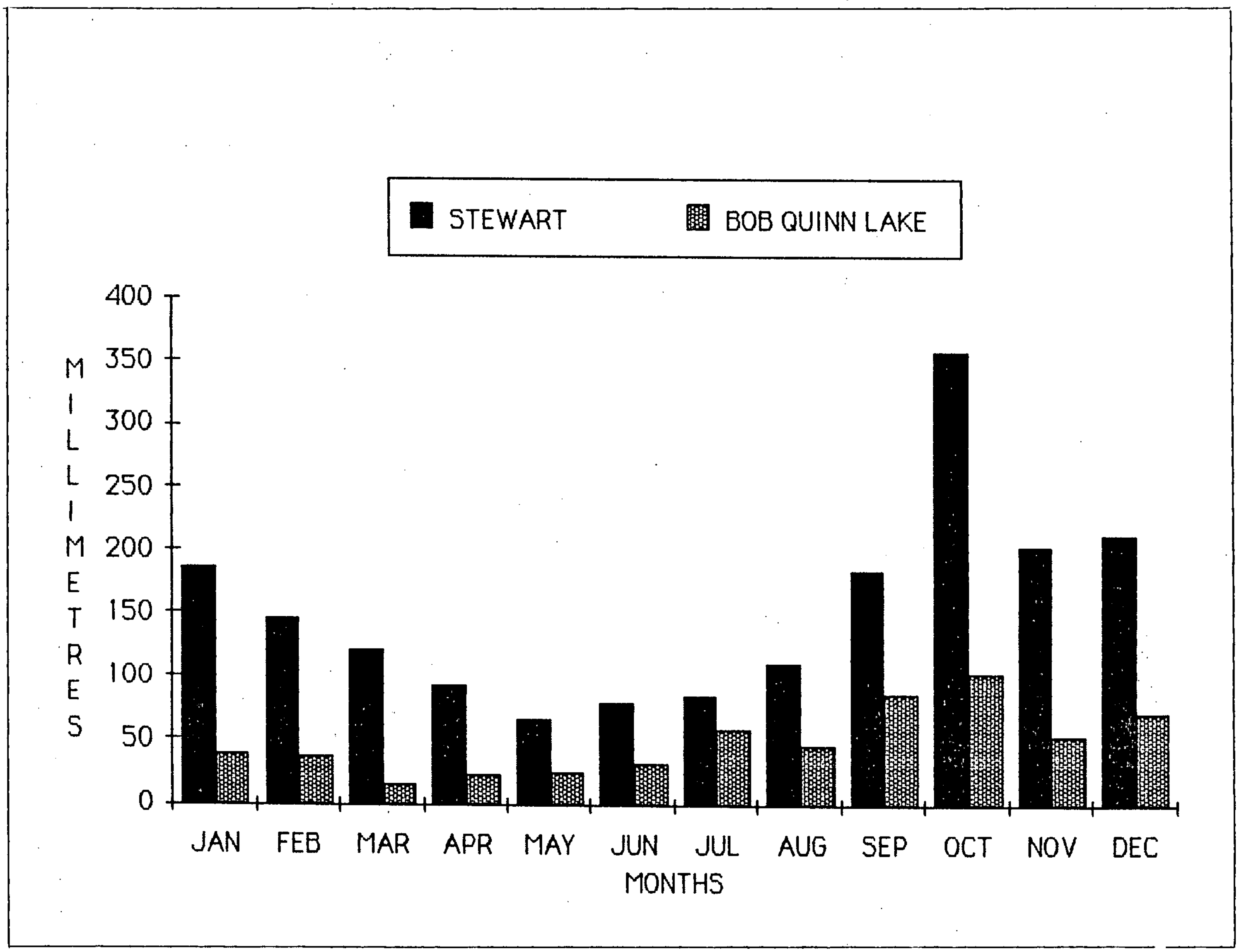


Figure 5 Histogram of Long-Term Precipitation - Stewart and Bob Quinn Lake

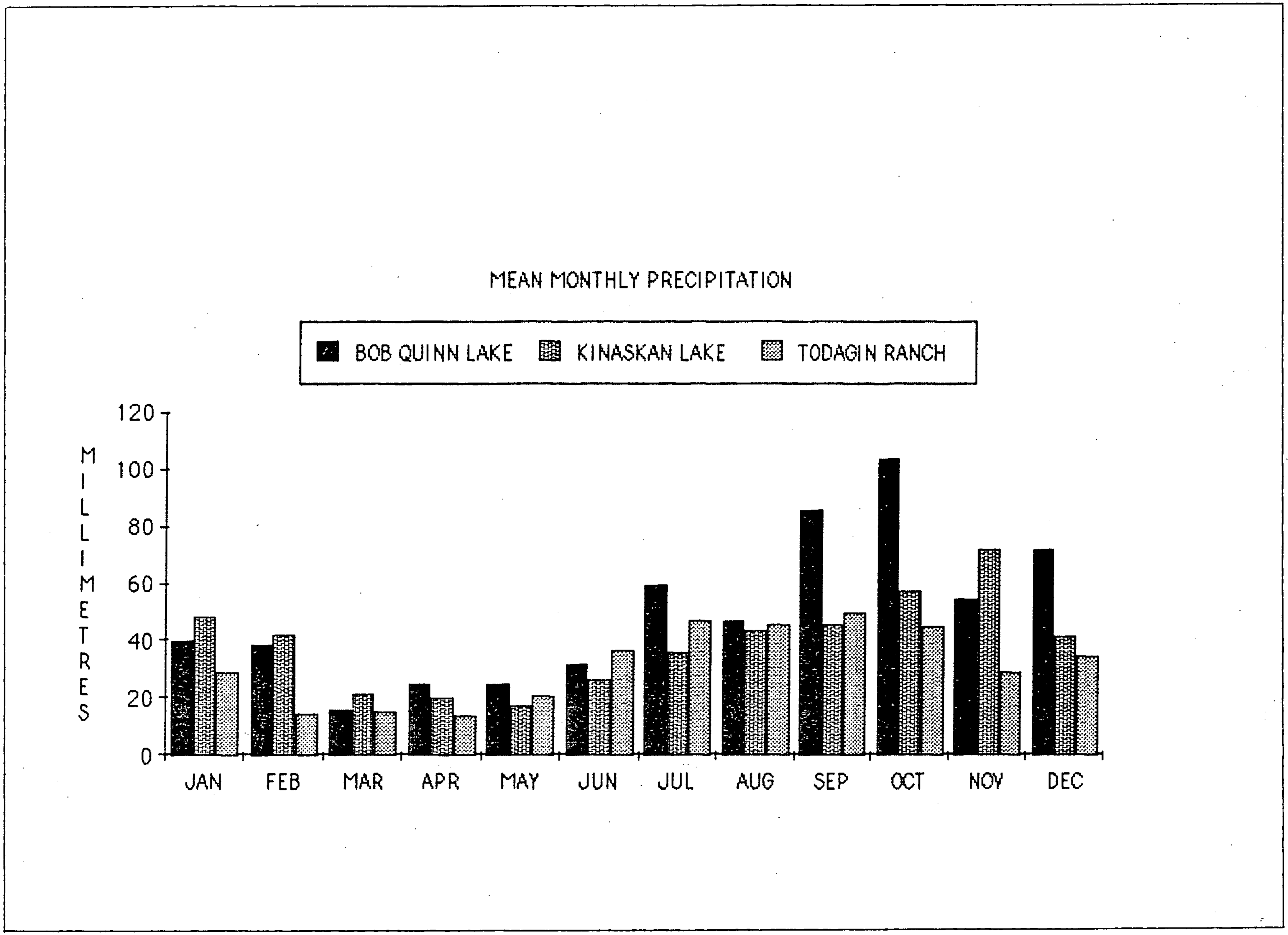


Figure 6 Long Term Monthly Precipitation for Bob Quinn Lake, Kinaskan Lake and Todagin Ranch

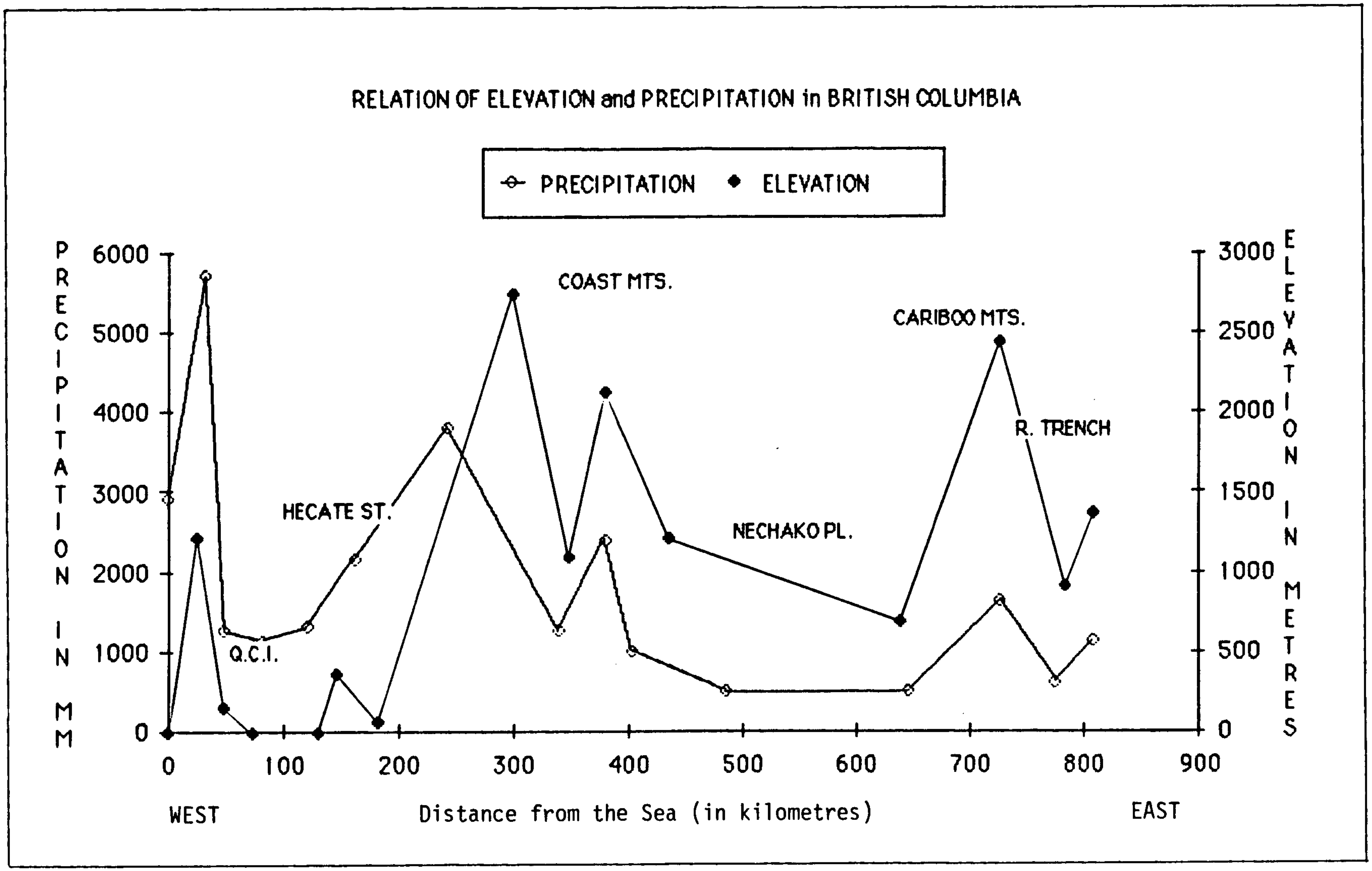
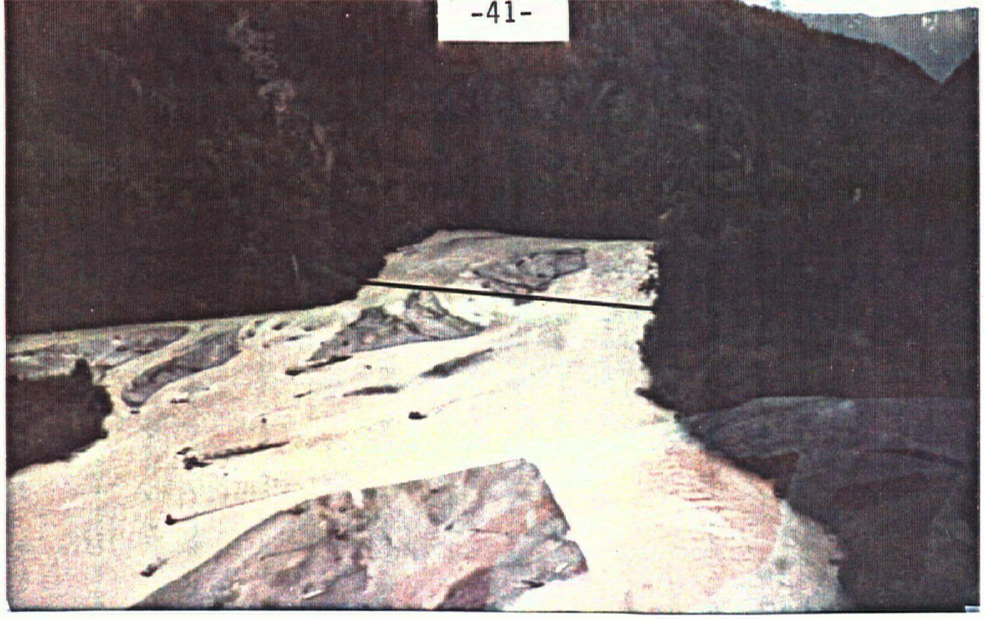
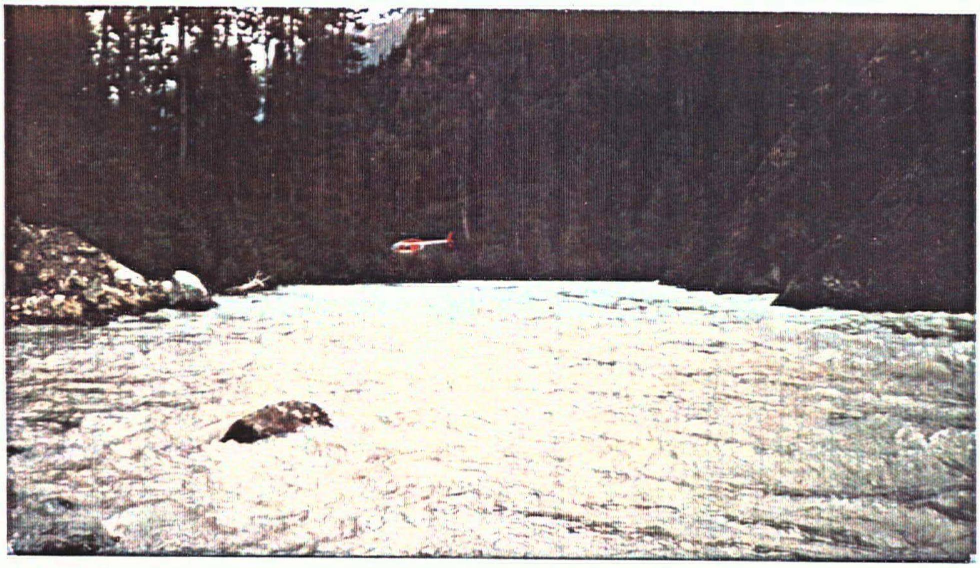


