Prepared for:
ENVIRONMENT CANADA
Inland Waters Directorate
and
B.C. ENVIRONMENT
Water Management Division

FLOODPLAIN MAPPING
SALMO RIVER

Design Brief

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December, 1990
P09569.01

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1 Introduction

This Design Brief and associated Floodplain Maps for the Salmo River and Erie Creek were prepared under the Canada-British Columbia Floodplain Mapping Agreement by Acres International Limited. The floodplain delineation study was conducted from August to December 1990 and encompassed a channel length of 38 km in the Salmo River basin located in the Kootenay region of British Columbia (see **Figure 1-1**). This Design Brief describes the data and analyses undertaken and summarizes the study findings.

Principal contacts within the Victoria offices of B.C. Environment, Water Management Division for the study were Mr. P.J. Woods, Head, Special Projects Section and Mr. R.W. Nichols, Senior Hydraulic Engineer. The Water Management Division contact in the Regional Office in Nelson was Mr. D.C. Boyer, Head, Engineering Section. Valuable assistance and guidance were provided to the study by these B.C. Environment staff members, and their contributions are gratefully acknowledged.

The floodplain delineation study for the Salmo River comprised the following principal tasks:

- completion of a hydrology study to assess flooding characteristics and estimate design flows for the study reaches

- calibration of a computer backwater model (HEC-2) to estimate flood profiles, using cross-sectional data and topographic maps provided by B.C. Environment as input data

- determination of 200- and 20-year flood levels for the study reaches, using the calibrated computer model

- delineation of land areas with elevations lower than the 200-year flood levels plus freeboard as the "200-year floodplain", using topographic maps provided by B.C. Environment

- preparation of this Design Brief and associated Floodplain Maps.

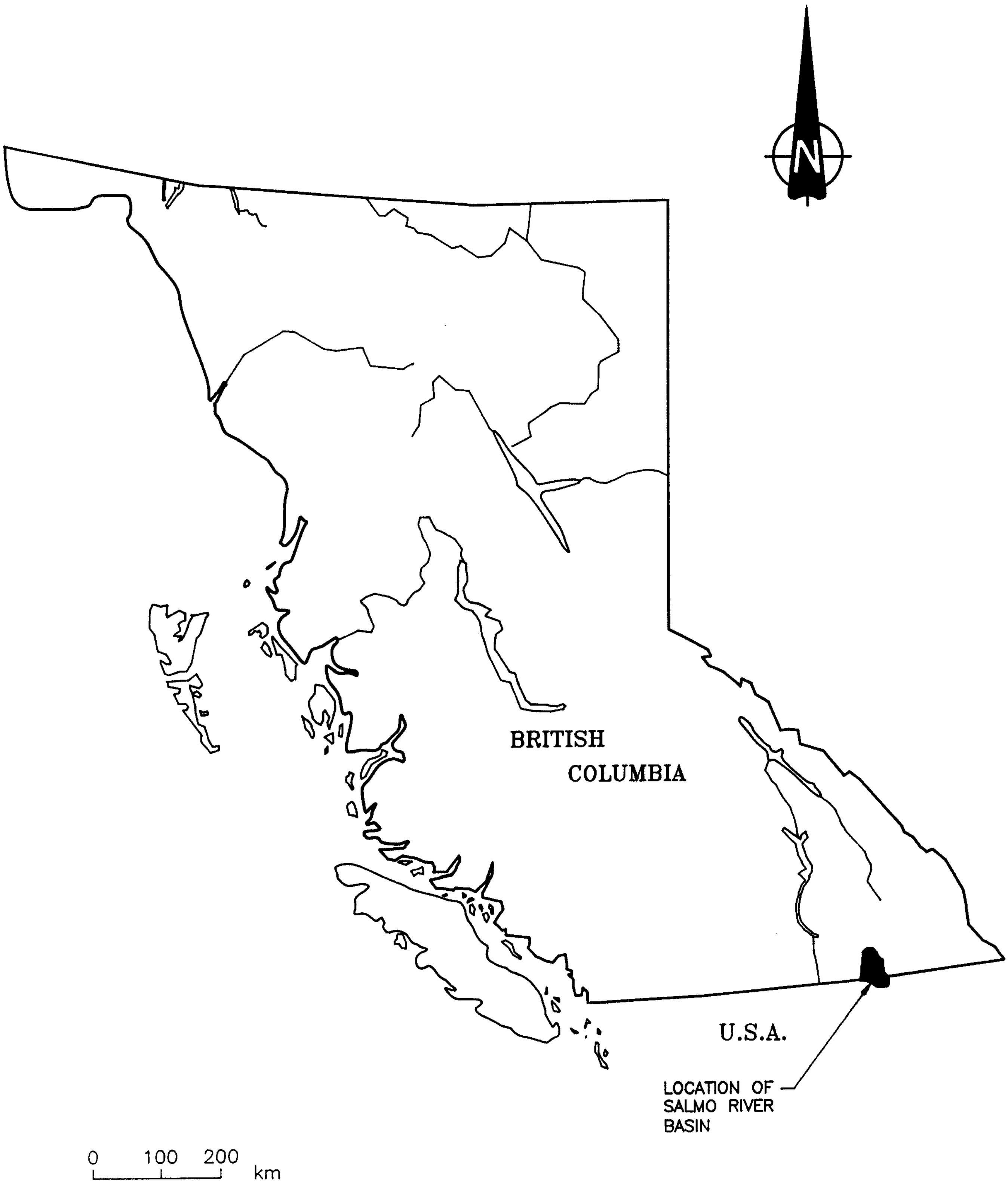

FIG. 1-1

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
LOCATION MAP

ACRES

2 Drainage Basin

2.1 Description of the Basin

The Salmo River basin lies within the Selkirk (Columbia) mountains bounded on the east and west by the Nelson and Bonnington ranges, respectively (see **Figure 2-1**). The basin is oriented north-south and is heavily forested. The terrain is generally very rugged with the mountain peaks rising to in excess of 2300 m and ground slopes as high as 50%. Significant mountain peaks in the basin are Toad (2200 m), Copper (2225 m), Erie (1650 m), Ymir (2400 m), Baldy (2320 m), Three Sisters (2375 m) and Ripple (2300 m).

The catchment area at the downstream end of the study reach is 1230 km^2. The principal town in the basin is Salmo with a population of about 1200[1]. The town originally grew in response to the extensive mining activity in the area. Over the years, mining has declined and has been replaced by forestry and, to a lesser extent, by tourism. There is also a limited amount of farming undertaken in the valley bottom in the vicinity of Salmo. Smaller communities in the basin are Ymir, Hall and Porto Rico.

2.2 Hydrological Characteristics

The Salmo River flows generally north to south and turns westward just prior to entering the Pend D'Oreille River, which flows into the Columbia River and onwards to the Pacific Ocean. The Salmo has several significant tributaries in the study reach including (from upstream to downstream) Ymir Creek, Porcupine Creek, Hidden Creek, Erie Creek, Sheep Creek and South Salmo River. The drainage area of the study reach varies as indicated in **Table 2-1**. All streams in the area have relatively steep grades and medium to large cobbles in the streambeds. Typically, the overbank areas are heavily forested.

The mean daily temperature ranges from -5.6°C. in January to 18.1°C. in July[2], with recorded temperature extremes of -27.0°C. and 40.6°C. Of the total annual precipitation of 860 mm, approximately two-thirds occurs as rain and one-third as snow.[3] The 100-year 24-hour maximum precipitation, as documented in the

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1 "Background Planning Study - Village of Salmo", Matheson, R. and F. Dykeman, Regional District of Central Kootenay Planning Department, 1981.

2 "Canadian Climatic Normals, Volume 2, Temperature, 1951-1980," Atmospheric Environment Service, Environment Canada, 1982.

3 "Canadian Climatic Normals, Volume 3, Precipitation, 1951-1980," Atmospheric Environment Service, Environment Canada, 1982.

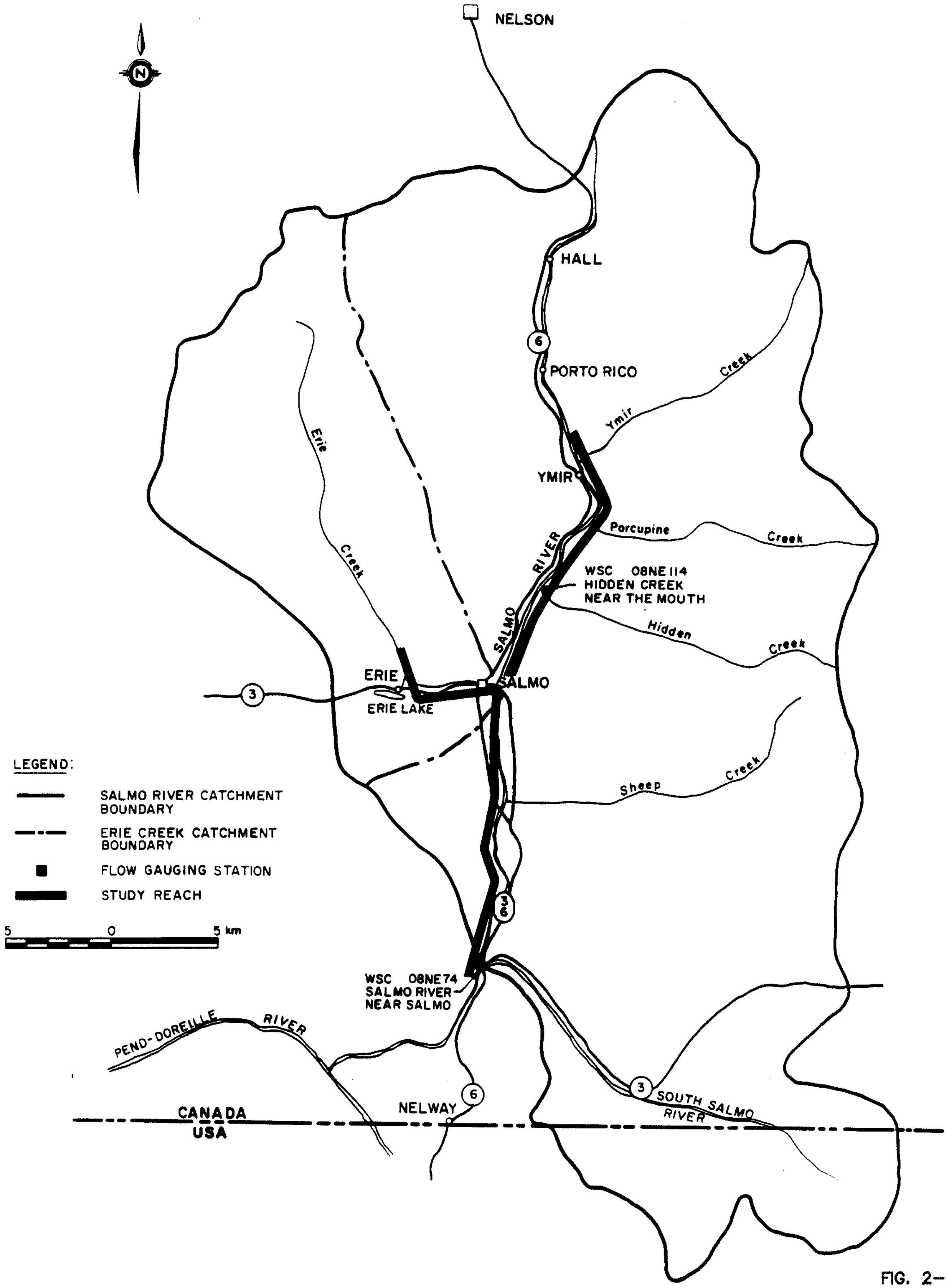


FIG. 2-1

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM - SALMO RIVER
STUDY AREA

TABLE 2-1
DRAINAGE AREAS

Location		Drainage Area (km^2)
(a)	**Salmo River - Main Stem**	
	Upstream End of Study Reach (above Ymir Creek)	231
	Upstream of Porcupine Cr. confluence	343
	Upstream of Hidden Cr. confluence	422
	Upstream of Erie Cr. confluence	518
	Upstream of Sheep Cr. confluence	784
	Upstream of South Salmo R. confluence	902
	Salmo Gauge 08NE74 (Downstream End of Study Reach)	1230
(b)	**Erie Creek at the Mouth**	232

Atmospheric Environment Service (AES) Rainfall Frequency Atlas for Canada[4], is quite low at 55 mm. It must be borne in mind, however, that recorded precipitation values are probably low in relation to basin-wide conditions. Meteorological stations are almost invariably located in valley bottoms and precipitation is generally greater at higher elevations, particularly on the windward slopes.

The two operating flow gauging stations within the study basin are shown in Figure 2–1. The mean annual runoff recorded at the long term station on the Salmo River near Salmo (WSC 08NE74) is 31.7 m^3/s. This is equivalent to a runoff depth of 813 mm, suggesting a coefficient of runoff of 95% (813 mm runoff versus 860 mm precipitation), which is unrealistically high for a heavily forested catchment. It suggests that recorded precipitation data do, in fact, underestimate catchment precipitation. The annual flood peak occurs from late April to mid June[5]. In fact, the annual runoff hydrograph is very much dominated by the spring freshet — on average, 70% of the annual flow is observed in April, May and June.

The snowmelt-dominated flow pattern observed for the Salmo River has been observed from the shorter flow record on Hidden Creek, a small tributary of the Salmo River (see Figure 2-1). This has important implications for the flood frequency analyses — it appears that throughout the basin, the maximum annual flow is attributable to spring snowmelt supplemented by rainfall. No consideration needs to be given to rainfall-induced events at other times of the year.

While the annual flood peak is a snowmelt event, damaging floods usually require the occurrence of significant rainfall in addition to rapid snowmelt. These rains usually result from frontal systems moving in from the west coast which are subjected to significant orographic effects from the local topography. During the early summer, non-frontal "cold lows" occasionally pass through the area from the northwest, west or southwest, and sometimes produce significant amounts of rainfall before moving eastwards. Convective rainstorms typically occur in the summer months, but do not produce large floods, except on very small creeks.

4 "Rainfall Frequency Atlas for Canada", Hogg, W.D. and D.A. Carr, Atmospheric Environment Service, Environment Canada, 1985.

5 "Historical Streamflow Summary to 1988, British Columbia," Inland Waters Directorate, Environment Canada, 1989.

2.3 Historical Floods

Over the years, the study area has been subjected to floods, some of which have caused significant damages. The following paragraphs describe the worst floods based on information obtained from newspaper files, discussions with long term residents of Salmo and, when available, Water Survey of Canada flow data.

May 1928

A heavy rainstorm on May 22nd, presumably supplementing snowmelt runoff, caused flooding at the small communities of Porto Rico and Hall, located near the northern end of the study basin. At Hall, 100 m of the highway (from Salmo to Nelson) was reportedly washed out.

June 1933

There was a significant regional flood in mid-June 1933, prompted by an unusual warm period occurring at a time of high runoff due to normal spring freshet conditions. The Nelson Daily News of June 16 reported, "Between Nelson and the international boundary at Nelway, the highway is cut in many places, and boulders are roaring and crashing in the turbid floods". Hall Creek at Hall cut through both sides of the bridge, prompted by the collapse of a brush and debris dam higher up the Hall Creek valley. By the time that crews cleared the blockage at the bridge, the creek had made a cut 5 m wide and over 1 m deep. A temporary bridge was installed, but later new log jams occurred, causing further damages. Sheep Creek ran high and a log jam backed the water up significantly to cause the temporary shutdown of a sawmill's power plant. The Great Northern railway line was washed out at Porto Rico for 30 to 40 m, including bridge No. 25.

June 1968

The flood of June 2, 1968 was the largest recorded on the Salmo River near Salmo in the 41 year period of record. The instantaneous peak flow of 462 m^3/sec corresponds to a return period of about 80 years (see Section 4). The flood resulted from nearly 50 mm of warm rain, coinciding with a period of rapid snowmelt.

Two bridges on Barrett Creek at Porto Rico were washed away during this flood event. The Great Northern Railway bridge, 21 km north of Salmo, was also washed out and a home near the bridge was threatened when flood waters flowed behind the house. Just south of Salmo, the highway (old Highway 3) was inundated to a depth of about 0.8 m over a length of about 100 m (see **Photograph 1**). Many homes along the Salmo River were surrounded by water and animals had to be led to higher ground. Sandbagging was required to prevent Erie Creek from eroding its banks adjacent to Salmo Secondary School and a local residence. The bridge piling was washed out on Sheep Creek at Rotters Mill and the road was closed.

May 1971

Flooding in mid-May 1971 forced the evacuation of Salmo Elementary School when the approaches to a bridge there were washed away by the Salmo River. Extensive sandbagging was undertaken to protect the school and nearby houses (see **Photograph 2**). The recorded peak flow at the Salmo River gauge was 326 m^3/sec, corresponding to a return period of about four years.

May 1975

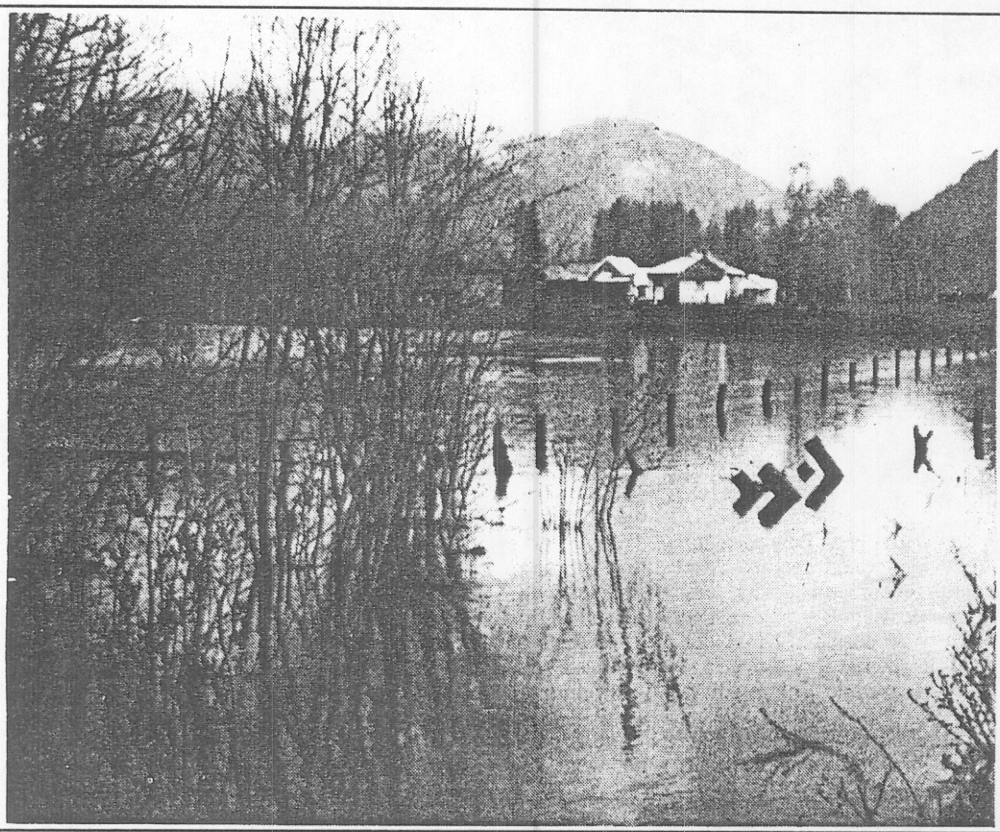
The highway just south of Salmo was once again inundated, with shallow flooding as shown in **Photograph 3**. Several homes were threatened by this "average" spring flood, for which the recorded instantaneous peak flow was 261 m^3/sec.

April 1980

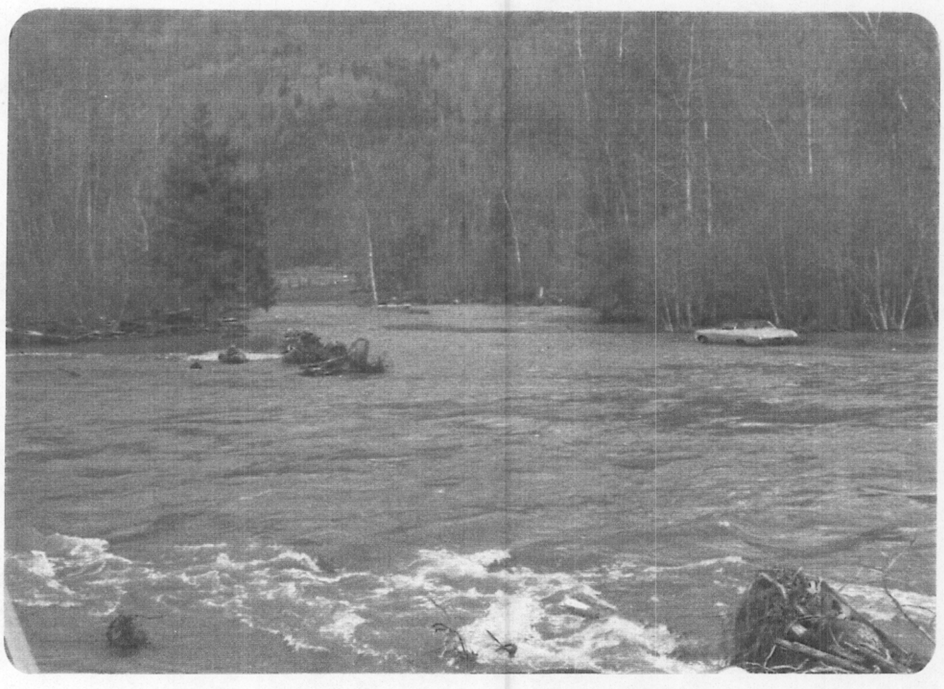
This was the second highest recorded flood on the Salmo River, with a recorded instantaneous peak flow of 439 m^3/s occurring on April 29. The flood was caused by unseasonably warm weather combined with thunderstorms. The estimated return period for this event is 50 years.

