FLOODPLAIN MAPPING PROGRAM

SALMON RIVER
SHUSWAP LAKE TO SPA CREEK

DESIGN BRIEF

ENVIRONMENT CANADA
INLAND WATERS DIRECTORATE

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF ENVIRONMENT
WATER MANAGEMENT BRANCH

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Environment Canada
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FLOODPLAIN MAPPING PROGRAM
SALMON RIVER, SHUSWAP LAKE TO SPA CREEK

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1.0 INTRODUCTION

This study was prepared under the Canada-British Columbia Floodplain Mapping Agreement. Floodplain mapping is used for administrative purposes related to:

1) the preparation of hazard map schedules for official plans;

2) flood proofing requirements in zoning and building bylaws; and

3) the identification of floodable lands by Subdivision Approving Office.

This design brief has been prepared by Crippen Consultants. The study involves the preparation of floodplain mapping for the Salmon River in south central British Columbia near the town of Salmon Arm. The specific reach of the Salmon River analyzed in this study was an approximately 22 kilometre long section from Shuswap Lake upstream to Spa Creek.

The Salmon River drains into Shuswap Lake (Salmon Arm). The Salmon River is one of the major tributaries of the South Thompson River. Total catchment area of the Salmon River at Shuswap Lake is 1510 km^2. The Salmon River's catchment elevations range from 350 m at Shuswap Lake up to 1520 m in the Thompson Plateau headwaters area approximately 70 km southwest of the town of Salmon Arm (120 km along the river). Total annual precipitation in the catchment varies from 320 mm to 530 mm.

2.0 ACKNOWLEDGEMENTS

Crippen Consultants would like to acknowledge the assistance of the following agencies in the preparation of this study:

Water Management Branch, Kamloops regional office

Water Survey of Canada, Vancouver and Kamloops

Water Management Branch, Victoria

Atmospheric Environment Service, Environment Canada

3.0 DATA SOURCES

3.1 General

This study utilized survey data and information supplied by the Ministry of Environment, Water Management Branch. This data included cross section data, water level data and photographs. Water level data for the 1990 flood was obtained from the Kamloops regional office of the Water Management Branch. Discharge data was supplied from Water Survey of Canada. A complete list of data sources and references is given in Appendix B1.

3.2 1981 River Cross Section Survey

The Ministry of Environment Water Management Branch provided Crippen with river cross section survey data for the approximately 22 kilometre reach of the Salmon River from Shuswap Lake upstream to Spa Creek covered by this study. In addition, one metre contour base maps at a scale of 1:5,000 and photo mosaics at a scale of 1:10,000 were also provided by the Ministry.

Within this reach of the Salmon River approximately 150 river cross sections and over 30 bridges were surveyed. The cross sectioning interval is from 100 to 700 metres.

The Ministry also provided sketches of all bridges with details of deck elevations, depth of chords, pier configurations and bridge lengths. An album with over 300 photographs covering the whole reach, including all the bridges, was also available for assisting with HEC2 input data preparation.

3.3 1990 Field Investigations

During the course of this study Crippen project staff made two field visits to the project area in addition to an initial reconnaissance visit prior to contract award. During the initial reconnaissance visit Crippen project staff met with personnel at the Kamloops regional office of the Water Management Branch. They provided valuable data and background information for the study. They were also helpful in summarizing the problems and concerns of area residents.

The first field visit (after contract award) was undertaken to update the inventory of bridges and to become more familiar with the characteristics of the Salmon River. Since the initial survey was done in 1981, a review was made to confirm the validity of the survey data. Because one of the most important factors affecting the hydraulic analyses is the proper modelling of the bridges, it was necessary to confirm bridge data details. The confirmation of bridge data entailed checks (comparison with survey data) and inspections at most of the bridge locations.

During the second site visit more detailed surveys were done at three new bridges. Confirmation of preliminary floodplain limits were also made during the second site visit.

The Salmon River, in the study area, has meandered over the years and many old meanders are evident on the photo mosaics. The site visits made during this study indicated that although some minor changes were observed, the channel location surveyed during 1981 remains largely unchanged. In the experience of the consultant, the 1981 survey data is adequate for backwater analyses under flood conditions and for the preparation of the necessary floodplain mapping. The only changes or corrections necessary was updating the data at some of the bridge locations.

Summary of the post 1981 bridge changes are tabulated in Table 1.

TABLE 1

POST 1981 BRIDGE CHANGES

LOCATION	BRIDGE STATUS	COMMENTS
XS-19/20 Salmon Valley Road (Photo 15-18)	Concrete bridge replaced old bridge at the same site.	Clear span, no piers. 0.3m high stumps of old piers remain.
XS-106a Brown Road (Photo 71-73)	New crossing with ex-railway Bridge.	
XS-112/113 Private bridge (Photo 75,76)	Log bridge at original site. Bridge was washed away during the June 1990 flood. New bridge was under construction at the time of our 2nd visit. Finished deck elevation is expected to be higher than the original level.	Channel cross section has been changed after the 1990 flood.
XS-115/116 Salmon Valley Road (Photo 78-81)	Steel girder bridge at 20m u/s of the original location.	Stumps of old piers remain.
XS-141/142 Private bridge (Photo 93,94)	Log bridge removed	Date unknown.
XS-142a Forbes Road (Photo 98-102)	New steel bridge	River changed course after the 1990 flood. Ponding and scouring around the right abutment were reported.

Appendix B2 contains sketches of the new bridges.

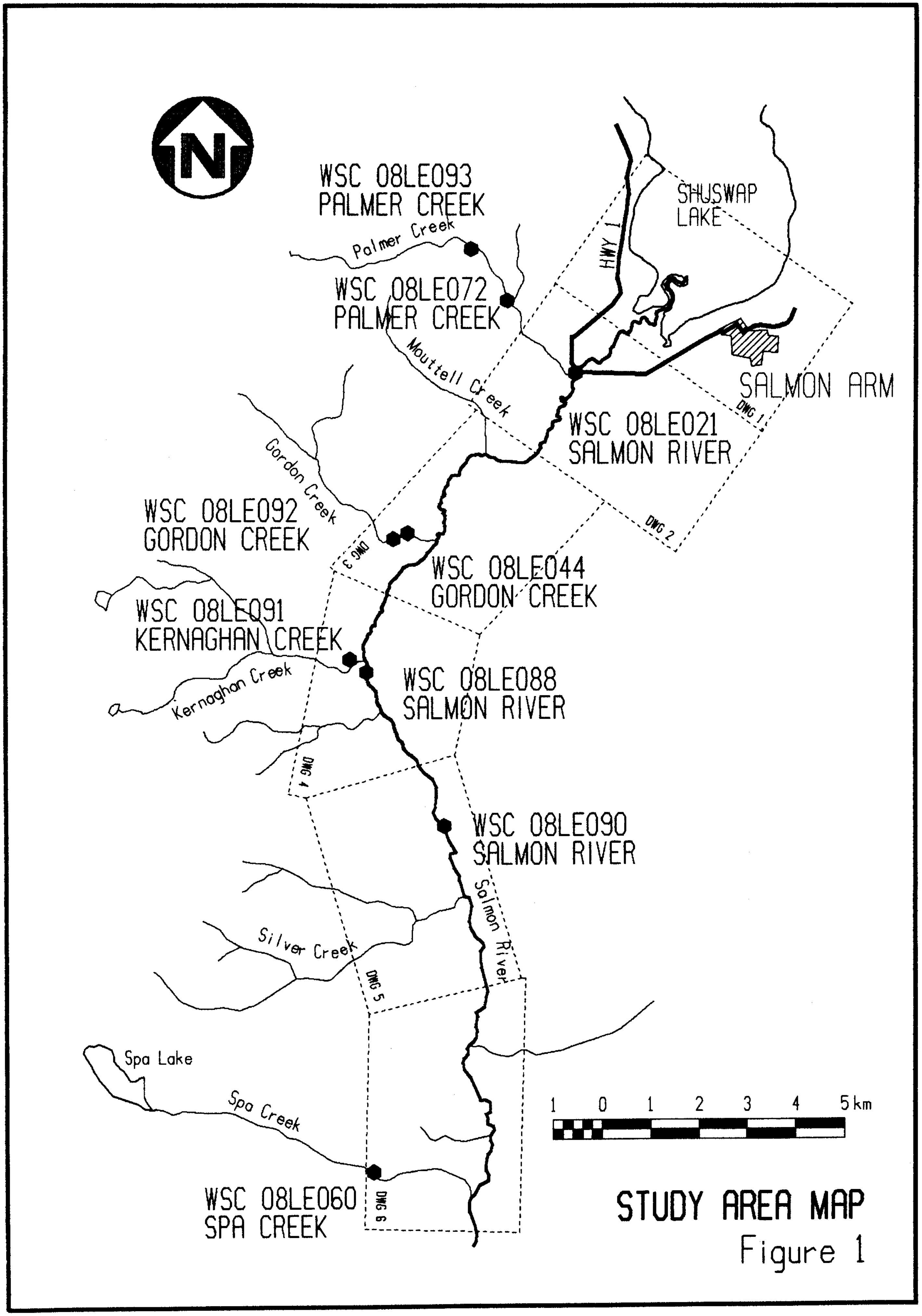
Appendix C (separate volume) includes photos from the 1990 site visits cross referenced with photos from the same general locations taken in 1981. These photos are intended to demonstrate changes to the channel and/or bridge locations since the original 1981 survey.

3.4 Water Survey of Canada Streamflow Data

The Salmon River has data available from several Water Survey of Canada (WSC) stream gauging stations (both active and discontinued) with records of varying lengths. In addition to the stations on the Salmon River there are several other WSC stations on tributaries of the Salmon River. The WSC stations are tabulated in Table 2 and nine of them are shown on the Study Area Map, Figure 1.

The Salmon River stations are reported by WSC to be regulated, but discussions with WSC indicate that the only regulating structure is a small structure approximately 100 kilometres upstream from Salmon Arm at the outlet of Salmon Lake. The regulation at Salmon Lake is considered inconsequential for flood flow analyses since the catchment area at this point on the Salmon River is approximately 10 percent of the downstream catchment area near Salmon Arm.

The other type of regulation on the Salmon River and its tributaries is that due to small in valley diversions for irrigation. These diversions are considered to be inconsequential for flood analyses, especially since irrigations are normally done during the dry season.