Figure 7 Relation of Altitude and Distance from the Sea to Precipitation



Cableway 200 Metres Upstream from Recorder Location



View Looking Upstream from 50 Metres Below Orifice

View Downstream from Orifice Location
July 8, 1986
Figure 8a

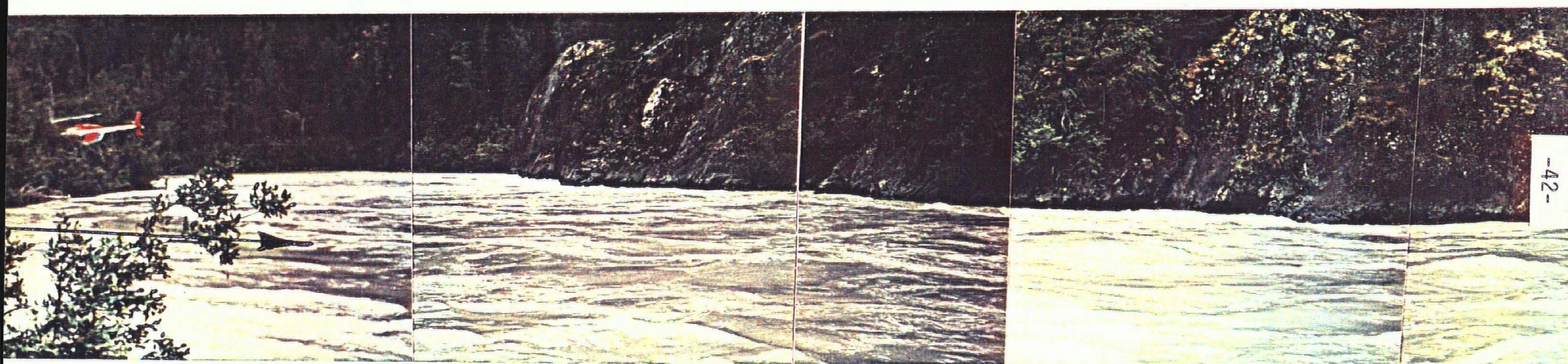


Figure 8b Panoramic View of Channel near Orifice July 8, 1986

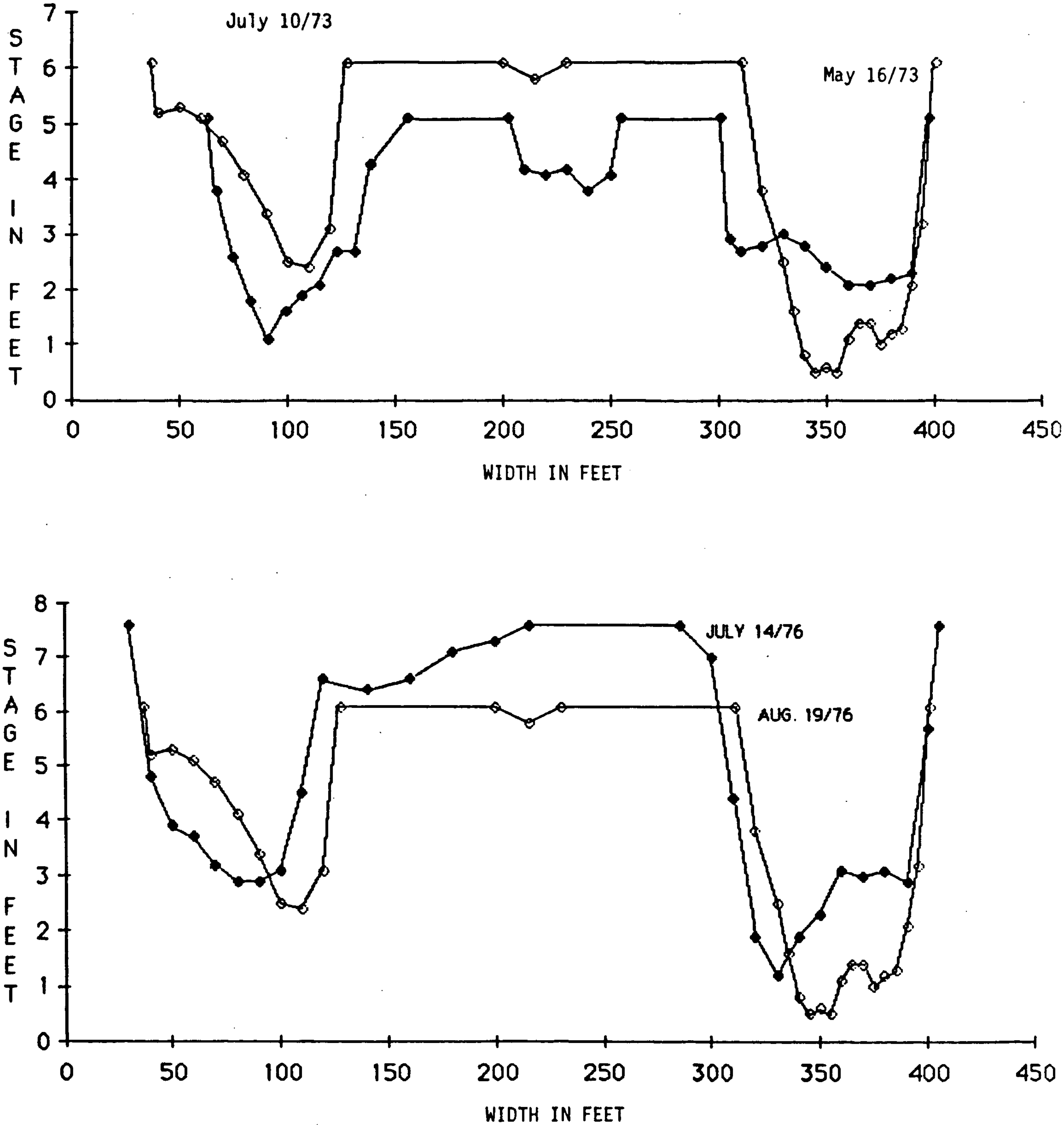
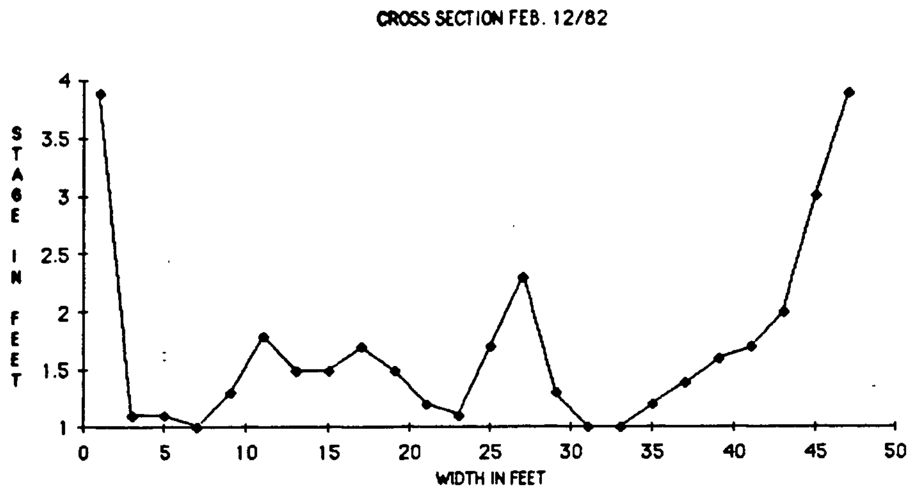
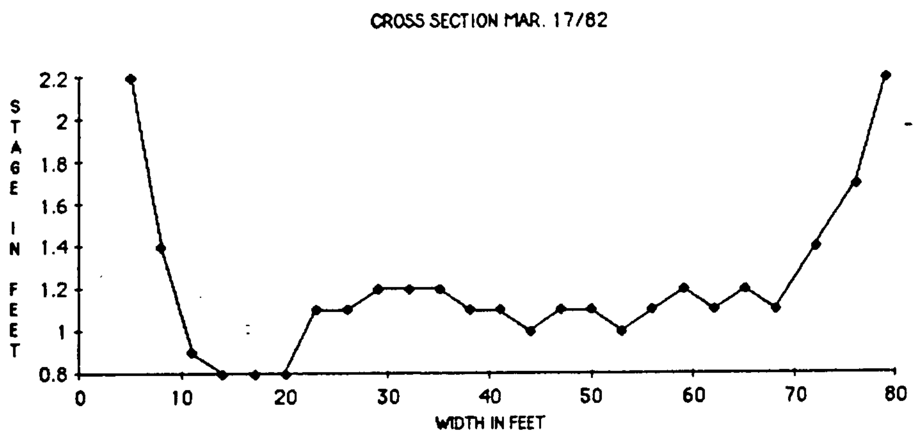


Figure 9 Cross Sections of More Creek at Metering Station Plotted to Gauge Heights from Recorder 500 feet Downstream





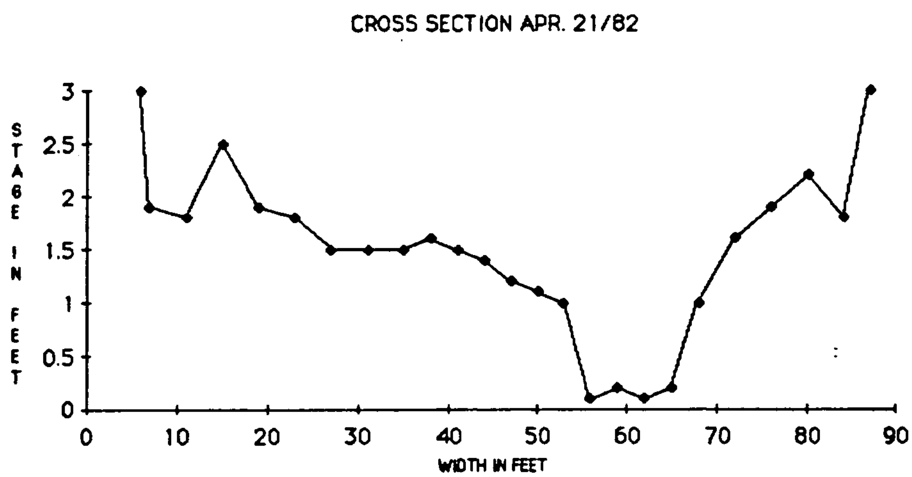


Figure 10 Cross Sections above Recorder
Used for Wading Measurements

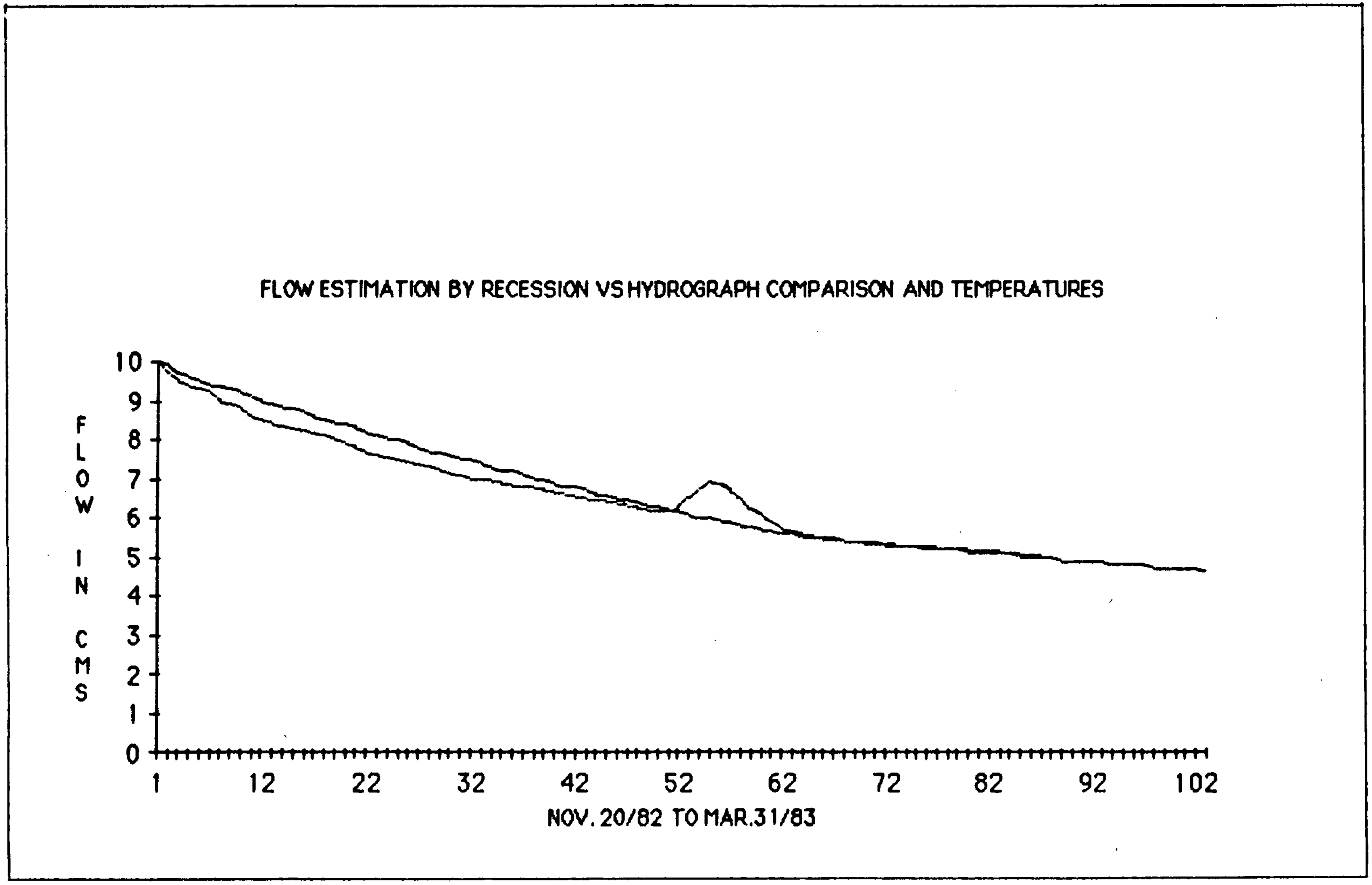


Figure 11 Comparison of Flow Estimation by Recession Analysis and by Usual Techniques