During this flood event, the Apex Creek bridge near Whitewater ski area was washed out, along with 400 m of the road. Extensive dyking measures were undertaken in Salmo to try to contain the Salmo River and Erie Creek. The highway near the airport was once again inundated by the flood. The railway line was washed out just north and south of Salmo. Additional evidence of flood damages is presented in **Photographs 4, 5 and 6.**

PHOTOGRAPH 2 - Sandbagging in Progress to Protect Salmo Elementary School (May, 1971)



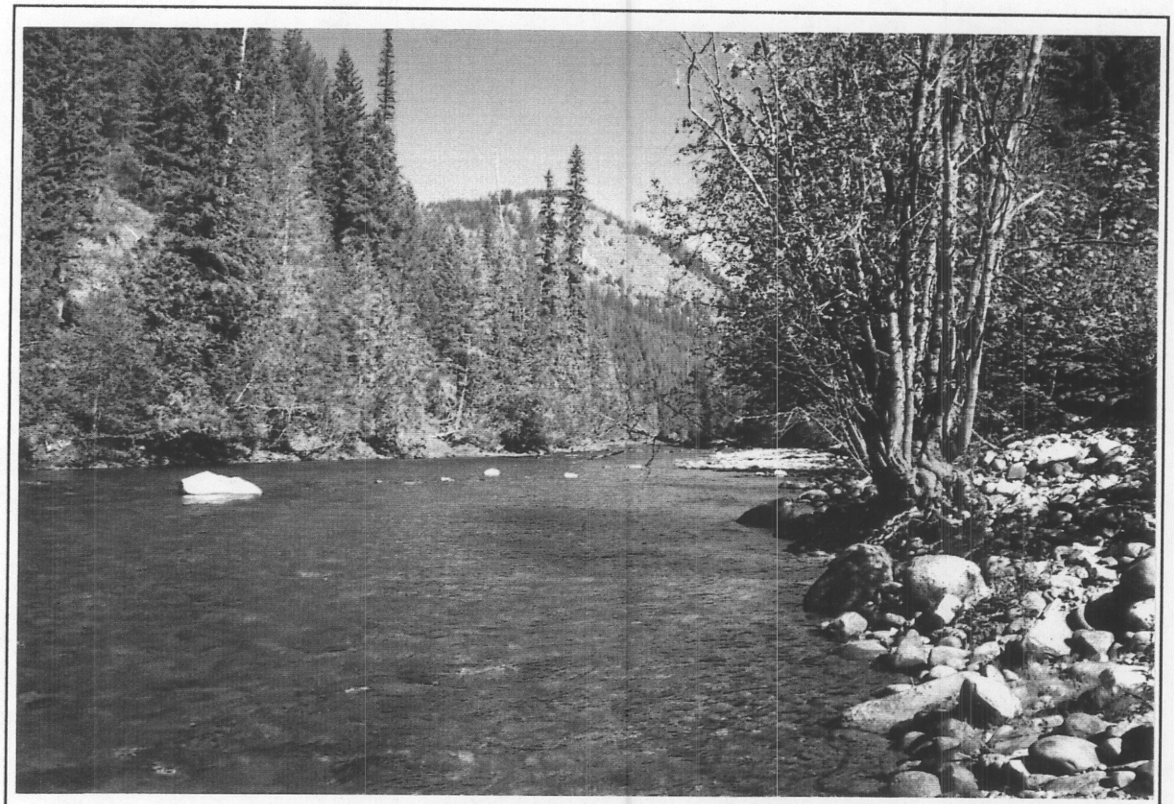
PHOTOGRAPH 3 - Old Highway 3, South of Salmo (May, 1975)



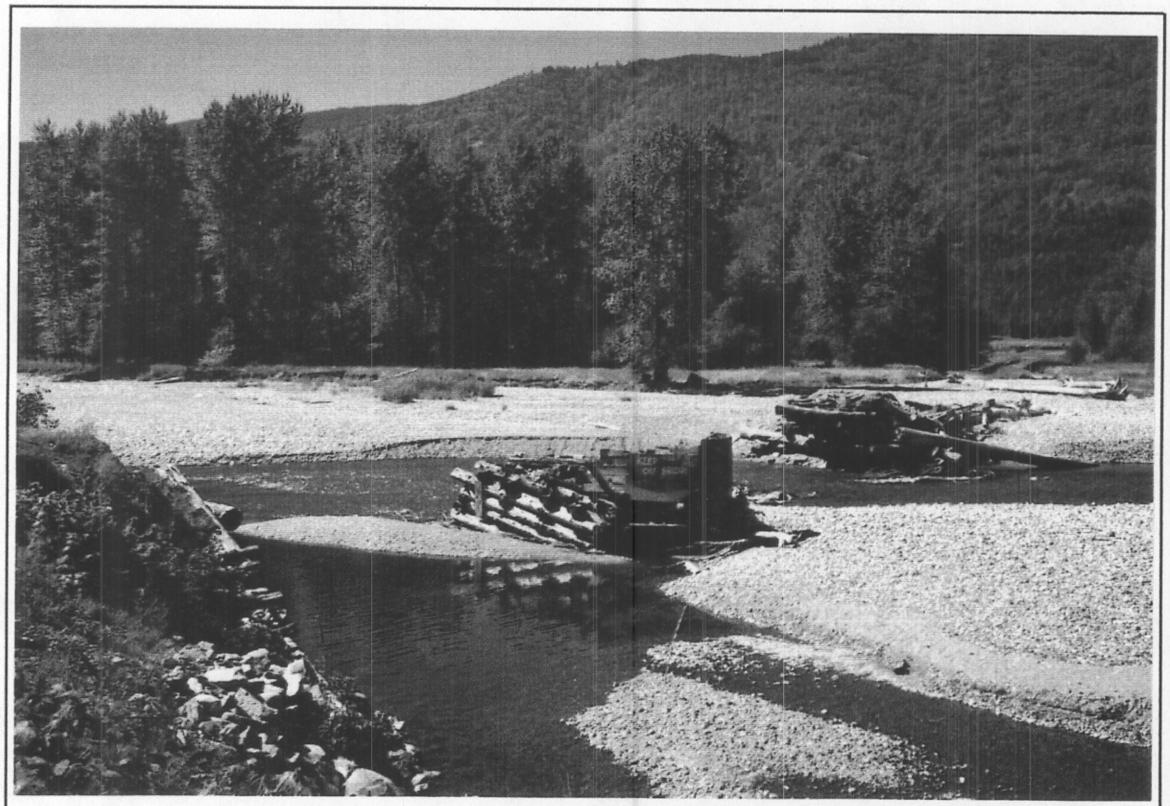
PHOTOGRAPH 4 - Flooding of Robertson's Farm at Bridge Crossing (April, 1980)

PHOTOGRAPH 5 - Halfway Creek (April, 1980)

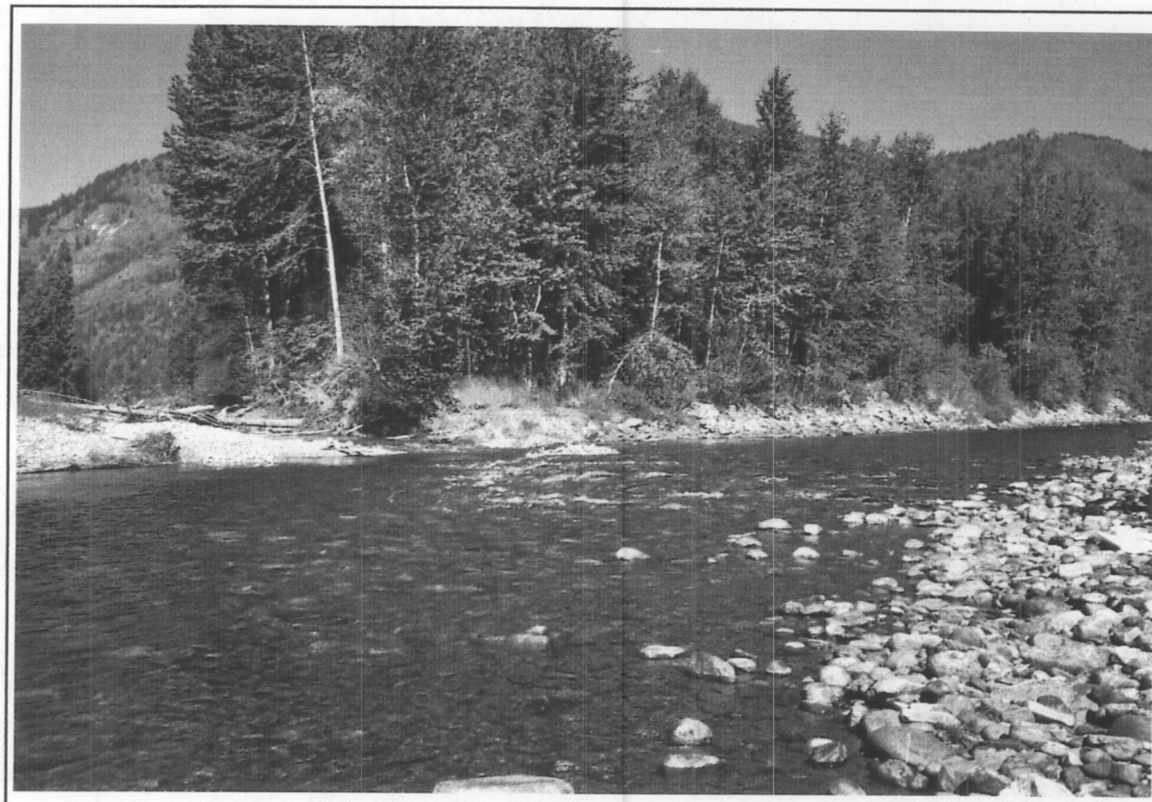
PHOTOGRAPH 6 - Halfway Creek - Water Overtopped Road Due to Channel Constrictions (April, 1980)



PHOTOGRAPH 7 - Salmo River, Downstream End of the Study Reach



PHOTOGRAPH 8 - Salmo River at Robertson's Farm Bridge Crossing



PHOTOGRAPH 9 - Confluence of Salmo River and Erie Creek

PHOTOGRAPH 10 - Salmo River near the Upstream End of the Study Reach

PHOTOGRAPH 11 - Erie Creek Near the Upstream End of the Study Reach

3 Data Used for the Study

3.1 Data Sources

3.1.1 The Study Basin

Flood frequency analysis requires at least ten years of data at a site before a meaningful analysis may be undertaken. Over the years, Water Survey of Canada has operated a number of gauging stations in the Salmo River basin but, typically, only for a few years. The two stations with usable records are the Salmo River near Salmo (WSC No. 08NE74) and Hidden Creek near the mouth (WSC No. 08NE114). The key characteristics of these stations are presented in **Table 3-1**.

3.1.2 The Study Region

In 1989, B.C. Environment undertook a regional flood frequency analysis for the Kootenay (Nelson) region[6]. In that study, no regional curves or regional equations were developed for estimating peak flows for ungauged basins, due to the diverse characteristics of the gauged basins and the influence of this diversity on flood characteristics. The plots of unit mean annual flood (mean annual flood divided by drainage area) versus drainage area presented in the B.C. Environment report showed significant scatter on a sub-region basis, with a general trend of increasing unit flood peaks with drainage area. Such a trend is not normally expected, as small basins typically generate higher unit flood peaks than do larger basins. This demonstrates that other factors (e.g. basin elevation, orientation, natural storage) exert a significant influence on the flood characteristics of Kootenay region watersheds.

3.2 Field Investigations

During the course of the study, two reconnaissance trips to the Salmo area were undertaken by the principal investigator. The dates of the trips were September 5-7 and November 1-2, 1990. On the first trip, a reconnaissance of the accessible study reaches was undertaken to estimate the hydraulic roughness of the overbank portions of the river and to make note of any features that would be relevant to the hydraulic analysis of floods. Some representative photographs were taken of the river along the study reaches (see **Photographs 7 to 11**). Discussions were held with Mr. Dwain Boyer (Head, Engineering Section, Water Management Division) in Nelson; he provided background material on the Salmo River basin and past flooding problems. Discussions were also held with Mr. Brent Tipple of the Water Survey of Canada in Nelson, concerning flood records and rating curves for stations in the area.

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6 "Guide to Peak Flow Estimation for Ungauged Watersheds in the Kootenay (Nelson) Region", Recksten, D.E. and L.J. Barr, B.C. Ministry of Environment, Water Management Branch, 1989.

TABLE 3-1
FLOW GAUGING STATIONS WITHIN THE STUDY BASIN WITH USABLE RECORDS

Item	Station	
	Salmo River Near Salmo	**Hidden Creek Near the Mouth**
Water Survey of Canada No.	08NE74	08NE114
Drainage Area (km^2)	1230	56.7[1]
Gauge Location	LAT 49-04-07 N LONG 117-16-37 W	LAT 49-14-04 N LONG 117-14-17 W
Period of Record[2]	1949-date	1973-date
Type of Flow	Natural	Natural
Rating Curve	Stable at medium and high flows	Stable at medium and high flows

1 The published drainage area of 75.4 km^2 was found to be incorrect. After consultation with Water Survey of Canada staff 56.7 km^2 was concluded to be the correct figure.

2 "Historical Streamflow Summary to 1988, British Columbia", Inland Waters Directorate, Environment Canada, 1989.

Interviews were held with several long-term residents of the area concerning floods. The assistance of the following individuals is gratefully acknowledged:

Mr. Art Field	-	School Vice Principal
Mr. Bill Dorey	-	Marathon Motors
Mr. Bill Bonderoff	-	Farmer
Mr. John Harris	-	Retired Superintendent Water Survey of Canada, Nelson

During the second field trip, uncertainties in the draft floodplain maps were reconciled. Further discussions were held with Mr. Boyer concerning the Erie Creek alluvial fan. The archives of the local newspaper held at the David Thompson Library, Nelson, were reviewed for additional information on past floods.

4 Flood Frequency Studies

The mountainous terrain of the Kootenay region in general and the Salmo area in particular, as described in Section 3.1.2, make conventional regional hydrology analysis difficult, as demonstrated in the B.C. Environment regional hydrology study. Accordingly, the present study relied primarily on the results of flood frequency analyses for the two gauges in the study basin. This essentially complies with the recommended approach of the B.C. Environment regional study.

The study required water levels to be computed using the HEC-2 computer model for the following flow conditions:

- 200-year Instantaneous Flow
- 200-year Mean Daily Flow
- 20-year Instantaneous Flow
- 20-year Mean Daily Flow

It is evident from Figure 2-1 and Table 2-1 that the catchment area varies appreciably along the study reach. It was therefore necessary to derive the four desired flood flows at several points along the study reach. The following sections of this report document the procedure used to estimate flood flows at two gauged points in the basin, and at other critical points.

4.1 Flood Frequency Analysis and Results

A total of four flood frequency analyses were undertaken: Salmo River near Salmo (Instantaneous and Daily) and Hidden Creek near the Mouth (Instantaneous and Daily). The Acres computer program used for the analysis, designated FDR, is based on Environment Canada's frequency analysis program "FDRPFFA". It incorporates slight modifications to the output format and the addition of graphics capabilities. The numerical results of FDR are identical to those of FDRPFFA. The program attempts to fit four different statistical distributions to the flood data:

- Gumbel (Extreme Value Type I)
- Two-Parameter Lognormal
- Three-Parameter Lognormal
- Log Pearson Type III

It is then the duty of the analyst to review the computer program output and to select the most appropriate distribution for the data. Over the years, a vast amount of effort has been devoted to the selection of the most appropriate distribution for a given set of data. In statistical terms, the sample sizes under consideration are usually too small to make a confident choice of distribution. However, there is often enough evidence to reject some of the choices, and the differences among the remaining candidates are quite small on many occasions.

The detailed results of the four flood frequency analyses are presented in Appendix A. The following discussion relates to the choice of distribution for each case.

(a) **Salmo River near Salmo (Instantaneous)**

All four candidate distributions provided a reasonable fit to the data, as indicated by their frequency plots and statistical indicators. A range of only 7% in estimates of the 200-year flood was found, which would translate to a very small range in water level.

(b) **Salmo River near Salmo (Daily)**

The results were very similar to those for the instantaneous flows — all four candidate distributions provided a reasonable "fit" to the data.

(c) **Hidden Creek near the Mouth (Instantaneous)**

The flow record for Hidden Creek is significantly shorter than that of the Salmo River. After consultation with B.C. Environment staff, it was decided to include the preliminary estimate of the 1990 flood peak on Hidden Creek in the analysis, to provide the largest possible data set. The frequency analysis results indicated that the Gumbel distribution yielded a very poor fit to the data, and it could be rejected. The frequency plots for the remaining candidates were similar, with a 19% range in the estimates of the 200-year flood. The Three-Parameter Lognormal distribution, which has been used in many of the past studies conducted under the Canada-British Columbia Floodplain Mapping Agreement, yielded somewhat higher (and thus more conservative) flood estimates than those provided by the Two-Parameter Lognormal and Log Pearson Type III distributions.

(d) **Hidden Creek near the Mouth (Daily)**

The results obtained for this data set were very similar to those obtained for the instantaneous flows. The Three-Parameter Lognormal distribution again yielded a somewhat more conservative estimate of the 200 year peak flow.

The Three-Parameter Lognormal distribution provided an adequate fit for all four data sets, and was adopted for use in this study. This was consistent with the approach followed on many other floodplain mapping studies and provided slightly conservative (high) flood peak estimates. Frequency plots based on the Three-Parameter

Lognormal distribution are shown in **Figures 4-1, 4-2, 4-3** and **4-4. Figure 4-5** shows the rating curve for the Salmo River station together with the estimated 200-year and 20-year instantaneous peak flows, and maximum recorded flows. The calculated flows of various return periods are presented in **Table 4-1**.

4.2 Derivation of Design Flows

Hidden Creek is a tributary of the Salmo River and it would be expected that the two stations fall in the same hydrological region. This was confirmed using Langbein's homogeneity test.[7] **Figure 4-6** shows the results of the frequency analyses in terms of unit flood peak versus drainage area. The slopes of the two relationships shown in Figure 4-6 are negative, reflecting the commonly observed phenomenon that smaller catchments produce larger unit flood peaks than larger catchments. This indicates that estimating flood peaks strictly by prorating drainage areas would yield unrealistically low flood peak estimates for smaller basins.

Using the information in Figure 4-6 and the drainage areas of Table 2-1 enabled design discharges to be calculated for segments of the study reach, as shown in **Table 4-2.** The figures presented in Table 4-2 were checked using two sources of information: the flow distribution observed during the 1989 high water survey (as discussed in Section 5.3), and the high flow current metering results obtained by WSC for the Salmo River gauge. Using the flow distribution observed during the high water survey of 1989, and scaling up so that the flow at the downstream end matched the design flow, enabled a comparison with the values of Table 4-2. In general, the correspondence was excellent. The significant exception was Erie Creek, where the high water survey data resulted in the calculation of a significantly lower flow. However, the Erie Creek design flows of Table 4-2 reflect the design conditions for Erie Creek and are expected to be higher than the Erie Creek contribution to the design flood for the main stem of the Salmo River. In other words, the 200-year flood on the Salmo River near Salmo is not as large as the sum of the 200-year floods at all the upstream tributaries. This is due to timing differences — the peak flow from Erie Creek would not be expected to coincide with the peak at the Salmo gauge.

The Salmo River gauge was recently (1988) relocated a short distance downstream from its previous site. Until that time, WSC staff conducting rating curve checks at high flows measured the flows on the Salmo River just upstream of the South Salmo River confluence and added these flows to the measured flow on the South Salmo River at the confluence, to yield the total flow at the gauge. The results of these high flow measurements were extracted from Water Survey of Canada files and analyzed.

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7 "Topographic Characteristics of Drainage Basins", Langbein, W.B. et al., U.S. Geol. Survey, Prof. Paper 968-C, 1947.

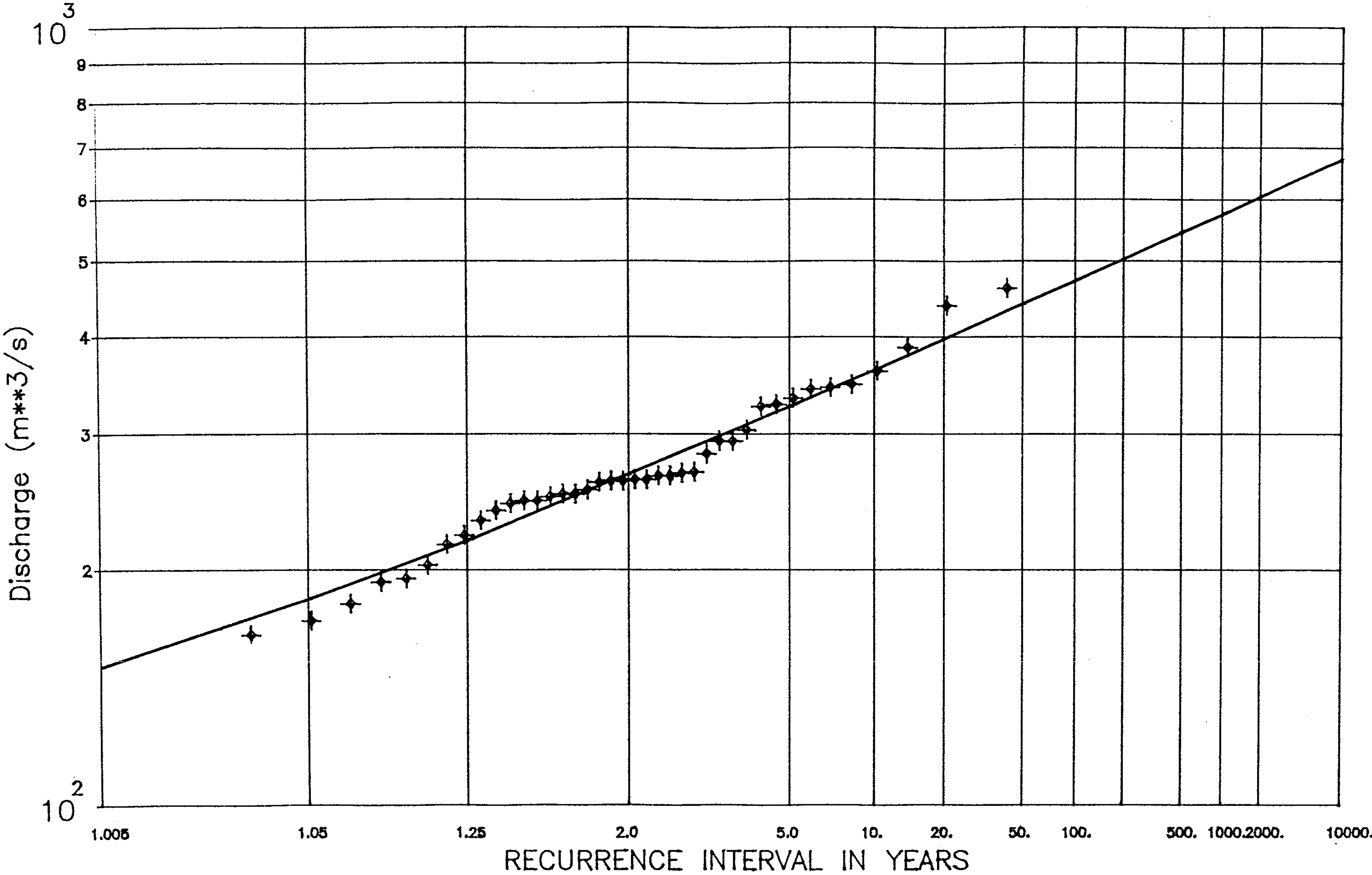

FIG. 4–1

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
FLOOD FREQUENCY DISTRIBUTION – STATION 08NE74 – INSTANTANEOUS PEAK FLOWS