STUDY AREA MAP
Figure 1

TABLE 2

WSC GAUGING STATIONS

Station Name	Station Number	D.A. (km^2)	Period of Record
Salmon River near Salmon Arm	08LE021	1510	1911-12 partial 1961-73 partial 1974-present
Salmon River below Silver Creek	08LE090	1210	1974-77
Salmon River at Falkland	08LE020	1040	1911-12 partial 1915-21 partial 1947-51 partial 1952-present
Salmon River above Kernaghan Creek	08LE088	400	1974-79
Salmon River above Fowler Creek	08LE089	1070	1974-80 1985-86
Palmer Creek above Diversions	08LE093	15.5	1974-79
Palmer Creek near Salmon Arm	08LE072	18.1	1963 partial 1967-69 partial 1970-77
Kernaghan Creek above Diversions	08LE091	8.29	1974-80 1987 partial
Spa Creek below Cowpersmith Diversion	08LE060	13.0	1945-48 partial
Gordon Creek near Salmon Arm	08LE044	18.9	1963 partial 1965 partial 1966-75
Gordon Creek above Divisions	08LE092	17.9	1974-79

4.0 HYDROLOGY

4.1 Historical Floods

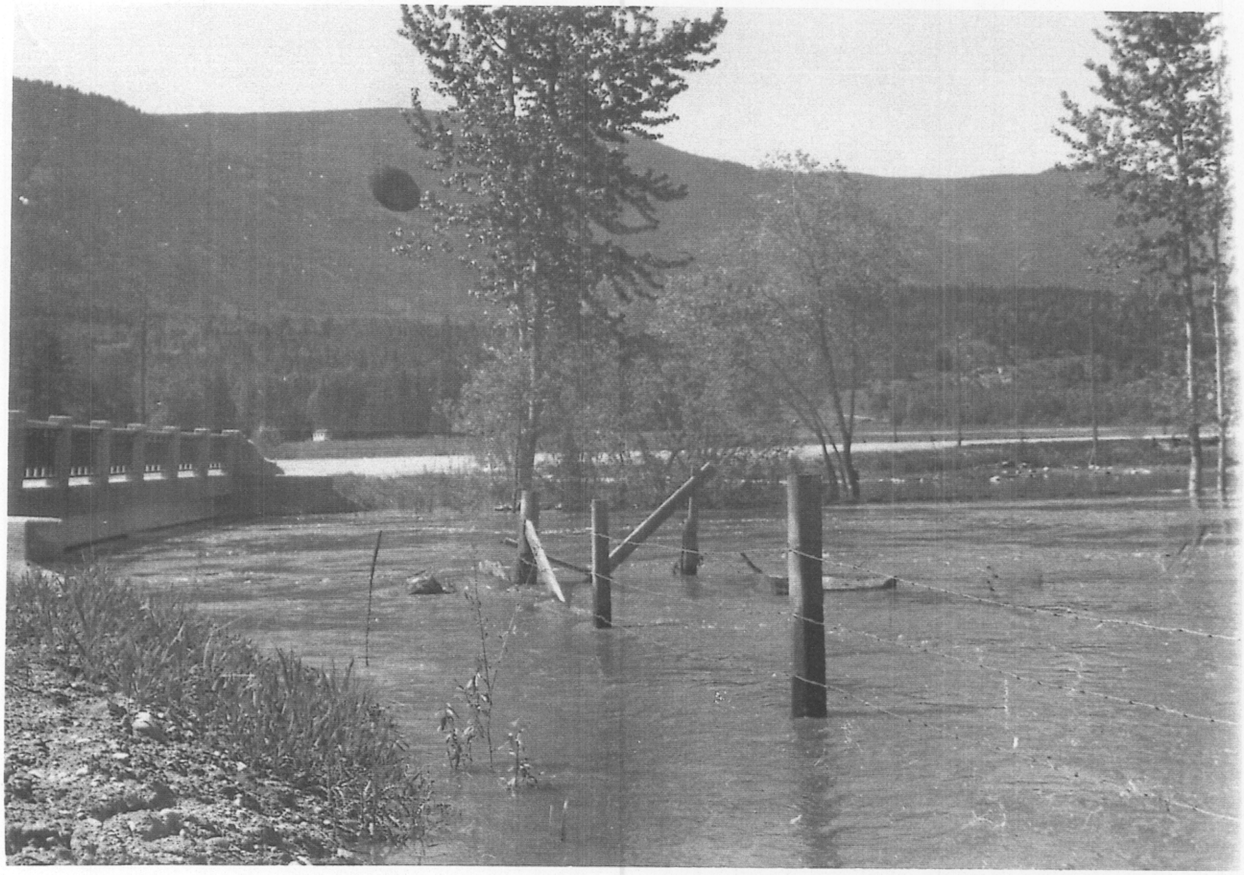
Floods on the Salmon River are freshet events which usually occur in May or June. Because the reach of the Salmon River considered by this study has a relatively flat slope and meandering channel in a shallow valley, extensive overbank flooding results for floods of long duration and high peaks.

Documents obtained during our reconnaissance visit from the Kamloops' regional office of the Water Management Branch and historical data provided by the WSC indicate that large floods occurred in 1948, 1971, 1972 and 1982. These flood events resulted in bank erosion and flooding problems within the study area. The 1948 flood had a return period of 50 years for the maximum daily discharge. However this flood was not recorded at the lower gauge (08LE021, Salmon Arm gauge) since it was not installed at that time. The 1948 flood has no instantaneous discharge records available.

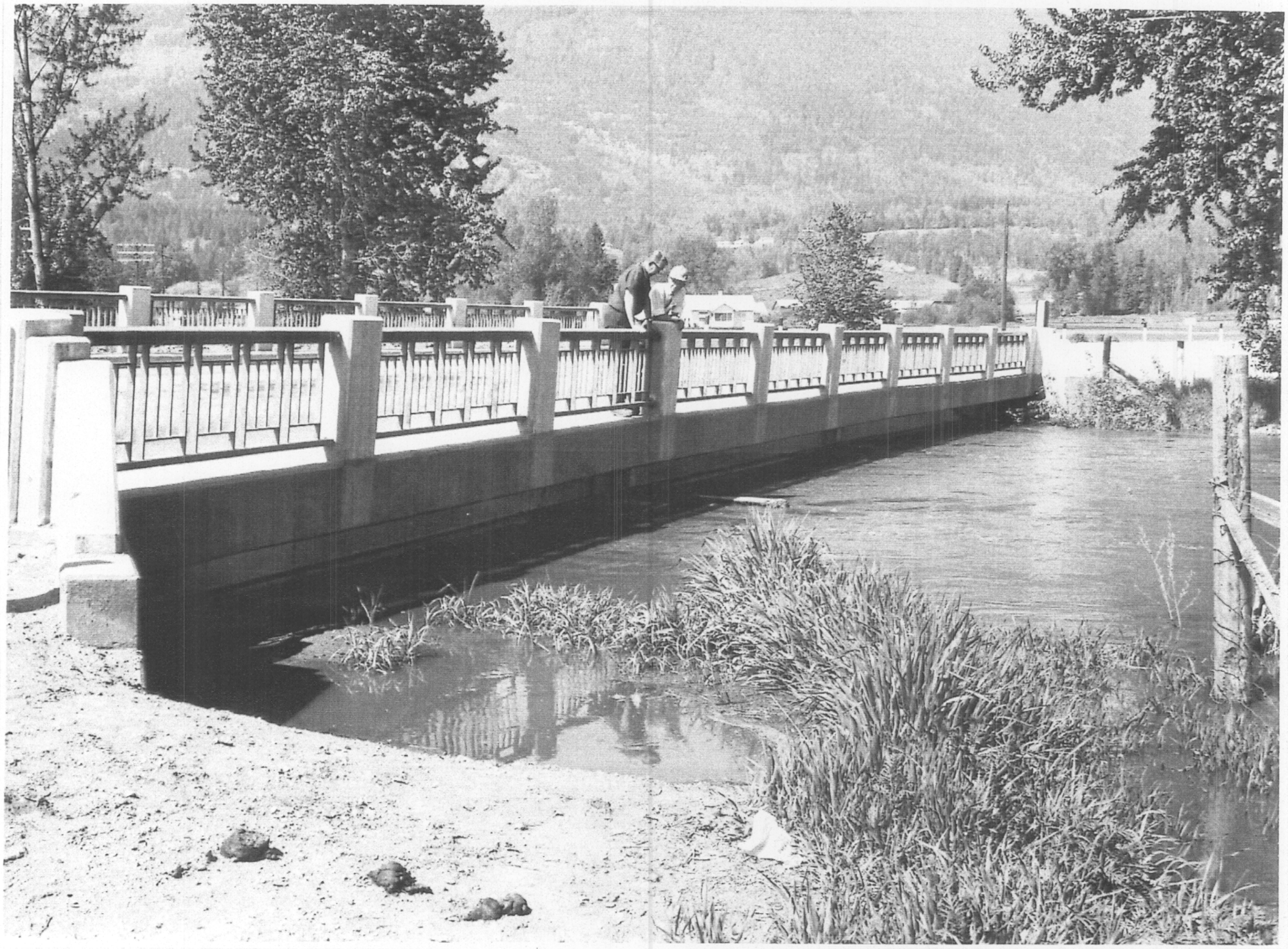
The 1982 flood had a maximum instantaneous discharge with a return period of approximately 20 years. Both of these floods resulted in overbank flood inundation throughout the study area. As is discussed in Section 4.2, the 1990 flood did not result in extensive flooding even though it had a very high peak.

According to flood reports documented by the Water Management Branch's regional office in Kamloops, the main flood damage complaint is not one of water damage but one of bank erosion and property damage due to lateral movement of the Salmon River channel. For future property and land development, the bank erosion problem should be taken into account when formulating a basis for building set-back requirements.

Photographs 1, 2, 3 and 4 are examples of flooding in 1948, 1969, 1971 and 1972, respectively.



1948



1969

1971

1972

4.2 1990 Flood

As Crippen was about to proceed with this study, the 1990 freshet was underway. This flood turned out to be a very significant event in terms of peak flows, but, not flood inundation. The maximum instantaneous and maximum daily discharge data from the 1990 flood have been included in this study's analyses. It should be noted that the 1990 flood flows used are preliminary values from WSC. The final confirmed values will not be available until 1991.

Crippen obtained the water level recorder chart for WSC station 08LE021 for the period 13 June to 18 June. This chart record includes the maximum instantaneous water level recorded at 14:55 on 13 June 1990. WSC also did a current metering very close to the time when flood waters crested. In fact, the recorder chart indicates that the maximum instantaneous water level was only an additional 2 cm above the water level recorded during the metering. Because the metering corresponds very closely in time and flood level magnitude to the actual peak flood level, the estimate of the peak water level and discharge are considered to be good. Once again, WSC will not be providing confirmed values until 1991. The maximum daily discharge for the 1990 flood was 50.1 m^3/s and the maximum instantaneous was 52.3 m^3/s.

Flood frequency analyses indicated that the maximum instantaneous discharge for the 1990 flood had an estimated return period in the range of 80 years (depending on the frequency distribution used). This was the largest historical maximum instantaneous flood event on record, yet it did not cause extensive damage in the Salmon River floodplain. One reason is that some bridges have been improved or rebuilt in recent years using clear spans rather than piles in the river. A second reason is that total flood volumes and durations were greater for some of the other historical floods compared with the 1990 flood volume and duration.

Figures 2 and 3 demonstrate the difference in flood volumes and durations between the 1990 flood and some of the other large historical floods. For example, when comparing the 1972 flood with the 1990 flood it can be seen that the 1972 flood had a total flow volume approximately 50 percent greater (depending on when the flood event is considered over) than that of the 1990 flood. The 1972 flood hydrograph maintained an average 20 day peak discharge of 38.6 m^3/s. Although the 1990 flood hydrograph peaked at 50.1 m^3/s (mean daily), it fell below the 1972 average peak value of 38.6 m^3/s within 6 days and had a 20 day average discharge of 31.5 m^3/s.

