Province of British Columbia
Ministry of Environment

Environment Canada

FLOODPLAIN MAPPING PROGRAM KOOTENAY RIVER AT CANAL FLATS AND COLUMBIA LAKE

Design Brief



KLOHN LEONOFF
CONSULTING ENGINEERS

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KLOHN LEONOFF
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October 30, 1990

British Columbia Ministry
of Environment
Water Management Branch
3rd Floor, 737 Courtney Street
Victoria, British Columbia
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Attention: Mr. P.J. Woods, P.Eng.

Re: Floodplain Mapping Program
Kootenay River at Canal Flats and Columbia Lake
(Your File: FPM-7)

Dear Sir:

We are pleased to enclose one original unbound volume and twelve bound copies of the Design Brief for the Floodplain Mapping Program: Kootenay River at Canal Flats and Columbia Lake. A copy of the study file and reproducible copies of the floodplain maps are also enclosed.

Thank you for this opportunity to provide consulting services to the Floodplain Mapping Program.

Yours very truly,

KLOHN LEONOFF LTD.

C. David Sellars, P.Eng.
Project Manager

CDS:fjo

Encls.

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PROJECT: FLOODPLAIN MAPPING PROGRAM

LOCATION: KOOTENAY RIVER AND COLUMBIA LAKE
CANAL FLATS, BRITISH COLUMBIA

CLIENT: BRITISH COLUMBIA MINISTRY OF ENVIRONMENT

OUR FILE: PB 5450 0101 OCTOBER 1990

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF REPORT

Klohn Leonoff Ltd. has completed a study for the Kootenay River and Columbia Lake under the joint Federal/Provincial Floodplain Mapping Agreement. The purpose of this study is to delineate the limits of the 200-year floodplain and to display flood elevations on a topographic base map.

The scope of this study includes:

- deriving the discharge versus return period relationship for the Kootenay River at Canal Flats and the Columbia River at Fairmont Hot Springs;
- developing a HEC-2 river profile model for the Kootenay River in the vicinity of Canal Flats;
- calibrating the river profile model with a river profile survey and with stage-discharge measurements at the highway bridge;
- determining the Columbia Lake stage-outflow relationship;
- estimating the 200-year still-water level (SWL) for Columbia Lake by using the stage-outflow relationship and by using the HEC-2 backwater model developed by the British Columbia Ministry of Environment;
- estimating the normal lake level during the season in which extreme high winds are probable;
- estimating the wave runup and wind setup on Columbia Lake for both normal spring winds and extreme high winds; and
- delineating the 200-year floodplain on the topographic maps supplied by the British Columbia Ministry of Environment.

The floodplain maps are included in Appendix III of this report. A study file, which contains the HEC-2 output for all runs, is bound separately.

To ensure compliance with Ministry of Environment standards and procedures, discussions were held throughout the study with Water Management Branch staff, Mr. Peter J. Woods, P.Eng., and Mr. Richard W. Nichols, P.Eng. Contact was also made with Mr. Dwain Boyer, P.Eng., of the Nelson office of the Ministry of Environment, who provided photographs of the 1986 Kootenay River flood. Messrs. Lloyd Hodge and Dave Gibb, engineering technicians with the Cranbrook office of the Water Survey of Canada, were contacted for information on the gauges on the Kootenay and Columbia rivers. Mr. Bruce Tutt, P.Eng., of the Hydroelectric Engineering Division of B.C. Hydro, provided river and lake data which was collected during the Kootenay River diversion assessment.

1.2 SITE DESCRIPTION

Four kilometres upstream from Canal Flats the Kootenay River emerges from a canyon through the Kootenay Ranges and becomes a braided gravel river. At Canal Flats the river enters the Rocky Mountain Trench and flows southward. Drawing A-1002 shows the location plan for the site.

The following geomorphic history of the site is condensed from a report, "Kootenay River Diversion Project Preliminary Engineering Assessment", by B.C. Hydro. The Rocky Mountain Trench was formed by glaciers of the Pleistocene era. When the glaciers receded into the mountains the Columbia River flowed southward by cutting into the glacial till of the trench, and the Kootenay River was a tributary. The Kootenay River deposited alluvium as it emerged from the steep mountain canyon; eventually, the alluvial fan divided the Columbia and Kootenay River systems at Canal Flats, creating Columbia Lake and forcing the Columbia to flow northward.