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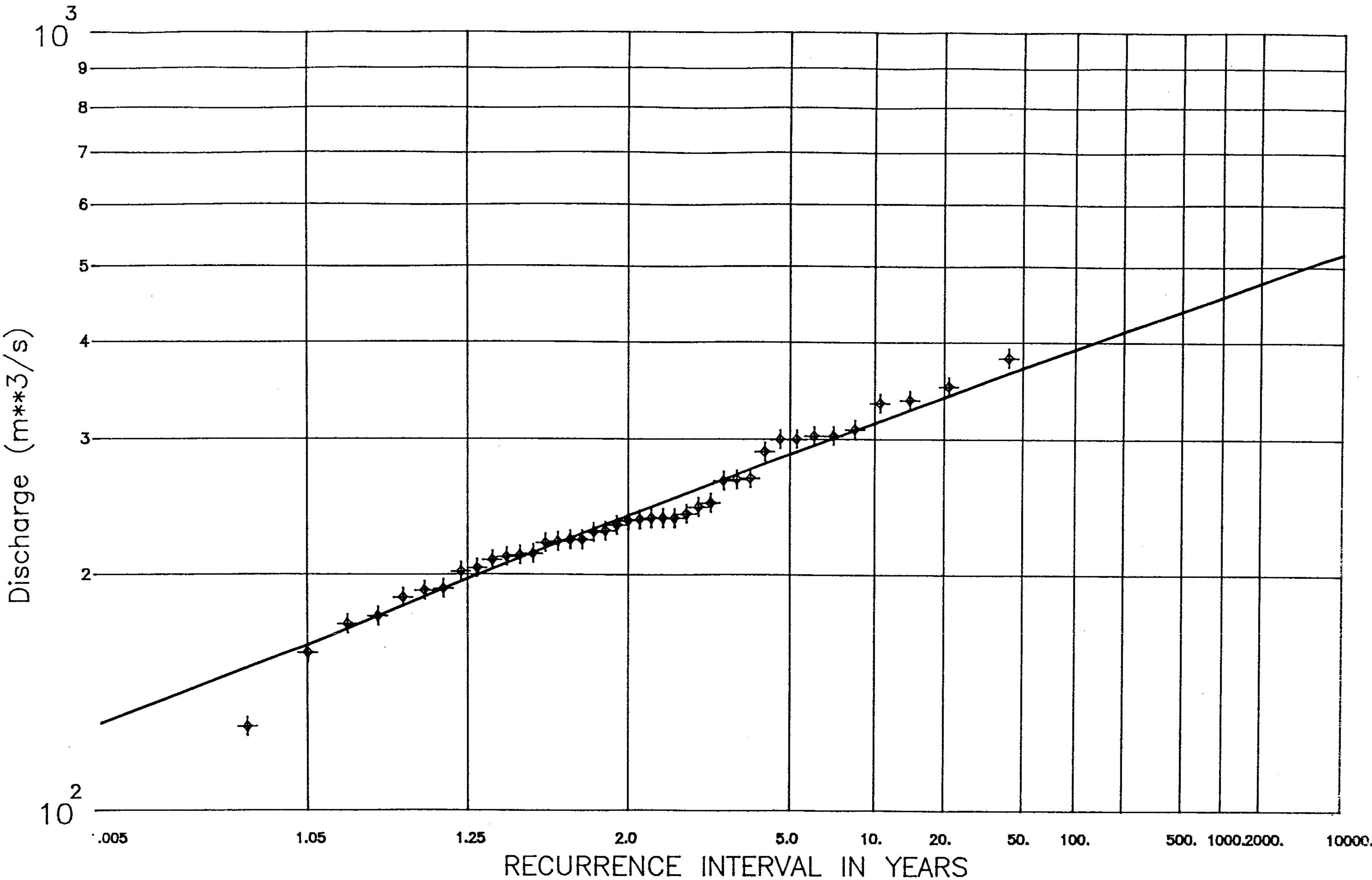

FIG. 4-2

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
FLOOD FREQUENCY DISTRIBUTION – STATION 08NE74 – DAILY PEAK FLOWS

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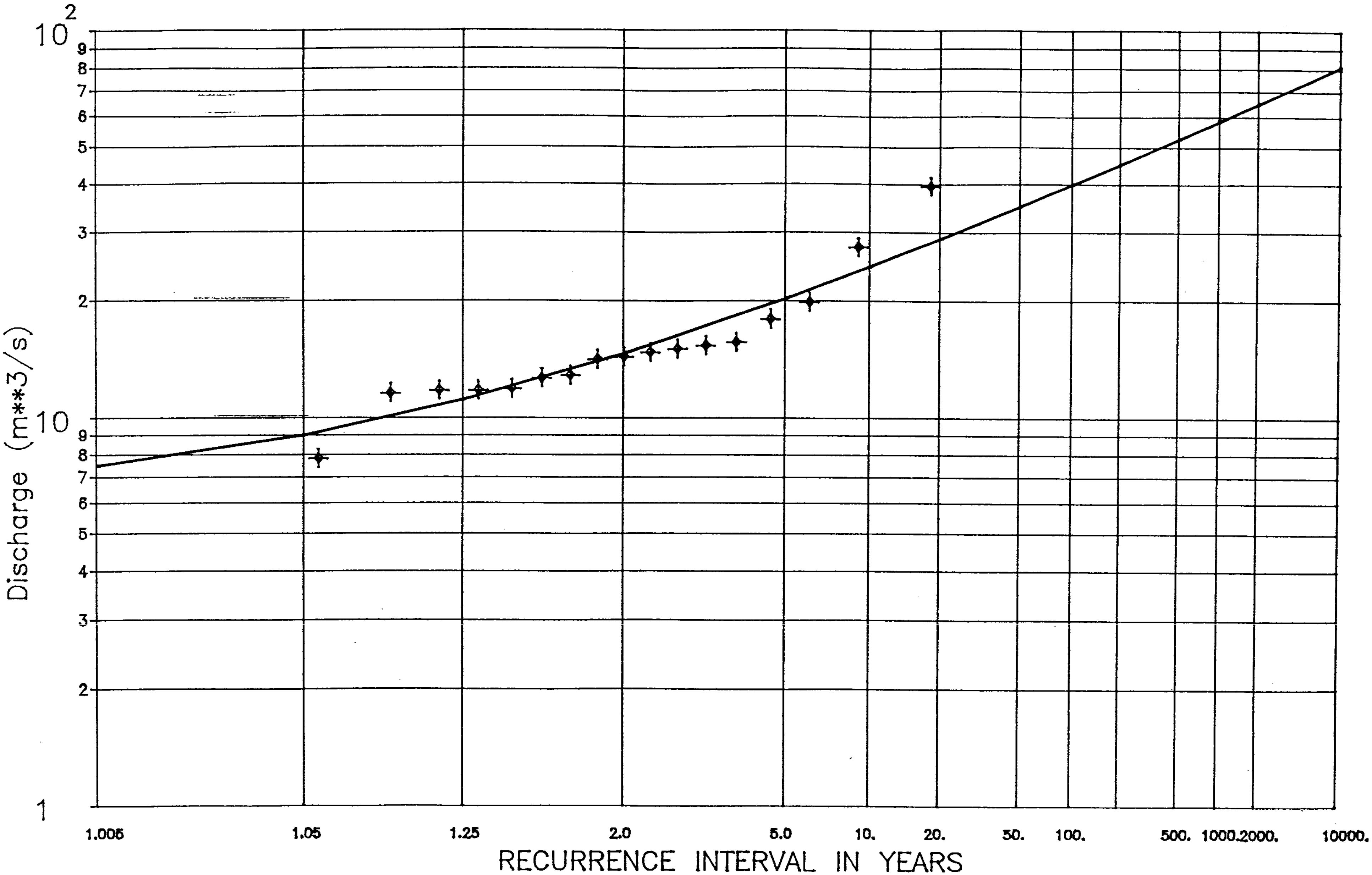

FIG. 4-3

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
FLOOD FREQUENCY DISTRIBUTION – STATION 08NE114 – INSTANTANEOUS FLOWS

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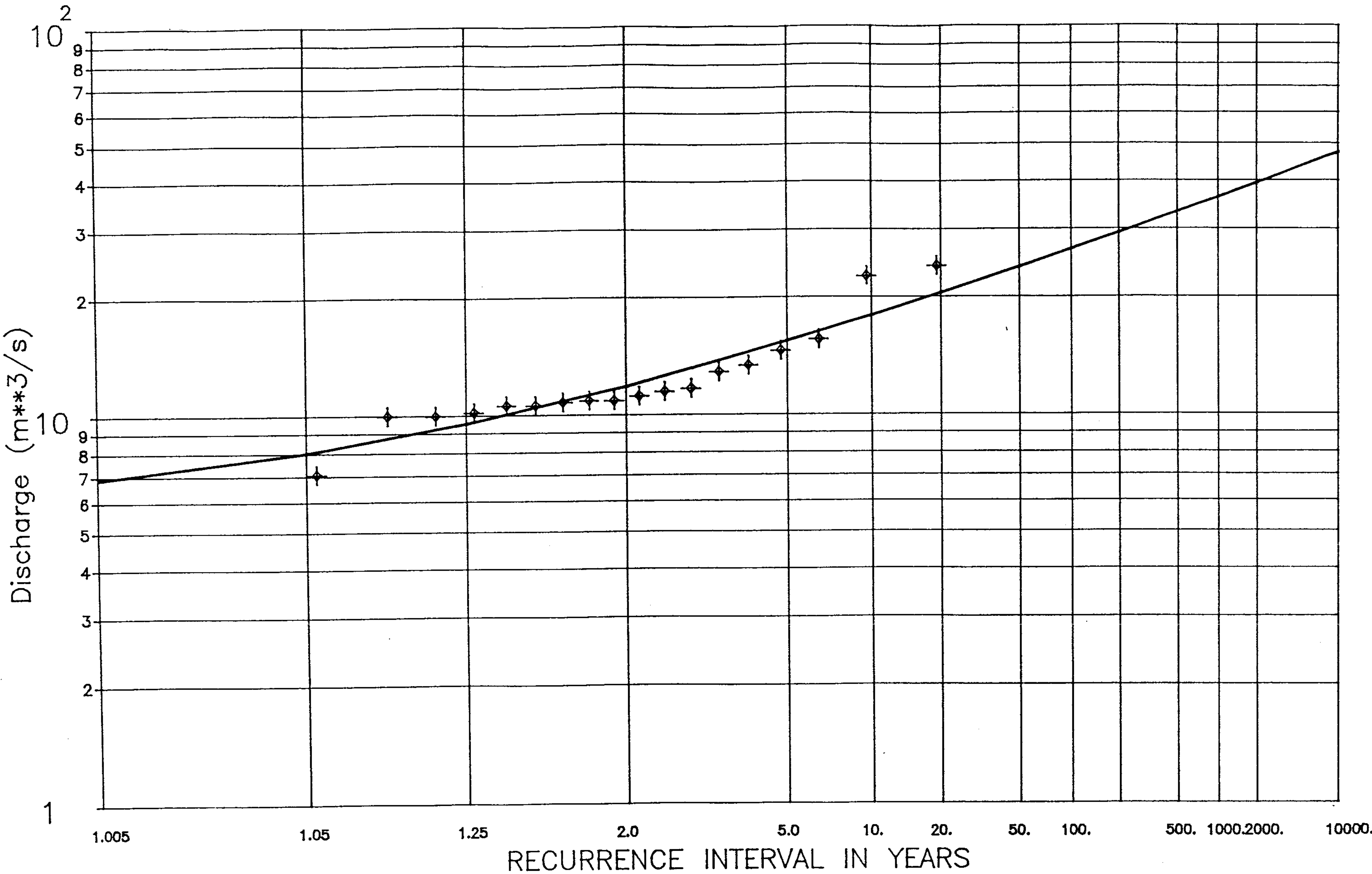

FIG. 4-4

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
FLOOD FREQUENCY DISTRIBUTION – STATION 08NE114 – DAILY PEAK FLOWS

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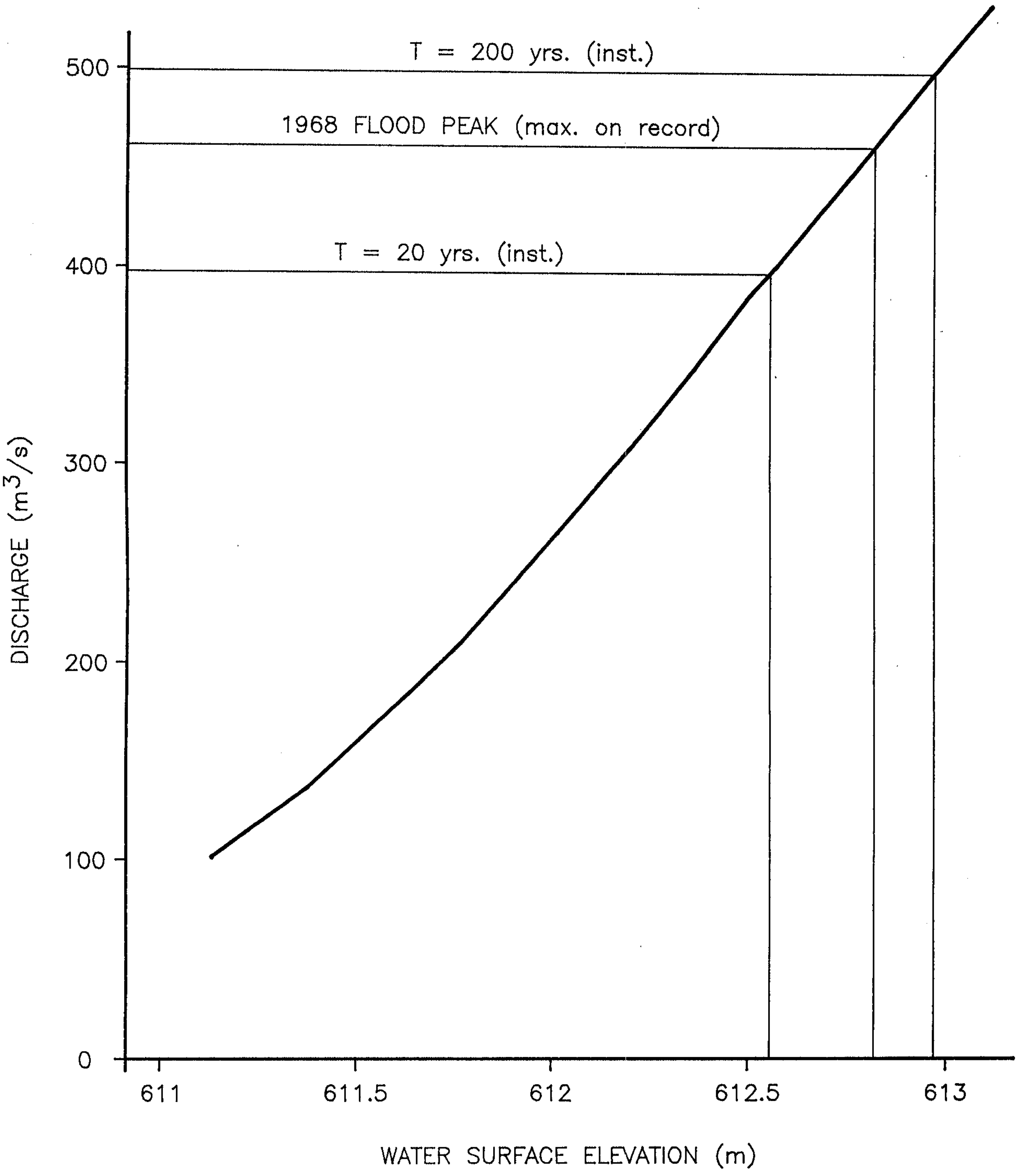

FIG.4–5

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
RATING CURVE – STATION 08NE74

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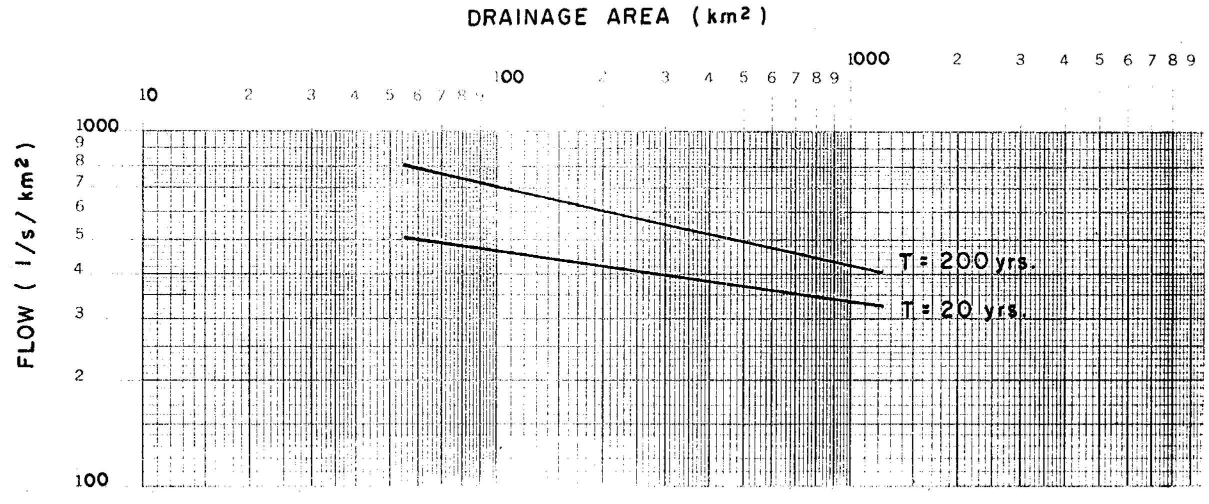
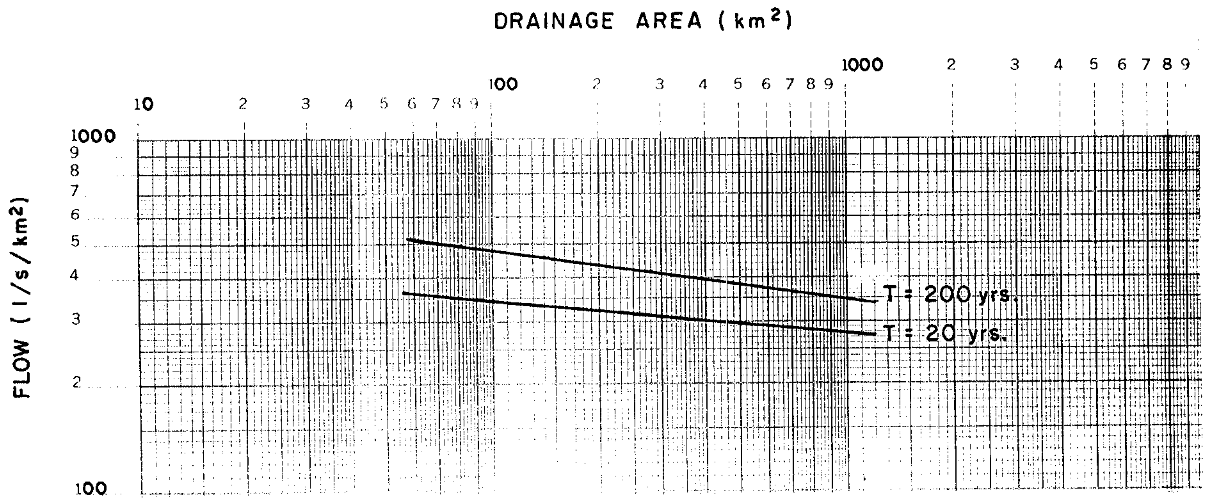


INSTANTANEOUS PEAK FLOWS



DAILY PEAK FLOWS

FIG. 4–6

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
TRENDS OF UNIT FLOOD PEAKS VERSUS DRAINAGE AREA

ACRES

TABLE 4-1
CALCULATED FLOOD PEAKS

RETURN PERIOD	STATION			
	SALMO RIVER NEAR SALMO		HIDDEN CREEK NEAR THE MOUTH	
	INST.	DAILY	INST.	DAILY
(yrs)	m^3/s	m^3/s	m^3/s	m^3/s
10	362	314	24.4	17.9
20	397	339	28.8	20.4
50	440	370	34.9	23.8
100	471	391	39.8	26.5
200	502	412	45.0	29.2

TABLE 4-2
DESIGN FLOWS FOR STUDY REACHES

Location	Q_{200}		Q_{20}	
	Inst.	Daily	Inst.	Daily
	m^3/s	m^3/s	m^3/s	m^3/s
(a) **Salmo River Main Stem**				
Upstream End of Study Reach (above Ymir Creek)	185	138	134	105
Upstream of Porcupine Cr. confluence	218	165	160	127
Upstream of Hidden Cr. confluence	255	197	191	153
Upstream of Erie Cr. confluence	353	281	271	224
Upstream of South Salmo R. confluence	394	317	306	254
Salmo Gauge 08NE74 (Downstream End of Study Reach)	502	412	397	339
(b) **Erie Creek at the Mouth**	136	98	96	74

The predicted values of the flows on the Salmo River just upstream of the South Salmo River confluence were found to be within 5% of the values given in Table 4-2.

The checks described above added confidence to the use of the design discharges of Table 4-2. These flows were used in the water surface profile studies, leading to the production of floodplain maps for the study reach.

5 Hydraulic Analyses

5.1 River Backwater Modelling

In the Salmo River floodplain mapping study, the hydraulic backwater analysis was undertaken using the most recent version of HEC-2[8]. The model was originally developed by the U.S. Army Corps of Engineers, and it has been widely used in North America and elsewhere. Starting with a known flow and water level, the model proceeds upstream (subcritical flow) or downstream (supercritical flow), calculating the unknown water levels using the Standard Step Method.

The use of the Standard Step Method assumes the following:

- flow is steady
- flow is gradually varied
- flow is one-dimensional
- river channels have small slopes, say less than 10%.

The model accounts for energy losses due to friction (Manning's "n"), flow contraction and expansion, and bridge losses of various types.

5.2 Data Requirements

The following types of data are required for a typical HEC-2 water surface profile study for a natural river under flood flow conditions:

- detailed river channel cross-sections, which are extended to include the floodplain area are based on topographic base mapping data

- estimates of the lengths of the flow paths between cross-sections (left overbank, right overbank and channel)

- estimates of Manning's "n" for the different parts of the cross-sections (often three values are sufficient: left overbank, right overbank and channel)

- when the flow width changes appreciably, values of expansion and contraction coefficient (the HEC-2 manual provides guidance on the choice of these coefficients)

- detailed descriptions of bridges within the reach of interest

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8 "HEC-2 Water Surface Profiles, Users Manual", Hydrologic Engineering Centre, U.S. Army Corps of Engineers, Davis, California, 1982.

- the flow values to be modelled and the starting elevation for the most downstream cross-section (for a subcritical run)

A total of 174 detailed river cross-sections were provided by B.C. Environment in HEC–2 — ready format. Of these, 137 were on the Salmo River and 37 on Erie Creek. The locations of the cross-sections were shown on 1:10,000 scale photo mosaics, which were also provided by B.C. Environment. The cross-sections essentially covered the "within-banks" portion of the river. These cross-sections were located on the provided 1:5,000 scale 1-m contour interval maps, and they were extended manually to include the overbank portions. The lengths of the flow paths between cross-sections were estimated using the same maps. Data for a total of eleven bridges, provided by B.C. Environment, were also input to the model.

5.3 Model Calibration

Prior to using HEC-2 to model the floods of interest, it is important to calibrate the model with some past recorded flood event. A successful calibration adds confidence to the water surface profiles estimated for other flows. The calibration exercise assists in achieving several important objectives:

- elimination of errors in the basic data files
- proper representation of flow through the bridges
- estimation of Manning's 'n' for the channel portion of the cross-sections

The Manning's "n" values for the overbank portions of the cross-sections were available from the field reconnaissance. The within-banks values were estimated as part of the calibration exercise. Expansion and contraction coefficients were estimated using guidance provided in the HEC-2 manual.

In May 1989, the Survey Branch of the B.C. Environment undertook a high water survey and a program of flow measurements over a period of two days. Calculations based on flow measurements were made to estimate flows at 63 high water locations along the study reach. The flow in the main stem of the Salmo River varied from 30 m^3/s at the upstream end to 103 m^3/s at the downstream end. The flow in Erie Creek was 19 m^3/s.

After removing errors from the data files and ensuring that proper representation of the flow was occurring throughout the study reaches and particularly through the bridges, the channel values of Manning's "n" were established to provide the best possible match between observed and calculated water levels corresponding to the high water survey. A satisfactory match was found with Manning's "n" ranging from .035 to .075, with the values generally increasing upstream as would be expected. Excluding one anomalous observed water level (at Cross-section 65; it is clearly in error when compared with the water levels recorded at the time of the cross-section survey), the mean absolute difference between observed and calculated water levels was estimated to be 0.10 m. **Figure 5-1** shows the calculated flood profile and the observed water levels.