During Crippen's site visits only minor flood inundation reports were given by area residents. Some of them were not aware of the magnitude of the flood event. Summary of these verbal reports are listed in Appendix B2.

12/14/90

SALMON RIVER AT SALMON ARM (08LE021) HISTORICAL FLOODS - HYDROGRAPHS

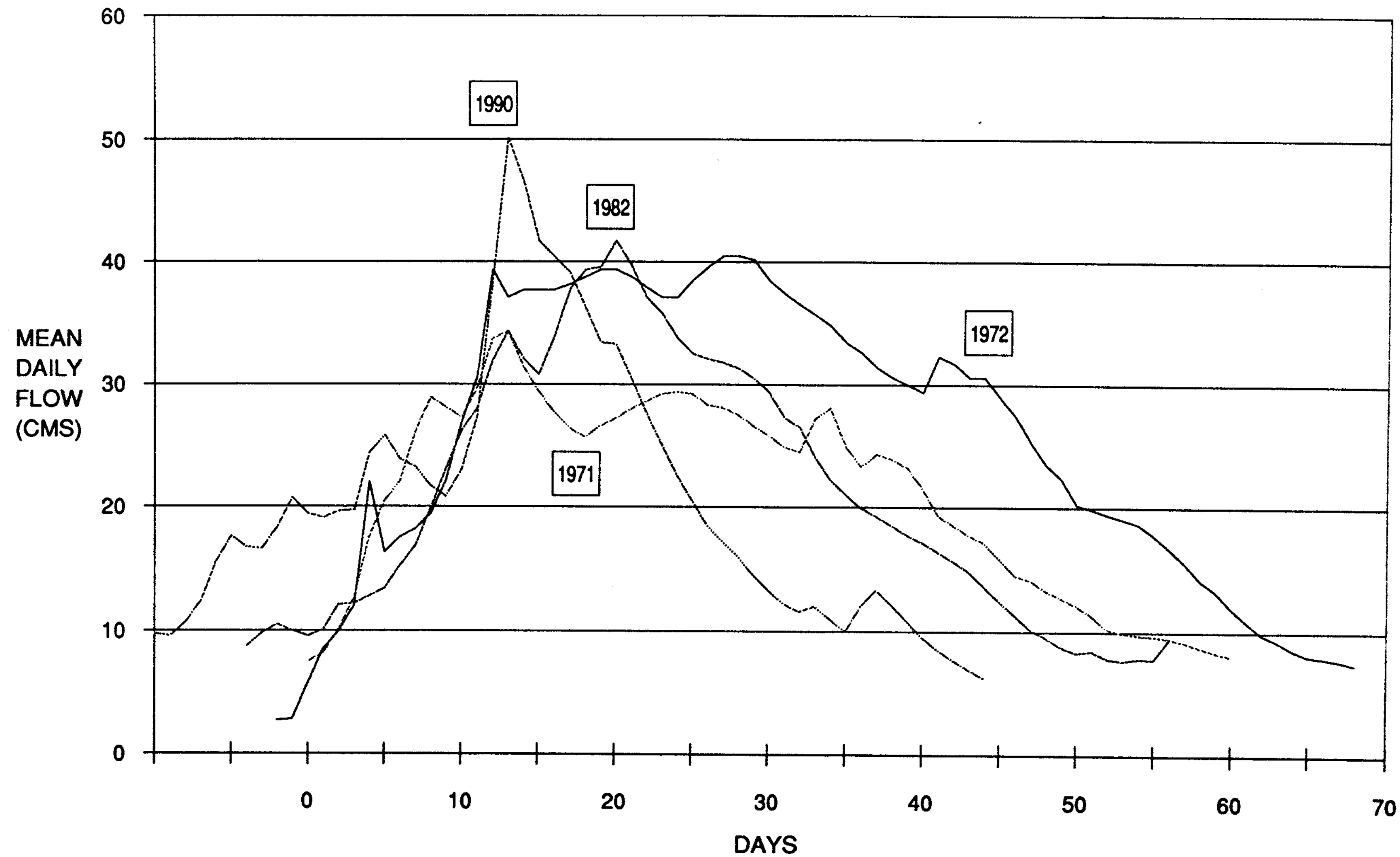


FIGURE - 2

SALMON RIVER AT SALMON ARM (08LE021)
HISTORICAL FLOODS - CUMULATIVE VOLUMES

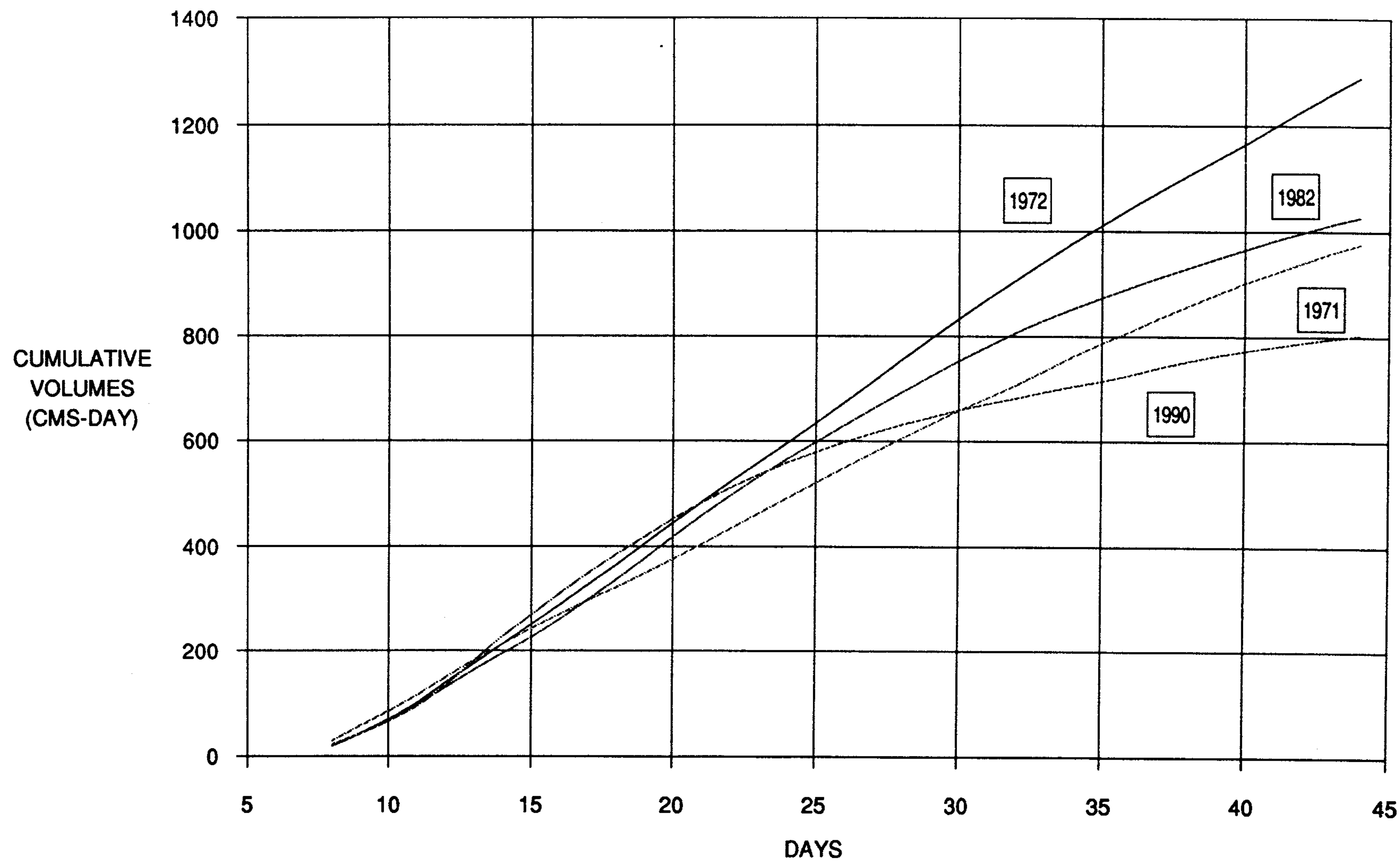


FIGURE - 3

4.3 Flood Frequency

Data from the Water Survey of Canada Salmon River near Salmon Arm Station 08LE021 was used as the basis for the flood frequency analyses. This station is located at the downstream end of the Salmon River floodplain at the old Trans Canada Highway bridge. The station location corresponds to survey cross section XS-7. The catchment area is 1510 km^2. This station has 17 complete years of daily data from 1974 to 1990 with an additional 10 years of daily data during the freshet period 1911 to 1912 and 1961 to 1973. Including the 1990 flood, this station has 27 years data for the maximum daily flood and 17 years data for the maximum instantaneous flood event.

The data from this station is the most relevant for the flood frequency analyses because:

1) the station is located at the downstream end of the Salmon River floodplain and gauges the total outflow from the floodplain

2) the station has a relatively long period of record

3) the data from this station compares well with discharges obtained from a regional hydrology analysis (i.e. no data anomalies)

4) the highest peak discharges metered on the Salmon River system were metered at this station during the 1990 flood

5) the 1990 discharge meterings corresponded very closely in time with the occurrence of the peak water levels

6) as a result of point 5), a high degree of confidence can be placed on the validity of the rating curve at high flows (i.e. during floods).

Flood frequency analyses were done for maximum daily and maximum instantaneous discharges for return periods of up to 200 years. The 200 year return period events were used as the basis for the floodplain mapping. The frequency analyses were computed using the computer program CFA88 from Inland Water Directorate of Environment Canada.

Using the data from the upstream WSC station 08LE020, Salmon River at Falkland, was also considered. However, the data showed anomalies at high discharges. These anomalies could not be reconciled with WSC or within the context of a regional hydrologic assessment as done by the Ministry of Environment. Therefore, data from station 08LE020 was not utilized. Station 08LE020 is not in the study area (approx. 30 km u/s of Spa Creek) and its data would not have been as relevant as that from the downstream station anyways.

The Ministry of Environment have informed Water Survey of Canada regarding the problems with the data from the Falkland gauge.

Results from the flood frequency analyses based on WSC station 08LE021 (drainage area 1510 km^2) and the design flood values are tabulated in Table 3. The design discharges used for the HEC2 computer runs are shown in Table 4. Frequency analyses plots generated by the computer program CFA88 are contained in Appendix A.

TABLE 3

FLOOD FREQUENCY

	GEV (EV1)	3-PAR LOGNORMAL	LOG PEARSON TYPE III
20 Year Flood			
daily	44.6	45.9	44.6
(inst.)	(48.0)	(49.4)	(48.0)
200 Year Flood			
daily	54.2	59.3	54.3
(inst.)	(56.5)	(61.7)	(56.2)

The 3-parameter lognormal values were used in this study for the HEC2 analyses.

5.0 HYDRAULIC ANALYSES - HEC2 WATER SURFACE PROFILES

5.1 HEC2 Program

Water surface profile calculations were made using the U.S. Army Corps of Engineers' computer program HEC2. This program uses the standard step method for computing water surface profiles. Channel friction losses, expansion and contraction losses and bridge losses are modelled by HEC2.