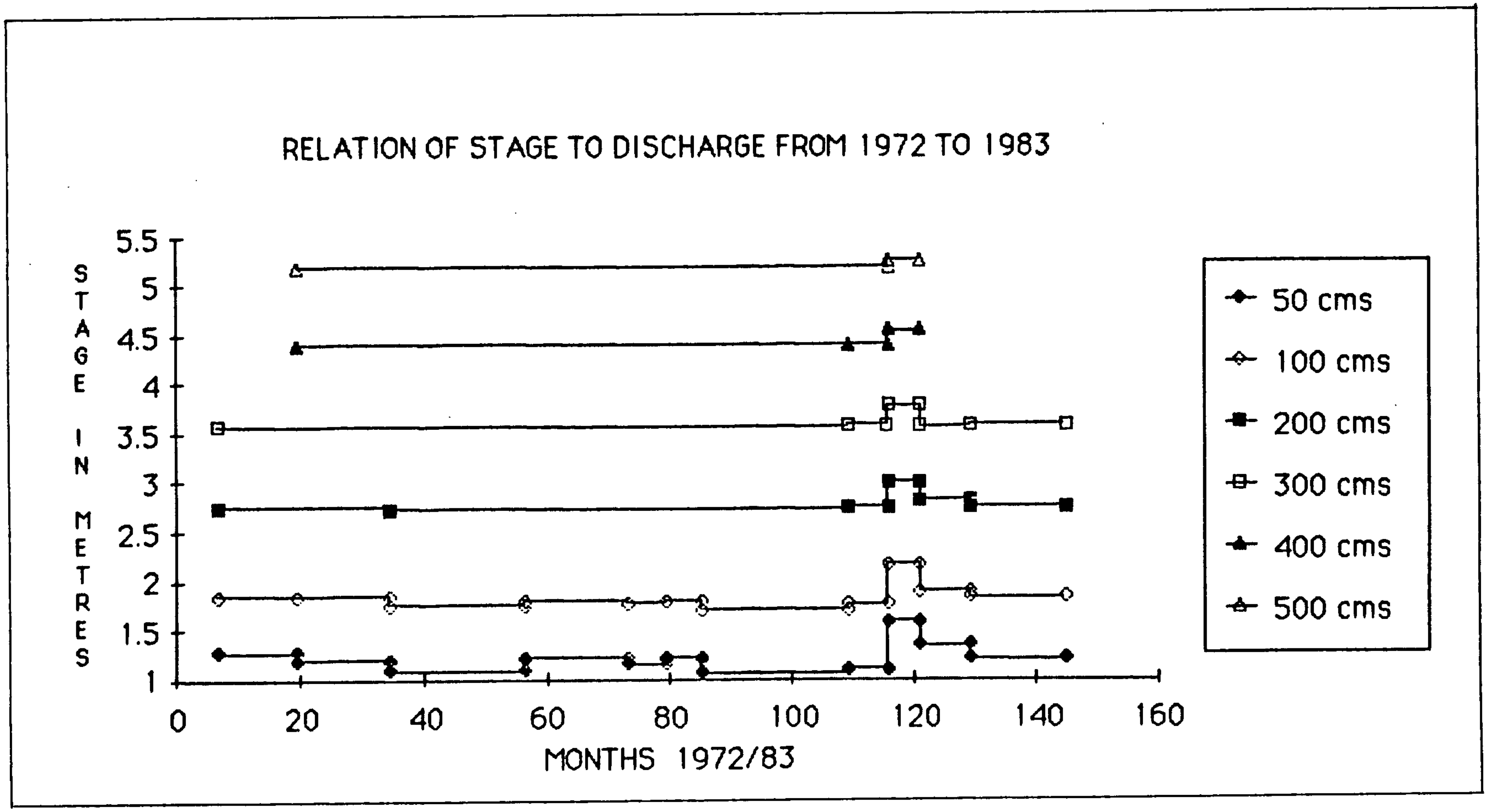


Figure 12 Stage Relationship with Selected Discharges

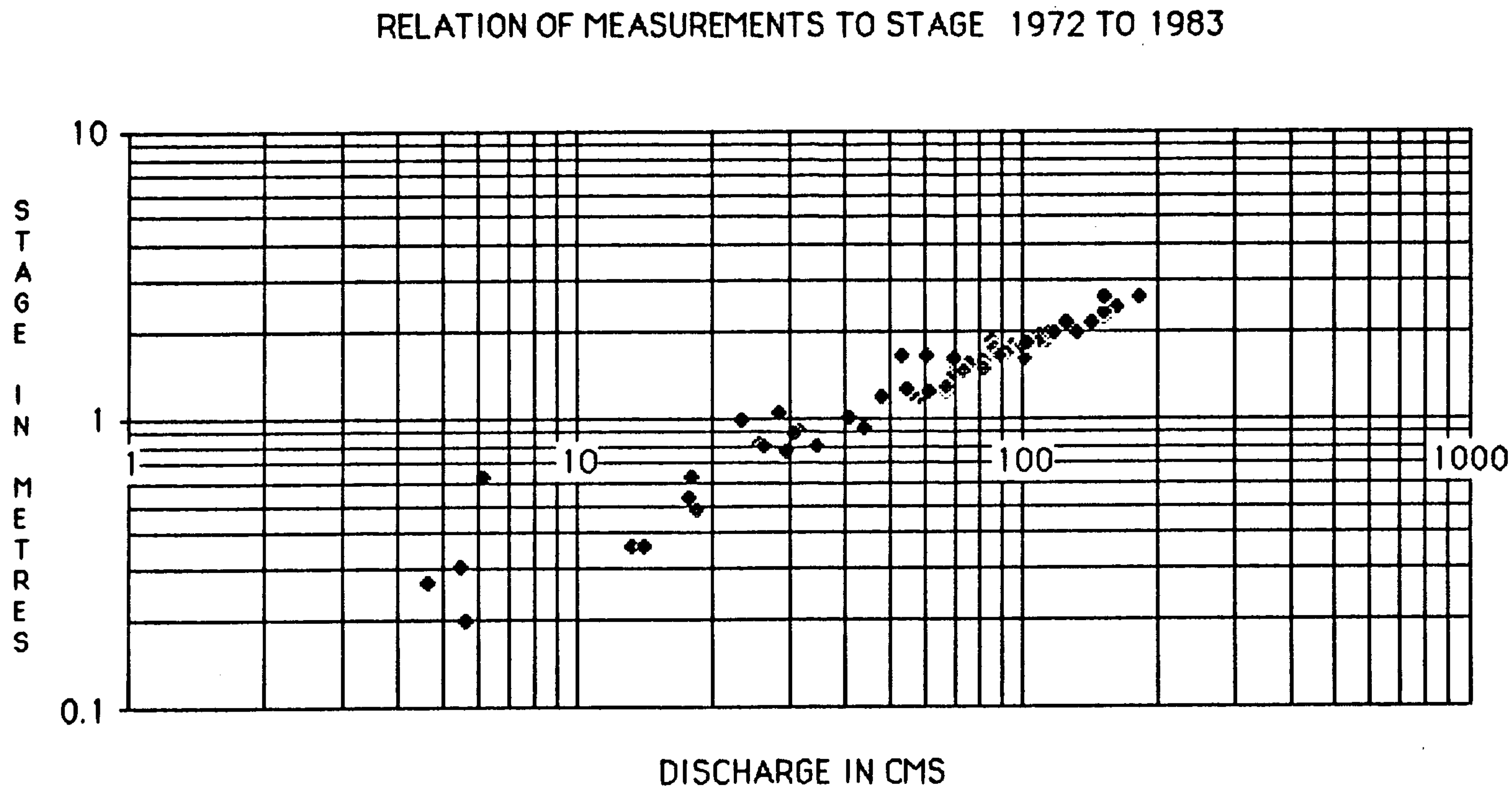


Figure 13 Composite Curve of all Open Water Measurements

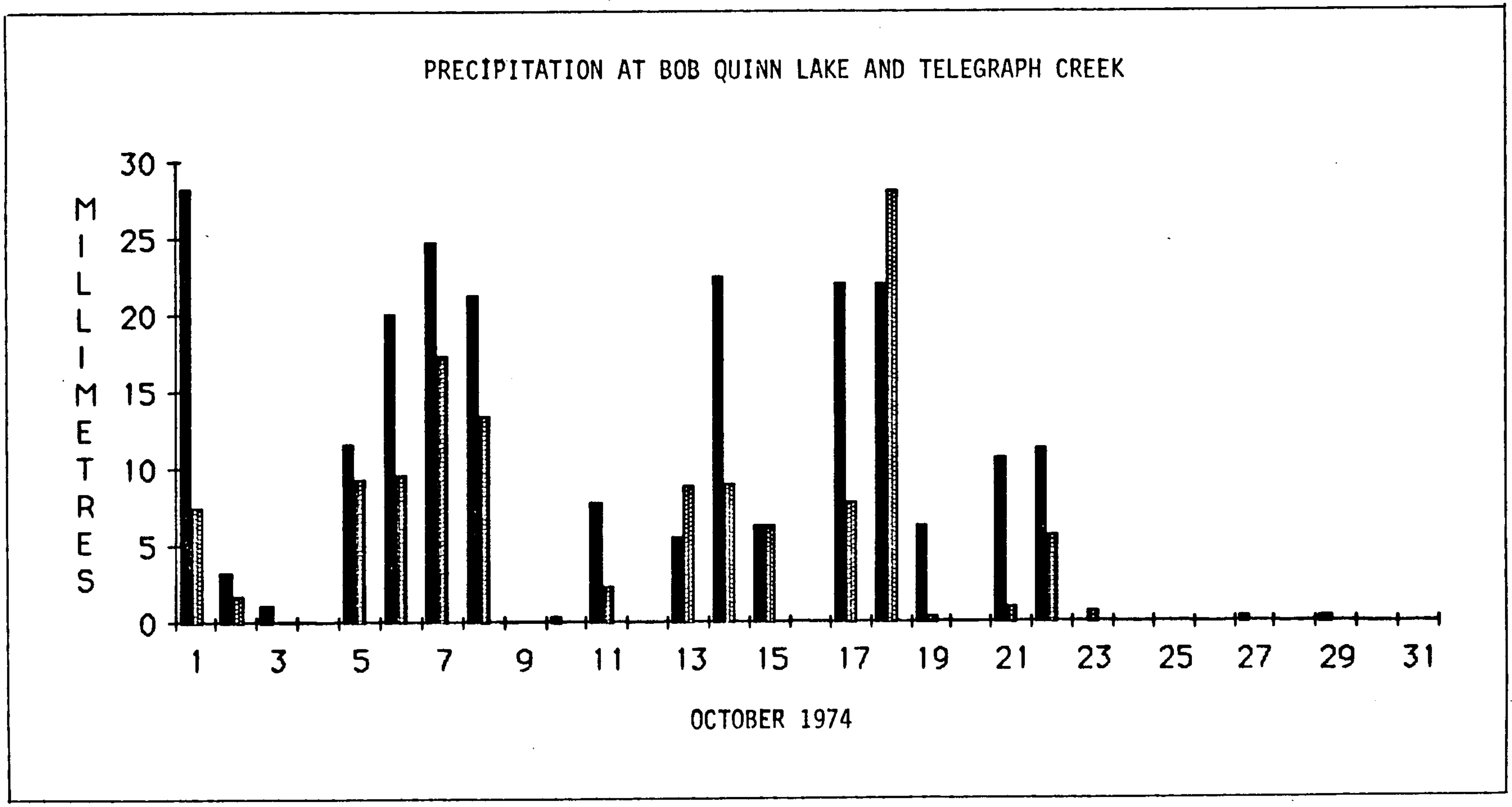


Figure 14 Histogram of Precipitation for Month of October 1974

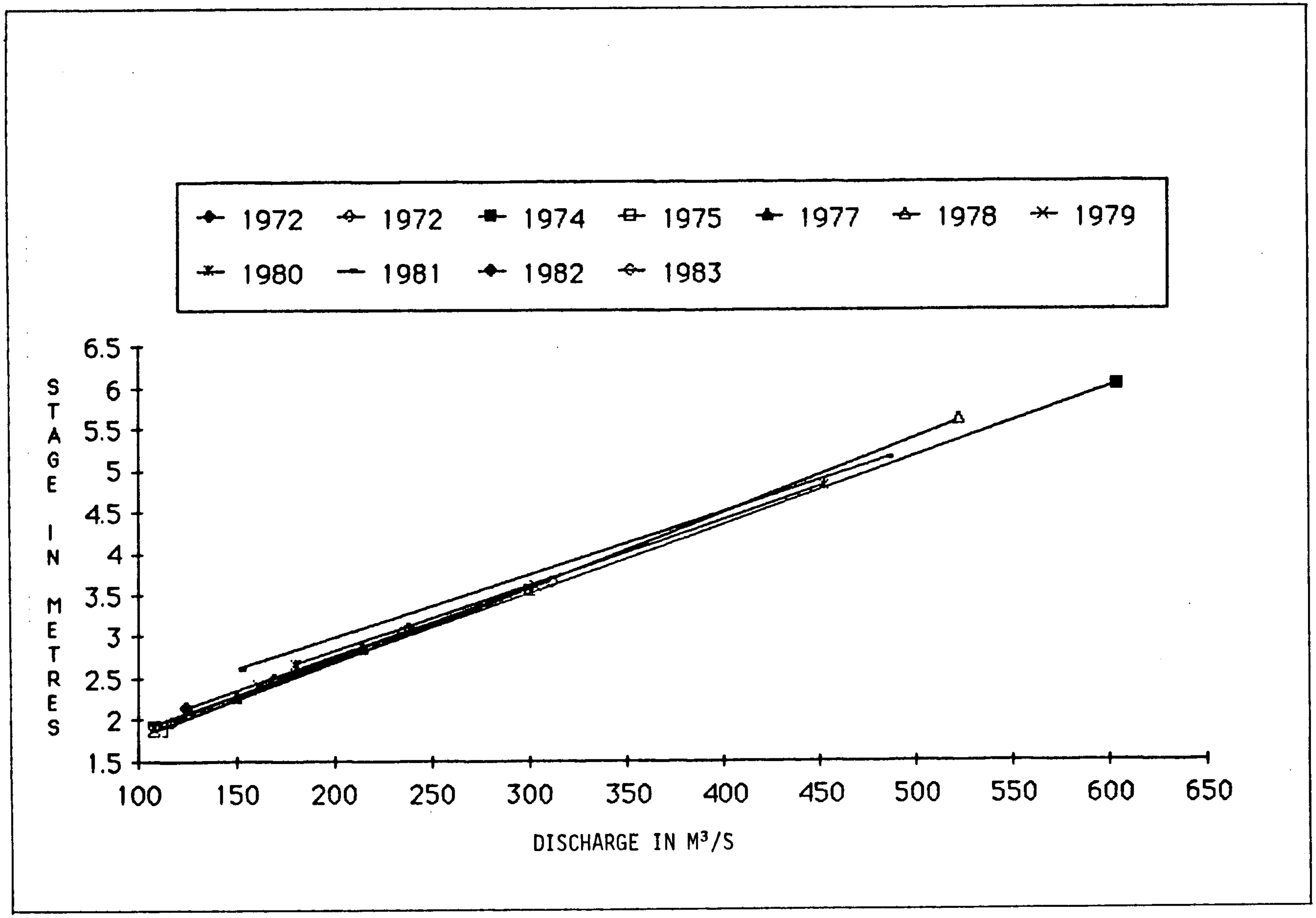
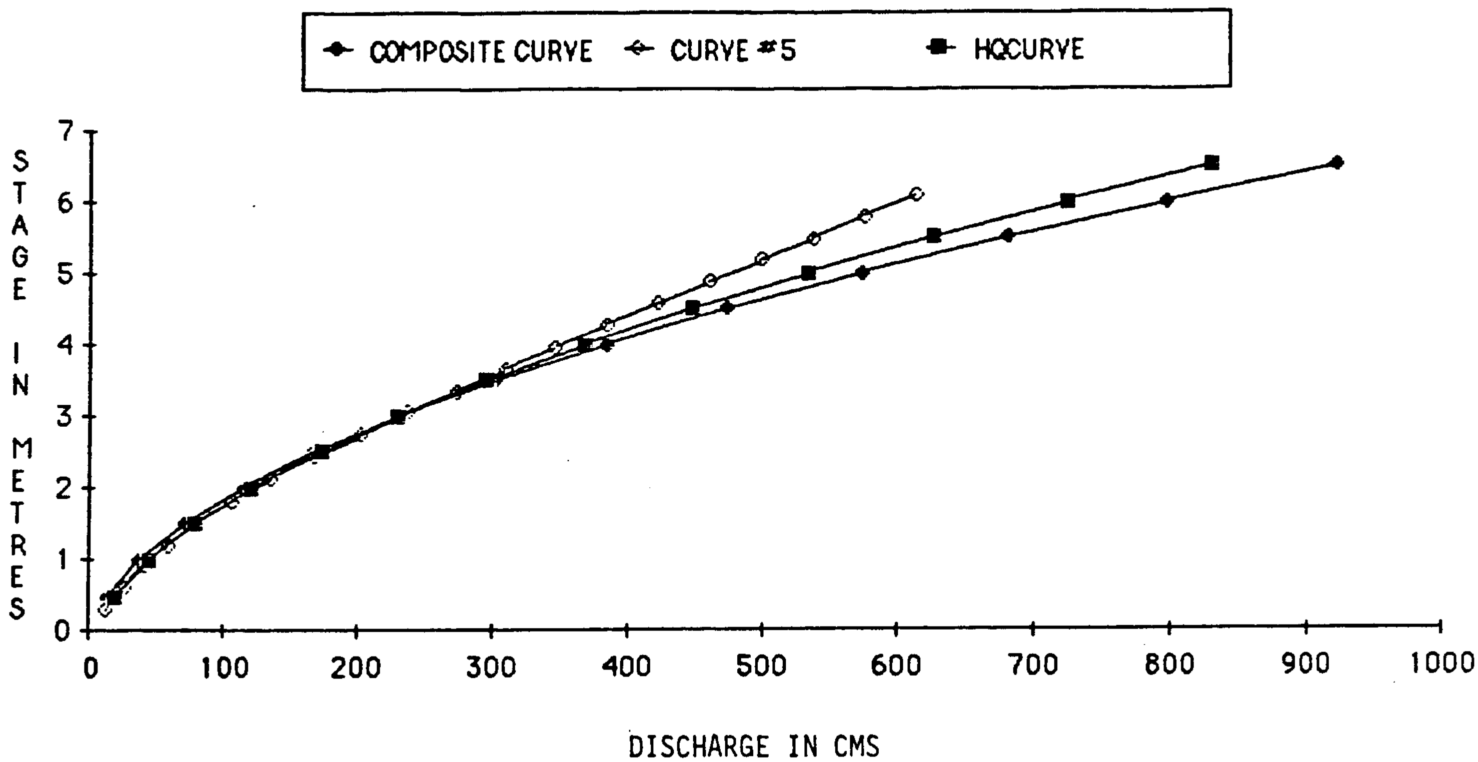


Figure 15 Measured vs. Estimated Discharges for Period of Record



Rating Curve #5 has been extended above a gauge height of 2.487 to a gauge height of 6.030. The computer curve and Composite Curve are the extension by computer of Curve 5 and the use of all open water measurements respectively.

Figure 16 Relationship of Extended Rating Curve #5, Computer Curve Extension and Composite Curve