5.4 Production Runs

Once the HEC-2 model was satisfactorily calibrated for the two study reaches, it was ready for calculation of the flood profiles of interest:

- 200-year instantaneous
- 200-year daily
- 20-year instantaneous
- 20-year daily

The required flows for each of the above runs are presented in Table 4-3. The starting water level at the downstream end of the study reach was obtained using the rating curve for the flow gauging station 08NE74 (Salmo River near Salmo).

Several adjustments were made to the model prior to accepting the results as being truly representative of the hydraulic conditions that would actually occur. In areas where the floodplain is very wide and flat, the model indicated a significant portion of the flow occurring on the floodplain. In reality, the water would primarily be ponded in these areas, with little flow being conveyed. The cross-sections used in the model were adjusted to reflect this likelihood. In some areas, the model indicated the possibility of supercritical flow when this seemed unlikely to be correct. Small adjustments to the relevant cross-section descriptions or the addition of intermediate smoothed-in cross-sections eliminated many of these unlikely supercritical sections.

The results of the analyses indicated that none of the bridges would be overtopped in the 200-year flood, although one bridge (located at the upstream end of the Salmo River study reach) was indicated to be in a pressure flow condition. It should be noted that these calculations assumed that no debris would choke the openings under the bridges. The presence of sufficient material to cause a partial blockage would cause higher water levels in the areas immediately upstream of the affected bridges. The flow profile computed for the 200-year instantaneous discharge case is presented in **Figure 5–2.**

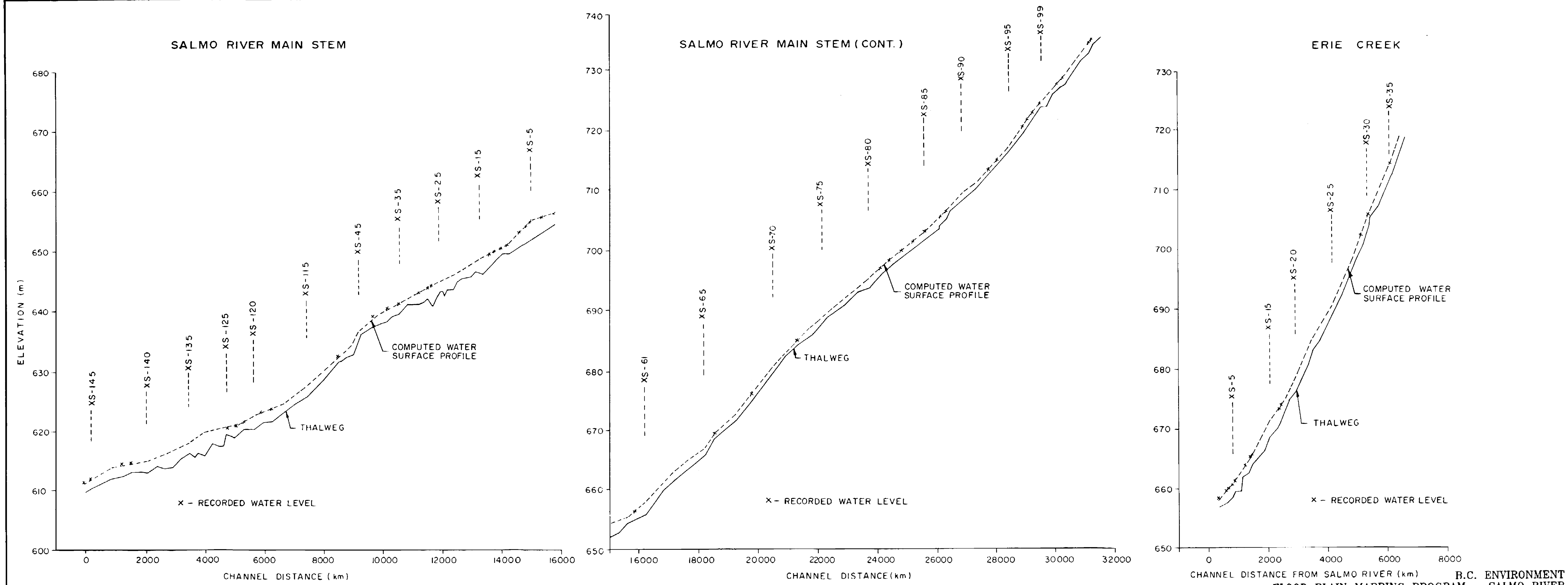


FIG. 5-1

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
CALIBRATION PROFILE

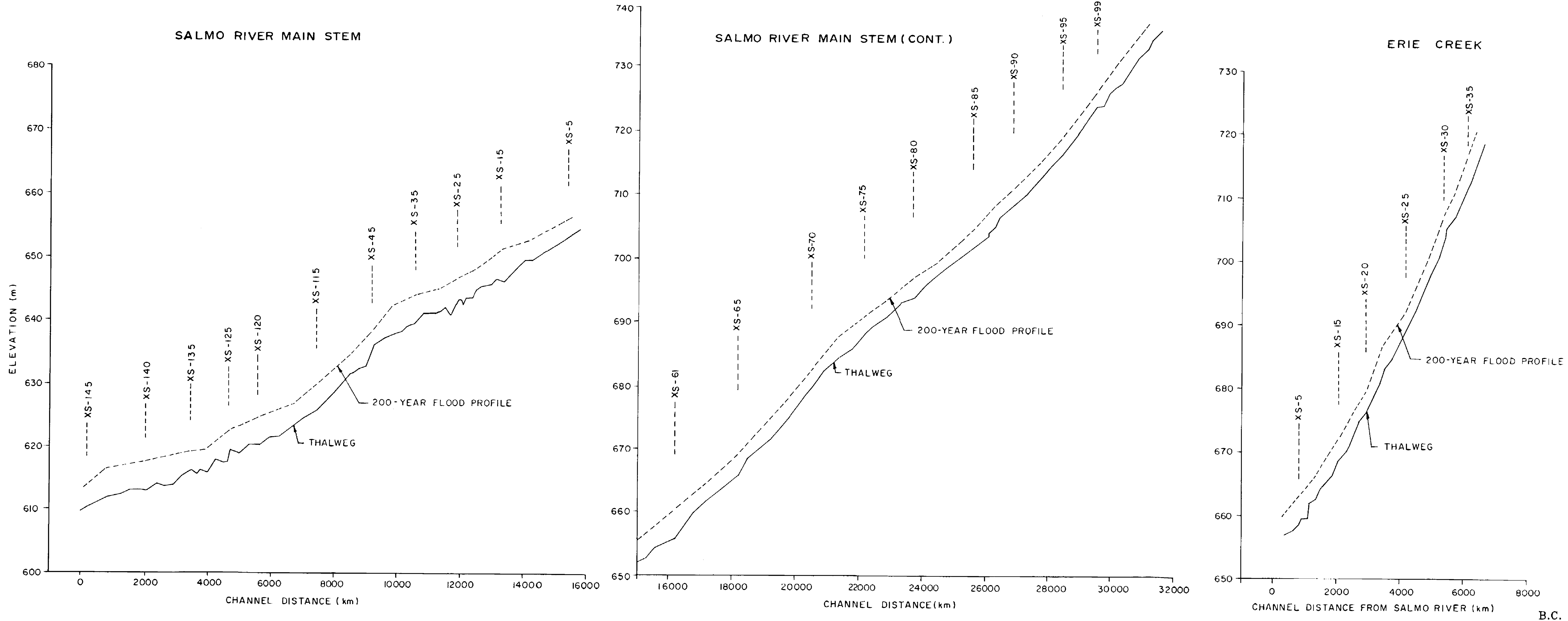


FIG.5-2

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM – SALMO RIVER
200-YEAR FLOOD PROFILE

ACRES

5.5 Sensitivity Analysis

The sensitivity analysis is intended to determine the sensitivity of the computed water levels to changes in the two most important parameters that were estimated: the design discharge and the hydraulic roughness (Manning's "n").

5.5.1 Sensitivity to Discharge

The design flows adopted for the study were based on two single-site flood frequency analyses and a limited amount of regionalization of the results. Sources of error include:

- flow measurement at the gauges used to estimate the rating curves, leading in turn to errors in peak flow estimates
- choice of frequency distribution
- fitting of the frequency distribution to the data
- regionalization of the results

The 200-year instantaneous discharge flood profiles were re-run with changes in discharge at all points of -10%, +10% and +25%. **Table 5-1** shows the resulting mean change in water level. The data show that, for a 25% increase in discharge, the mean water level increase is within the 0.3 m freeboard allowance used in calculating flood levels for floodplain delineation purposes.

5.5.2 Sensitivity to Manning's "n"

The Manning's "n" values for the overbank portions of the cross-sections were based on observation and tables of "n" values for different types of vegetation. The channel values were derived in the calibration. Some uncertainty exists in these estimates.

The 200-year daily discharge flood profile was re-run with changes in Manning's "n" of -10%, +10% and +25%. **Table 5-1** shows the resulting mean change in water level. The results show that sensitivity to changes in Manning's "n" is comparable to sensitivity to changes in discharge.

TABLE 5-1
RESULTS OF SENSITIVITY ANALYSIS

ITEM	(a) Salmo River Main Stem	(b) Erie Creek	(c) Combined
	Mean Increase in Water Level (m)		
A. DISCHARGE[1]			
-10%	-0.14	-0.12	-0.14
+10%	0.13	0.11	0.13
+25%	0.22	0.26	0.23
B. MANNING'S "n"[2]			
-10%	-0.11	-0.08	-0.11
+10%	0.11	0.08	0.11
+25%	0.25	0.19	0.24

[1]Compared to 200-year instantaneous discharge run.

[2]Compared to 200-year daily discharge run.

5.6 Floodplain Mapping

The Terms of Reference for the present study called for the 200-year floodplain to be delineated as the maximum of:

(a) 200-year instantaneous water level plus 0.3 m freeboard
(b) 200-year daily water level plus 0.6 m freeboard

It was found that neither of the above conditions dominated over the entire study reach, as the calculated water levels were typically separated by less than 0.2 m. The calculated 200-year and 20-year flood levels, including freeboard, are presented in **Appendix B**; the 200-year floodplain limits, including freeboard, are delineated on the mylar base maps of the study area.

The following points should be noted regarding the manner in which the floodplain was delineated:

(a) In areas where dykes exist, whether the dyke was estimated to be capable of containing the flow or not, the floodplain was delineated as if the dyke was not present. However, dykes were assumed to be capable of restricting conveyance of flows to the dyked channel. This is in accordance with Ministry policy (see Note 4 on the floodplain maps).

(b) Strictly defining floodplain limits on the basis of hydraulic calculations without considering topographic limitations can produce floodplain maps that are impractical to administer, based on B.C. Environment's experience in the Flood Damage Reduction Program. For example, a gentle rise in the middle of a floodplain could lead to the definition of a low-lying "island" in the floodplain that should, for practical purposes, be included in the floodplain. Similarly, a "backslope" area may be nominally excluded from the hydraulically defined floodplain, but it may be subject to flooding from a tributary that was not explicitly included in the hydraulic analysis. In keeping with B.C. Environment's practice, these considerations led to the definition of the floodplain limit in some areas based on engineering judgement, together with the results of the hydraulic analysis. In all areas, however, the water levels estimated from the hydraulic analyses are defined on the isograms shown on the maps.

(c) On Erie Creek, the computed flood levels indicated that "breakout" would be likely to occur at two locations with the 200 year instantaneous peak flow: at the upper end into Erie Lake, and at the lower end, possibly into Haywood Creek. This prompted further consideration of whether Erie Creek's alluvial fan is currently active. Discussions with Mr. Boyer of B.C. Environment indicated that in lower Erie Creek, channel maintenance due to sediment deposition has been required three times in the past 15 years. Also, bank erosion is a continuing concern for residents in that area. These observations led to the conclusion that the fan is potentially active, and that Erie Creek could form a new channel under extreme flood conditions. Accordingly, the floodplain limit for the entire Erie Creek study reach has been set at the physiographic limit of the floodplain and the calculated isograms have not been depicted.

(d) It was not within the terms of reference of this study to prepare a floodplain map for Sheep Creek. However, B.C. Environment's Nelson regional office recognizes its possibly active alluvial fan as a potential problem; an appropriate note has been made on the relevant map sheet.

6 Recommendations

The maps that were prepared together with this Design Brief depict the 200-year floodplain limits for the study reaches, based on technical standards established by B.C. Environment. It is recommended that these maps be designated under the terms of the joint Canada-British Columbia Floodplain Mapping Agreement.

Hydraulic calculations to define the floodplain limits have been undertaken in a careful and rigorous manner. However, some uncertainties do exist. For example, should bridge openings or narrow constrictions in the channel become clogged with debris, the water level immediately upstream of such blockages may surcharge to greater values than those indicated by the hydraulic analyses. The assumption of open channel flow conditions is in accordance with B.C. Environment practice.

The floodplain maps have been prepared based on the physical conditions as they existed in 1989/90. If any significant changes occur (e.g. construction of new bridges, filling in of floodplains to accommodate new development), the local authorities should report such changes to B.C. Environment who are charged with the responsibility of monitoring the maps.

APPENDIX A

FLOOD FREQUENCY ANALYSIS

ACRES

SALMO RIVER NEAR SALMO (INSTANTANEOUS)

08NE74 SALMO RIVER NR SALMO (INST)

YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
1949	328.000	462.000	1	.024	41.000
1950	216.000	439.000	2	.049	20.500
1951	262.000	388.000	3	.073	13.667
1952	232.000	362.000	4	.098	10.250
1953	244.000	348.000	5	.122	8.200
1954	362.000	345.000	6	.146	6.833
1955	294.000	343.000	7	.171	5.857
1956	348.000	334.000	8	.195	5.125
1957	345.000	328.000	9	.220	4.556
1958	283.000	326.000	10	.244	4.100
1959	251.000	304.000	11	.268	3.727
1960	343.000	294.000	12	.293	3.417
1962	172.000	294.000	13	.317	3.154
1963	181.000	283.000	14	.341	2.929
1964	246.000	268.000	15	.366	2.733
1965	193.000	267.000	16	.390	2.563
1966	222.000	265.000	17	.415	2.412
1967	267.000	265.000	18	.439	2.278
1968	462.000	262.000	19	.463	2.158
1969	249.000	262.000	20	.488	2.050
1970	195.000	261.000	21	.512	1.952
1971	326.000	261.000	22	.537	1.864
1972	334.000	260.000	23	.561	1.783
1973	262.000	254.000	24	.585	1.708
1974	388.000	251.000	25	.610	1.640
1975	261.000	251.000	26	.634	1.577
1976	265.000	249.000	27	.659	1.519
1977	165.000	246.000	28	.683	1.464
1978	246.000	246.000	29	.707	1.414
1979	203.000	244.000	30	.732	1.367
1980	439.000	239.000	31	.756	1.323
1981	268.000	232.000	32	.780	1.281
1982	261.000	222.000	33	.805	1.242
1983	294.000	216.000	34	.829	1.206
1984	260.000	203.000	35	.854	1.171
1985	265.000	195.000	36	.878	1.139
1986	251.000	193.000	37	.902	1.108
1987	304.000	181.000	38	.927	1.079
1988	239.000	172.000	39	.951	1.051
1989	254.000	165.000	40	.976	1.025

08NE74 SALMO RIVER NR SALMO (INST)

SAMPLE STATISTICS

MEAN = 275. S.D. = 66.6 C.S. = .8734 C.K. = 4.2027

SAMPLE STATISTICS (LOGS)

MEAN = 5.5877 S.D. = .2351 C.S. = .1764 C.K. = 3.3618

SAMPLE MIN = 165. SAMPLE MAX = 462. N = 40

PARAMETERS FOR GUMBEL I A = .018701 U = 244.

PARAMETERS FOR LOGNORMAL M = 5.5877 S = .2351

NO MAXIMUM LIKELIHOOD SOLUTION FOR THREE PARAMETER LOGNORMAL

PARAMETERS FOR THREE PARAMETER LOG NORMAL BY MOMENTS A = .3957E+02 M = 5.4206 S = .2781

STATISTICS OF LOG(X-A)

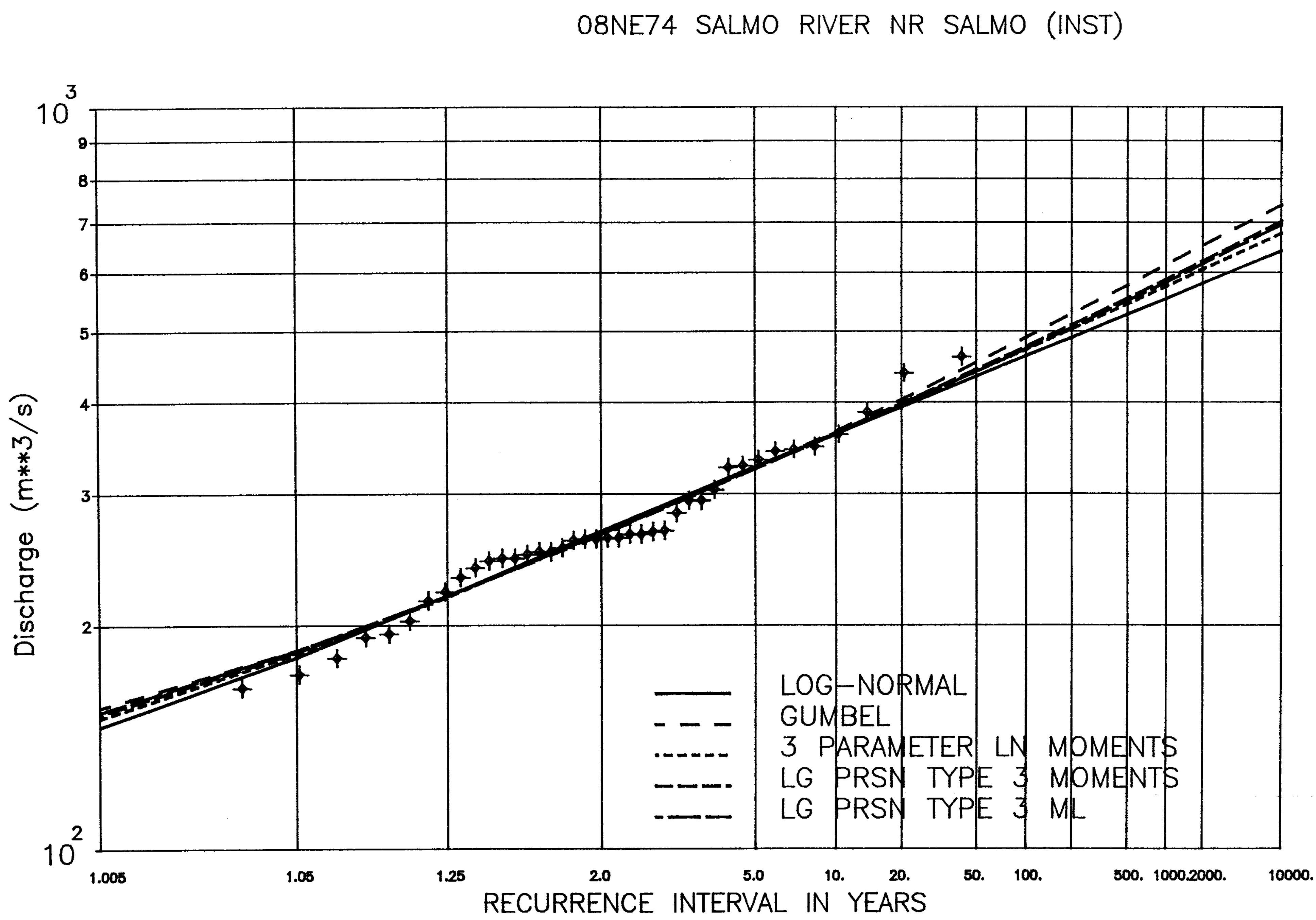
MEAN = 5.4218 S.D. = .2768 C.S. = .0535 C.K. = 3.3456