5.2 HEC2 Calibration

Because this study is concerned with flood events, calibration of the HEC2 backwater program at high water levels is more important than calibration at lower discharges and water levels.

Since water levels were recorded at each cross section during the 1981 survey, the initial calibration of the HEC2 model was made using the 1981 survey's water levels. Discharges were varied over the 22 kilometre reach of channel. The discharge variation was obtained from a regional hydrology analysis. For the initial calibration run, the bridge data was of course that that was existing in 1981. The water surface profile for this calibration is shown as Figure 4.

The model was then modified to reflect the new bridge geometry and re-calibrated based on the 1990 flood observations. Once again, discharges were varied. The water surface profile for this calibration is shown as Figure 5.

The calibrated model was then used for the 20 year flood simulation and also for the 200 year flood simulation. For the 200 year event, left and right overbank reach lengths were adjusted to reflect the degree of overbank flooding and effective areas of discharge in the overbank area.

Manning's roughness coefficients that were used in the final model varied from 0.030 to 0.070 for the channels, and 0.100 to 0.120 for the overbank areas.

5.3 Flood Levels for Shuswap Lake

The initial downstream water level used as a starting point of the HEC2 analyses is set equal to the flood level of Shuswap Lake. As stated in the Invitation for Proposal for Engineering Services, Appendix D, the water level to be used is 351.0 metres minus freeboard of 0.94 metres equals 350.06 metres. This level has been set for administrative purposes and was not subject to review by the consultant.

The Shuswap Lake 200 year design water level of 350.06 metres was taken from "Figure 1 - Shuswap Lake Levels" from Floodplain Mapping Program, Seymour River at Seymour Arm, Design Brief dated March 1990 by Hay & Company Consultants Inc.

5.4 HEC2 Design Discharge Modelling

Subsequent to the calibration runs and the confirmation of model reliability for the intended range of discharges, the HEC2 model was run for the 20 and 200 year events. The discharge was varied within the study reach. The water surface profile for the design, 200 year flood event is shown as Figure 6. The design floods at the downstream and upstream ends of the study reach are as follows.

TABLE 4

HEC2 DESIGN DISCHARGES

FLOOD CRITERION	LOCATION Shuswap Lake XS-0B	Gordon Creek XS-29	Silver Creek XS-95
200 year max. daily	59.3 m^3/s	56.9 m^3/s	52.8 m^3/s
200 year max. instant.	61.7 m^3/s	59.2 m^3/s	54.9 m^3/s
20 year max. daily.	45.9 m^3/s	44.0 m^3/s	40.9 m^3/s
20 year max. instant.	49.4 m^3/s	47.4 m^3/s	44.0 m^3/s

5.5 Sensitivity of HEC2 Model

It is usual in this type of computer modelling to perform sensitivity analyses which indicate the potential magnitude for changes in output data for changes to key items of input data. For HEC2 modelling, the key input data affecting the output water surface elevations are the channel roughness and the discharge.

Table 5 summarizes the sensitivity of predicted water surface elevations and inundated areas to changes in channel roughness of up to ±40% and to changes in discharge of -20% to +40%.

TABLE 5

SENSITIVITY ANALYSES

SENSITIVITY CASE	DIFFERENCE IN INUNDATED AREA (percent)	DIFFERENCE IN FLOOD LEVEL (metres)
Discharge		
Q_{design} - 20%	-12.5 %	-0.21 m
Q_{design}	0.0 %	0.00 m
Q_{design} + 20%	+9.1 %	+0.20 m
Q_{design} + 40%	+20.2 %	+0.37 m
Manning's 'n'		
n_{design} - 40%	-23.9 %	-0.34 m
n_{design} - 20%	-10.4 %	-0.16 m
n_{design}	0.0 %	0.00 m
n_{design} + 20%	+7.1 %	+0.15 m
n_{design} + 40%	+14.3 %	+0.29 m

NOTE: The "Difference in Flood Level" is an average weighted (by reach length) change in water level for the total study reach.

6.0 FLOODPLAIN MAPPING

6.1 Freeboard

Freeboard is a factor of safety adopted by the Ministry of Environment for administrative purposes to account for uncertainties in the hydrological studies and assumptions made in the flood profile calculations.

The governing floodplain delineation criterion was found to be the 200 year maximum daily flood level plus 0.6 metres of freeboard. At all river cross sections, this value was greater than the value calculated using the other possible criterion of 200 year maximum instantaneous flood level plus 0.3 metres of freeboard.

6.2 Floodplain Maps

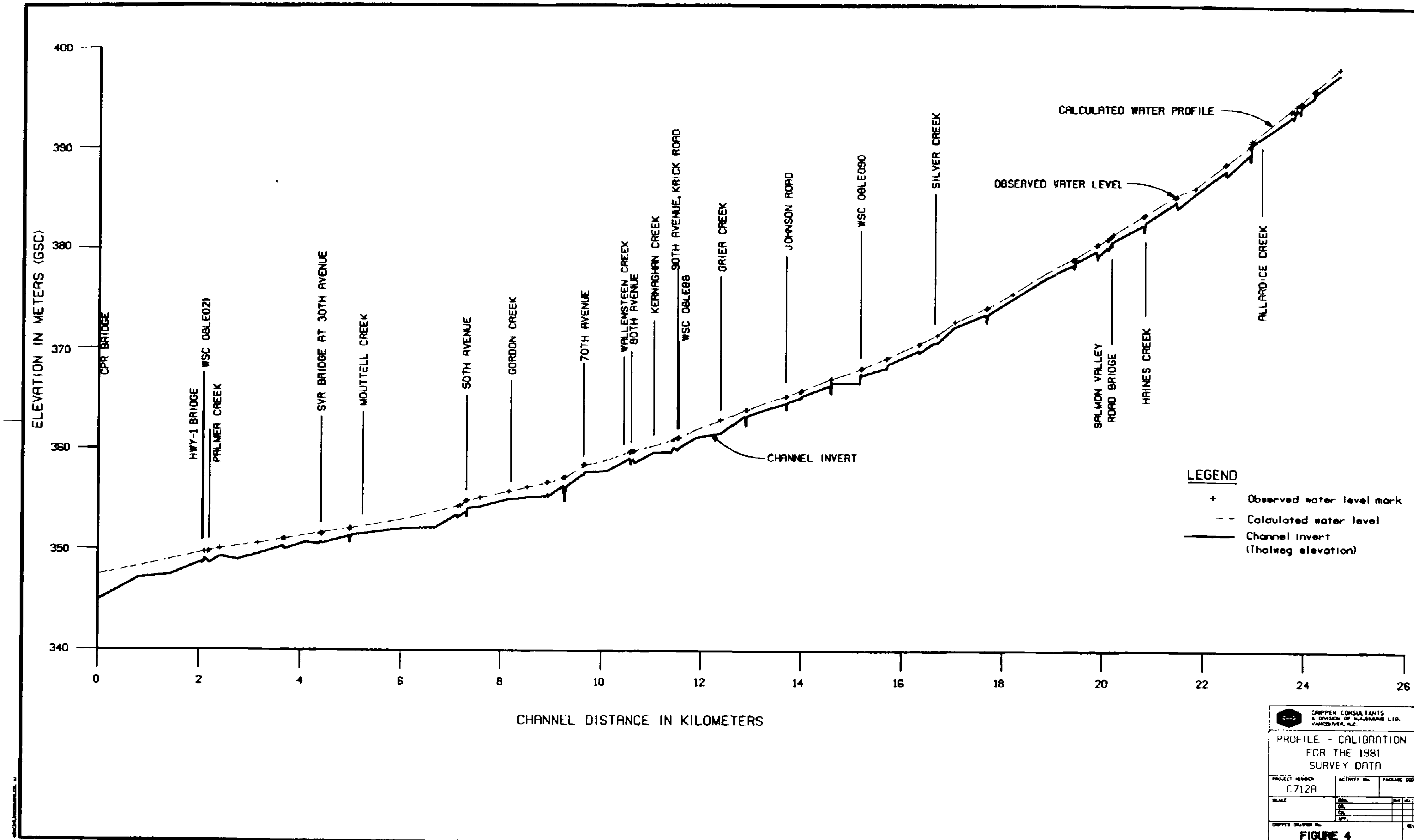
Flood inundation extents were checked in the field to ensure that no discrepancies resulted between the mapping produced during this study and the actual situation in the field.

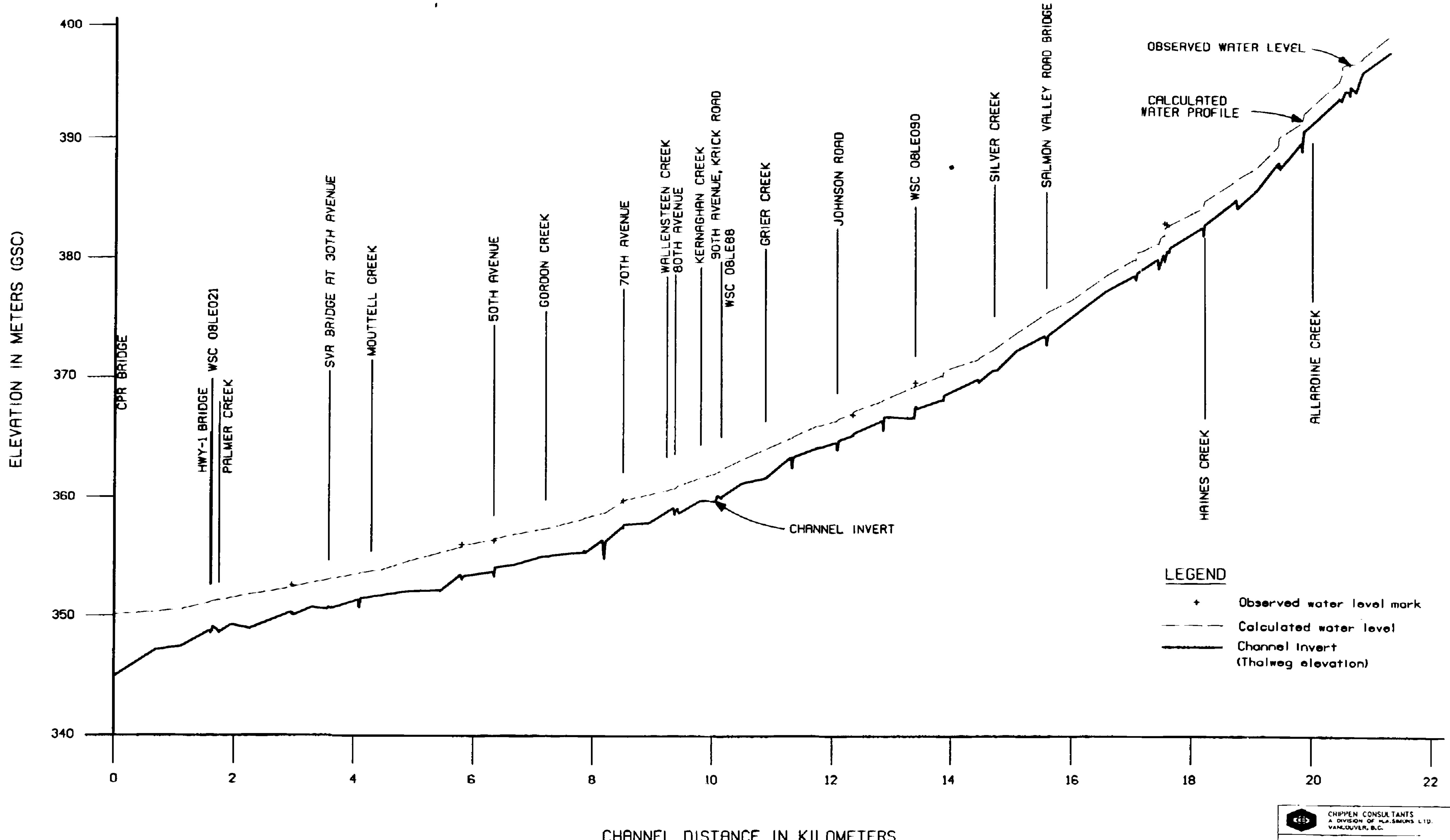
The floodplain mapping is shown on a series of six drawings numbered 89-14-1 through 89-14-6.