In 1976 B.C. Hydro carried out an exploratory drilling program at Canal Flats. The drilling results indicated that alluvial, glaciofluvial, glaciolacustrine, and glacial deposits form the divide between the Kootenay River and Columbia Lake to at least 90 m depth. B.C. Hydro

concluded that the divide consists mainly of gravels and sands of fluvial and glaciofluvial origin deposited by the Kootenay River.

At Canal Flats the river has a drainage area of 5390 km^2. The fan that separates the Kootenay River from Columbia Lake is some 3 km wide with an apex adjacent to the river near the highway bridge. The fan apex is about 10 m above the average level of Columbia Lake, and this difference in elevation decreases to about 5 m at the toe of the fan along the west side of the trench.

In 1889 a canal was completed along the toe of the fan to join the river and lake. Only three passages by boats were made before it was permanently blocked because of concerns about excess flows into the Columbia River system. Many decades later the idea of another passage from the river to the lake was considered. Up to 1980 B.C. Hydro was investigating the feasibility of diverting some of the Kootenay River flow across the fan and into the Columbia River System for increased hydroelectricity production from their Columbia River facilities.

Columbia Lake is long and narrow, extending some 15 km in the Rocky Mountain Trench. The lake was formed by the blockage of the Columbia River at Canal Flats and by the alluvial fan of Dutch Creek flowing from the Columbia mountains. Dutch Creek, which has a drainage area of 686 km^2, enters the lake near its outlet to the Columbia River. Columbia Lake, excluding Dutch Creek, has a drainage area of 200 km^2.

Critical months of the year for heavy runoff in the watersheds of Kootenay River and Columbia Lake are May through July as a result of snowmelt or rain-on-snow events. The Kootenay River can experience quick changes in river discharge and stage; in contrast, the stage of Columbia Lake changes relatively slowly because of its large storage capacity.

2. DATA USED FOR STUDY

2.1 DATA SOURCES

Data sources are referenced below with brief explanations of their applicability:

a) Water Survey of Canada data for:

Station 08NF002 - Kootenay River at Canal Flats
Station 08NA064 - Columbia Lake at Canal Flats
Station 08NA045 - Columbia River near Fairmont Hot Springs
Station 08NG005 - Kootenay River at Wardner
Station 08NG042 - Kootenay River at Newgate
Station 08NG053 - Kootenay River near Skookumchuck
Station 08NK005 - Elk River at Phillips Bridge
Station 08NK016 - Elk River at Natal

Data from station 08NG053 was used to extend the period of record for station 08NF002. A site flood frequency analysis was carried out on the extended data set for station 08NF002. A regional flood frequency analysis with stations 08NG005, 08NG042, 08NG053, 08NK005, and 08NK016 was carried out to check the validity of the site frequency analysis at 08NF002.

Data from stations 08NA064 and 08NA045 was correlated to establish the stage-outflow relationship for Columbia Lake. A site flood frequency analysis was also carried out on the data from station 08NA045.

Details of the hydrologic data analyses are in Appendix I.

b) River Survey, Project 8906F028, British Columbia Ministry of Environment, Surveys Section.

The following was provided in digital and plot format:

- 20 cross sections of the main channel of the Kootenay River in the vicinity of Canal Flats;
- four cross sections of a side channel;
- profiles of the Highway 93/95 bridge and bank protection; and
- water surface profile of the river on May 25, 1989.

In addition, photographs of all cross sections were provided.

Survey data was used to prepare and calibrate the HEC-2 river profile model.

c) Ministry of Transportation and Highways plan for Highway 93/95 bridge across the Kootenay River at Canal Flats.

The bridge plan was used to identify the bridge pier dimensions and the size of the flow area under the bridge.

d) Columbia Lake to Windermere Lake Floodplain Mapping Program, 1977-78, British Columbia Ministry of Environment, Special Projects Section.