PARAMETERS FOR LOG PEARSON III BY MOMENTS A = .0207 B = .1286E+03 LOG(M) = 2.9218 M = .1857E+02

PARAMETERS FOR LOG PEARSON III BY MAXIMUM LIKELIHOOD A = .0209 B = .1238E+03 LOG(M) = 3.0041 M = .2017E+02

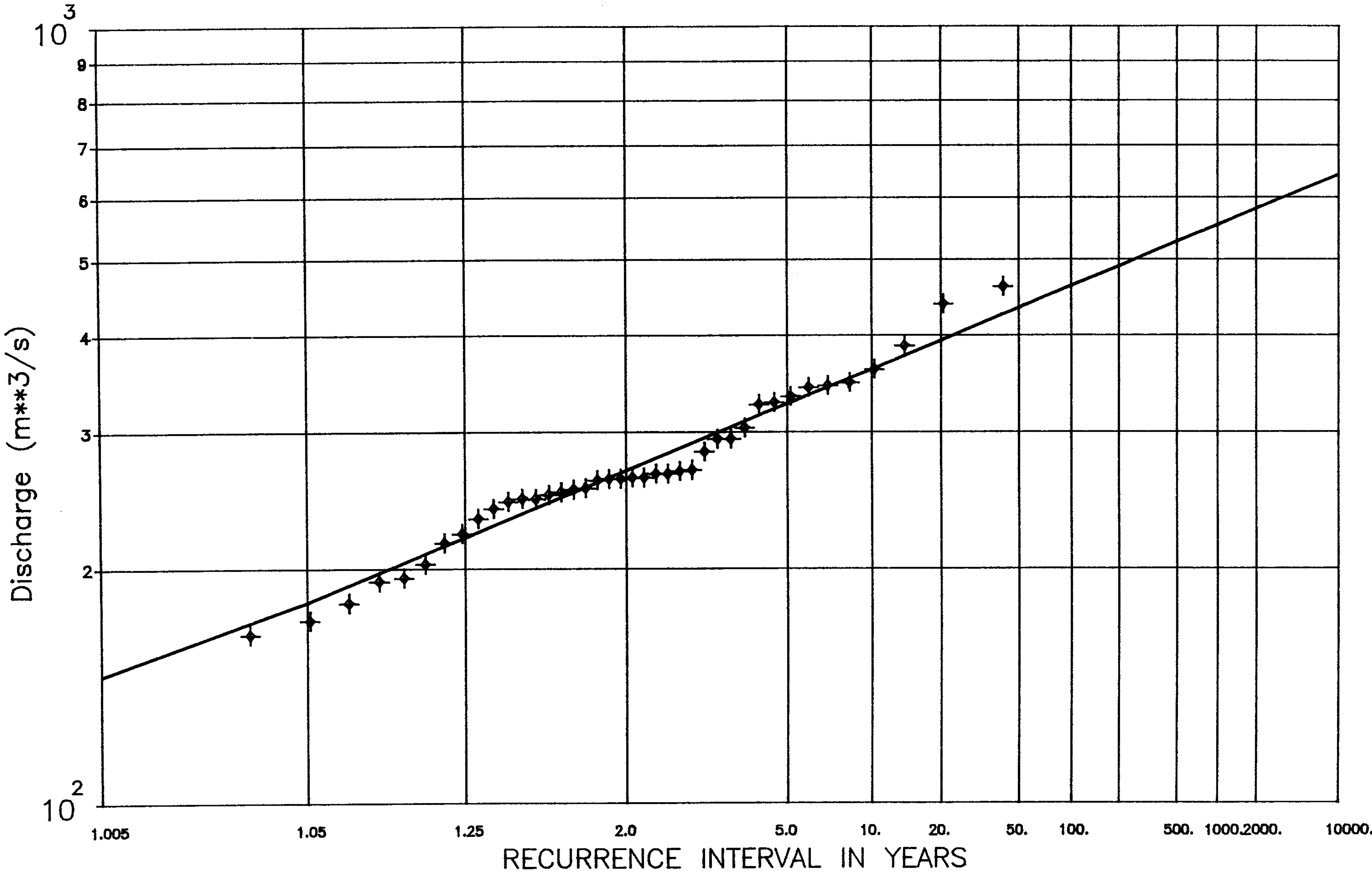
DISTRIBUTION STATISTICS MEAN = 5.5877 S.D. = .2322 C.S. = .1797

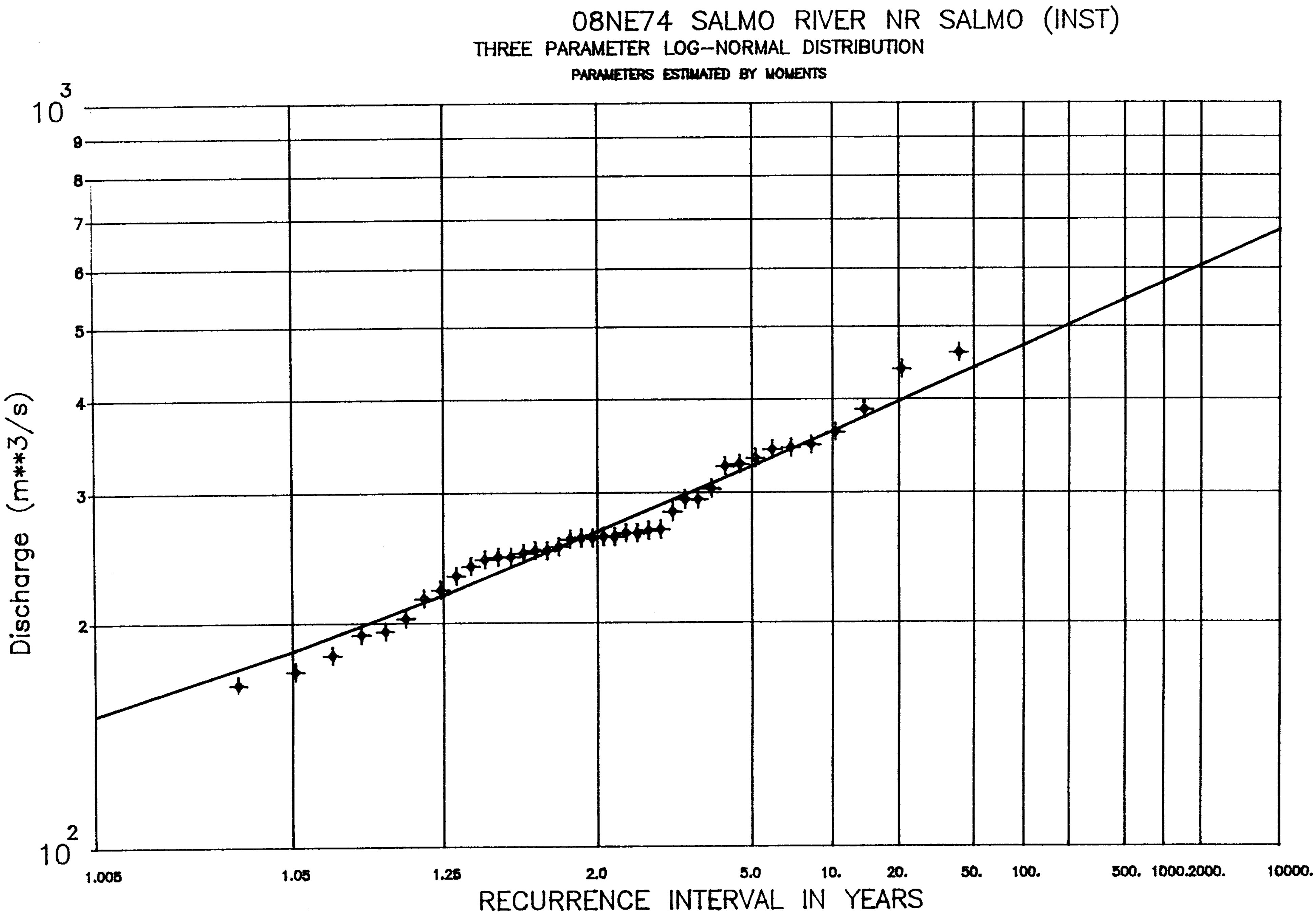
	GUMBEL I		LOGNORMAL		THREE PARAMETER LOGNORMAL		LOG PEARSON III MAX. LIKELIHOOD		LOG PEARSON III MOMENTS	
RETURN PERIOD	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST.ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT
1.005	155.0		146.0		150.0		153.0		152.0	
1.050	185.0		181.0		183.0		185.0		184.0	
1.250	219.0		219.0		218.0		219.0		219.0	
2.000	264.0		267.0		266.0		265.0		265.0	
5.000	324.0	4.70	326.0	4.33	325.0	4.59	324.0	3.96	325.0	4.55
10.000	365.0	5.36	361.0	5.02	362.0	5.45	361.0	4.96	363.0	5.52
20.000	403.0	5.93	393.0	5.70	397.0	6.98	396.0	6.23	398.0	6.90
50.000	453.0	6.57	433.0	6.55	440.0	9.56	440.0	8.17	443.0	9.15
100.000	490.0	6.97	462.0	7.16	471.0	11.70	473.0	9.76	476.0	11.00
200.000	527.0	7.33	489.0	7.72	502.0	13.90	505.0	11.40	509.0	13.00
500.000	576.0	7.73	526.0	8.43	543.0	16.90	549.0	13.70	553.0	15.80
1000.000	614.0	7.99	552.0	8.93	573.0	19.10	581.0	15.50	586.0	17.90
2000.000	651.0	8.23	579.0	9.41	604.0	21.40	615.0	17.30	620.0	20.10
10000.000	737.0	8.70	640.0	10.50	675.0	26.50	694.0	21.60	701.0	25.30


08NE74 SALMO RIVER NR SALMO (INST)
Discharge (m**3/s)
10^3
9
8
7
6
5
4
3
2
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS
LOG-NORMAL
GUMBEL
3 PARAMETER LN MOMENTS
LG PRSN TYPE 3 MOMENTS
LG PRSN TYPE 3 ML

08NE74 SALMO RIVER NR SALMO (INST)

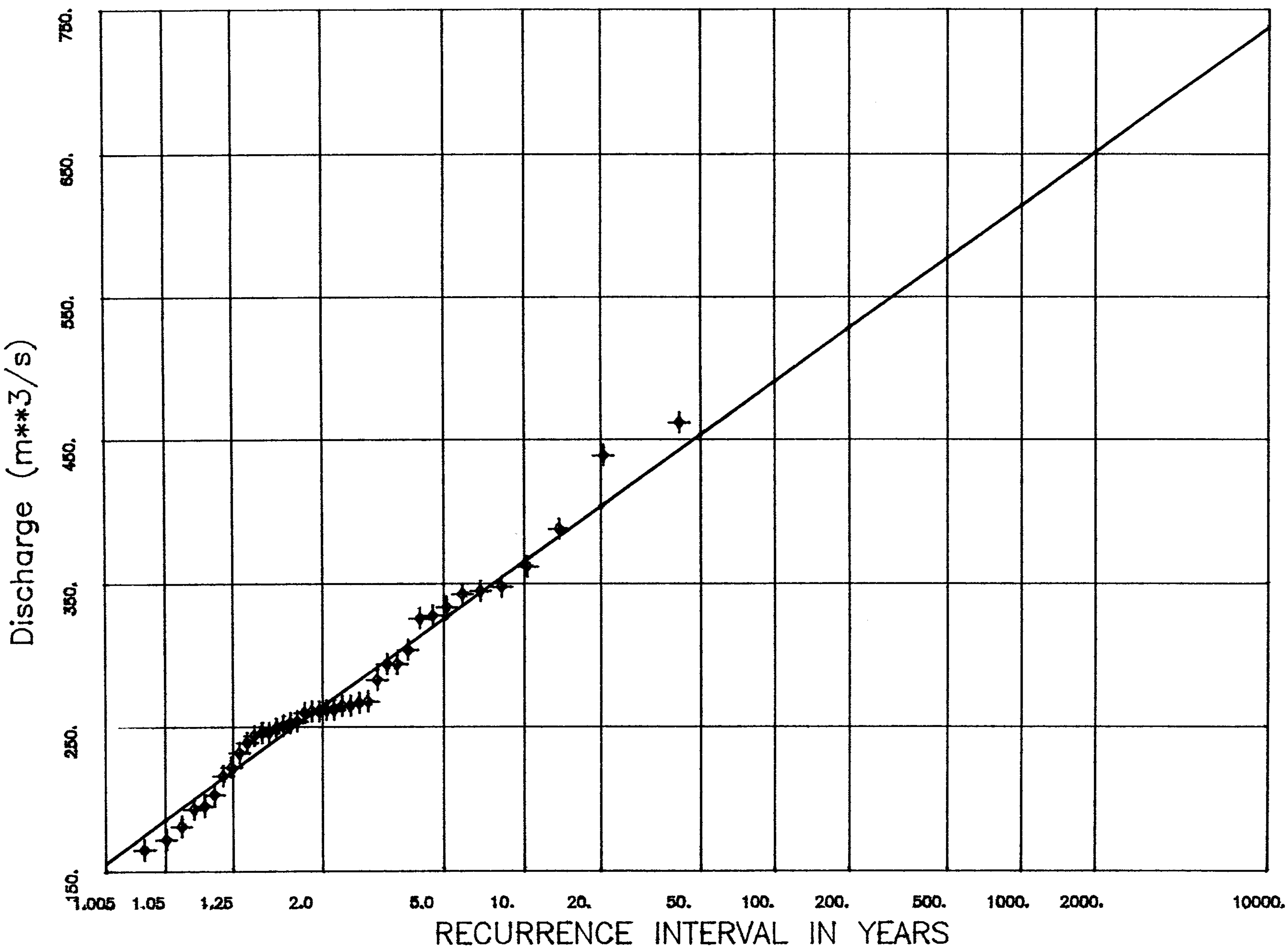
LOG–NORMAL DISTRIBUTION

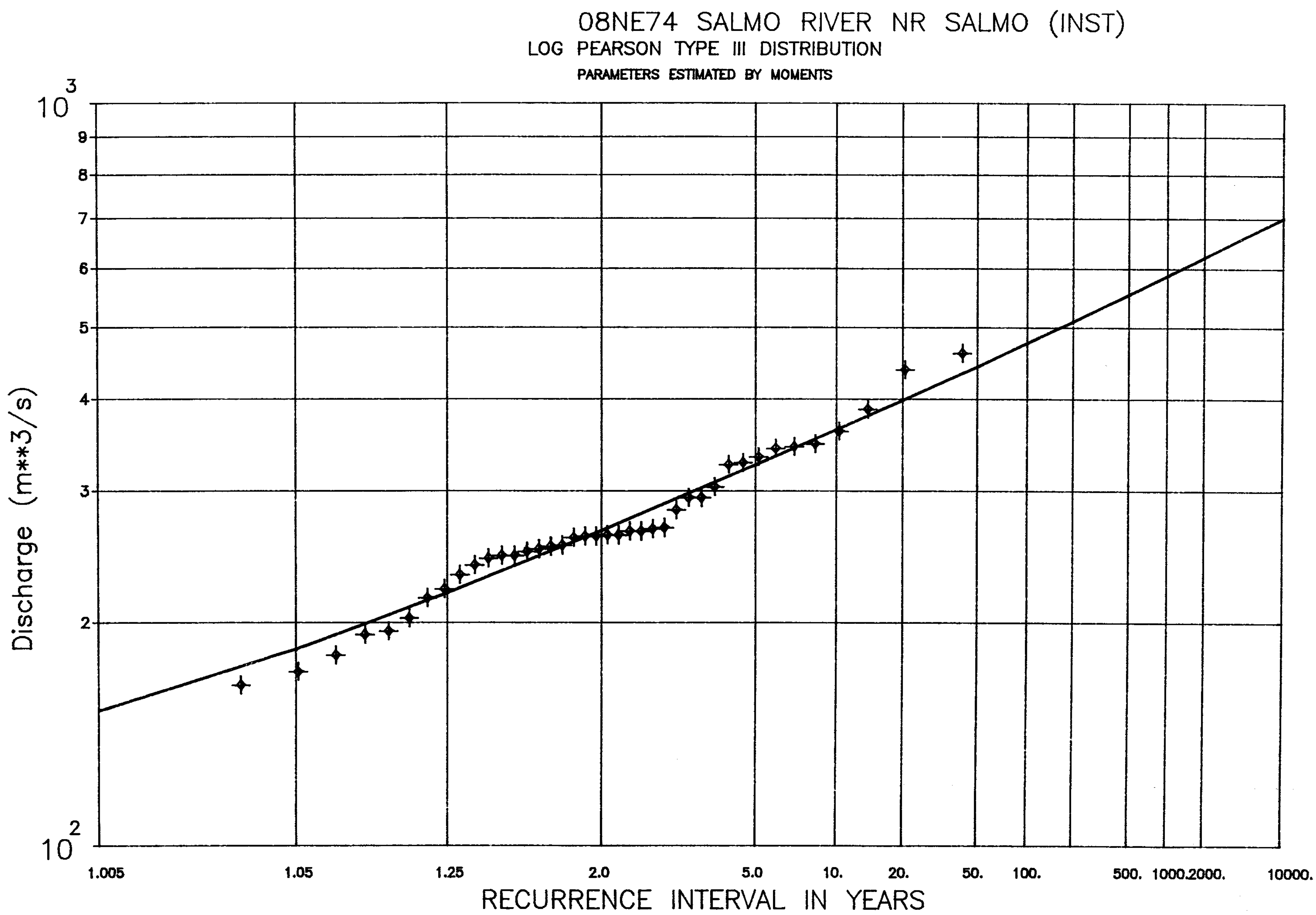




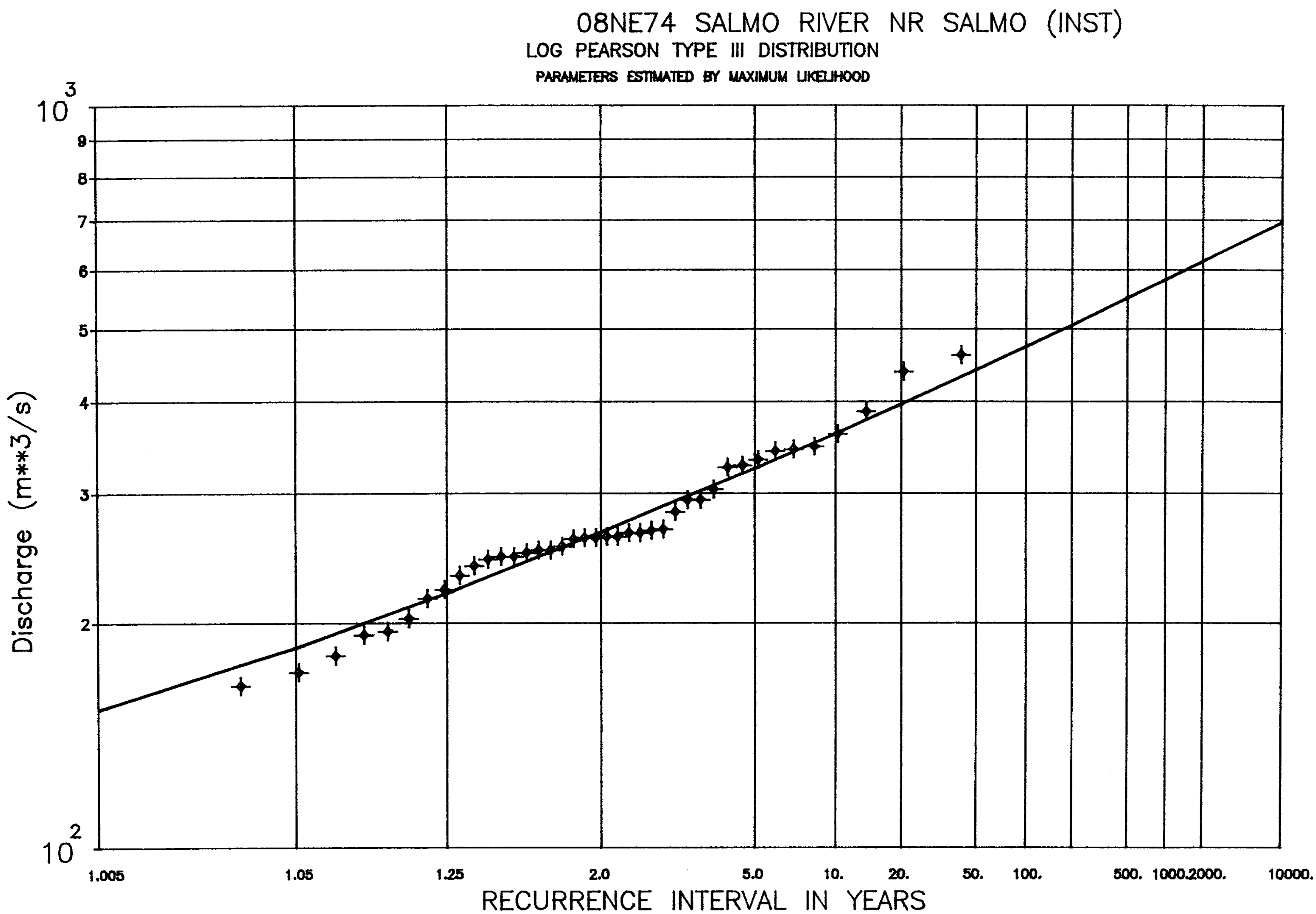
08NE74 SALMO RIVER NR SALMO (INST)
THREE PARAMETER LOG-NORMAL DISTRIBUTION
PARAMETERS ESTIMATED BY MOMENTS
Discharge (m**3/s)
10^3
9
8
7
6
5
4
3
2
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.2000.
10000.
RECURRENCE INTERVAL IN YEARS

GUMBEL I DISTRIBUTION





08NE74 SALMO RIVER NR SALMO (INST)
LOG PEARSON TYPE III DISTRIBUTION
PARAMETERS ESTIMATED BY MOMENTS
Discharge (m**3/s)
10^3
9
8
7
6
5
4
3
2
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS


08NE74 SALMO RIVER NR SALMO (INST)
LOG PEARSON TYPE III DISTRIBUTION
PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD
Discharge (m**3/s)
10^3
9
8
7
6
5
4
3
2
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS

SALMO RIVER NEAR SALMO (DAILY)

08NE74 SALMO R NR SALMO (DAILY)

YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
1949	303.000	382.000	1	.024	42.000
1950	191.000	351.000	2	.048	21.000
1951	240.000	337.000	3	.071	14.000
1952	212.000	334.000	4	.095	10.500
1953	228.000	309.000	5	.119	8.400
1954	337.000	303.000	6	.143	7.000
1955	266.000	303.000	7	.167	6.000
1956	309.000	300.000	8	.190	5.250
1957	303.000	300.000	9	.214	4.667
1958	248.000	289.000	10	.238	4.200
1959	237.000	267.000	11	.262	3.818
1960	289.000	266.000	12	.286	3.500
1961	202.000	265.000	13	.310	3.231
1962	159.000	248.000	14	.333	3.000
1963	177.000	245.000	15	.357	2.800
1964	220.000	240.000	16	.381	2.625
1965	173.000	237.000	17	.405	2.471
1966	204.000	237.000	18	.429	2.333
1967	245.000	237.000	19	.452	2.211
1968	334.000	236.000	20	.476	2.100
1969	232.000	235.000	21	.500	2.000
1970	187.000	232.000	22	.524	1.909
1971	300.000	228.000	23	.548	1.826
1972	300.000	227.000	24	.571	1.750
1973	236.000	222.000	25	.595	1.680
1974	351.000	222.000	26	.619	1.615
1975	235.000	221.000	27	.643	1.556
1976	237.000	220.000	28	.667	1.500
1977	128.000	213.000	29	.690	1.448
1978	211.000	212.000	30	.714	1.400
1979	192.000	211.000	31	.738	1.355
1980	382.000	209.000	32	.762	1.313
1981	222.000	204.000	33	.786	1.273
1982	222.000	202.000	34	.810	1.235
1983	267.000	192.000	35	.833	1.200
1984	213.000	191.000	36	.857	1.167
1985	237.000	187.000	37	.881	1.135
1986	227.000	177.000	38	.905	1.105
1987	265.000	173.000	39	.929	1.077
1988	209.000	159.000	40	.952	1.050
1989	221.000	128.000	41	.976	1.024

08NE74 SALMO R NR SALMO (DAILY)

SAMPLE STATISTICS

MEAN = 243.   S.D. = 54.3   C.S. = .5515   C.K. = 3.4581

SAMPLE STATISTICS (LOGS)

MEAN = 5.4676   S.D. = .2238   C.S. = -.1367   C.K. = 3.7202

SAMPLE MIN = 128.   SAMPLE MAX = 382.   N = 41

PARAMETERS FOR GUMBEL I   A = .021187   U = 217.