At the lower end of the study area near Shuswap Lake the floodplain is over one kilometre wide. At a distance of approximately 3.0 km upstream of Shuswap Lake the floodplain narrows down to a width of from 100 to 500 metres. This width, averaging 200 metres, is typical of the next 5 km of the Salmon River up to Gordon Creek.

From Gordon Creek upstream to Silver Creek, a distance of approximately 8 km, the floodplain is more confined with an average width of 100 metres.

Past Silver Creek to the top end of the study area near Spa Creek the floodplain widens out once again. Through this 6 km reach the floodplain is up to 500 metres wide with an average width of approximately 250 metres.


ELEVATION IN METERS (GSC)
CHANNEL DISTANCE IN KILOMETERS
CPR BRIDGE
HWY-1 BRIDGE
WSC 08LE021
PALMER CREEK
SVR BRIDGE AT 30TH AVENUE
MOUTTELL CREEK
50TH AVENUE
GORDON CREEK
70TH AVENUE
WALLENSTEEN CREEK
80TH AVENUE
KERNAGHAN CREEK
90TH AVENUE, KRICK ROAD
WSC 08LE088
GRIER CREEK
JOHNSON ROAD
WSC 08LE090
SILVER CREEK
SALMON VALLEY ROAD BRIDGE
HAINES CREEK
ALLARDICE CREEK
CALCULATED WATER PROFILE
OBSERVED WATER LEVEL
CHANNEL INVERT
LEGEND
Observed water level mark
Calculated water level
Channel invert (Thalweg elevation)
CRIPPEN CONSULTANTS
PROFILE - CALIBRATION FOR THE 1981 SURVEY DATA
C712A
FIGURE 4



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VANCOUVER, B.C.

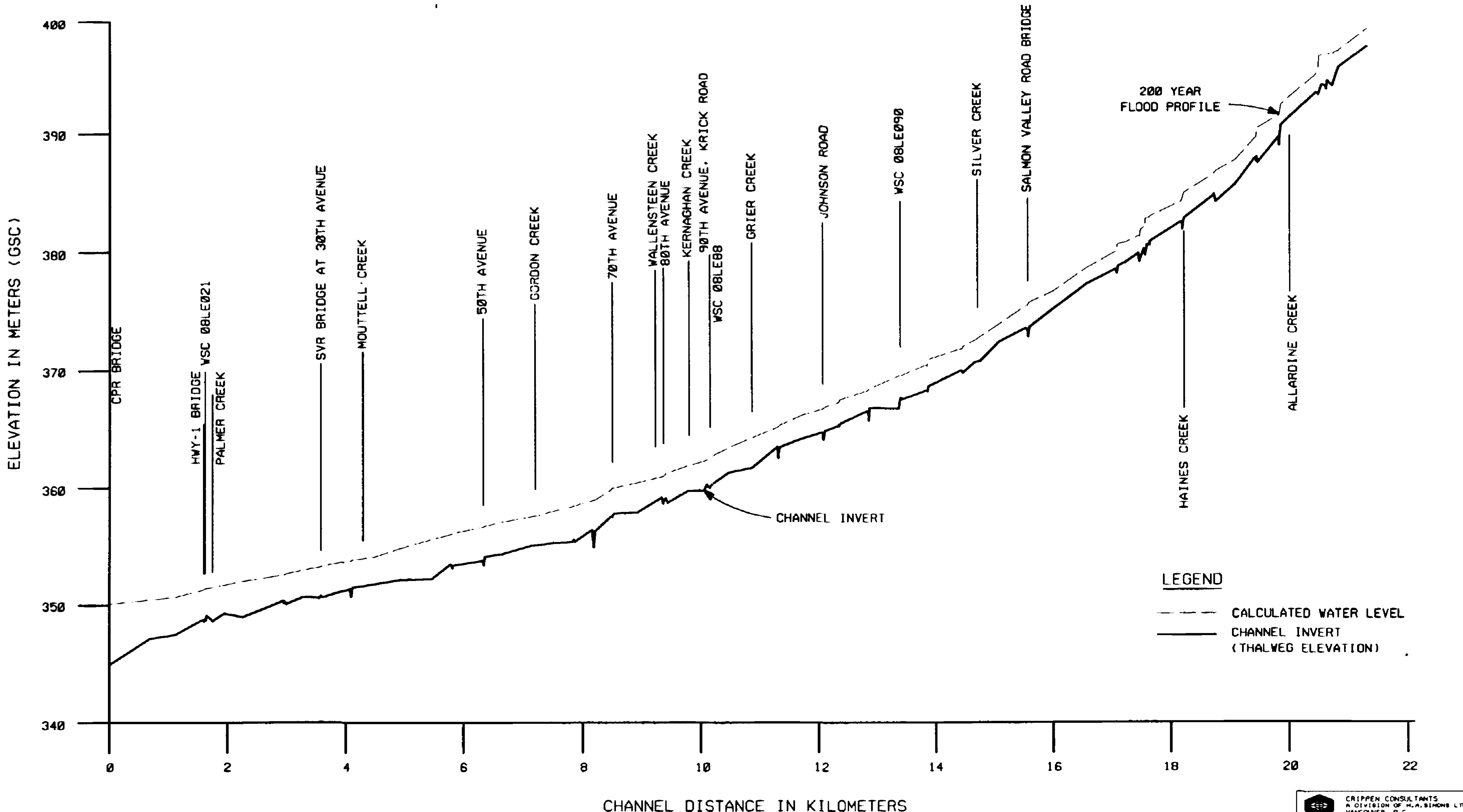
PROFILE - CALIBRATION
1990 FLOOD

PROJECT NUMBER	ACTIVITY No.	PACKAGE CODE
C/12A		

SCALE

CRIPPEN DRAWING No.

FIGURE 6



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PROFILE
200 YEAR FLOOD

PROJECT NUMBER: C7120

FIGURE 6

7.0 CONCLUSIONS AND RECOMMENDATIONS

1) The floodplain maps prepared for the Salmon River between Salmon Arm and Spa Creek as presented herein, should be "Designated" under the terms of the joint 1987 Canada-British Columbia Floodplain Mapping Agreement.

2) The floodplain maps should be reviewed and updated periodically as more data becomes available or when there are major physical changes affecting the river regime.

APPENDIX A

RESULTS FROM FREQUENCY ANALYSES

WSC STATION NO=08LED21
WSC STATION NAME=SALMON RIVER AT SALMON ARM (DAILY)

MONTH (1)	YEAR (2)	DATA (3) (CMS)	ORDERED (4) (CMS)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
5	1912	30.600	50.100	1	2.21	45.333
5	1963	16.500	41.800	2	5.88	17.000
6	1964	29.700	40.800	3	9.56	10.462
6	1965	27.200	40.500	4	13.24	7.556
5	1966	22.700	38.700	5	16.91	5.913
5	1969	25.900	37.700	6	20.59	4.857
5	1970	20.100	36.500	7	24.26	4.121
5	1971	34.300	36.200	8	27.94	3.579
5	1972	40.500	34.300	9	31.62	3.163
5	1973	26.700	31.400	10	35.29	2.833
5	1974	36.200	30.600	11	38.97	2.566
6	1975	40.800	30.300	12	42.65	2.345
5	1976	31.400	29.700	13	46.32	2.159
5	1977	19.200	28.300	14	50.00	2.000
5	1978	36.500	28.000	15	53.68	1.863
5	1979	19.100	27.200	16	57.35	1.744
4	1980	15.900	26.700	17	61.03	1.639
5	1981	21.800	25.900	18	64.71	1.545
5	1982	41.800	25.300	19	68.38	1.462
5	1983	37.700	22.700	20	72.06	1.388
6	1984	38.700	21.800	21	75.74	1.320
5	1985	25.300	20.100	22	79.41	1.259
5	1986	28.300	19.200	23	83.09	1.204
5	1987	30.300	19.100	24	86.76	1.153
5	1988	17.900	17.900	25	90.44	1.106
5	1989	28.000	16.500	26	94.12	1.062
6	1990	50.100	15.900	27	97.79	1.023

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
08LED21 SALMON RIVER AT SALMON ARM (DAILY)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	29.378	8.863	0.302	0.356	2.915
LN X SERIES	3.335	0.310	0.093	-0.196	2.568