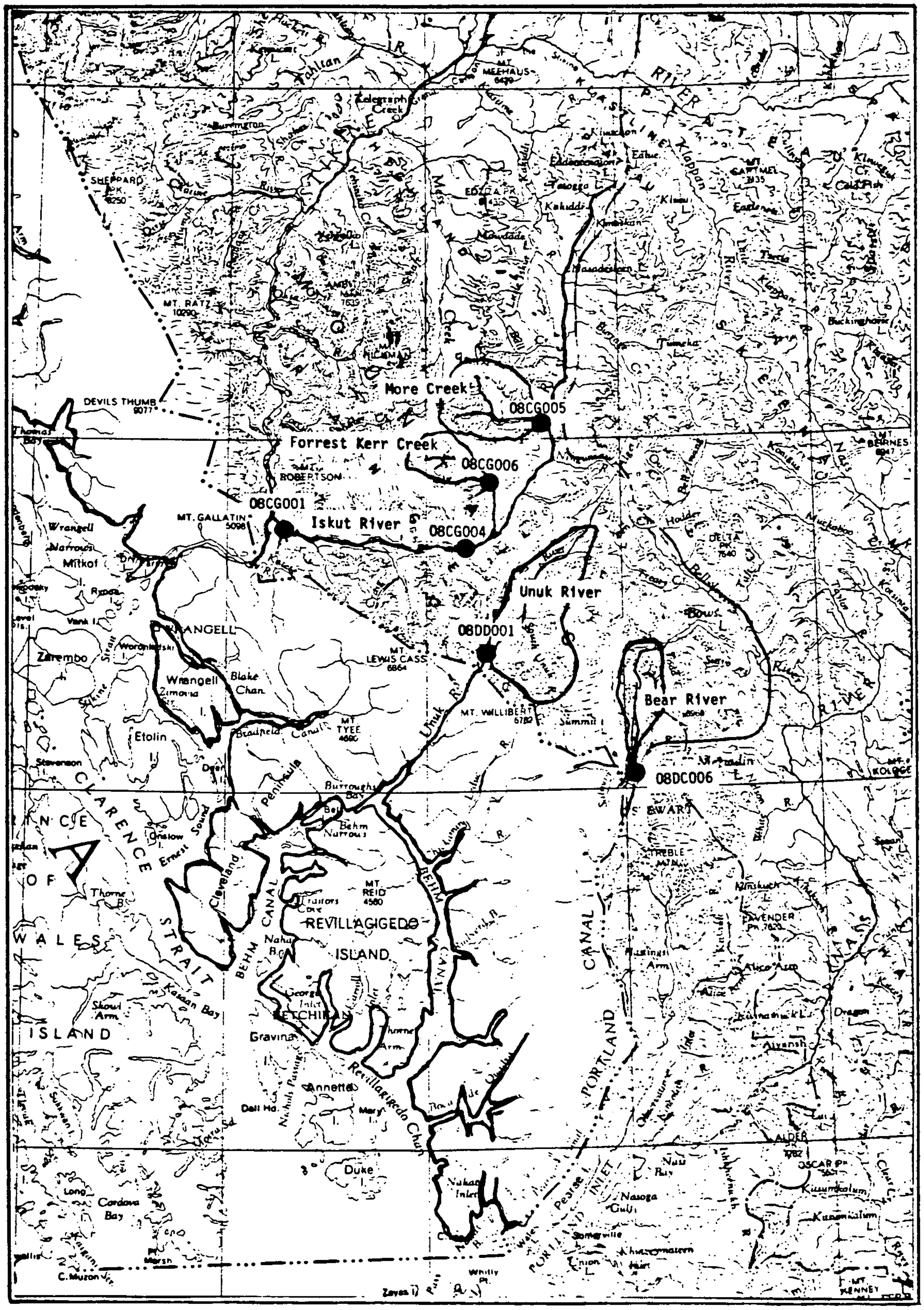


Figure 17 Map of Surrounding Basins

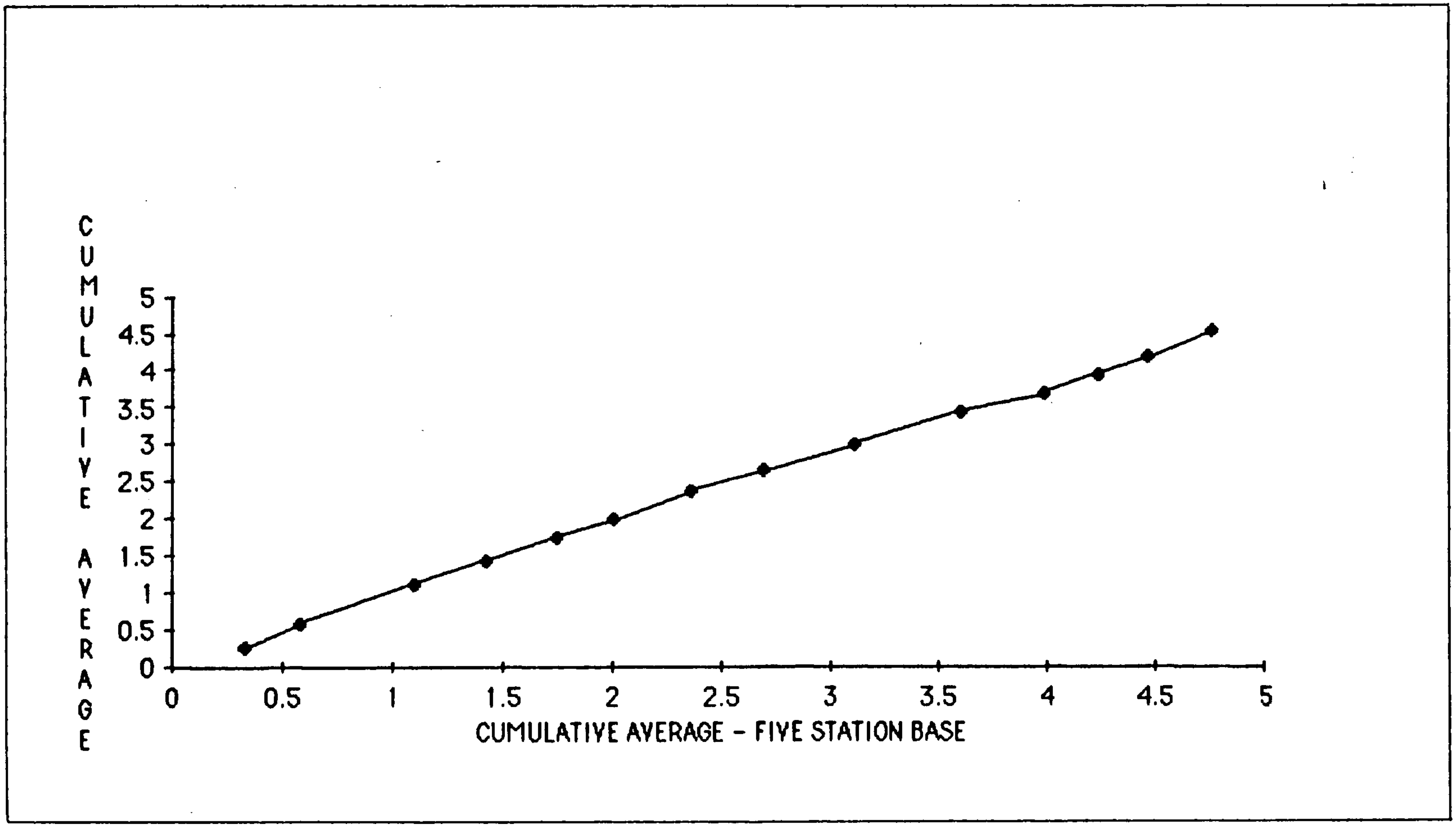
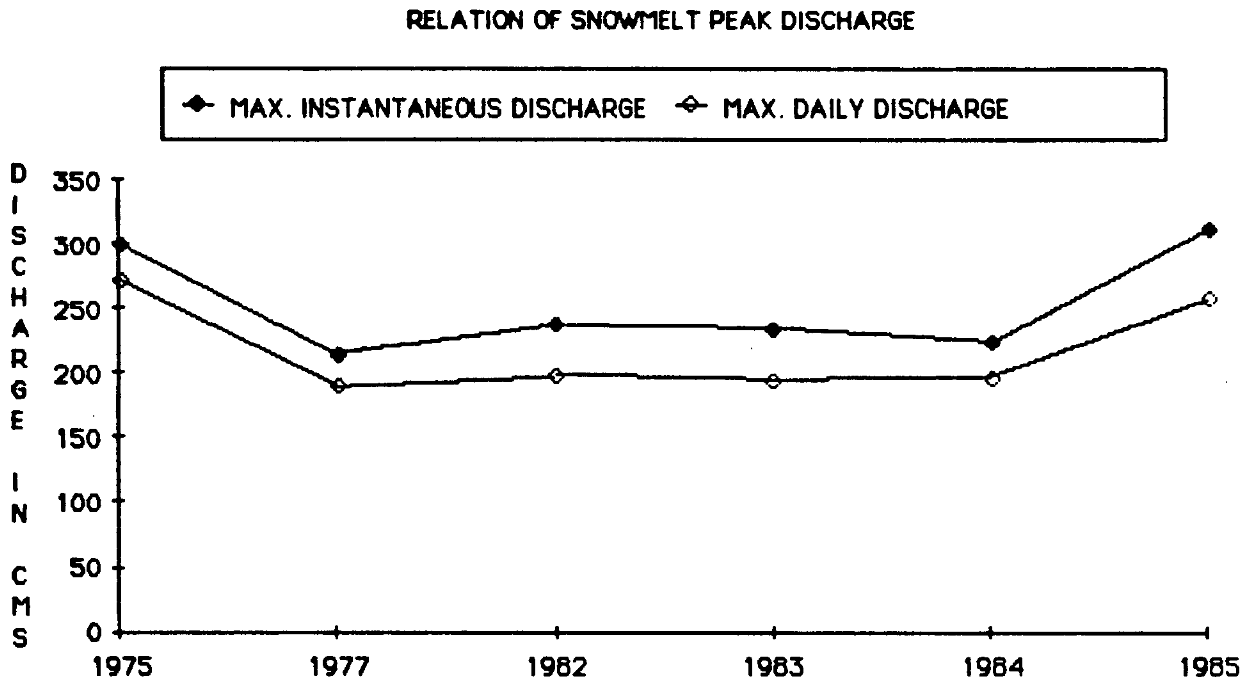


Figure 18 Double-Mass Curve Analysis of Maximum Daily Discharge per Square Kilometre - More Creek



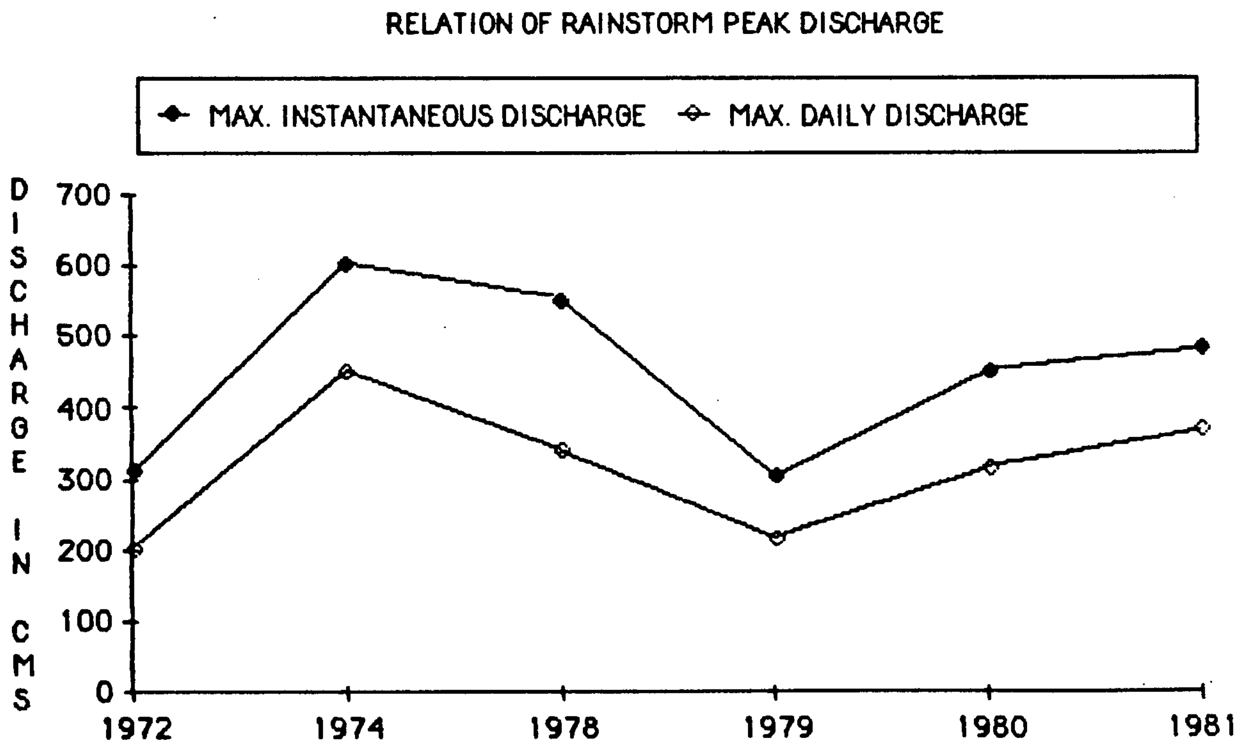


Figure 19 Relationship of Maximum Daily Discharge to Maximum Instantaneous Discharge for Snowmelt and Rainstorms

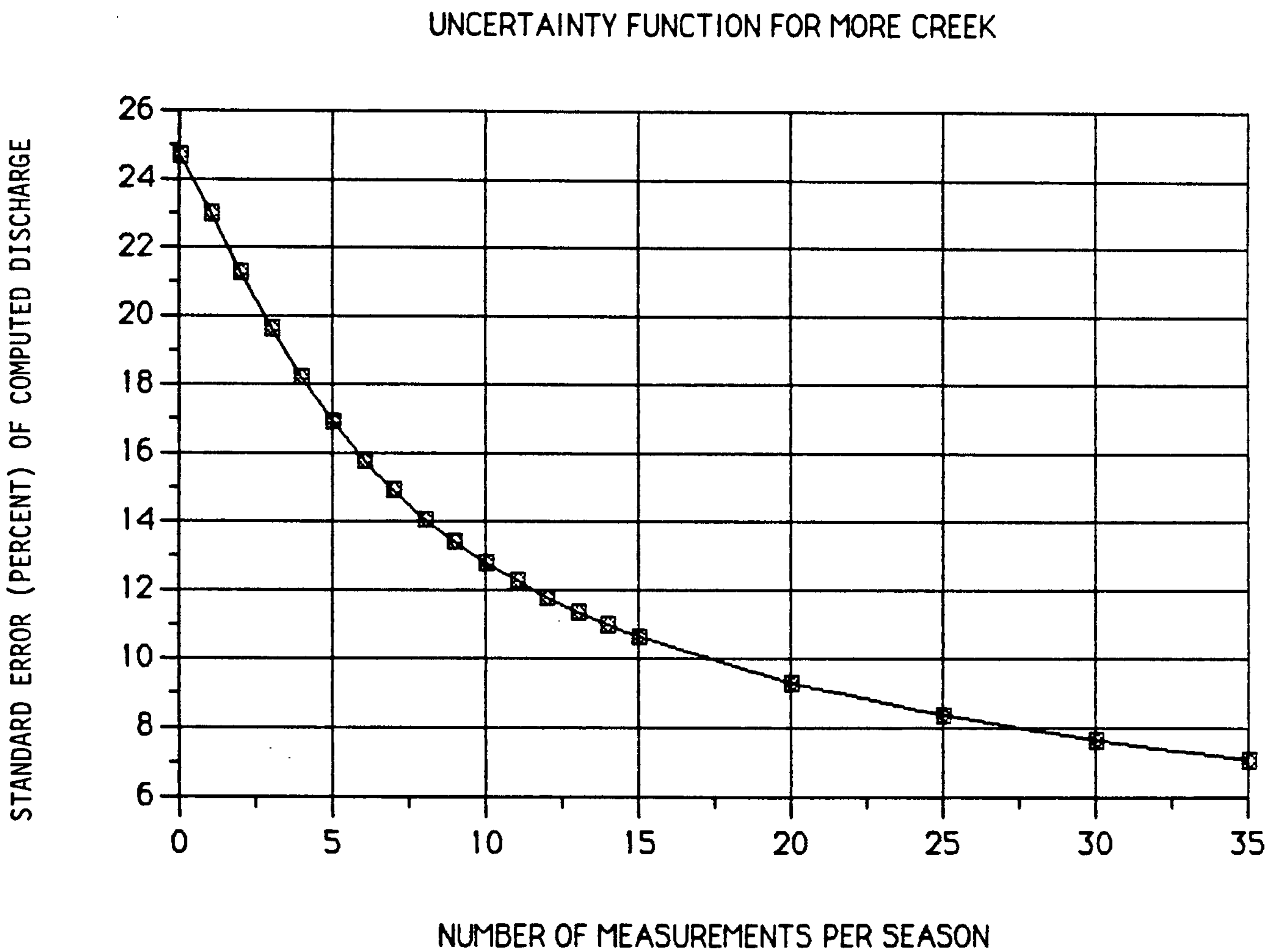


Figure 20 Relation of Standard Error of Computed Discharge to Number of Measurements per Season