The following information was provided:

- design file;
- Drawing Nos. A5286-1 and -2 issued February 1981, which cover the northern end of Columbia Lake to Fairmont Hot Springs;
- mosaic which identifies surveyed cross sections on the Columbia River and Dutch Creek;
- disc and hard copies of the HEC-2 input file used to estimate the flood profile of the Columbia River.

This information was used to review the current estimate of the Columbia Lake flood level.

e) "Kootenay River Diversion Project Preliminary Engineering Assessment, Volume 2", October 1977, B.C. Hydro.

This report provided the following information for this study:

- soundings of Columbia Lake;
- geologic exploration findings;
- specific discharge plots for the river gauge at Canal Flats;
- a description of the regional geology.

f) The Atmospheric Environment Service of Environment Canada provided wind data from Cranbrook Airport and Kimberly Airport (data to 1969).

The wind data was used to prepare the estimates of the wave runup and wind setup on Columbia Lake.

g) Water Survey of Canada's Cranbrook office provided the current rating curve for the Kootenay River at Canal Flats and streamflow measurement data, which is used to check the accuracy and adjust the rating curve.

The stage-discharge data was used to calibrate the HEC-2 model at a variety of discharges and thus determine changes in channel roughness (in terms of Manning's "n") with stage.

h) The Nelson office of the British Columbia Ministry of Environment provided photographs of the May 1986 flood. A selection of these photographs is in Appendix II.

The extent of the flood shown in the photographs was useful in calibrating the HEC-2 model and in defining the areas of noneffective flow in the floodplain.

i) The book "Tales of the Kootenays" by Fred J. Smyth provided historical information on the abandoned canal between the Kootenay River and Canal Flats.

2.2 HISTORIC FLOODING

On July 5 and 6, 1990, C. David Sellars, P.Eng., and Robert Baker, P.Eng., visited Canal Flats to study the morphology of the Kootenay River and Columbia Lake and to speak with local residents about historic flood events. Three knowledgeable Canal Flats residents were contacted: Mr. Malcolm Pounder, Mr. George Cockshott, and Mrs. Gloria Perry.

Mr. Pounder, the yard boss for Crestwood Forest Products in Canal Flats, moved to the area 27 years ago. As part of his job he monitors the stage of the Kootenay River adjacent to the sawmill's yard, and said that he has never seen the river flood property in Canal Flats but he had heard there was flooding in the 1940s. Mr. Pounder suggested that we speak with long-time local resident Mr. George Cockshott.

Mr. Cockshott has resided in Canal Flats since 1931. He said he is unaware of the Kootenay River ever inundating part of Canal Flats. He went on to say that the village was flooded at least twice several decades ago by water from a mill pond which was used to store railway ties. Apparently, the mill pond dam breached on occasion, flooding the village for about an hour while the water flowed to Columbia Lake.

Mrs. Perry, head of the Canal Flats Improvement District, stated that she has never heard of the Kootenay River causing flooding problems in the village.

Although flooding has not been recorded in the community, flooding has occurred both upstream and downstream of Canal Flats. Mr. Dwain Boyer, P.Eng., of the Kootenay Regional Office of the British Columbia Ministry of Environment, took photos while flying over the area on May 29, 1986, the day of the record flow on the Kootenay River at Canal Flats. The photos show extensive flooding at the J2 and K2 ranches. The J2 Ranch is some 4 km upstream from Canal Flats, situated at the base of Mount Grainger on the alluvial deposits of the Kootenay River. A resident of the ranch in 1986, Mrs. Tana Gertner, was contacted in Alberta. She said that the fields and road were inundated for almost one month in 1986 and a large amount of their land was eroded by the river. After the flood, riprap was placed along the banks and the main river channel was excavated. The maximum instantaneous discharge recorded at Canal Flats on May 29, 1986 was 876 m^3/s, and the daily discharge for this date was 844 m^3/s.

No information was found to identify any historic floods at Columbia Lake.