X(MIN)= 15.900
X(MAX)= 50.100
LOWER OUTLIER LIMIT OF X= 12.855

TOTAL SAMPLE SIZE= 27
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

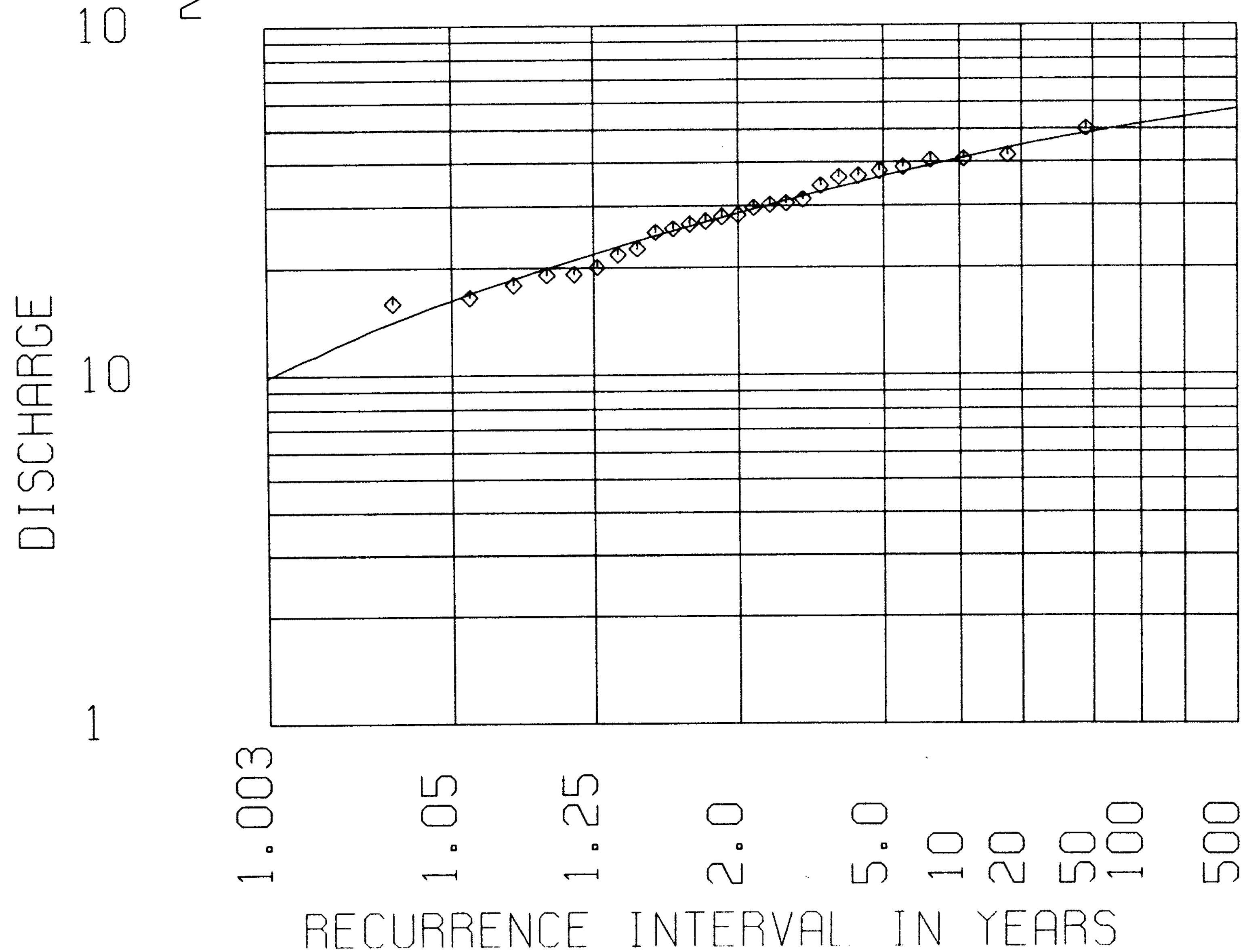
DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= 0.7645E+02
GEV PARAMETERS: U= 25.82 A= 7.882 K= 0.156

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	9.86
1.050	0.952	16.20
1.250	0.800	21.90
2.000	0.500	28.60
5.000	0.200	36.40
10.000	0.100	40.80
20.000	0.050	44.60
50.000	0.020	48.90
100.000	0.010	51.70
200.000	0.005	54.20
500.000	0.002	57.20

FREQUENCY ANALYSIS - 08LED21

GENERALIZED EXTREME VALUE-MAX LIKELIHOOD



FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
08LED21 SALMON RIVER AT SALMON ARM (DAILY)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	29.378	8.863	0.302	0.356	2.915
LN X SERIES	3.335	0.310	0.093	-0.196	2.568
LN(X-A) SERIES	3.599	0.238	0.066	-0.076	2.560

X(MIN)= 15.900 TOTAL SAMPLE SIZE= 27
X(MAX)= 50.100 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 12.855 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

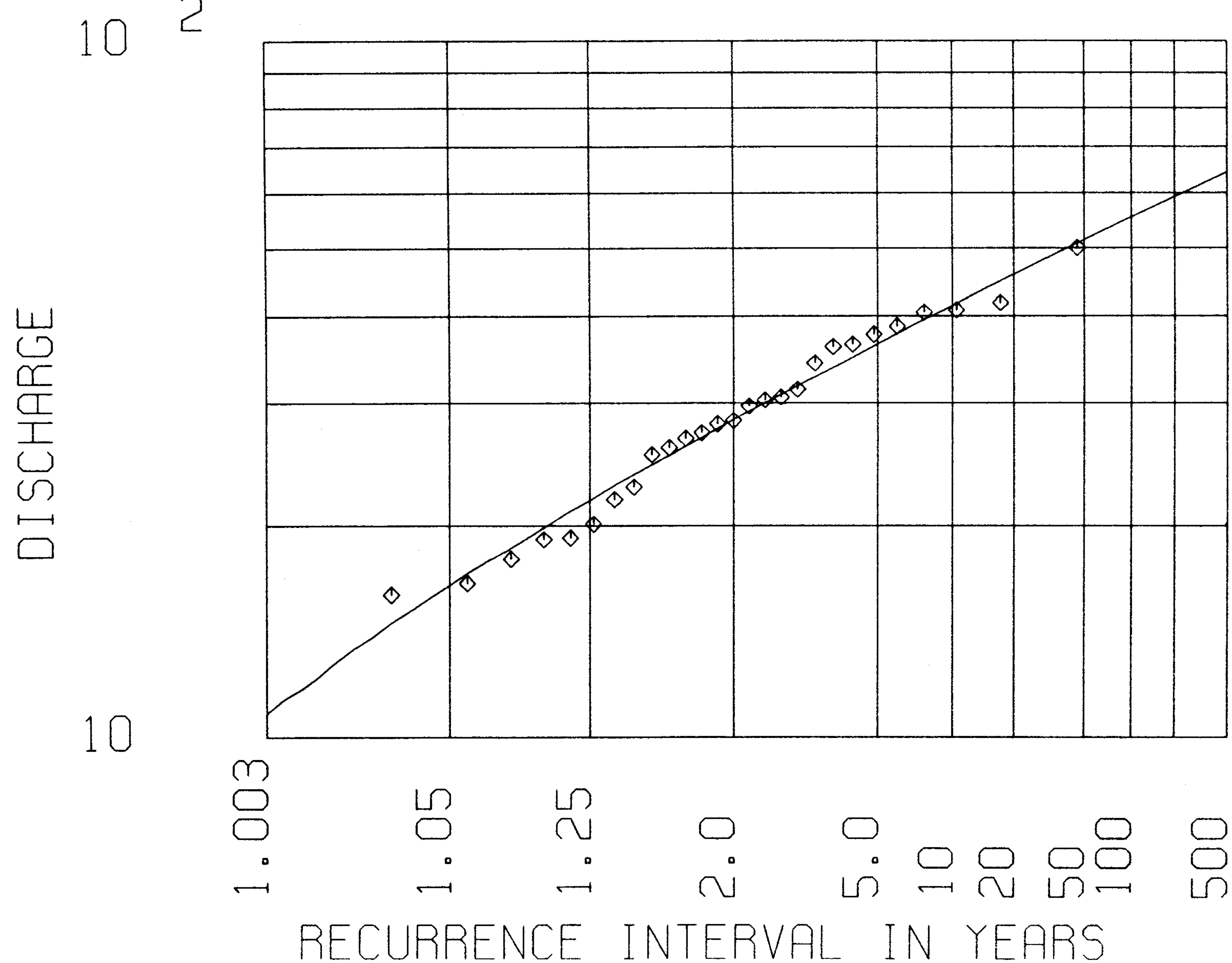
3LN PARAMETERS: A= -8.175 M= 3.599 S= 0.238

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	10.80
1.050	0.952	16.40
1.250	0.800	21.70
2.000	0.500	28.40
5.000	0.200	36.50
10.000	0.100	41.40
20.000	0.050	45.90
50.000	0.020	51.40
100.000	0.010	55.40
200.000	0.005	59.30
500.000	0.002	64.30

FREQUENCY ANALYSIS - 08LED21

THREE PARAMETER LOGNORMAL-MAX LIKELIHOOD



FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
08LED21 SALMON RIVER AT SALMON ARM (DAILY)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	29.378	8.863	0.302	0.356	2.915
LN X SERIES	3.335	0.310	0.093	-0.196	2.568

X(MIN)= 15.900
X(MAX)= 50.100
LOWER OUTLIER LIMIT OF X= 12.855

TOTAL SAMPLE SIZE= 27
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

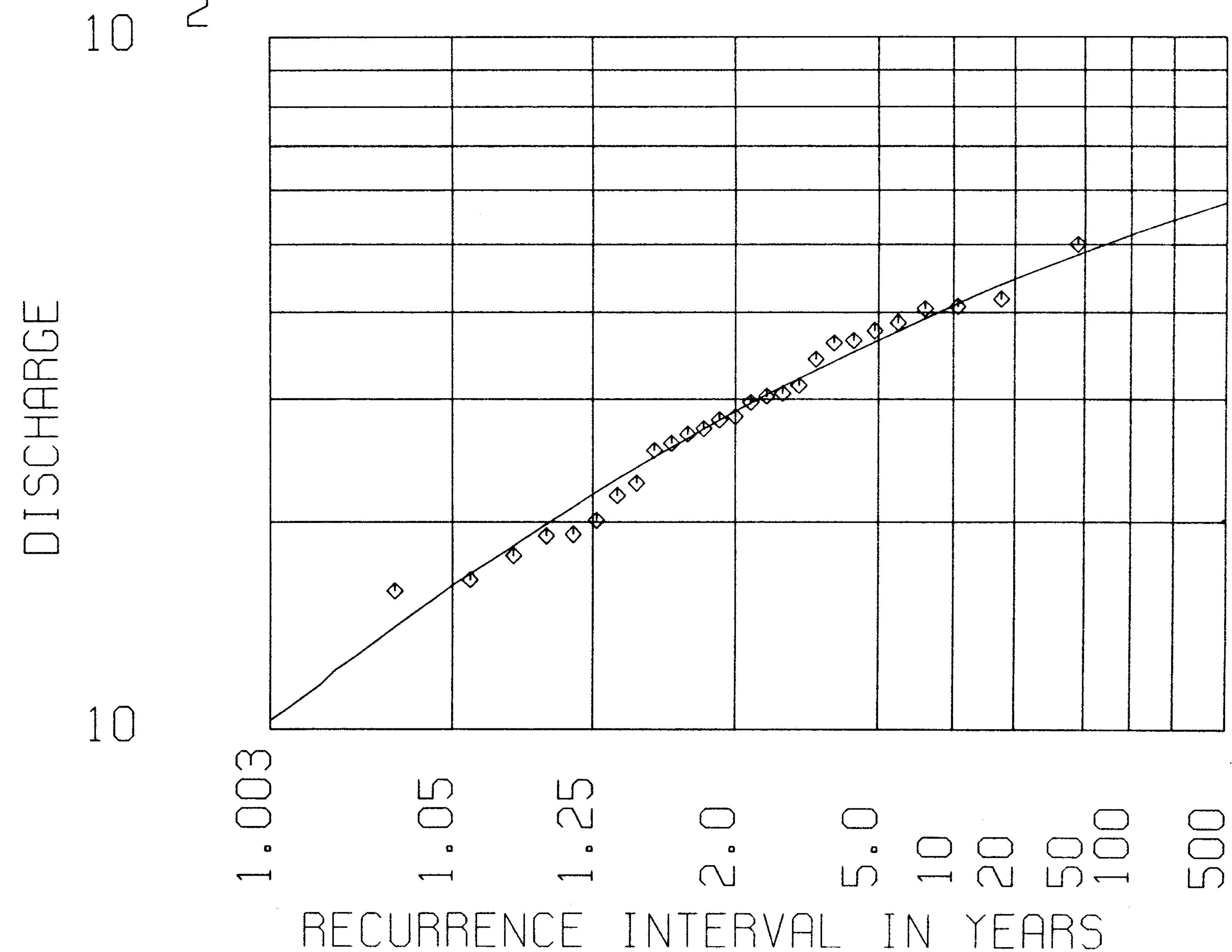
DISTRIBUTION IS UPPER BOUNDED AT M= 105.3
LP3 PARAMETERS: A=-0.7163E-01 B= 18.45 LOG(M)= 4.657
M = 105.3

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	10.30
1.050	0.952	16.20
1.250	0.800	21.90
2.000	0.500	28.80
5.000	0.200	36.50
10.000	0.100	40.90
20.000	0.050	44.60
50.000	0.020	48.80
100.000	0.010	51.70
200.000	0.005	54.30
500.000	0.002	57.50

FREQUENCY ANALYSIS - 08LED21

LOG PEARSON TYPE III-MAX LIKELIHOOD



WSC STATION NO=08LEI21
WSC STATION NAME=SALMON RIVER AT SALMON ARM (INS.)