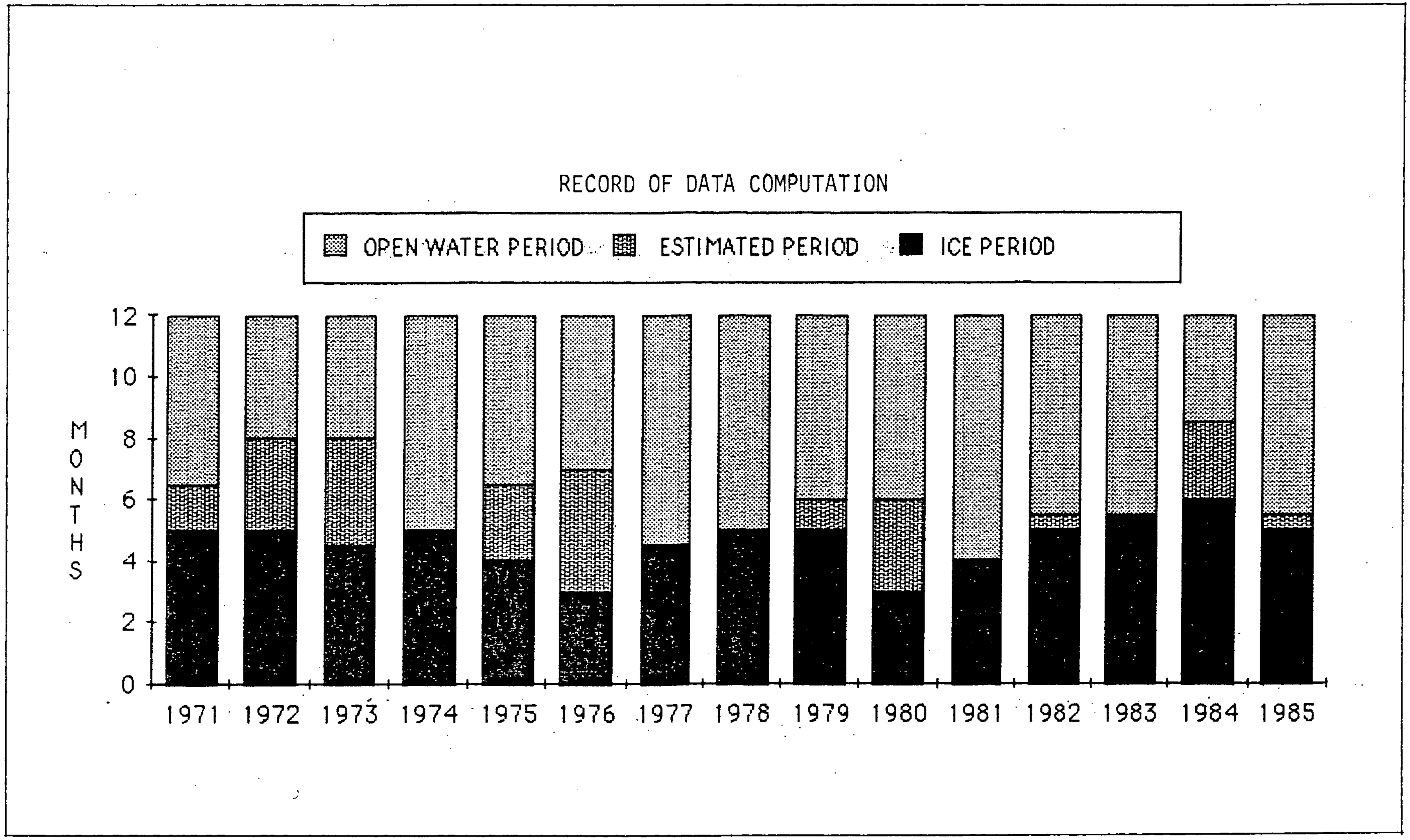
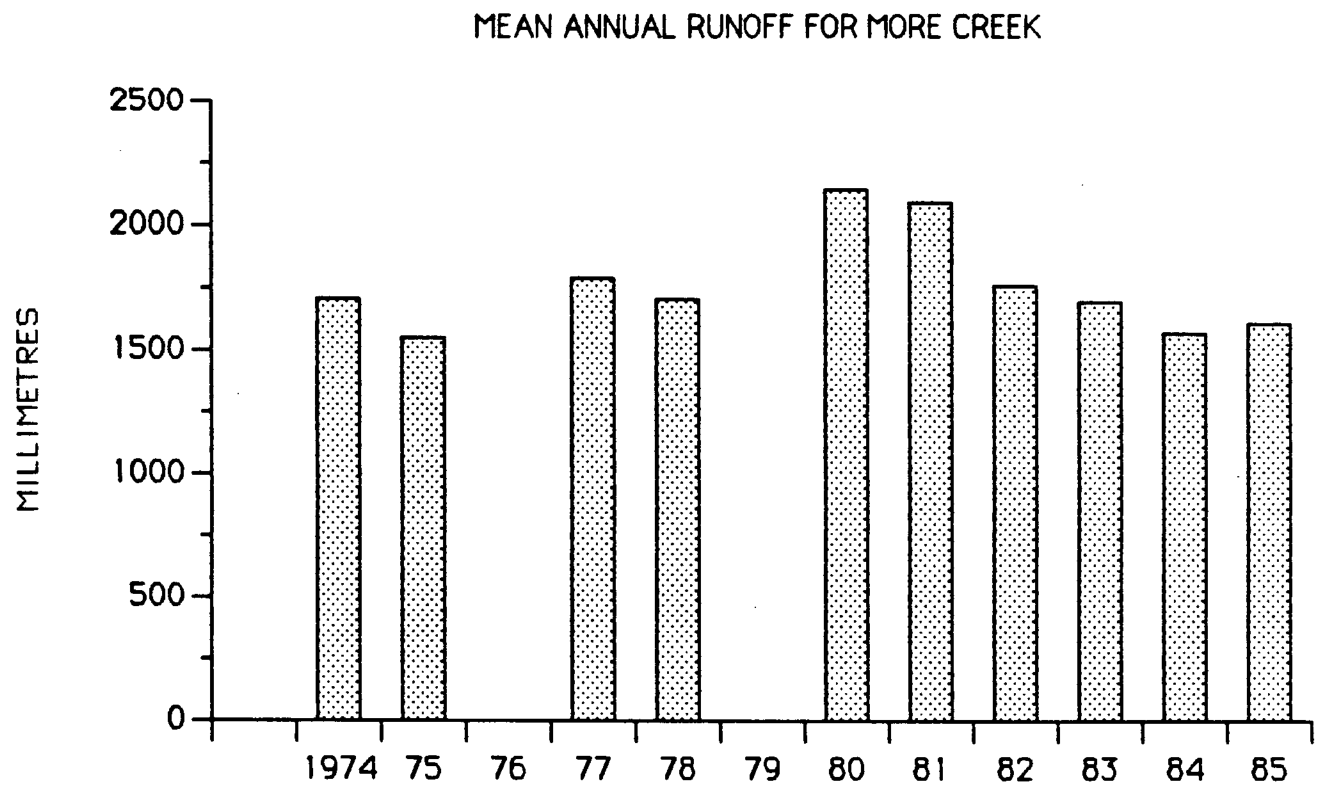