3. FLOOD FREQUENCY ANALYSES

Flood frequency analyses were carried out to estimate the 20-year and 200-year return period discharges of the Kootenay River at Canal Flats and the Columbia River near Fairmont Hot Springs. The results are as follows:

- Kootenay River at Canal Flats:
  - 20-year daily discharge: 769 m^3/s
  - 20-year instantaneous discharge: 815 m^3/s
  - 200-year daily discharge: 939 m^3/s
  - 200-year instantaneous discharge: 995 m^3/s
- Columbia River near Fairmont Hot Springs:
  - 20-year daily discharge: 73 m^3/s
  - 20-year instantaneous discharge: 79 m^3/s
  - 200-year daily discharge: 103 m^3/s
  - 200-year instantaneous discharge: 113 m^3/s

Details of the flood frequency analyses were presented in a progress report, included as Appendix I.

4. HYDRAULIC ANALYSES

4.1 RIVER PROFILE MODEL

Water surface profiles of the Kootenay River were estimated with the HEC-2 computer program for river profile calculations. Input to this program includes cross section geometry, reach lengths, flows, ineffective flow areas, and estimates of energy loss coefficients. Calibration of the input data with known flows and corresponding river elevations is required to model river levels at other flows.

Cross section geometry and reach lengths were obtained from a detailed survey which had been carried out by the Ministry of Environment in 1989. The survey included 20 river cross sections and four side-channel cross sections. Cross section data was provided to Klohn Leonoff along with a topographic map showing their locations and a set of photographs at each cross section showing the banks and views looking upstream and downstream. Extensions to the cross sections were made, where required, with the topographic map data.

On May 25, 1990 the Ministry of Environment surveyed the water level elevation at each cross section location. The chart from the gauge at Canal Flats bridge shows that the stage was fairly constant at 1.32 m on that day; the discharge was measured to be 104 m^3/s from the rating curve. Two conflicting Geological Survey of Canada (GSC) datums were provided for this gauge; therefore, the datum was calculated from the water level profile data and gauge reading. The GSC correction was calculated to be 814.20 m GSC at zero gauge elevation.

Ineffective flow areas were identified during the site visit and by observing the photographs taken during the 1986 flood. The ranch land along the left bank of the river upstream from Canal Flats stores water at

high stage and contributes little to conveyance of river flow because of the high bench immediately downstream.

For analysis of water surface profiles, energy loss coefficients include contraction, expansion, and channel roughness (Manning's "n") coefficients. Expansion and contraction coefficients were estimated by observing changes in the shape of river cross sections. Channel roughness coefficients were used to calibrate the river profile model.

The first calibration was carried out at 104 m^3/s with the surveyed profile. The survey profile was input to the program to solve for the weighted Manning's "n" of the river. The results of the calibration for 104 m^3/s are listed in Table 1.

The value of Manning's "n" for gravel bed rivers changes with stage. At low stage the large bed material is partially exposed, making the channel bottom rougher than at higher stages. A representative Manning's "n" for the extreme flood stages had to be estimated.

Water Survey of Canada regularly takes stage and discharge measurements at Canal Flats to check the rating curve. Stage measurements were taken at 70, 332, 404, 526, and 818 m^3/s (the latter measurement was taken May 30, 1986, one day after the extreme discharge for the period of record). The HEC-2 model was calibrated at these flows to attain the measured water surface elevation by adjusting the input channel roughness. The results show that channel roughness decreases with stage as the rough gravel bars of the river are submerged. The model was calibrated with the stage-discharge data for a narrow range of Manning's "n" from 0.032 for 526 m^3/s to 0.036 for 70 m^3/s.