MONTH (1)	YEAR (2)	DATA (3) (CMS)	ORDERED (4) (CMS)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
5	1974	37.700	52.300	1	3.49	28.667
6	1975	41.900	42.700	2	9.30	10.750
5	1976	33.100	41.900	3	15.12	6.615
5	1977	19.900	39.100	4	20.93	4.778
5	1978	37.100	39.000	5	26.74	3.739
5	1979	19.700	37.700	6	32.56	3.071
4	1980	17.200	37.100	7	38.37	2.606
5	1981	23.100	33.100	8	44.19	2.263
5	1982	42.700	31.400	9	50.00	2.000
5	1983	39.000	30.900	10	55.81	1.792
6	1984	39.100	30.600	11	61.63	1.623
5	1985	26.100	26.100	12	67.44	1.483
5	1986	30.900	23.100	13	73.26	1.365
5	1987	31.400	19.900	14	79.07	1.265
5	1988	19.800	19.800	15	84.88	1.178
5	1989	30.600	19.700	16	90.70	1.103
6	1990	52.300	17.200	17	96.51	1.036

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
08LEI21 SALMON RIVER AT SALMON ARM (INS.)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	31.859	9.895	0.311	0.193	3.064
LN X SERIES	3.413	0.327	0.096	-0.318	2.673

X(MIN) = 17.200
X(MAX) = 52.300
LOWER OUTLIER LIMIT OF X= 14.288

TOTAL SAMPLE SIZE= 17
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

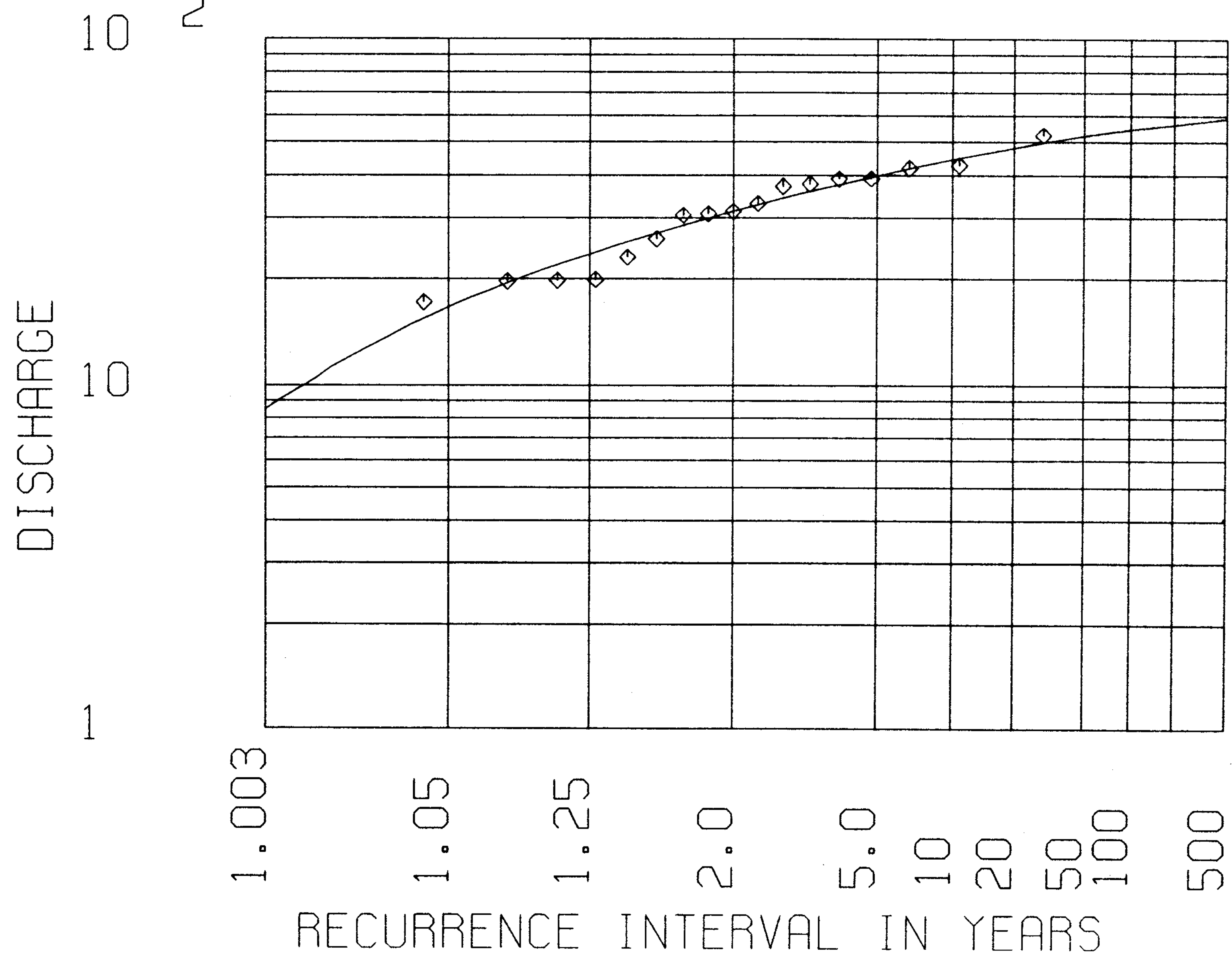
DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= 0.6897E+02
GEV PARAMETERS: U= 28.21 A= 9.133 K= 0.224

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	8.50
1.050	0.952	16.70
1.250	0.800	23.60
2.000	0.500	31.40
5.000	0.200	39.80
10.000	0.100	44.40
20.000	0.050	48.00
50.000	0.020	52.00
100.000	0.010	54.40
200.000	0.005	56.50
500.000	0.002	58.80

FREQUENCY ANALYSIS - 08LEI21

GENERALIZED EXTREME VALUE-MAX LIKELIHOOD



FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
08LEI21 SALMON RIVER AT SALMON ARM (INS.)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	31.859	9.895	0.311	0.193	3.064
LN X SERIES	3.413	0.327	0.096	-0.318	2.673
LN(X-A) SERIES	4.257	0.139	0.033	-0.050	2.770

X(MIN)= 17.200
X(MAX)= 52.300
LOWER OUTLIER LIMIT OF X= 14.288

TOTAL SAMPLE SIZE= 17
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

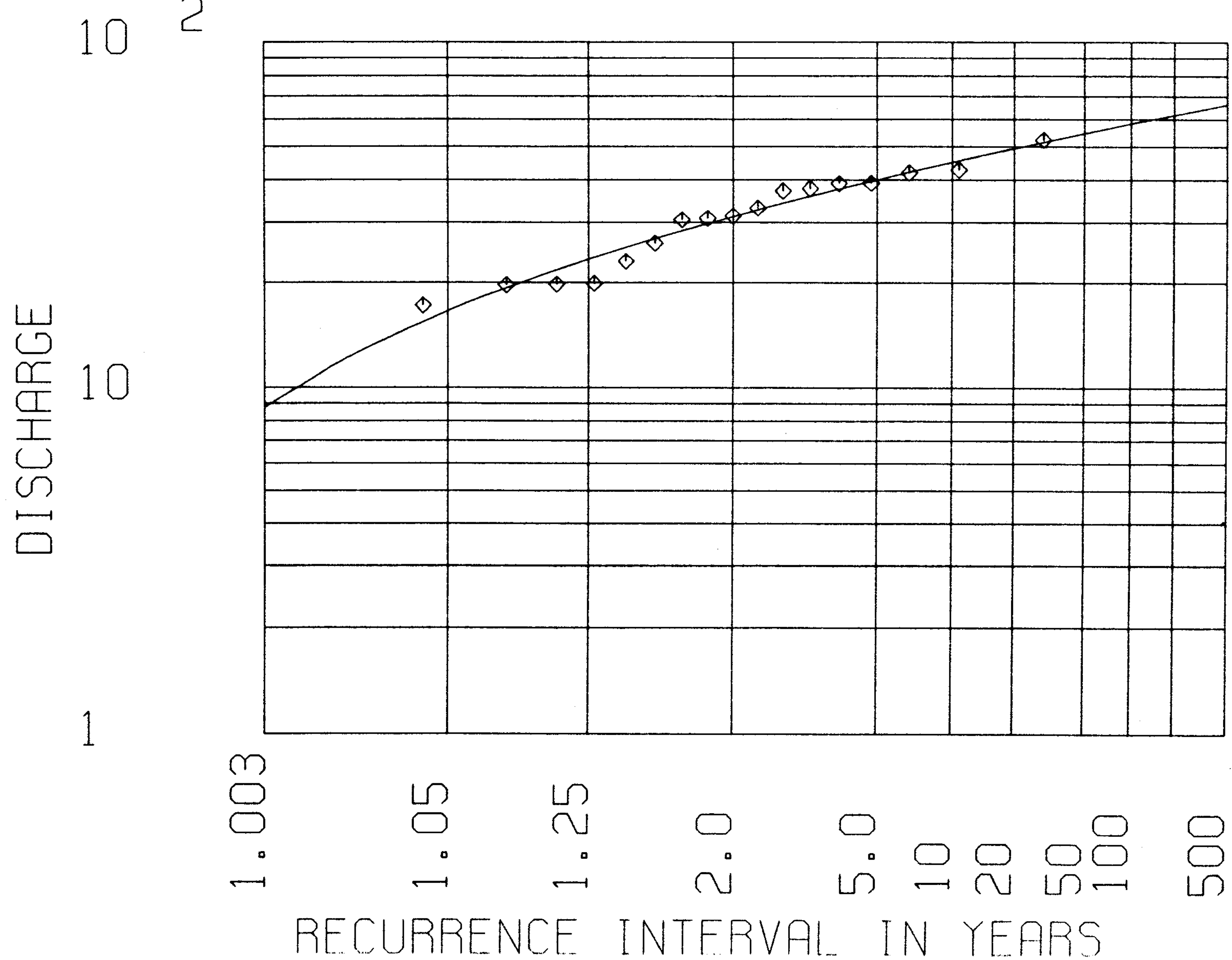
3LN PARAMETERS: A= -39.363 M= 4.257 S= 0.139