Figure 21 Methods of Data Compilation



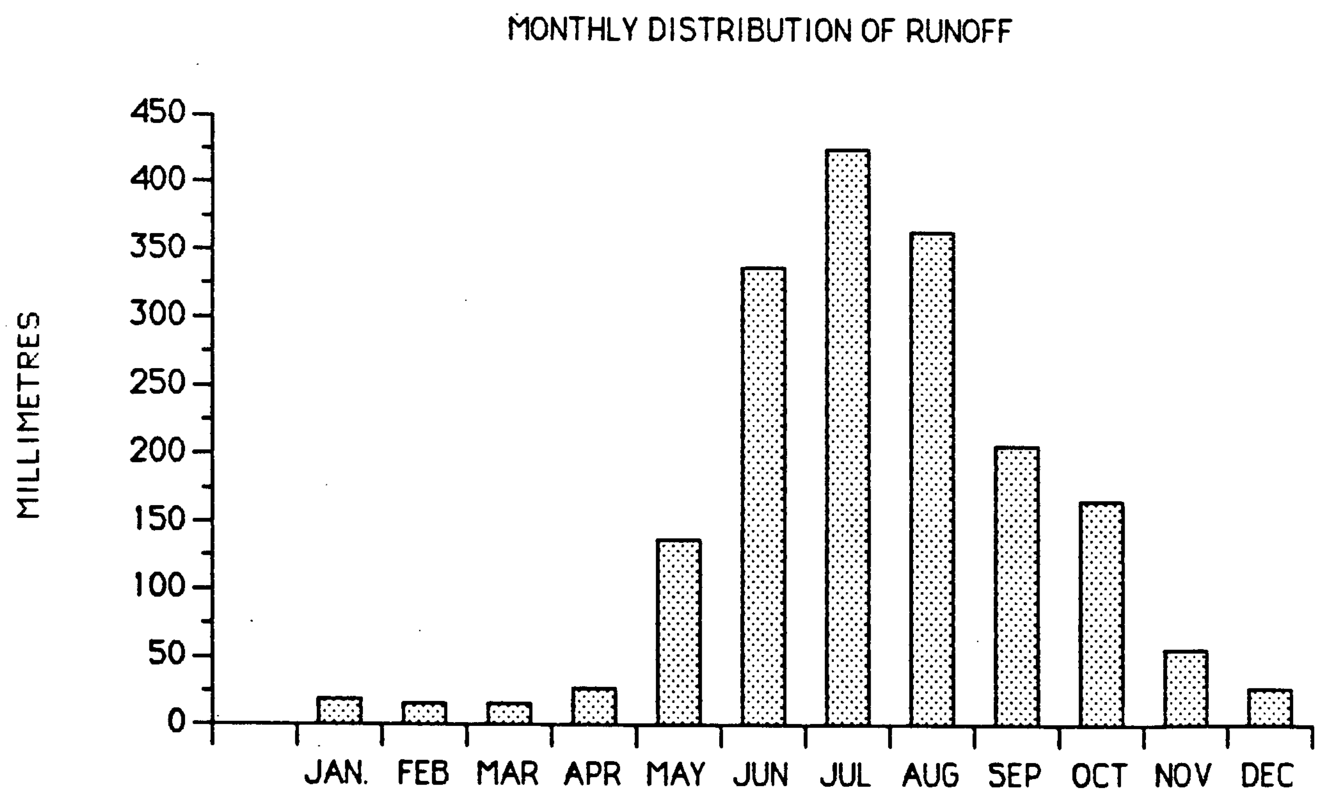


Figure 22 Mean Annual Runoff and Monthly Runoff

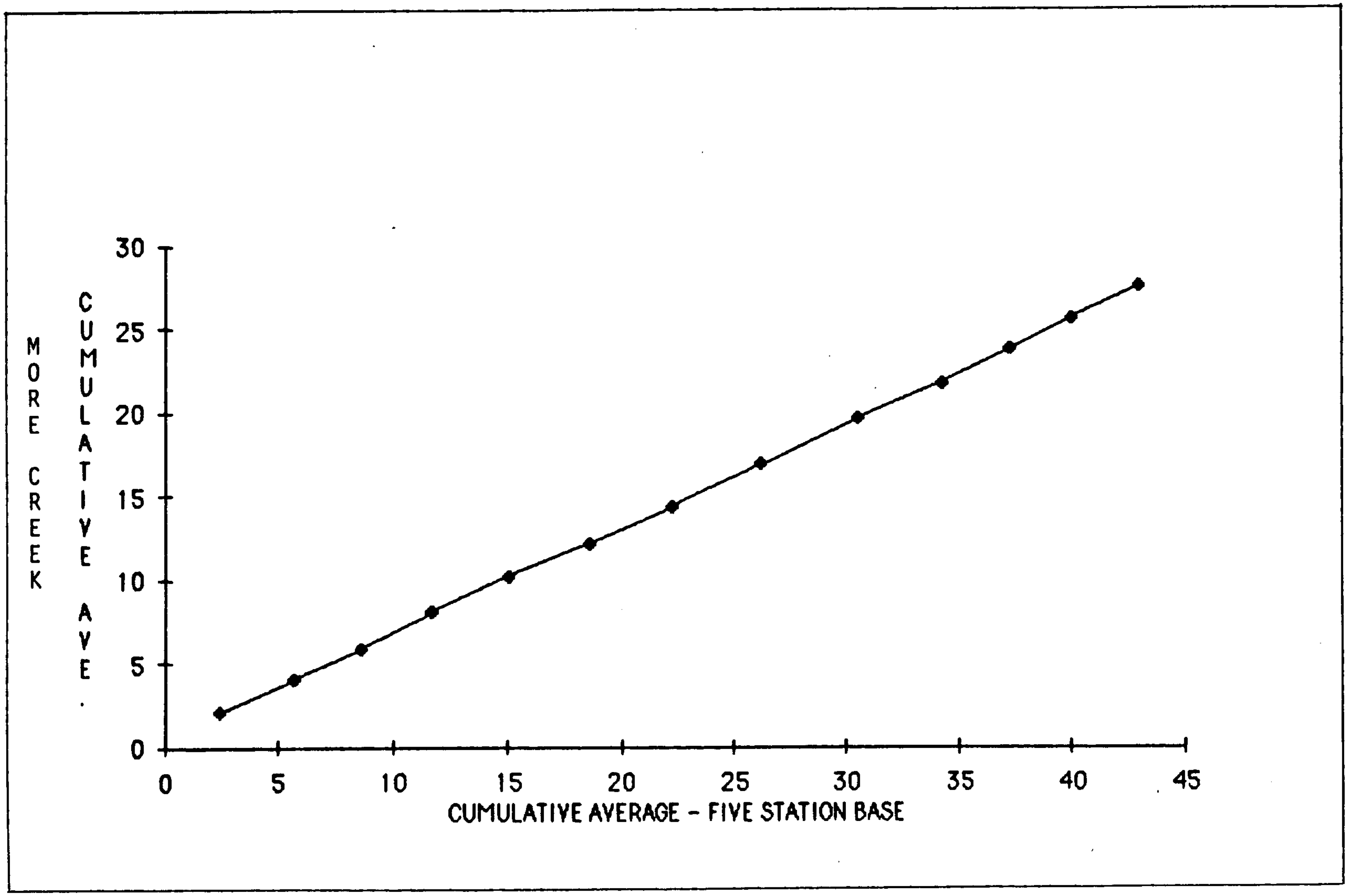


Figure 23 Double-Mass Curve Analysis of Annual Discharge

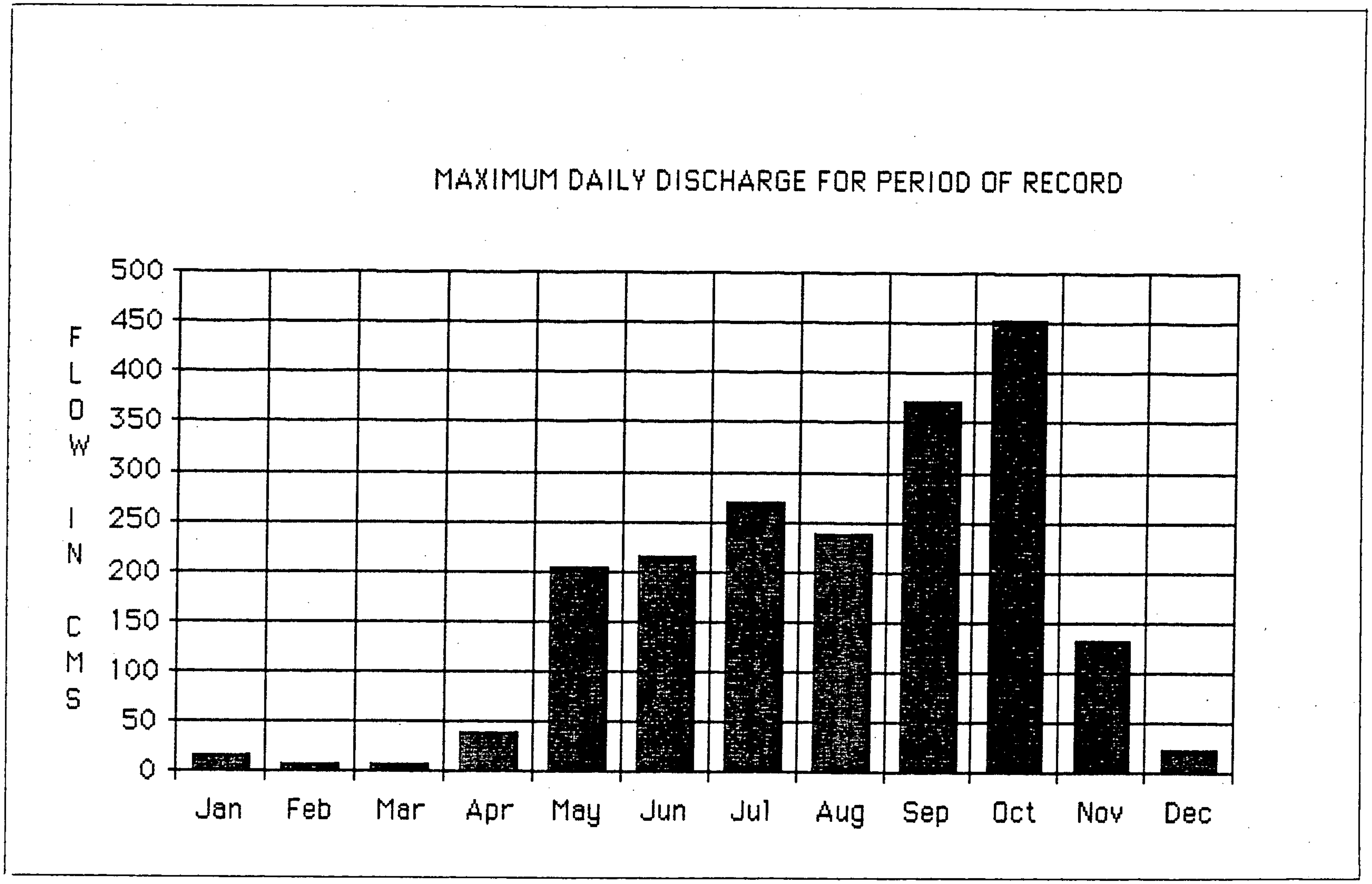


Figure 24 Distribution of Maximum Daily Discharge for Period of Record

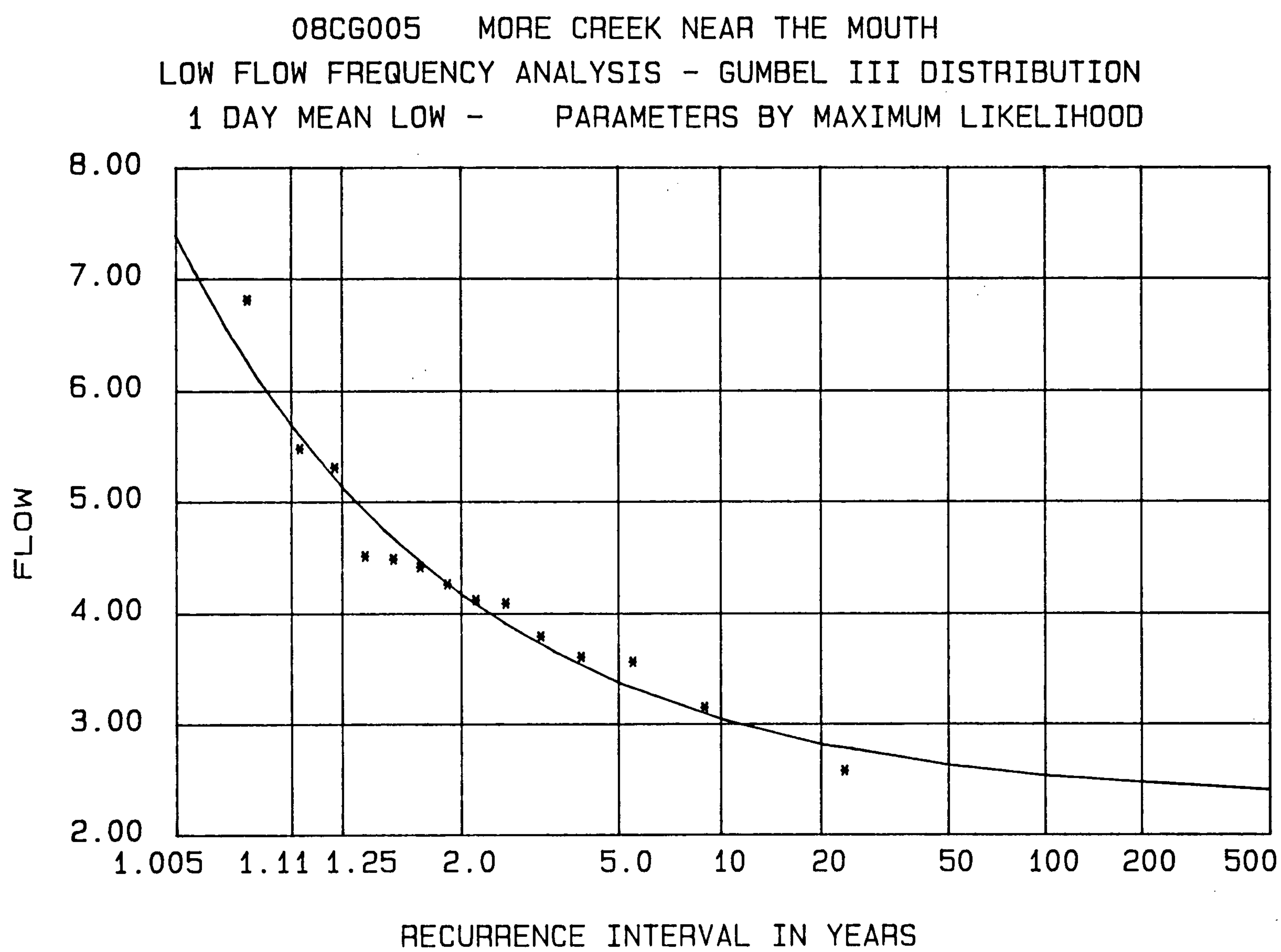