PARAMETERS FOR LOGNORMAL   M = 5.4676   S = .2238

NO MAXIMUM LIKELIHOOD SOLUTION FOR THREE PARAMETER LOGNORMAL

PARAMETERS FOR THREE PARAMETER LOG NORMAL BY MOMENTS   A = -.5578E+02   M = 5.6825   S = .1804

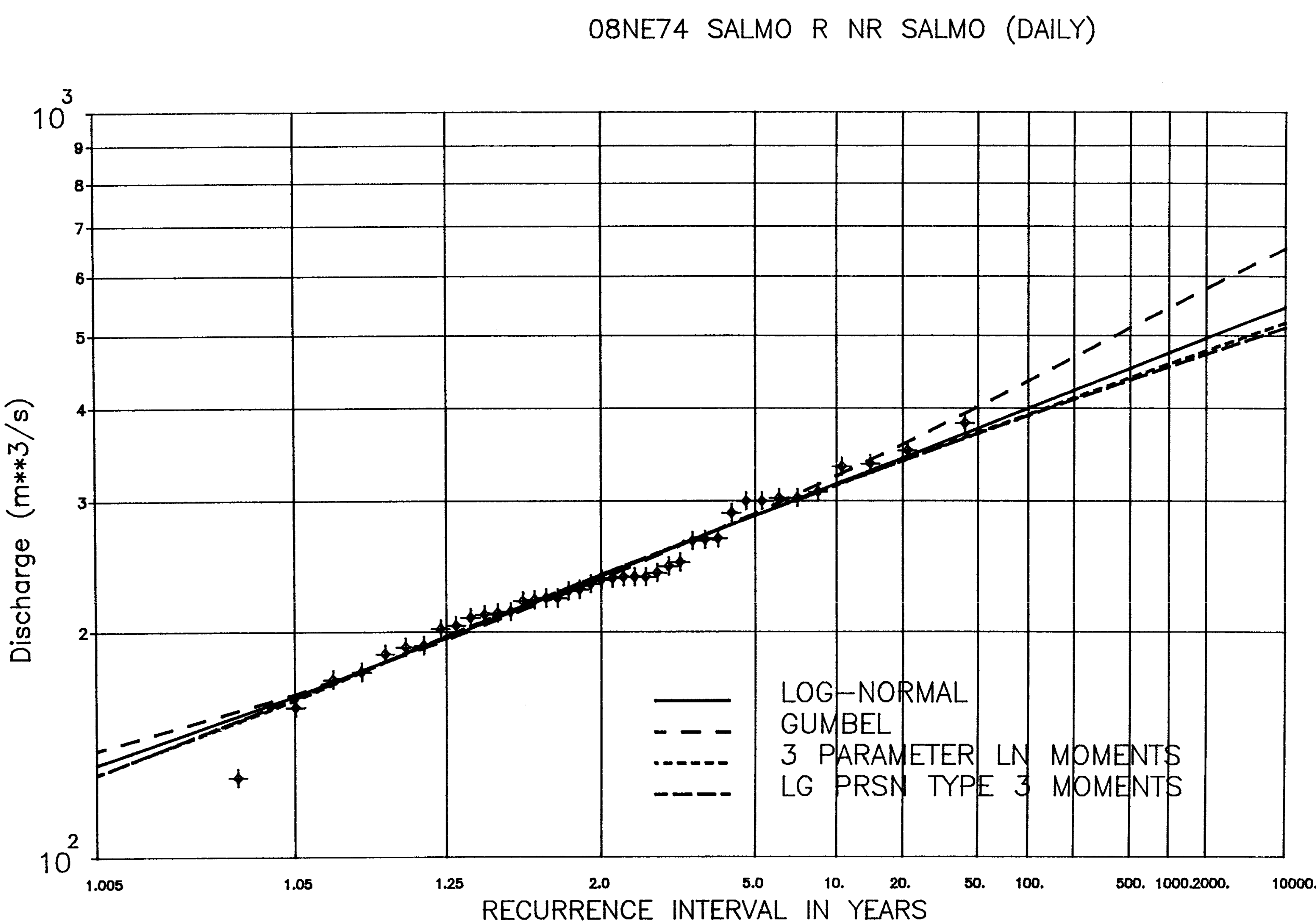
STATISTICS OF LOG(X-A)

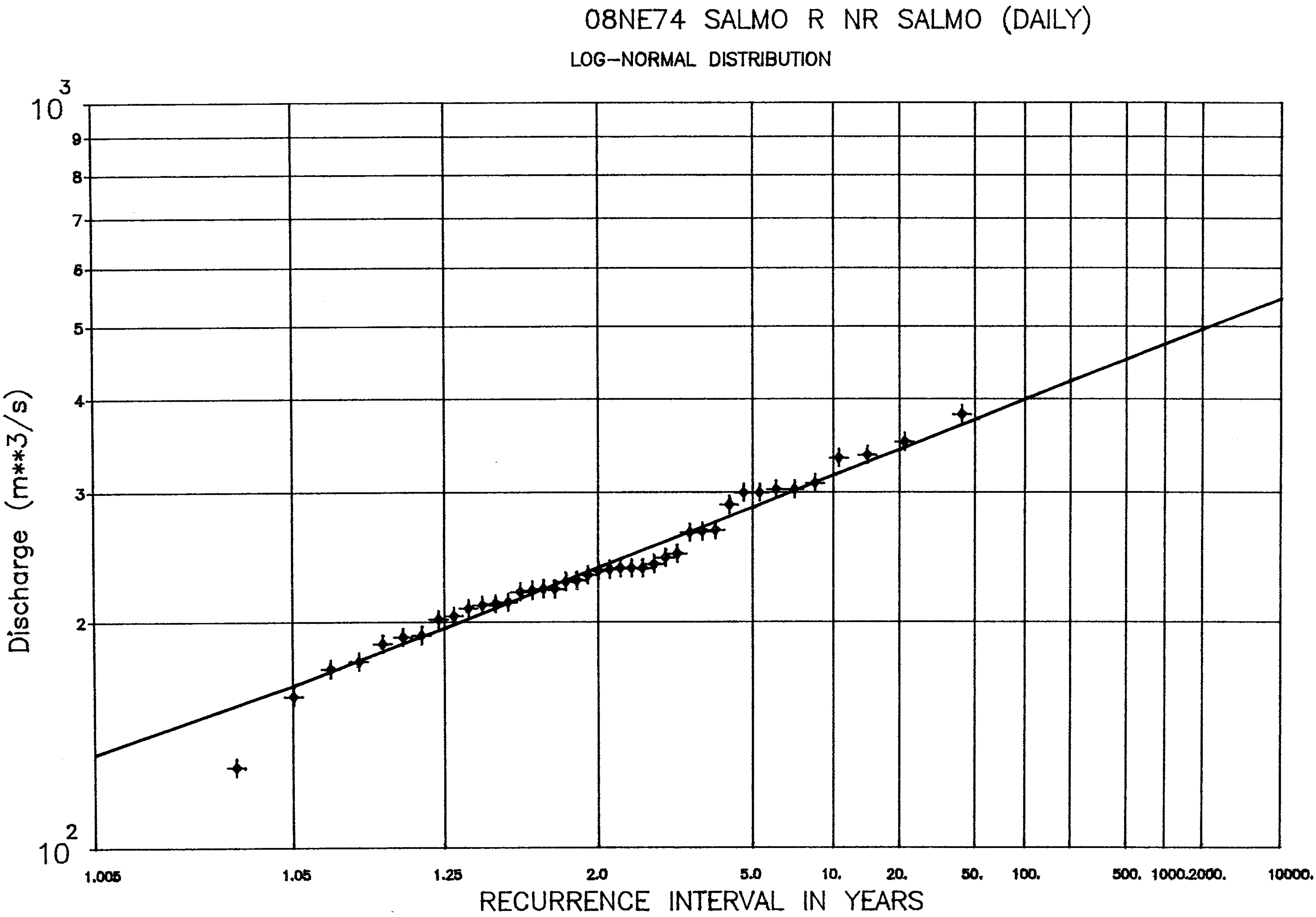
MEAN = 5.6829   S.D. = .1801   C.S. = .0158   C.K. = 3.5267

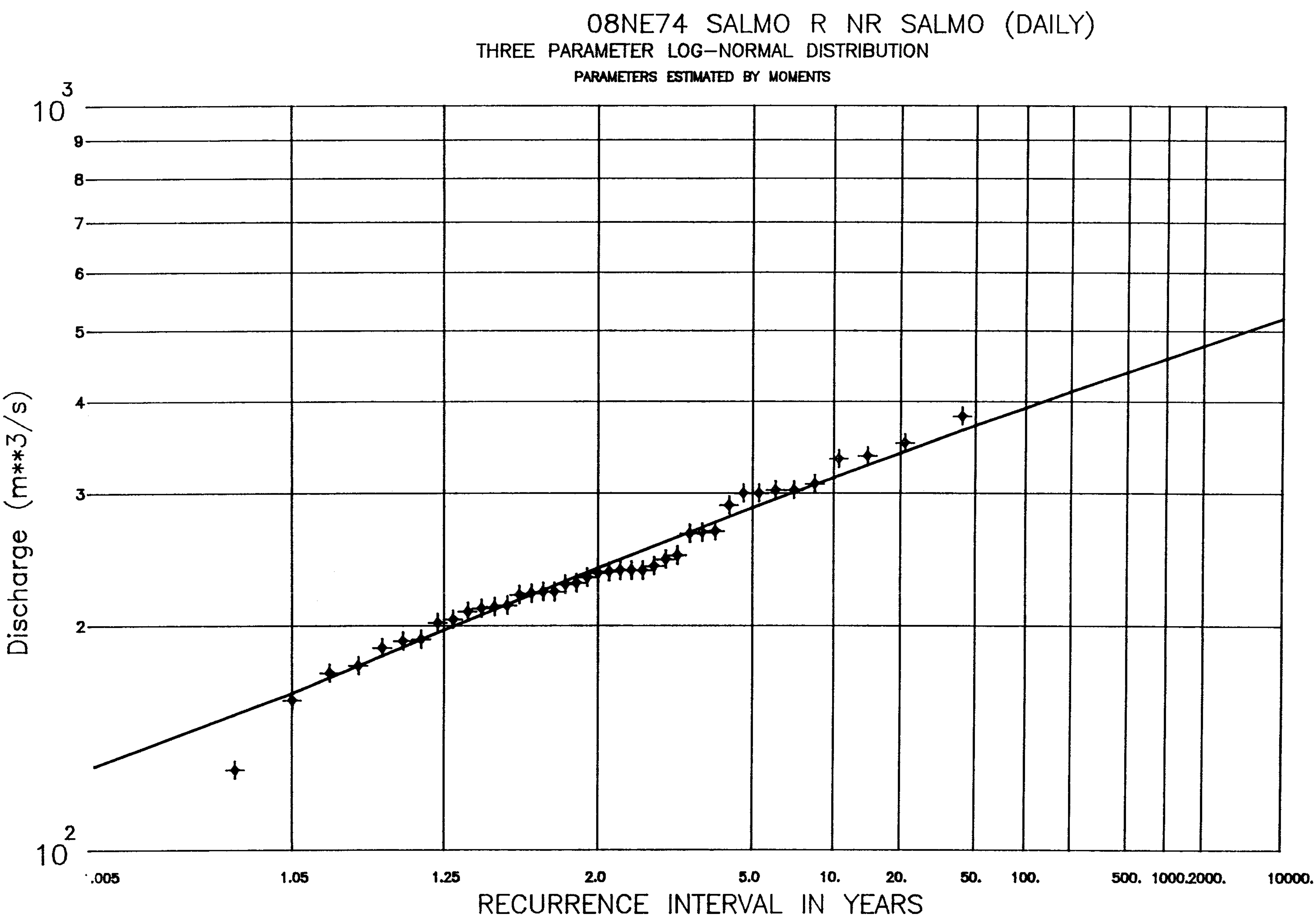
PARAMETERS FOR LOG PEARSON III BY MOMENTS   A = -.0153   B = .2140E+03   LOG(M) = 8.7413   M = .6256E+04

NO MAXIMUM LIKELIHOOD SOLUTION FOR LOG PEARSON III

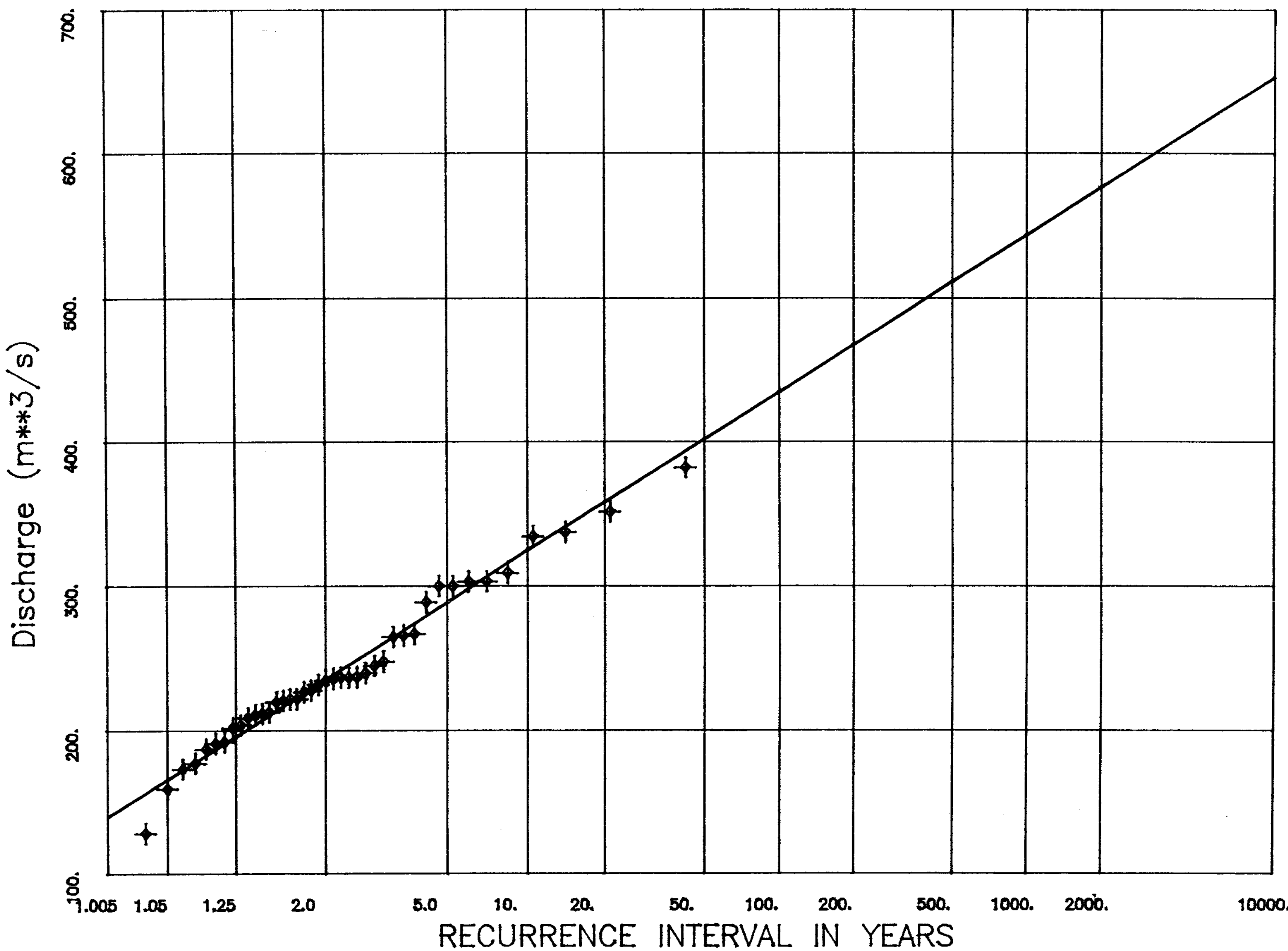
	GUMBEL I		LOGNORMAL		THREE PARAMETER LOGNORMAL		LOG PEARSON III MAX. LIKELIHOOD		LOG PEARSON III MOMENTS	
RETURN PERIOD	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST.ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT
1.005	139.0		133.0		129.0		.0		129.0	
1.050	165.0		164.0		162.0		.0		163.0	
1.250	195.0		196.0		197.0		.0		197.0	
2.000	235.0		237.0		238.0		.0		238.0	
5.000	288.0	4.61	286.0	4.07	286.0	3.94	.0	.00	286.0	3.94
10.000	324.0	5.27	316.0	4.72	314.0	4.60	.0	.00	315.0	4.51
20.000	357.0	5.83	342.0	5.36	339.0	5.66	.0	.00	339.0	5.45
50.000	401.0	6.46	375.0	6.16	370.0	7.39	.0	.00	369.0	7.08
100.000	434.0	6.86	399.0	6.73	391.0	8.80	.0	.00	390.0	8.48
200.000	467.0	7.21	422.0	7.26	412.0	10.30	.0	.00	410.0	9.97
500.000	511.0	7.61	451.0	7.93	438.0	12.20	.0	.00	435.0	12.00
1000.000	543.0	7.87	473.0	8.40	457.0	13.60	.0	.00	453.0	13.60
2000.000	576.0	8.11	495.0	8.85	476.0	15.10	.0	.00	471.0	15.30
10000.000	652.0	8.57	544.0	9.83	519.0	18.40	.0	.00	511.0	19.10

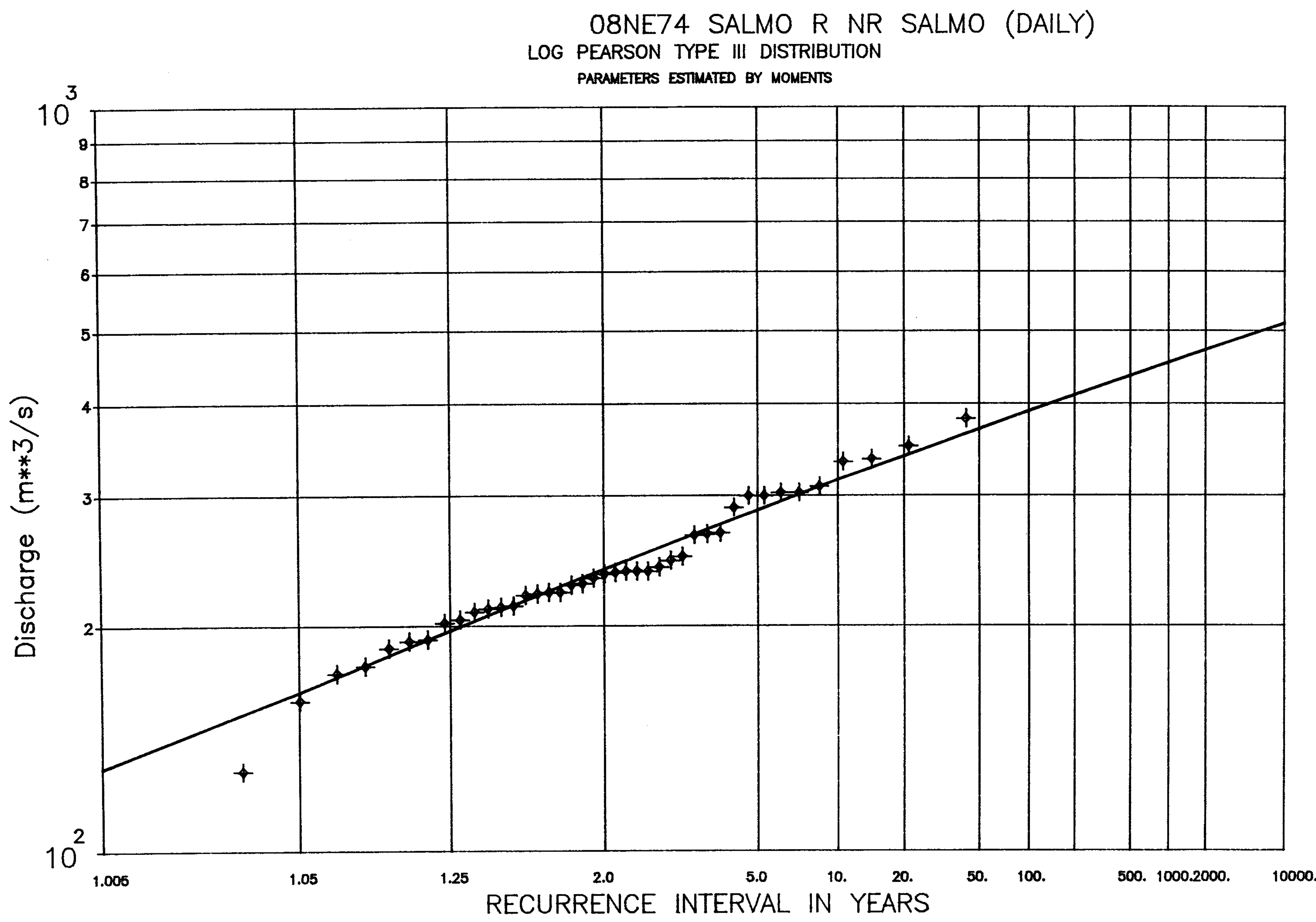

08NE74 SALMO R NR SALMO (DAILY)
Discharge (m**3/s)
10^3
9
8
7
6
5
4
3
2
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS
LOG-NORMAL
GUMBEL
3 PARAMETER LN MOMENTS
LG PRSN TYPE 3 MOMENTS


08NE74 SALMO R NR SALMO (DAILY)
LOG-NORMAL DISTRIBUTION
Discharge (m**3/s)
10^3
9
8
7
6
5
4
3
2
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS


08NE74 SALMO R NR SALMO (DAILY)
THREE PARAMETER LOG-NORMAL DISTRIBUTION
PARAMETERS ESTIMATED BY MOMENTS
Discharge (m**3/s)
10^3
9
8
7
6
5
4
3
2
10^2
.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS

GUMBEL I DISTRIBUTION




08NE74 SALMO R NR SALMO (DAILY)
LOG PEARSON TYPE III DISTRIBUTION
PARAMETERS ESTIMATED BY MOMENTS
Discharge (m**3/s)
10^3
9
8
7
6
5
4
3
2
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS

HIDDEN CREEK NEAR THE MOUTH (INSTANTANEOUS)

08NE114 HIDDEN CREEK NEAR THE MOUTH (INST)

YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
1973	11.600	39.600	1	.056	18.000
1974	27.500	27.500	2	.111	9.000
1975	18.000	19.900	3	.167	6.000
1976	19.900	18.000	4	.222	4.500
1977	7.840	15.700	5	.278	3.600
1978	11.900	15.400	6	.333	3.000
1979	11.800	15.100	7	.389	2.571
1980	39.600	14.800	8	.444	2.250
1981	14.400	14.400	9	.500	2.000
1982	15.100	14.200	10	.556	1.800
1983	15.400	12.900	11	.611	1.636
1984	11.800	12.700	12	.667	1.500
1985	14.800	11.900	13	.722	1.385
1986	12.900	11.800	14	.778	1.286
1988	12.700	11.800	15	.833	1.200
1989	14.200	11.600	16	.889	1.125
1990	15.700	7.840	17	.944	1.059

08NE114 HIDDEN CREEK NEAR THE MOUTH (INST)

SAMPLE STATISTICS

MEAN = 16. S.D. = 7.4 C.S. = 2.3341 C.K. = 9.8649

SAMPLE STATISTICS (LOGS)

MEAN = 2.7126 S.D. = .3654 C.S. = 1.1597 C.K. = 6.1713

SAMPLE MIN = 8. SAMPLE MAX = 40. N = 17

PARAMETERS FOR GUMBEL I A = .241455 U = 13.