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	8.74
1.050	0.952	16.60
1.250	0.800	23.40
2.000	0.500	31.20
5.000	0.200	40.00
10.000	0.100	45.00
20.000	0.050	49.40
50.000	0.020	54.60
100.000	0.010	58.30
200.000	0.005	61.70
500.000	0.002	66.10

FREQUENCY ANALYSIS - 08LEI21

THREE PARAMETER LØGNØRMAL-MAX LIKELIHØØD



FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
08LEI21 SALMON RIVER AT SALMON ARM (INS.)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	31.859	9.895	0.311	0.193	3.064
LN X SERIES	3.413	0.327	0.096	-0.318	2.673

X(MIN)= 17.200
X(MAX)= 52.300
LOWER OUTLIER LIMIT OF X= 14.288

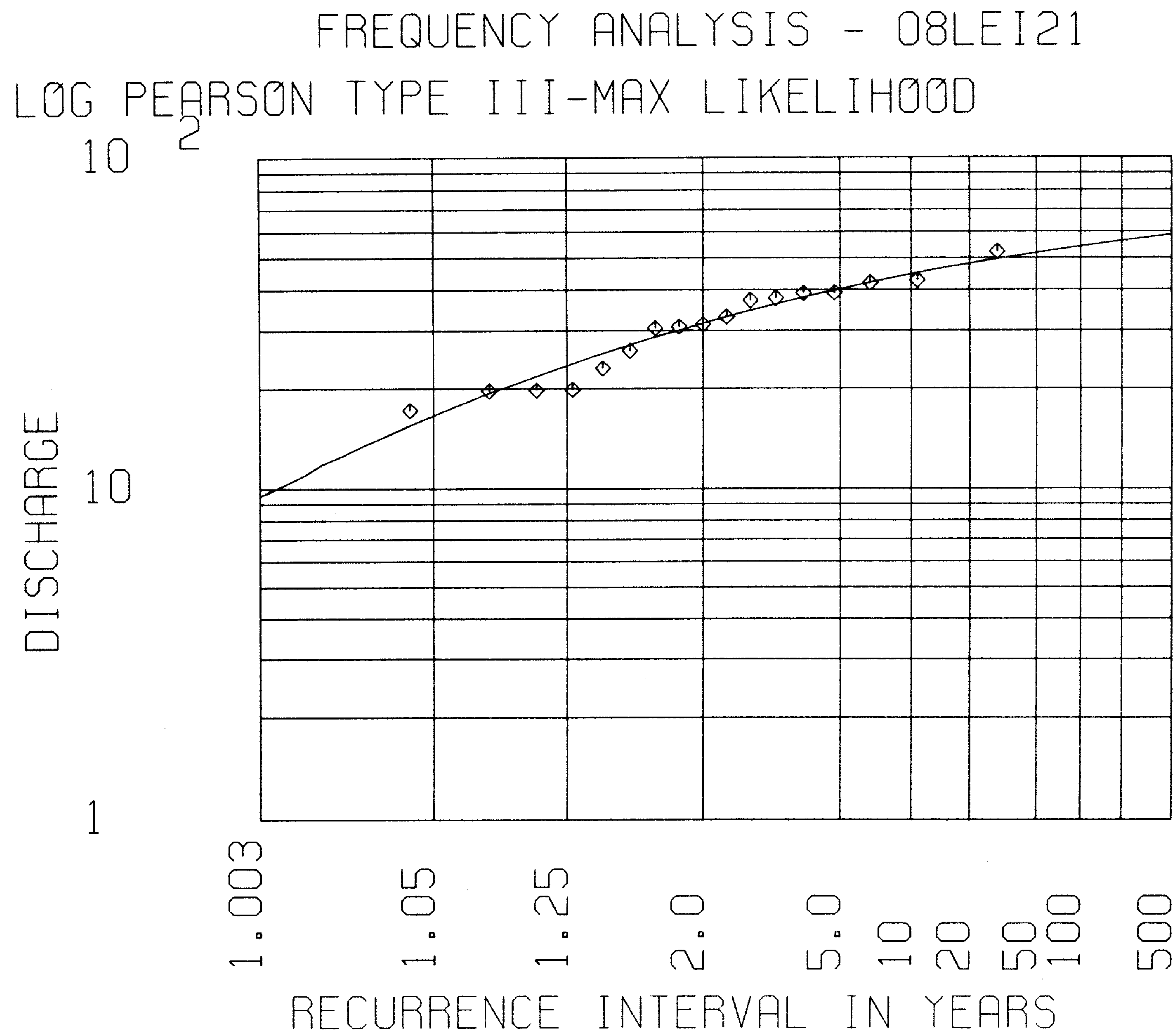
TOTAL SAMPLE SIZE= 17
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT M= 72.86
LP3 PARAMETERS: A=-0.1205 B= 7.267 LOG(M)= 4.289
M = 72.86

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	9.52
1.050	0.952	16.60
1.250	0.800	23.50
2.000	0.500	31.60
5.000	0.200	40.10
10.000	0.100	44.50
20.000	0.050	48.00
50.000	0.020	51.80
100.000	0.010	54.20
200.000	0.005	56.20
500.000	0.002	58.60


FREQUENCY ANALYSIS - 08LEI21
LØG PEARSØN TYPE III-MAX LIKELIHØØD
10^2
10
1
DISCHARGE
1.003
1.05
1.25
2.0
5.0
10
20
50
100
500
RECURRENCE INTERVAL IN YEARS

APPENDIX B1

SUMMARY OF DATA SOURCES AND REFERENCES

Appendix B1

Summary of Data Sources and References

1) <u>River Survey</u> - Project 81-FDC-3 (July 1981)

   a) Cross section data

      i) left to right profile data plots at scale H1:100, V1:100.

      ii) photographs at cross sections

      iii) water levels at cross sections

   b) HEC2 GR data file for survey cross sections in digital format.

   c) Bridge sketches.

   d) Water Survey of Canada gauge descriptions.

2) <u>Streamflow</u>

   a) Daily streamflow data in digital format for all stations related to this study (listed in Table 2).

   b) Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Surface Water Data for British Columbia to 1988.

   c) Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Historical Streamflow Summary for British Columbia, 1988.

   d) Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Reference Index, 1988.

   e) Study of anomalous flows at the Salmon River Falkland gauge by W. Obedkoff, P.Eng., Senior Hydrologic Engineer, Hydrology Section, Water Management Branch. Memorandum dated 7 November 1990. File No. S2105, Study No. 325.

3) Drawings

Base maps - Advance and final drawings 89-14-1 to 89-14-6 titled "Floodplain Mapping, Salmon River, Salmon Arm to Spa Creek". Scale 1:5000 with 1.0 metre contours including the locations of the river cross sections as surveyed in 1). Base maps not dated, but, based on survey project 81-FDC-3.

Photo mosaics - Photo mosaic drawing sheets 5467-1 to 5467-13 titled "Floodplain Mapping Program, Uncontrolled Mosaic of Salmon River (Salmon Arm to Westwold)". Scale 1:10000 including the locations of the river cross sections as surveyed in 1). Photo mosaics dated June 1982 and based on survey project 81-FDC-3.

4) Mapping

a) 1:250,000 National Topographic Mapping, Energy, Mines and Resources, Canada.

82L Edition 1 Vernon

b) 1:50,000 National Topographic Mapping, Energy, Mines and Resources, Canada.

82L/5 Edition 2 Westwold
82L/6 Edition 4 Vernon
82L/11 Edition 2 Salmon Arm
82L/12 Edition 2 Monte Creek

5) Shuswap Lake Freeboard

a) Invitation for Proposal for Engineering Services, Floodplain Mapping Program, Appendix D dated 27 April 1990 states:

> "The Shuswap Lake flood level (freeboard included) presently used for administrative purpose is 351.0".

b) "Figure 1 - Shuswap Lake Levels" from Floodplain Mapping Program, Seymour River at Seymour Arm, Design Brief dated March 1990 by Hay & Company Consultants Inc. gives 200 year lake level of 350.06 metres.

c) From points a) and b) above, freeboard on Shuswap Lake is determined to be 0.94 metres (3 feet).

6) Salmon River Bridge Crossings

a) New bridge locations.

b) Old bridges removed.

c) Photos, sketches and dimensions/elevations of new bridges or changes to bridges since 1981 survey.

7) Water Act Application Records

a) Listing of applications from September 1981 to present.

8) Local Contacts

a) List of local persons and agencies who supplied information regarding this study.

APPENDIX B2

1990 FIELD VISITS

1, Summary of Interviews
2, Cross Sections at Post 1981 Bridges

Summary of 1990 flood notes			
SECTION	**INFORMATION**	**W.L.**	**SOURCES**
XS-15	HWM 0.15m (0.5 ft) below bridge lower chord	352.57	Residence
XS-20	HWM 1.5m (5.0 ft) below bridge deck	356	WMB
XS-35	HWM 1.46m (4.8 ft) below concrete bridge deck	356.34	WMB
XS-49	Big log blocking the water way		Photo 12/13
XS-50	HWM 1.71m (5.6 ft) below bridge deck	359.7	WMB
XS-60	HWM nearly up to bridge deck		Residence
XS-76	HWM 0.30m (1.0 ft) below bridge lower chord	366.88	Residence
XS-84	HWM 1.62m (5.3 ft) below top of wooden wing wall	369.56	WMB
XS-113	Bridge washed away during 1990 flood		Residence
XS-115	HWM 0.15m (0.5 ft) below bridge lower chord	382.83	Residence
XS-116	HWM 2.04m (6.7 ft) below top of wooden stringer	382.75	WMB
XS-142a	HWM at tree line (photo 95)	396.4	Residence
XS-142a	Forbes Road Bridge required bank protection		J. Zapone

CROSS SECTIONS AT POST 1981 BRIDGES
(in HEC-2 GR format)

XS-113
GR382.75 1975.00 382.75 1995.00 382.21 2001.22 380.42 2003.70 379.83 2005.47
GR379.65 2006.97 379.95 2009.75 380.46 2010.97 381.53 2014.02 382.75 2020.00
GR382.75 2040.00

XS-115
GR384.86 1969.65 385.18 1985.55 385.41 2008.05 385.29 2024.20 382.83 2041.15
GR381.98 2044.85 380.45 2048.50 380.48 2049.40 380.95 2052.15 381.06 2055.80
GR381.84 2059.50 382.39 2063.15 382.55 2066.75 385.30 2070.00 385.26 2082.00
GR384.93 2098.20

XS-116
GR384.86 1969.65 385.18 1985.55 385.41 2008.05 385.29 2024.20 382.08 2041.15
GR382.11 2044.85 380.81 2049.40 380.81 2049.40 381.14 2052.15 381.08 2055.80
GR381.15 2059.50 382.10 2063.15 385.30 2070.00 385.26 2082.00 384.93 2098.20

XS-142A
GR399.06 2002.10 398.89 2008.15 396.53 2010.10 395.42 2011.65 394.60 2013.50
GR393.95 2014.40 394.16 2015.30 394.61 2017.10 394.82 2019.05 395.06 2020.85
GR395.14 2022.75 395.76 2024.60 396.48 2026.35 397.31 2029.70 398.53 2030.00
GR398.14 2037.50