Figure 25 One Day Low Flow Frequency Curve for Gumbel III

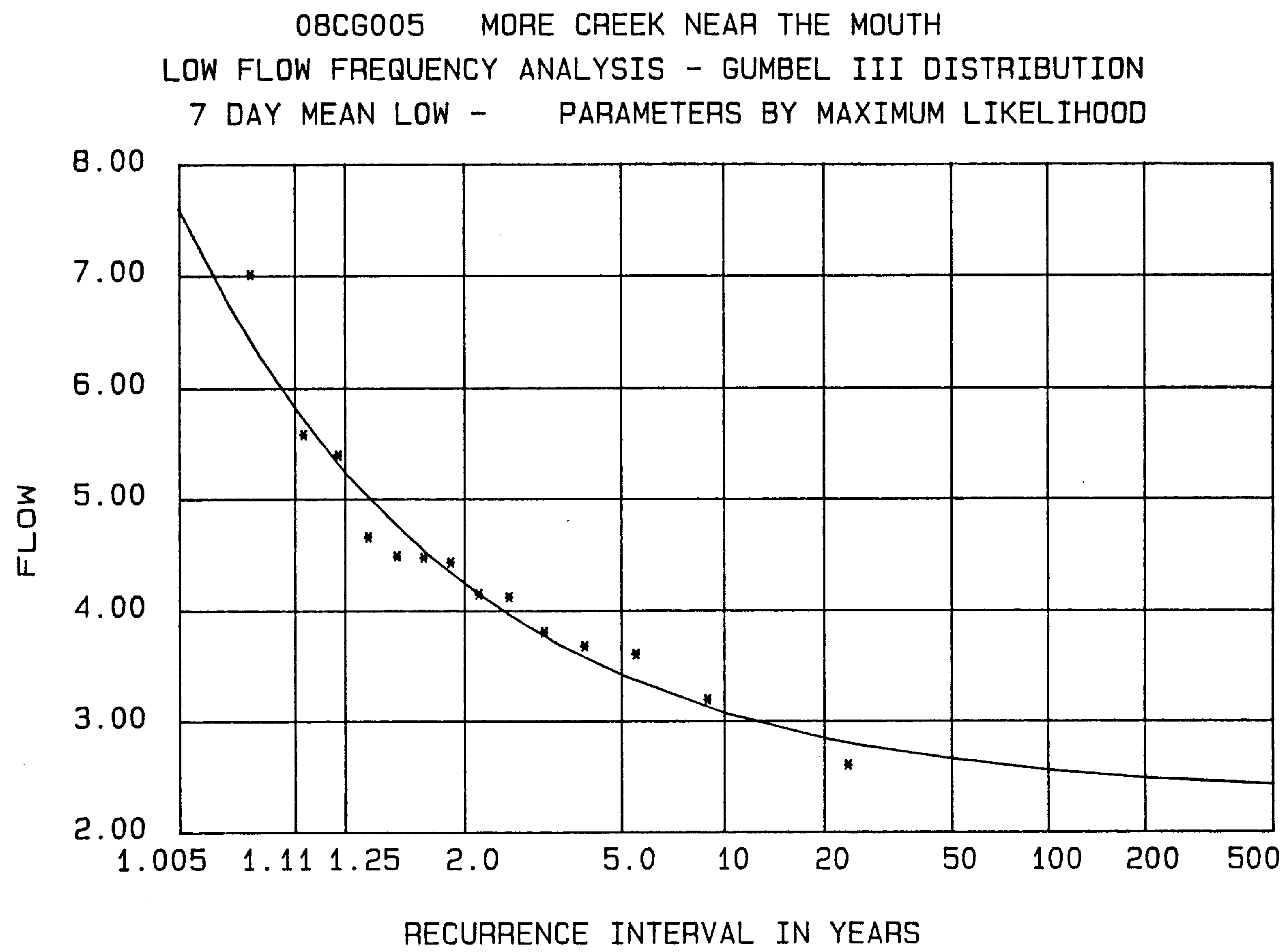


Figure 26 Seven Day Low Flow Frequency Curve for Gumbel III

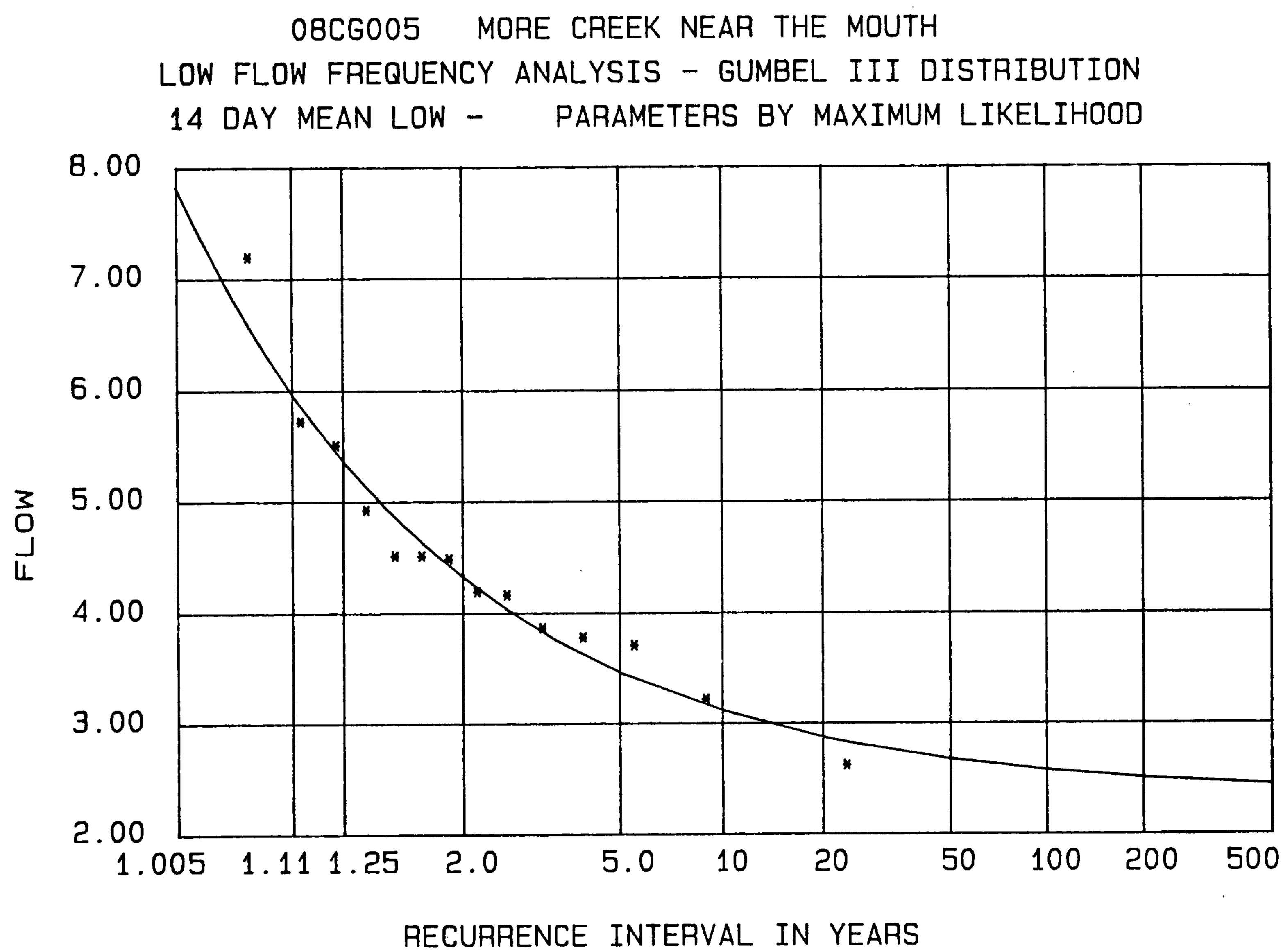


Figure 27 Fourteen Day Low Flow Frequency Curve for Gumbel III

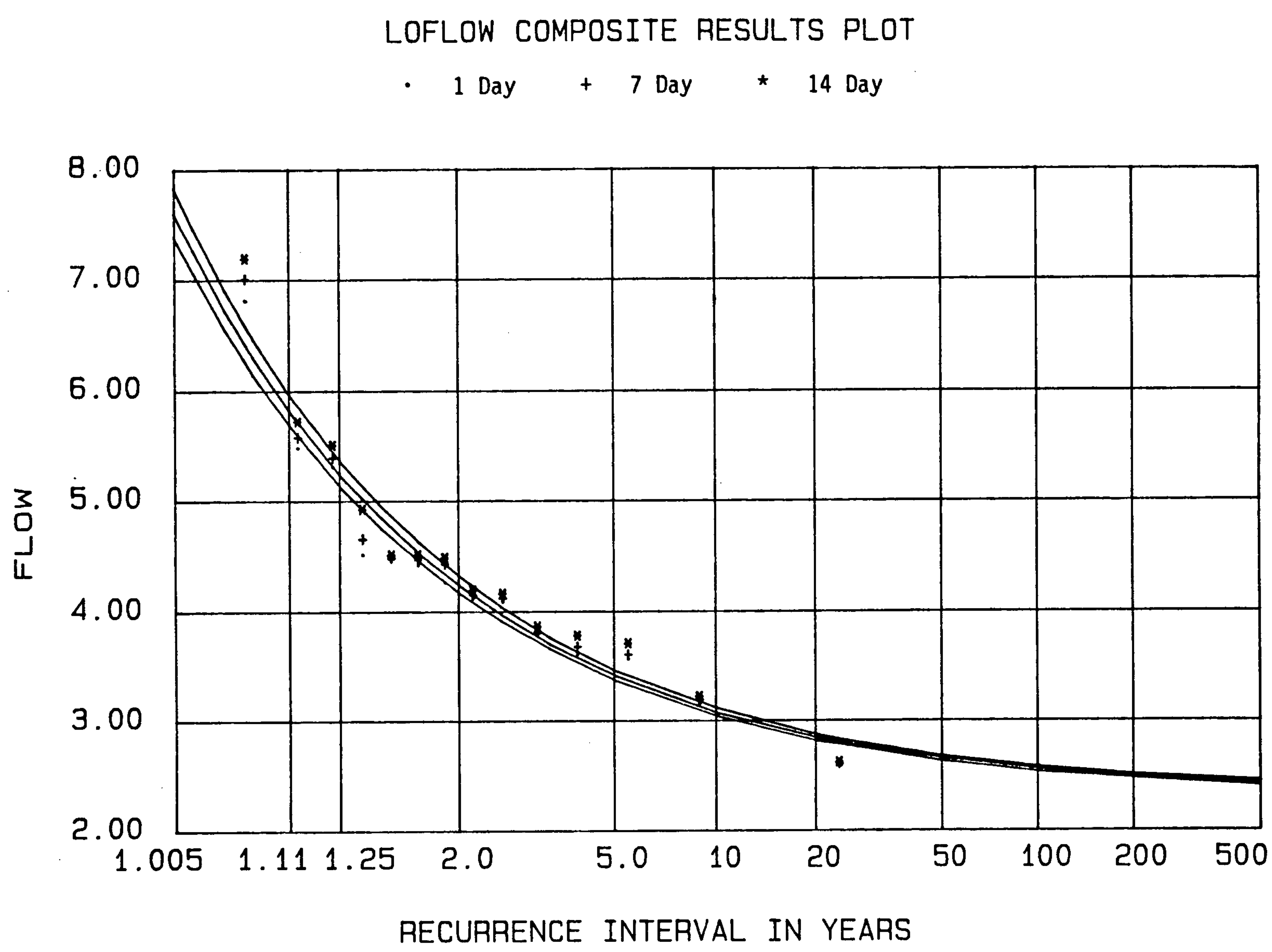