PARAMETERS FOR LOGNORMAL M = 2.7126 S = .3654

PARAMETERS FOR THREE PARAMETER LOGNORMAL A = 5. M = 2.2278 S = .5640

STATISTICS OF LOG(X-A)

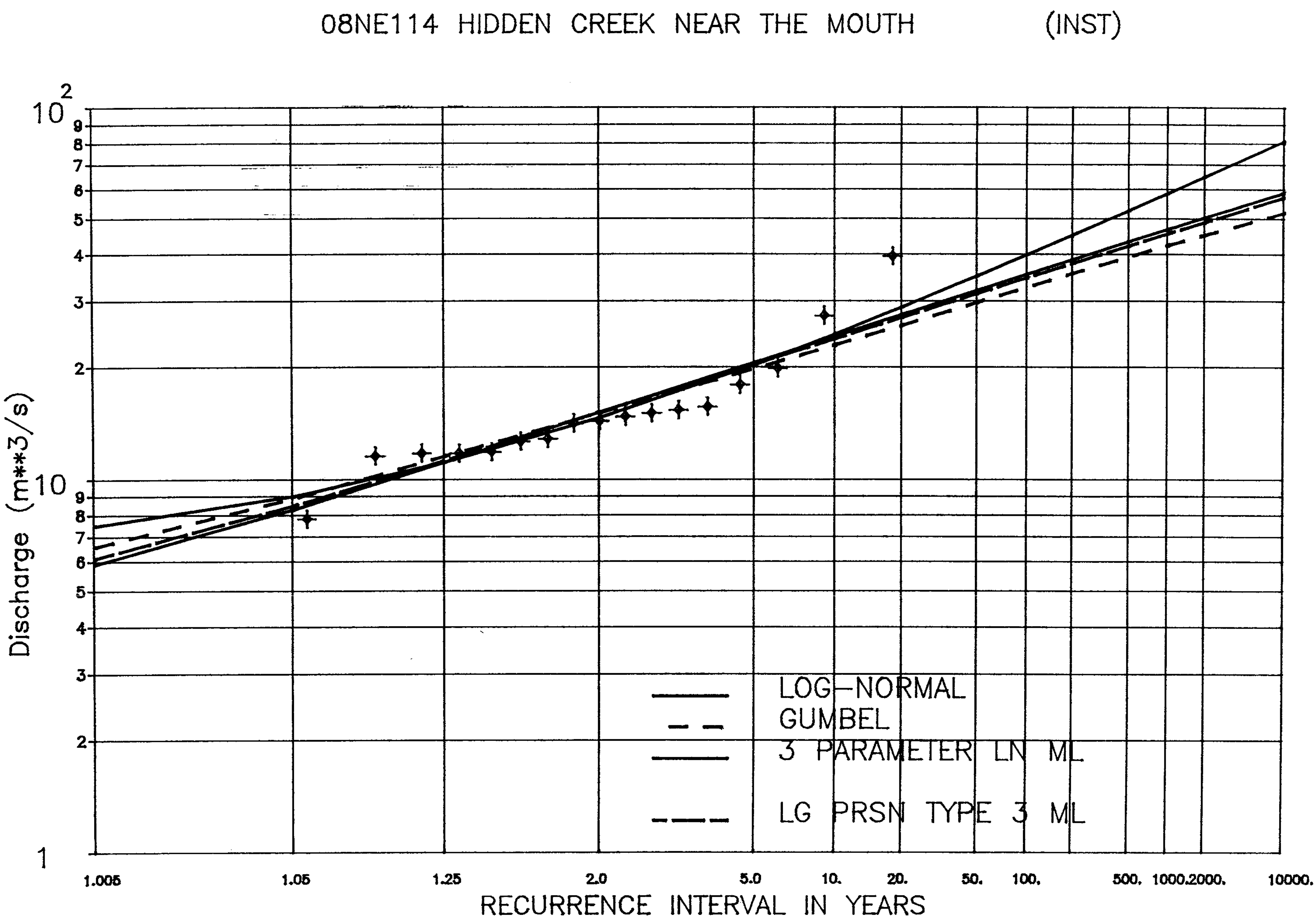
MEAN = 2.2278 S.D. = .5640 C.S. = .2530 C.K. = 5.7998

PARAMETERS FOR LOG PEARSON III BY MOMENTS A = .2119 B = .2974E+01 LOG(M) = 2.0824 M = .8024E+01

PARAMETERS FOR LOG PEARSON III BY MAXIMUM LIKELIHOOD A = .0030 B = .1411E+05 LOG(M) =******* M = .8479E-17

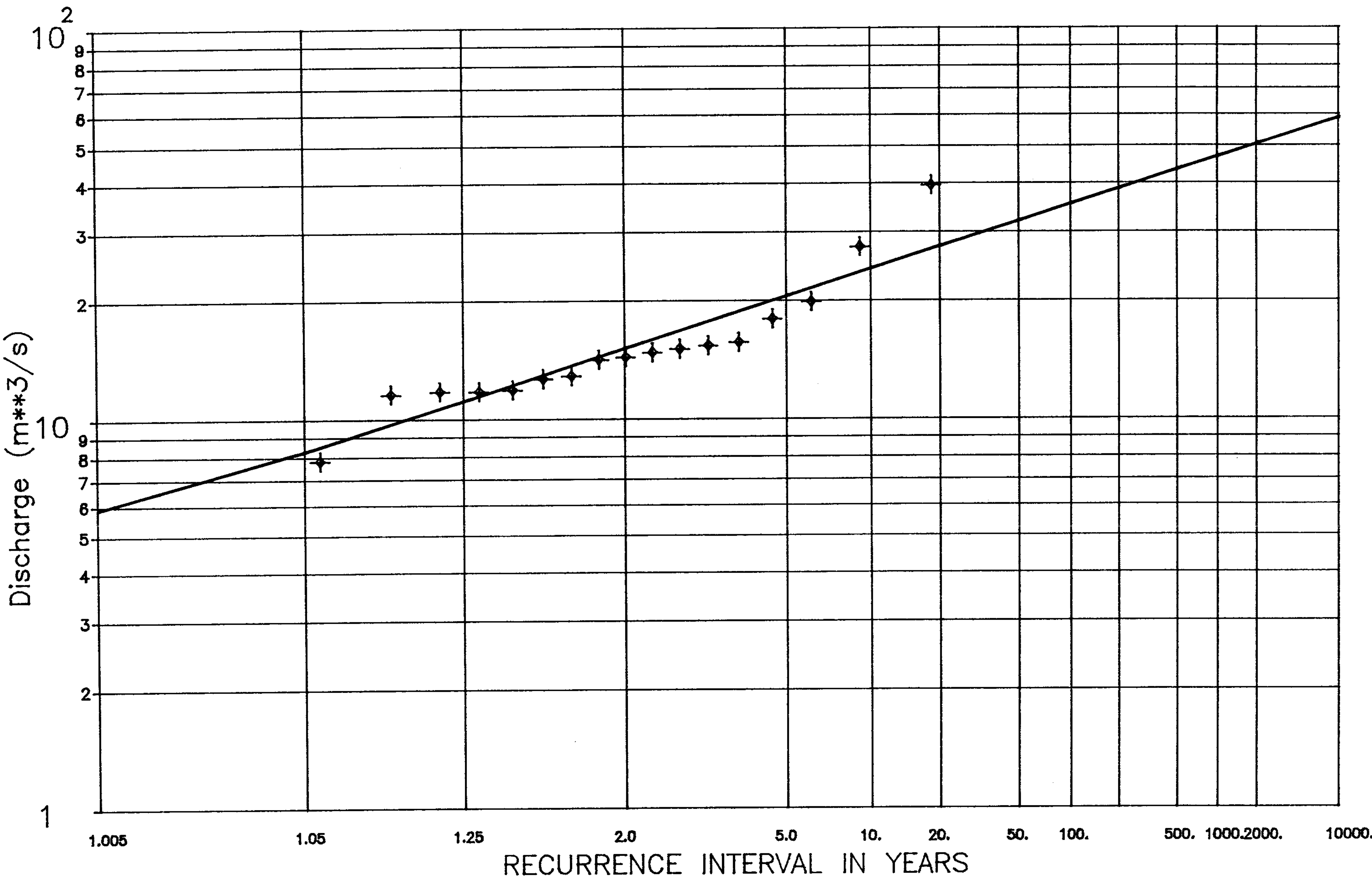
DISTRIBUTION STATISTICS MEAN = 2.7126 S.D. = .3537 C.S. = .0168

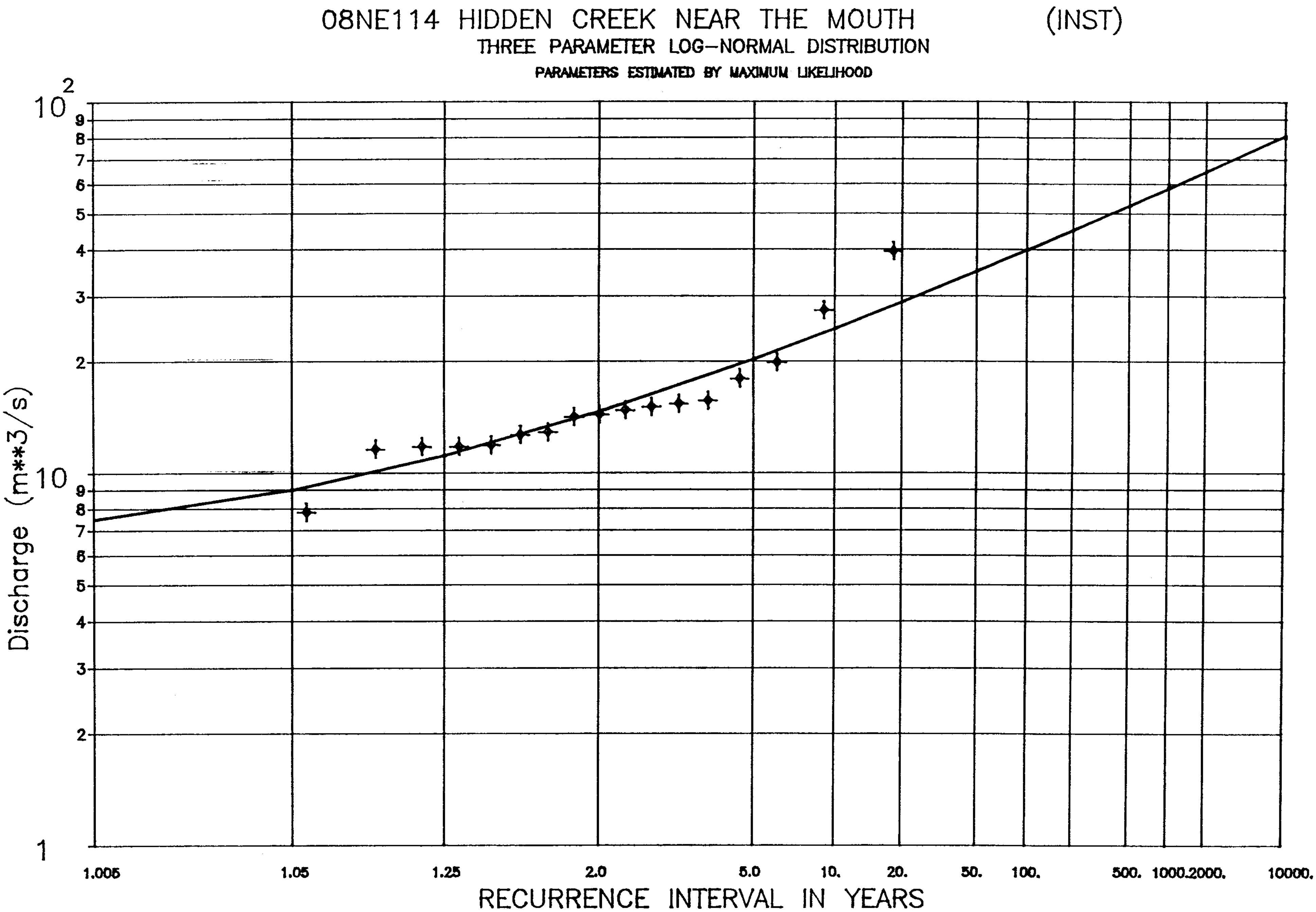
	GUMBEL I		LOGNORMAL		THREE PARAMETER LOGNORMAL		LOG PEARSON III MAX. LIKELIHOOD		LOG PEARSON III MOMENTS	
RETURN PERIOD	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST.ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT
1.005	6.5		5.9		7.5		6.1		.0	
1.050	8.8		8.3		9.0		8.4		.0	
1.250	11.5		11.1		11.1		11.2		.0	
2.000	15.0		15.1		14.6		15.1		.0	
5.000	19.7	9.21	20.5	10.30	20.2	11.70	20.3	17.60	.0	.00
10.000	22.8	10.20	24.1	12.00	24.4	14.90	23.7	18.60	.0	.00
20.000	25.7	11.00	27.5	13.60	28.8	18.50	27.0	19.70	.0	.00
50.000	29.6	11.90	31.9	15.60	34.9	23.60	31.3	21.10	.0	.00
100.000	32.5	12.50	35.3	17.10	39.8	27.50	34.5	22.10	.0	.00
200.000	35.4	13.00	38.6	18.40	45.0	31.30	37.7	23.20	.0	.00
500.000	39.2	13.50	43.2	20.10	52.4	36.30	42.0	24.50	.0	.00
1000.000	42.1	13.90	46.6	21.30	58.3	39.90	45.3	25.50	.0	.00
2000.000	44.9	14.20	50.2	22.40	64.7	43.50	48.7	26.40	.0	.00
10000.000	51.6	14.80	58.6	24.90	80.9	51.40	56.9	28.50	.0	.00


08NE114 HIDDEN CREEK NEAR THE MOUTH (INST)
Discharge (m**3/s)
10^2
10
1
9
8
7
6
5
4
3
2
LOG-NORMAL
GUMBEL
3 PARAMETER LN ML
LG PRSN TYPE 3 ML
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS

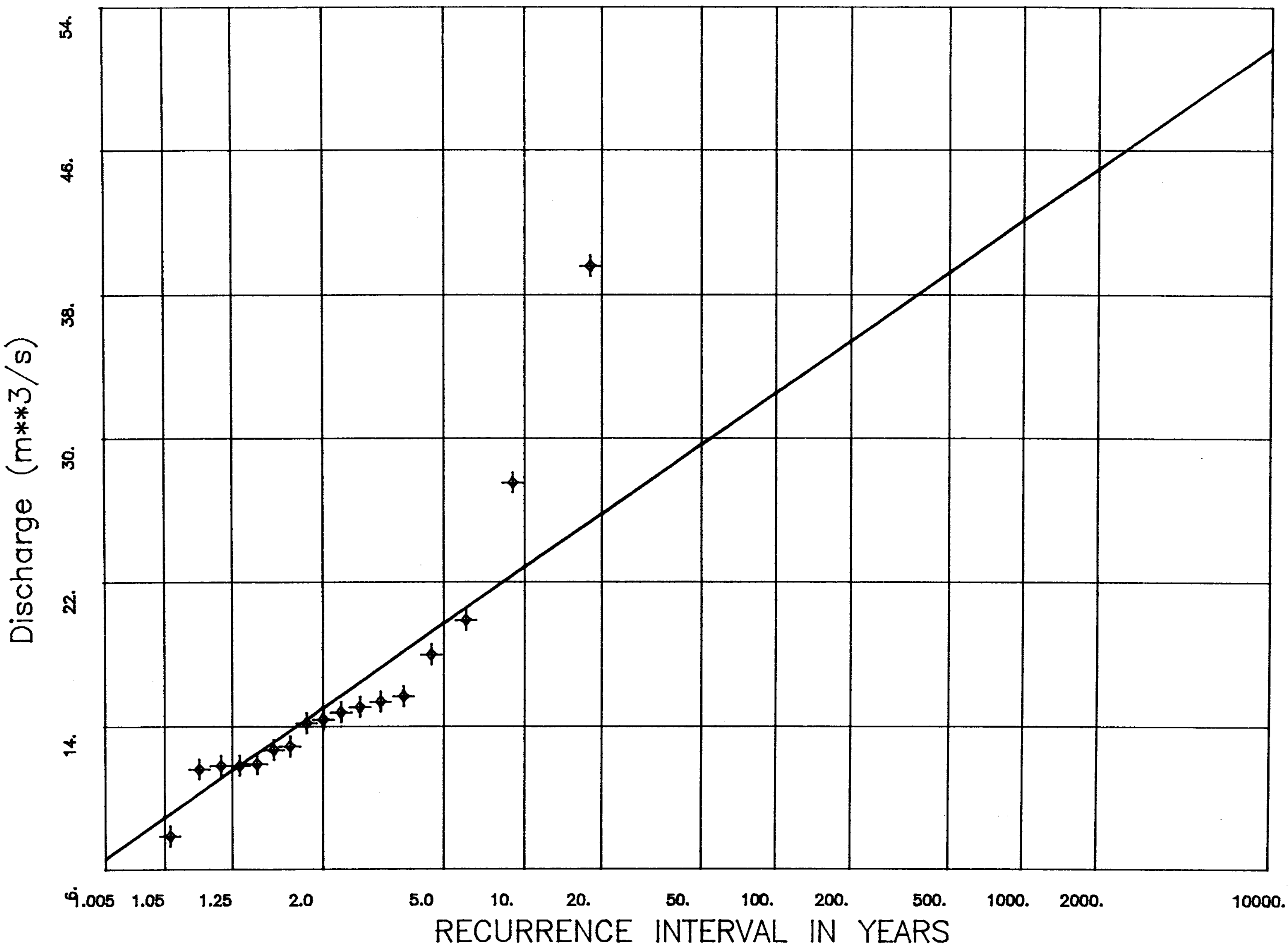
08NE114 HIDDEN CREEK NEAR THE MOUTH (INST)

LOG-NORMAL DISTRIBUTION




08NE114 HIDDEN CREEK NEAR THE MOUTH (INST)
THREE PARAMETER LOG-NORMAL DISTRIBUTION
PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD
Discharge (m**3/s)
10^2
9
8
7
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
RECURRENCE INTERVAL IN YEARS

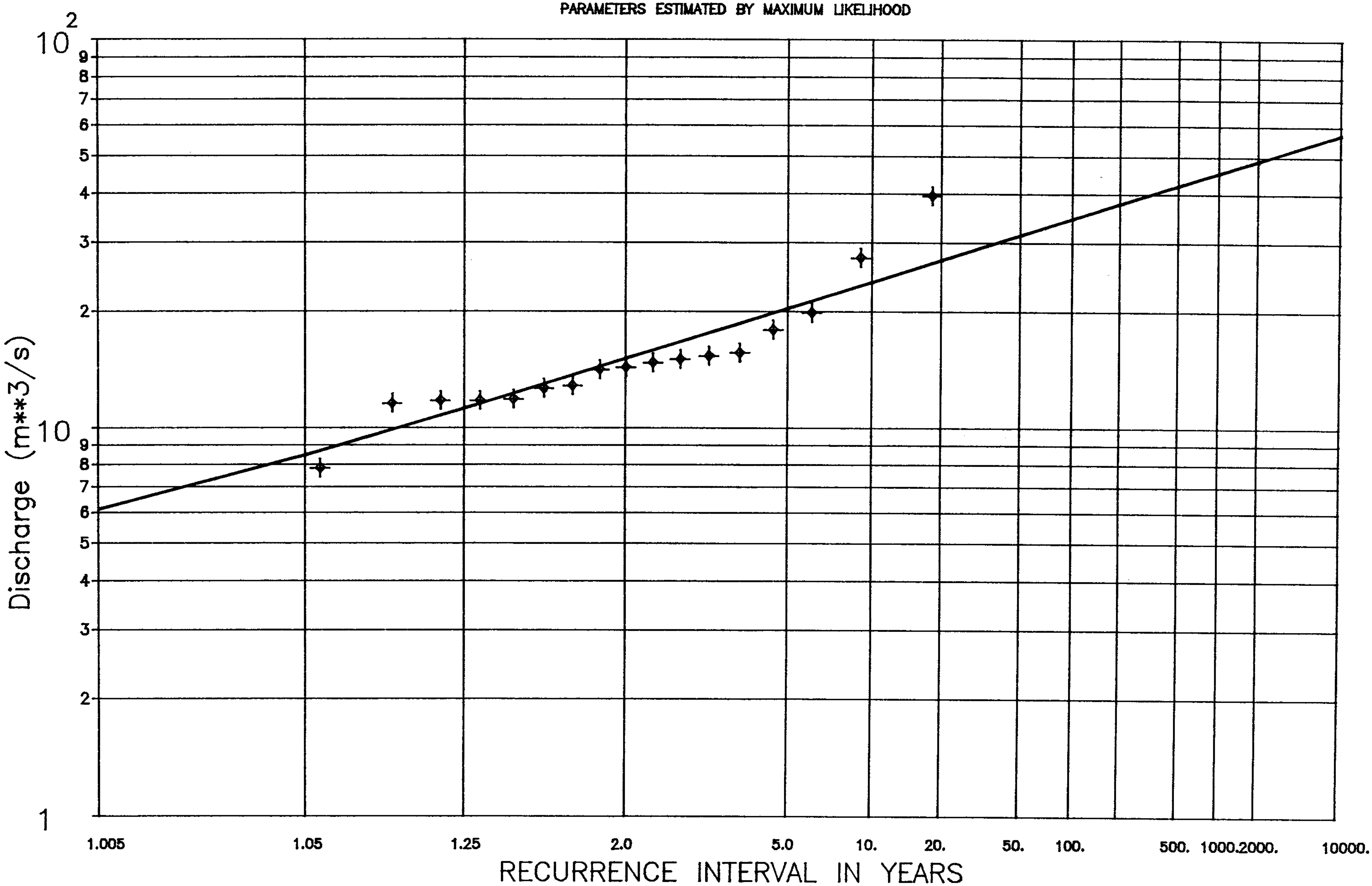
GUMBEL I DISTRIBUTION



08NE114 HIDDEN CREEK NEAR THE MOUTH (INST)

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD



HIDDEN CREEK NEAR THE MOUTH (DAILY)

08NE114 HIDDEN CREEK NEAR THE MOUTH (DAILY)

YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
1973	10.600	24.100	1	.053	19.000
1974	22.700	22.700	2	.105	9.500
1975	12.900	15.600	3	.158	6.333
1976	14.600	14.600	4	.211	4.750
1977	7.080	13.400	5	.263	3.800
1978	10.600	12.900	6	.316	3.167
1979	10.000	11.700	7	.368	2.714
1980	24.100	11.500	8	.421	2.375
1981	10.800	11.200	9	.474	2.111
1982	11.500	10.900	10	.526	1.900
1983	13.400	10.900	11	.579	1.727
1984	10.000	10.800	12	.632	1.583
1985	11.200	10.600	13	.684	1.462
1986	11.700	10.600	14	.737	1.357
1987	10.900	10.200	15	.789	1.267
1988	10.200	10.000	16	.842	1.188
1989	10.900	10.000	17	.895	1.118
1990	15.600	7.080	18	.947	1.056

08NE114 HIDDEN CREEK NEAR THE MOUTH (DAILY)

SAMPLE STATISTICS

MEAN = 13. S.D. = 4.3 C.S. = 1.8179 C.K. = 6.7115

SAMPLE STATISTICS (LOGS)

MEAN = 2.4982 S.D. = .2924 C.S. = 1.0517 C.K. = 5.3536

SAMPLE MIN = 7. SAMPLE MAX = 24. N = 18

PARAMETERS FOR GUMBEL I A = .374177 U = 11.