Figure 28 One, Seven, and Fourteen Day Low Flow Frequency Curves for Gumbel III

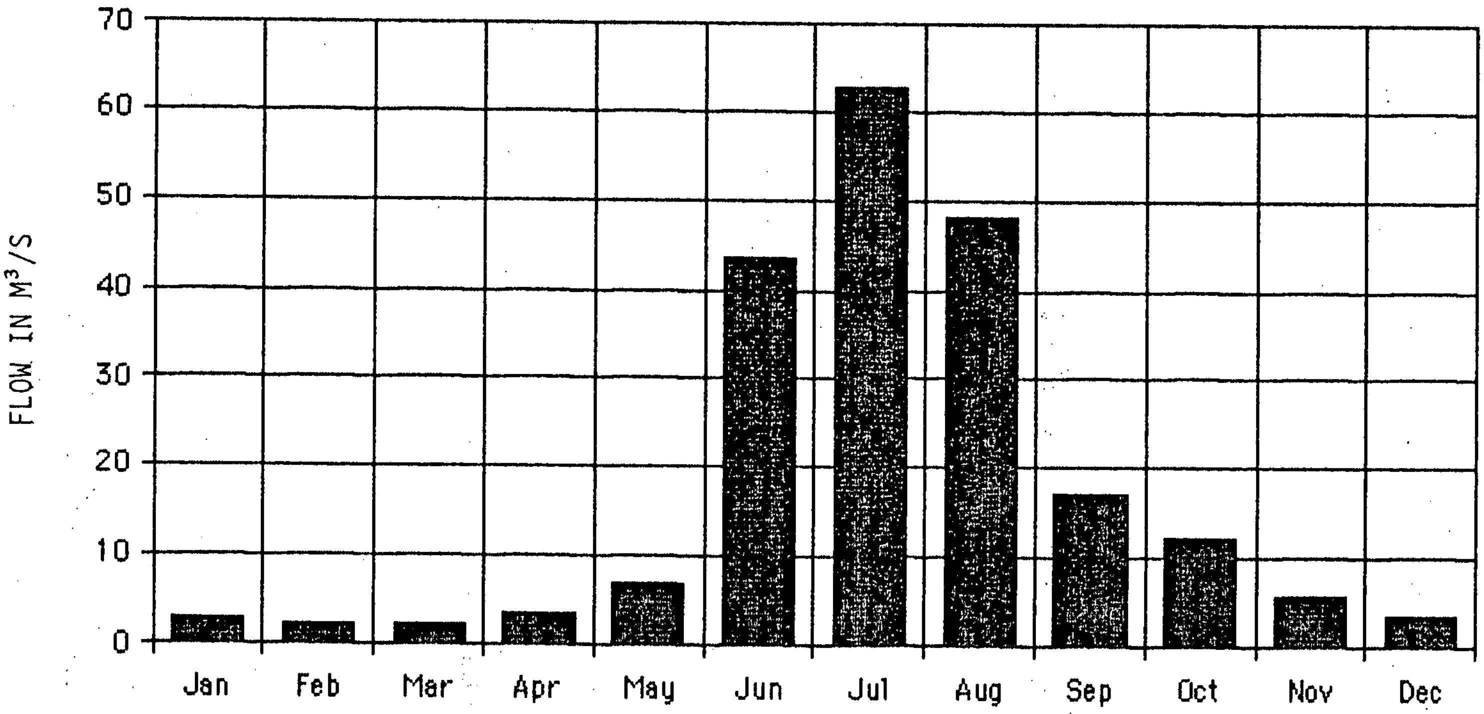


Figure 29 Distribution of Minimum Discharge for Period of Record

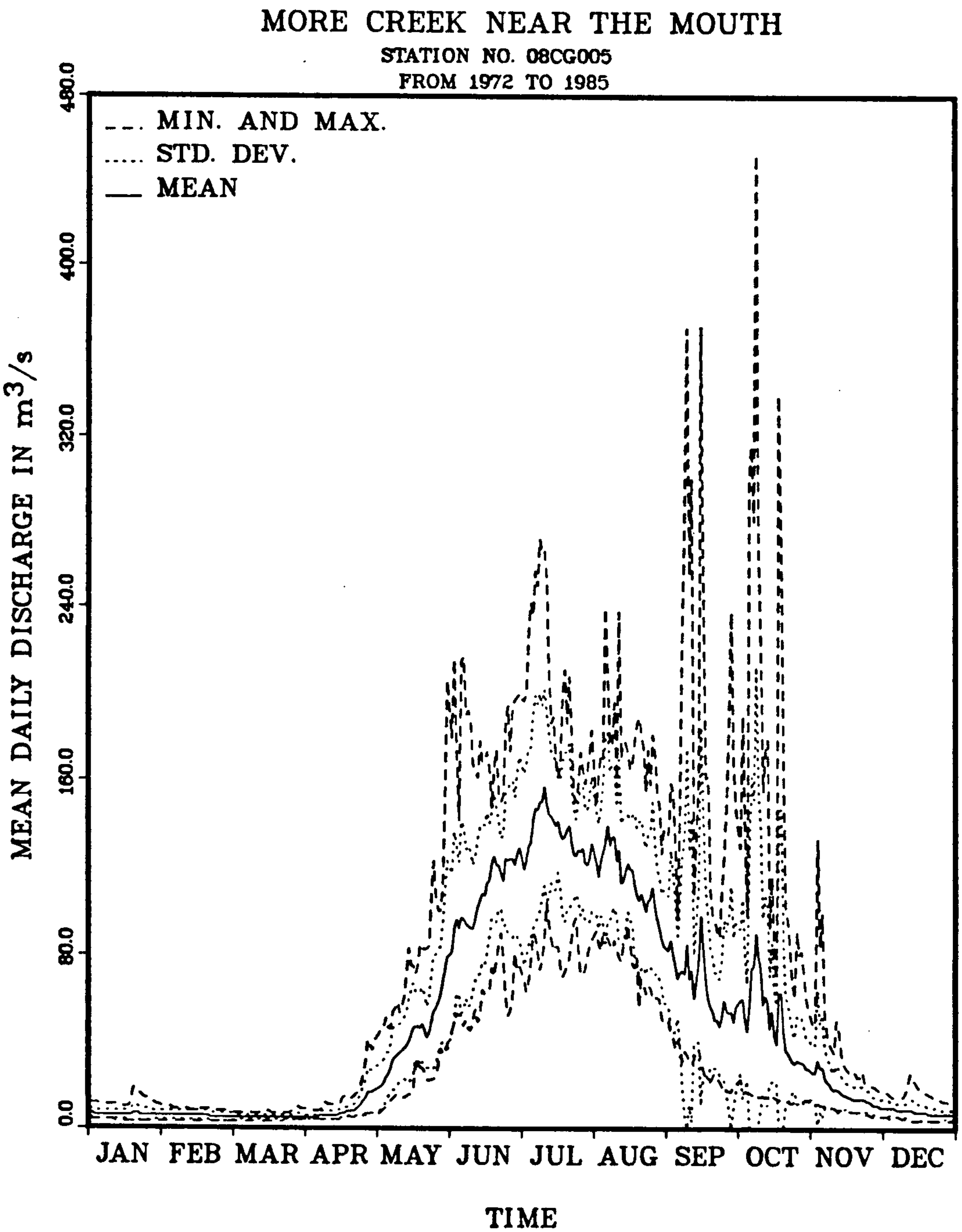


Figure 30 Hydrograph of Maximum, Minimum, Mean, and Standard Deviation of the Daily Discharges

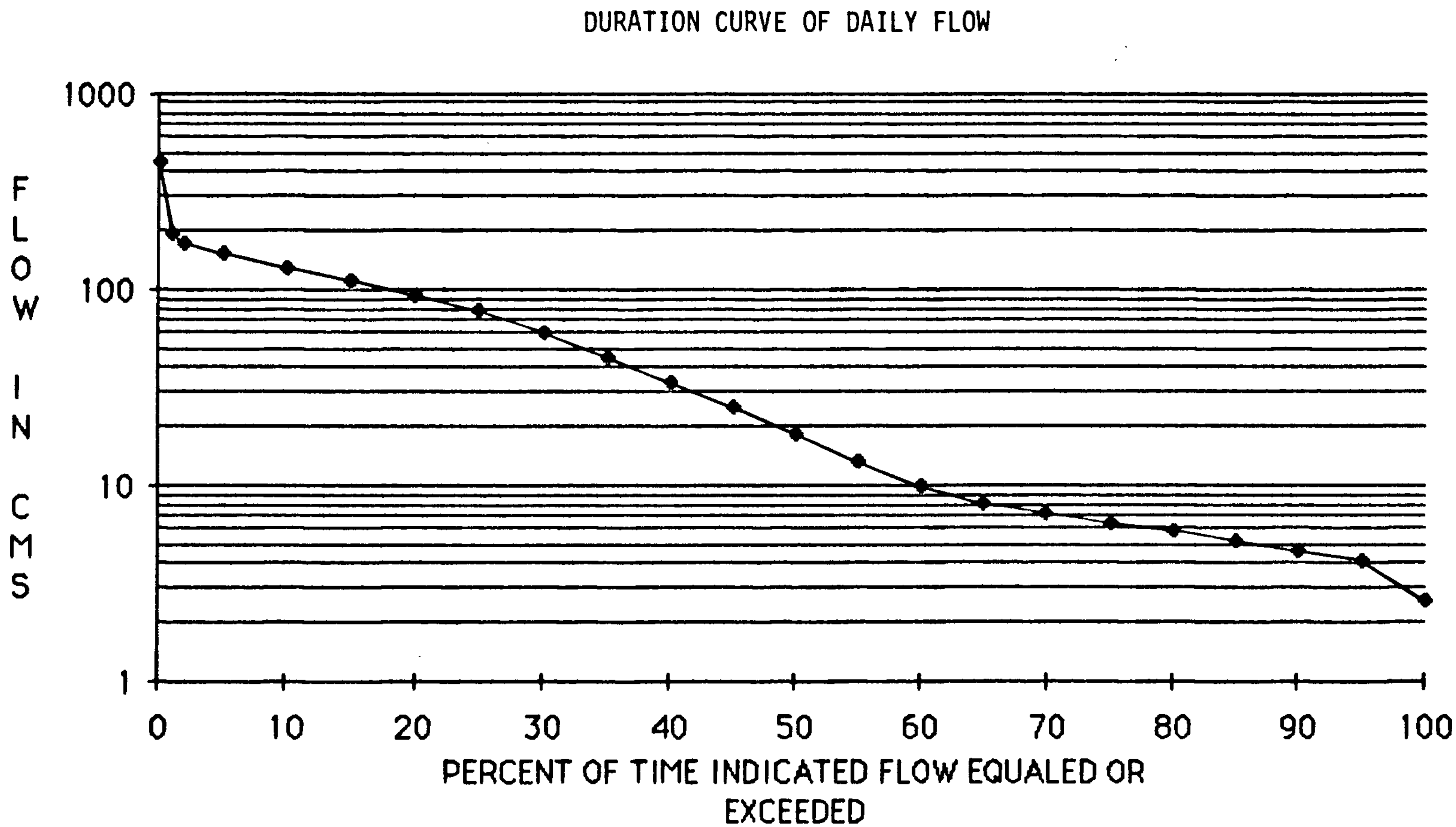


Figure 31 Duration Curve of Daily Flow