PARAMETERS FOR LOGNORMAL M = 2.4982 S = .2924

PARAMETERS FOR THREE PARAMETER LOGNORMAL A = 5. M = 1.9435 S = .4852

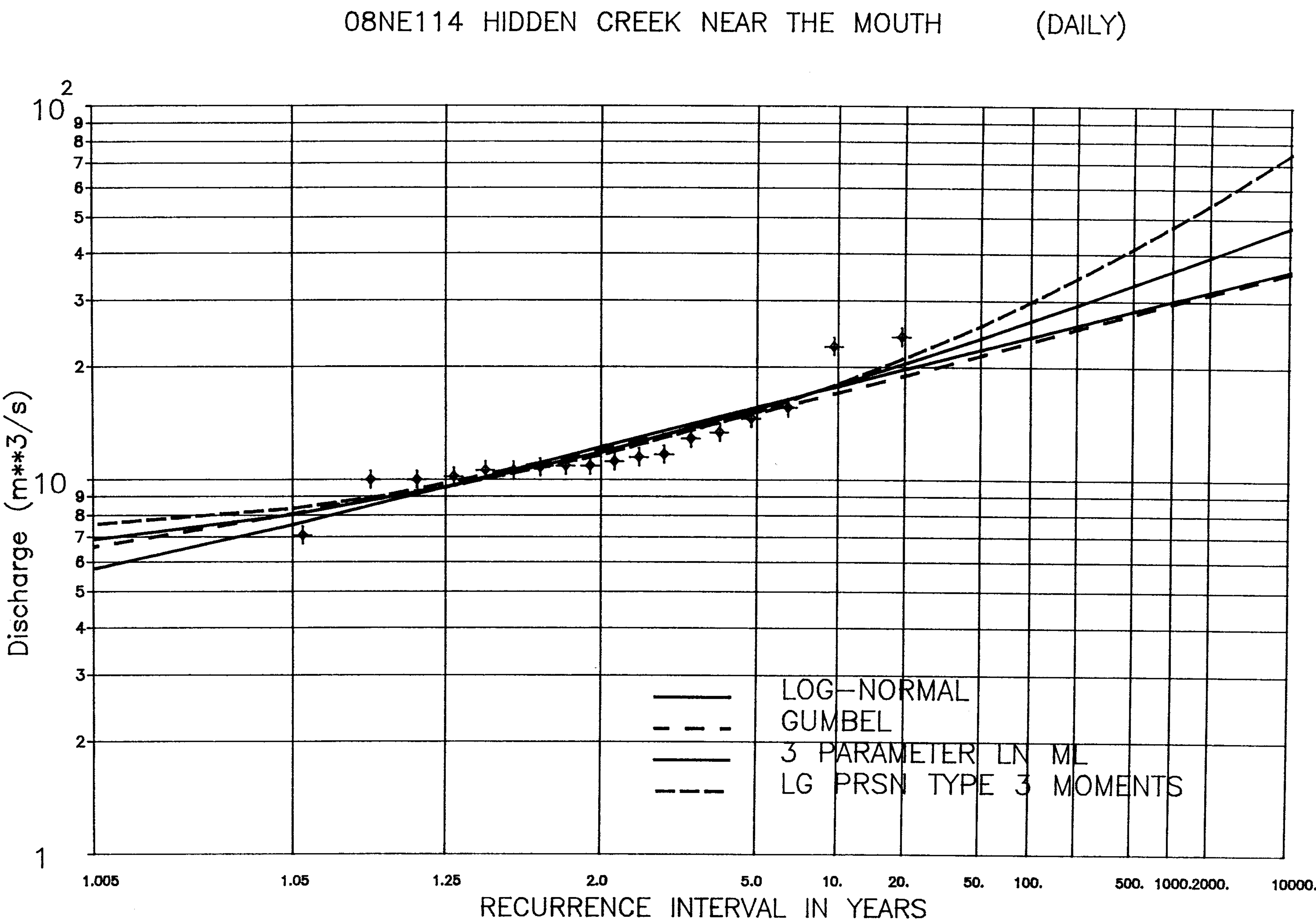
STATISTICS OF LOG(X-A)

MEAN = 1.9435 S.D. = .4852 C.S. = .2146 C.K. = 5.5130

PARAMETERS FOR LOG PEARSON III BY MOMENTS A = .1537 B = .3616E+01 LOG(M) = 1.9422 M = .6974E+01

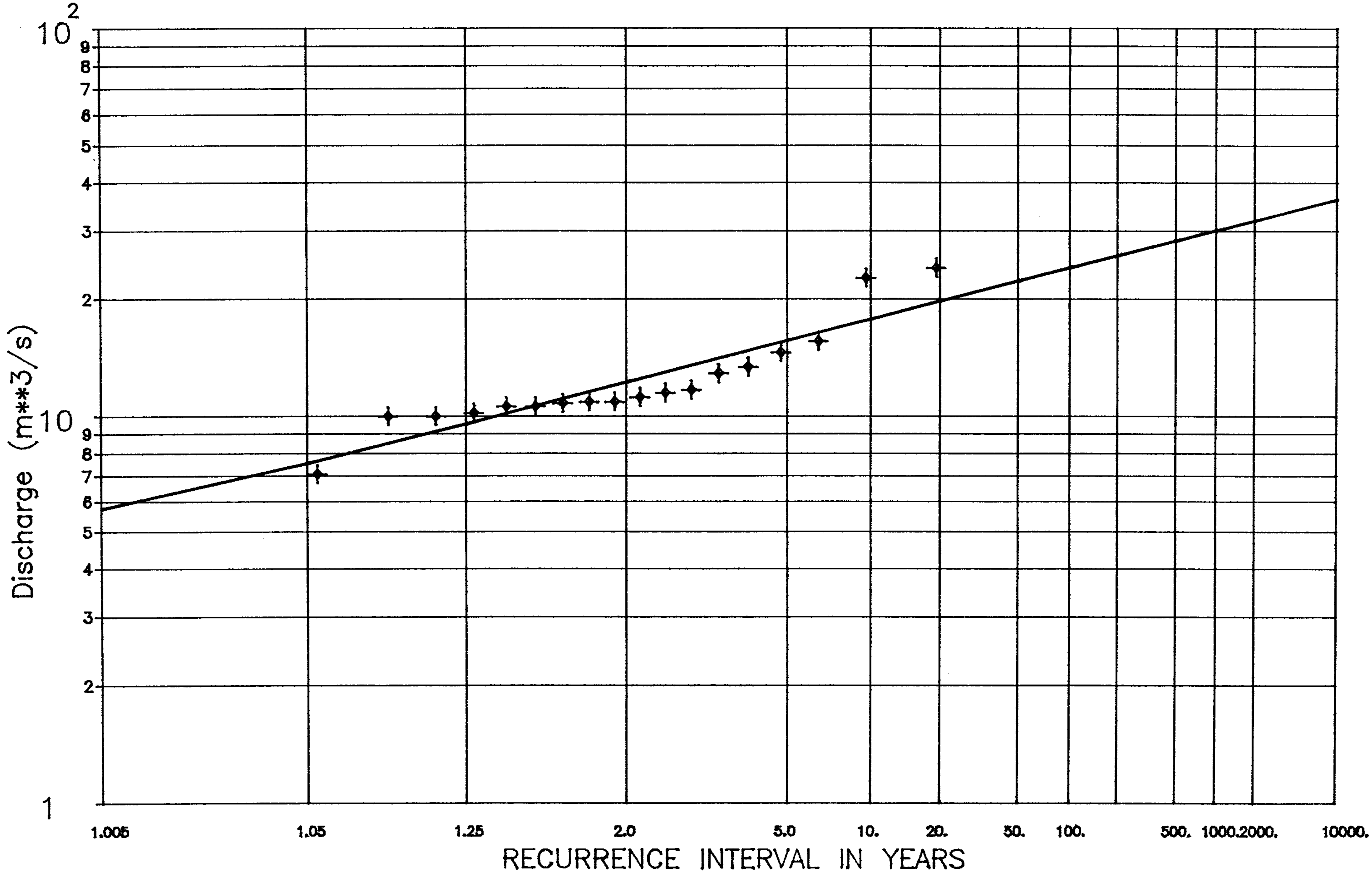
NO MAXIMUM LIKELIHOOD SOLUTION FOR LOG PEARSON III

	GUMBEL I		LOGNORMAL		THREE PARAMETER LOGNORMAL		LOG PEARSON III MAX. LIKELIHOOD		LOG PEARSON III MOMENTS	
RETURN PERIOD	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST.ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT	FLOOD ESTIMATE	ST. ERROR PERCENT
1.005	6.6		5.7		6.9		.0		7.5	
1.050	8.0		7.5		8.0		.0		8.3	
1.250	9.7		9.5		9.5		.0		9.5	
2.000	12.0		12.2		11.8		.0		11.6	
5.000	15.0	7.56	15.6	8.02	15.4	9.10	.0	.00	15.1	10.20
10.000	17.0	8.56	17.7	9.30	17.9	11.60	.0	.00	18.0	13.80
20.000	18.9	9.40	19.7	10.60	20.4	14.50	.0	.00	21.1	19.30
50.000	21.4	10.30	22.2	12.20	23.8	18.80	.0	.00	25.7	28.70
100.000	23.3	10.90	24.0	13.30	26.5	22.00	.0	.00	29.8	36.80
200.000	25.2	11.40	25.8	14.30	29.2	25.30	.0	.00	34.4	45.50
500.000	27.6	12.00	28.2	15.60	33.1	29.70	.0	.00	41.4	57.90
1000.000	29.5	12.40	30.0	16.60	36.1	32.90	.0	.00	47.5	67.60
2000.000	31.3	12.70	31.8	17.50	39.3	36.00	.0	.00	54.4	77.80
10000.000	35.6	13.40	36.1	19.40	47.3	43.10	.0	.00	74.5	103.00


08NE114 HIDDEN CREEK NEAR THE MOUTH (DAILY)
Discharge (m**3/s)
10^2
10
1
RECURRENCE INTERVAL IN YEARS
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.
2000.
10000.
LOG-NORMAL
GUMBEL
3 PARAMETER LN ML
LG PRSN TYPE 3 MOMENTS

08NE114 HIDDEN CREEK NEAR THE MOUTH (DAILY)

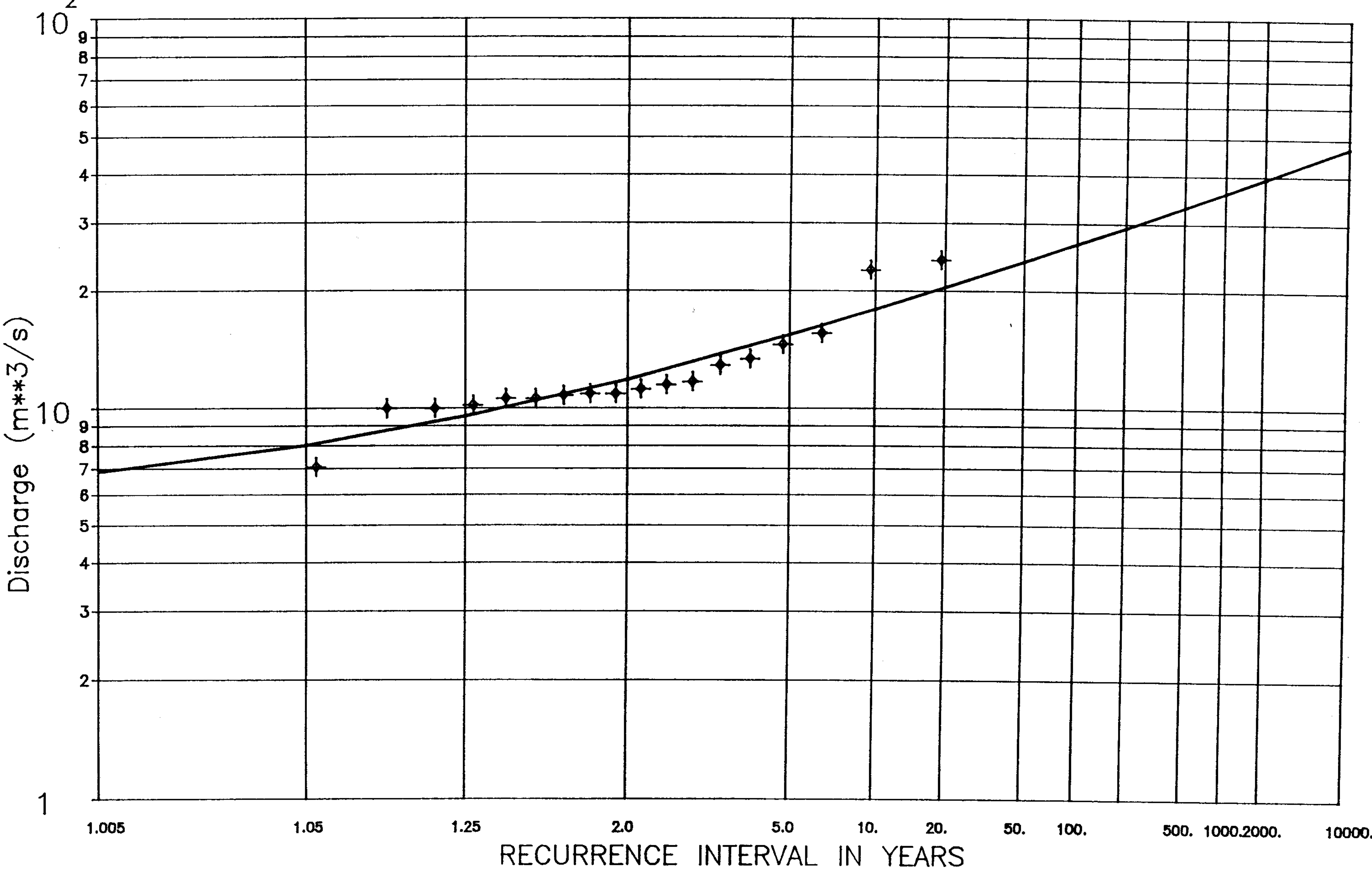
LOG–NORMAL DISTRIBUTION



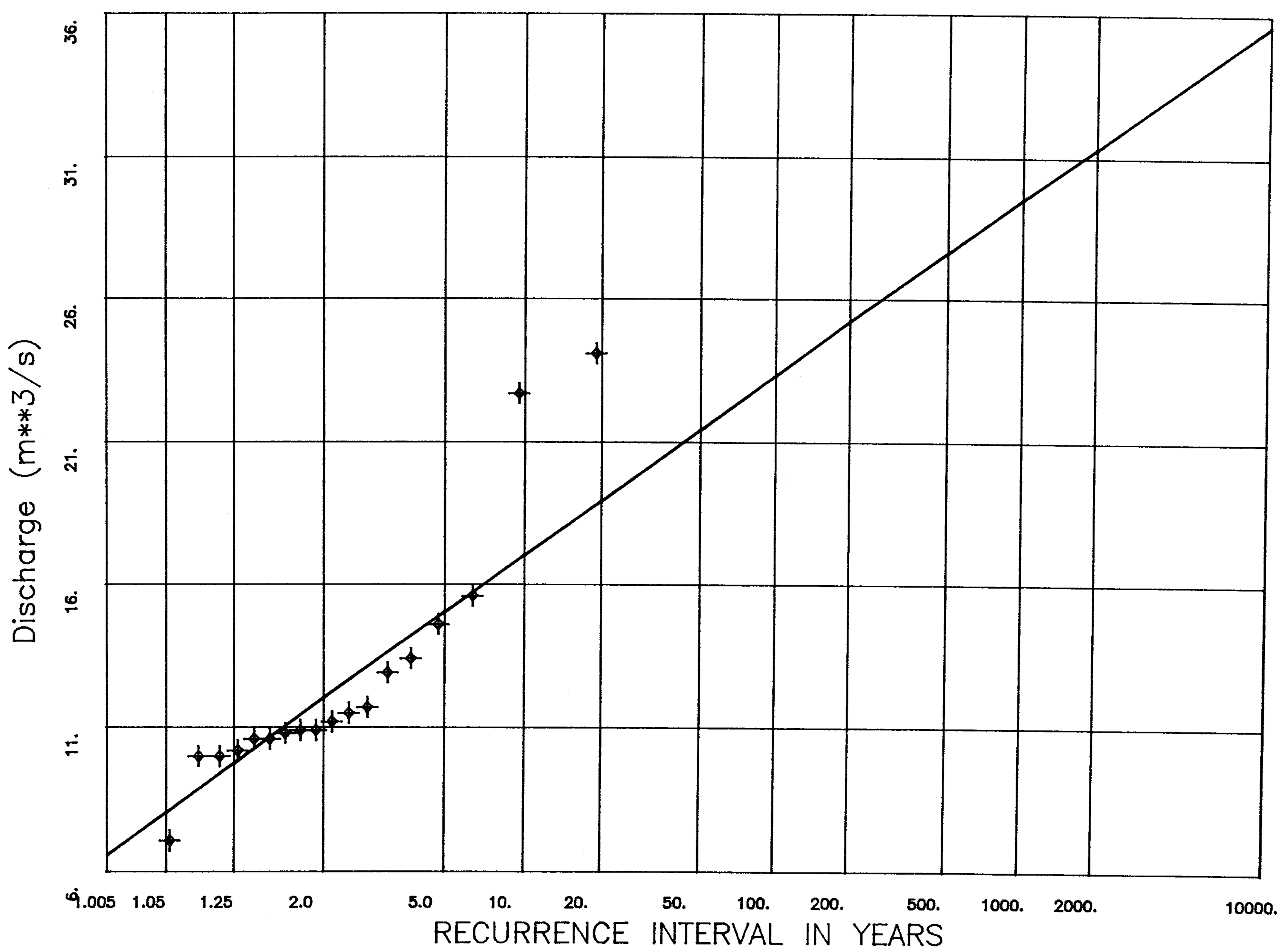
08NE114 HIDDEN CREEK NEAR THE MOUTH (DAILY)

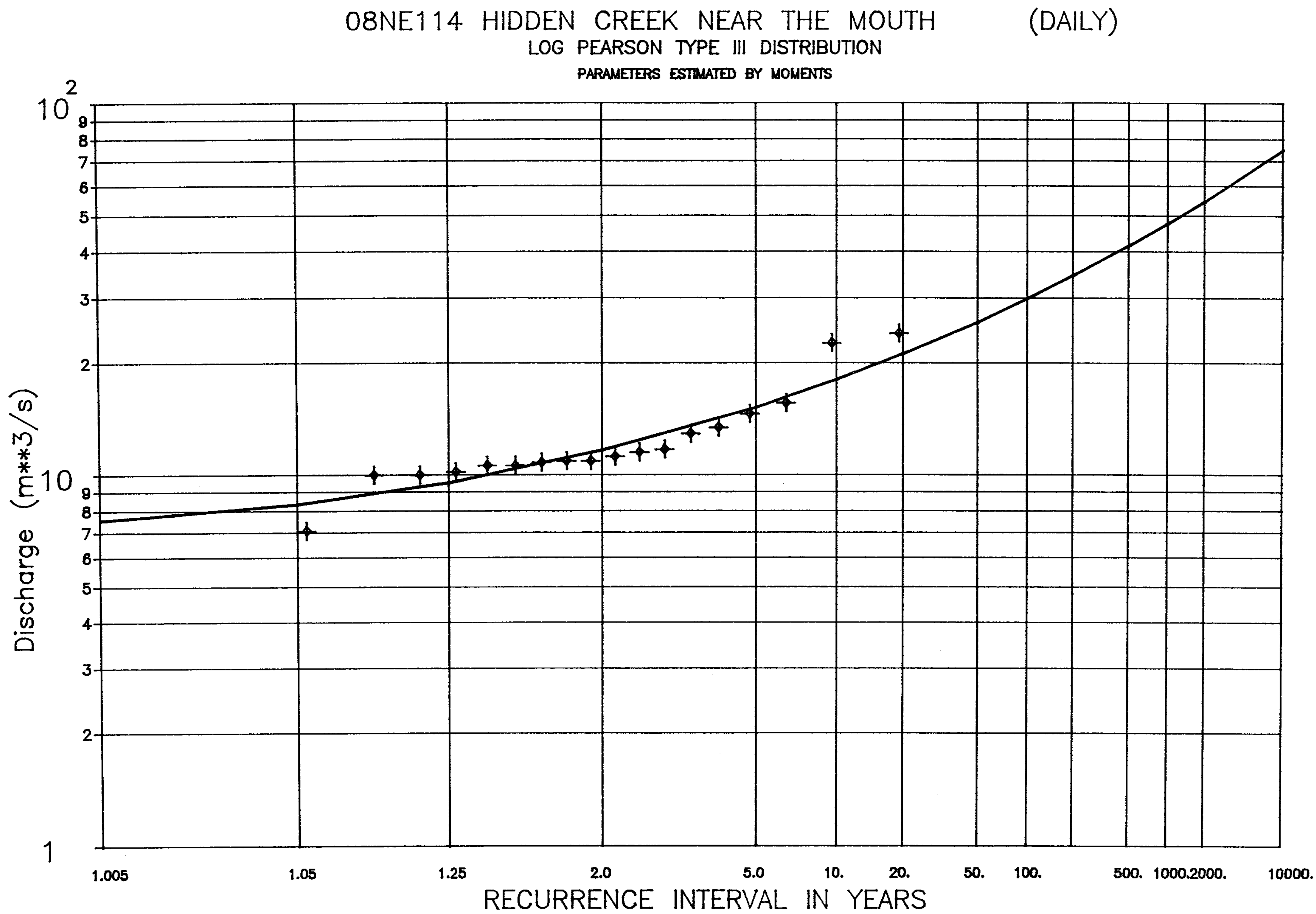
THREE PARAMETER LOG-NORMAL DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD



GUMBEL I DISTRIBUTION




08NE114 HIDDEN CREEK NEAR THE MOUTH (DAILY)
LOG PEARSON TYPE III DISTRIBUTION
PARAMETERS ESTIMATED BY MOMENTS
Discharge (m**3/s)
10^2
9
8
7
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
500.
1000.2000.
10000.
RECURRENCE INTERVAL IN YEARS

APPENDIX B

CALCULATED FLOOD LEVELS

ACRES

SALMO RIVER MAIN STEM

SEC. NO.	200-YEAR (m)	20-YEAR (m)
146	613.25	612.92
145	613.86	613.58
144	615.02	614.59
143	616.22	615.74
142	616.68	616.19
141	617.07	616.58
140	617.29	616.82
139	617.47	617.05
138	617.73	617.40
137	617.79	617.59
136	618.54	618.22
135	618.88	618.61
134	619.28	619.07
130	619.73	619.52
129	619.89	619.69
128	620.14	619.94
127	621.07	620.51
126	622.82	622.14
125	622.87	622.45
124	622.96	622.53
123	623.20	622.71
122	623.33	622.88
121	623.98	623.53
120	624.34	624.09
119	624.99	624.80
118	625.73	625.54
117	626.66	626.41
116	628.15	627.85
115	629.20	629.02
114	631.53	631.33
50	634.40	634.19
49	634.56	634.37
48	635.19	634.95
47	636.37	636.00
45	638.46	638.38
44	640.53	640.30
43	641.10	640.87
42	641.25	640.98
40	642.16	641.76
39	642.90	642.44
38	643.25	642.75
37	643.46	642.96
36	643.77	643.27
35	643.88	643.37
34	643.98	643.49
33	644.13	643.71
32	644.25	643.94
31	644.65	644.40
30	644.90	644.67
29	645.11	644.90
28	645.39	645.22
27	645.98	645.83
26	646.32	646.13
25	646.39	646.12
24	646.72	646.48
23	647.15	646.85

22	647.13	646.93
21	647.44	647.22
20	647.93	647.67
19	648.29	648.05
18	649.18	648.94
17	649.61	649.35
16	650.37	650.21
15	650.79	650.55
14	650.83	650.60
13	650.91	650.69
12	651.44	651.21
11	652.30	652.04
10	652.75	652.50
9	654.18	653.73
8	654.78	654.40
7	655.54	655.18
6	656.64	656.29
51	657.23	656.81
5	657.54	657.07
4	657.63	657.22
3	658.08	657.68
2	658.10	657.73
1	658.64	658.16
61	660.42	659.88
62	662.18	661.92
63	664.16	664.01
64	666.28	666.09
65	668.72	668.53
66	670.71	670.45
67	674.76	674.45
68	677.46	677.21
69	680.49	680.33
70	682.08	681.85
71	684.48	684.26
72	687.14	686.80
73	689.11	688.64
74	690.76	690.32
75	690.73	690.38
76	690.77	690.43
77	691.82	691.50
78	693.46	693.22
79	695.35	695.16
80	696.74	696.56
81	698.29	698.00
82	699.03	698.84
83	700.60	700.44
84	703.04	702.66
85	704.50	704.28
86	706.93	706.70
87	707.12	706.83
88	708.42	708.00
89	709.14	708.79
90	710.29	710.20
91	713.01	712.71
92	713.68	713.44
93	714.83	714.65
94	715.74	715.45
95	718.82	718.60
96	722.39	721.97
97	723.32	722.98

98	724.29	723.96
99	726.36	726.12
101	727.19	726.89
101.1	727.25	726.92
102	727.54	727.03
103	728.02	727.81
104	729.33	729.23
105	730.33	730.13
106	731.89	731.68
107	733.72	733.52
109	736.86	736.43
110	737.16	736.51
111	737.43	736.73
112	737.75	737.09
113	738.65	738.31

ERIE CREEK

SEC. NO.	200-YEAR (m)	20-YEAR (m)
1	657.55	657.22
2	659.70	659.54
3	661.65	661.34
4	661.87	661.48
5	663.19	662.63
6	663.56	662.97
7	664.11	663.59
8	665.04	664.45
9	666.22	666.01
10	666.23	666.02
11	667.53	666.98
12	667.60	667.06
13	668.23	667.89
14	669.97	669.57
15	671.62	671.46
16	673.89	673.47
17	674.78	674.47
18	676.28	675.96
19	677.57	677.40
20	679.53	679.35
21	681.23	681.09
22	683.75	683.57
23	686.51	686.21
24	689.09	688.87
25	691.66	691.43
26	695.35	695.21
27	700.16	699.99
28	703.94	703.56
29	706.65	706.49
30	707.14	706.89
31	708.05	707.70
32	710.77	710.52
33	712.47	712.14
34	716.51	715.97
35	716.59	716.05
36	719.11	718.67
37	722.01	721.76