TABLE 1

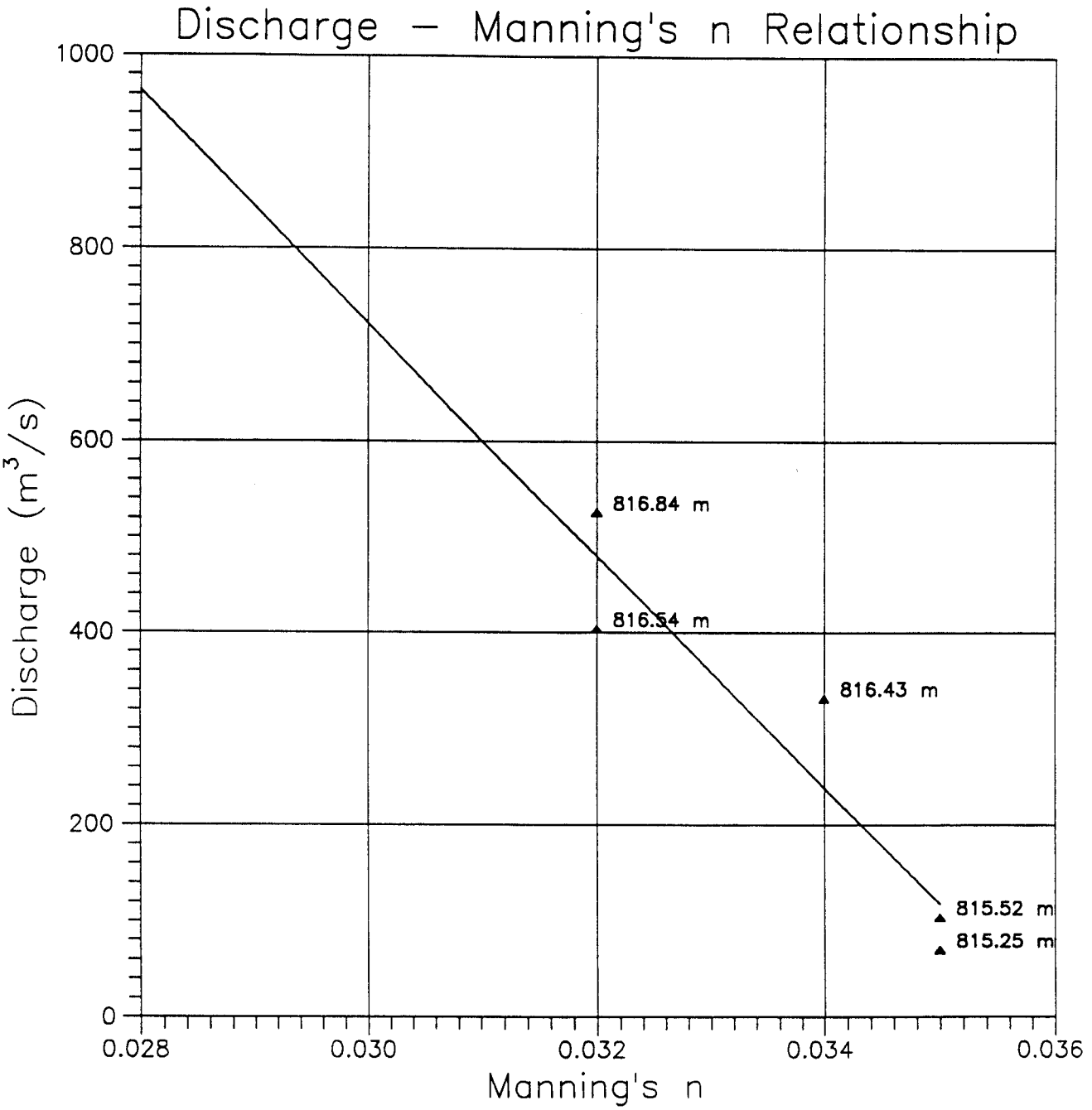
KOOTENAY RIVER PROFILE MODEL CALIBRATION RESULTS

Cross Section No.	Recorded Level (m)	Calibrated Level (m)	Difference (m)
19	809.75	809.67	-0.08
18	810.60	810.66	0.06
17	811.67	811.78	0.11
16	813.48	813.23	-0.25
15	814.80	814.90	0.10
14	815.40	815.43	0.03
13	815.52	815.53	0.01
12	815.52	815.54	0.02
11	815.57	815.57	0.00
10	816.68	816.61	-0.07
9	817.46	817.59	0.13
8	818.75	818.04	-0.71
7	819.35	819.00	-0.35
6	820.81	820.93	0.12
5	822.67	822.21	-0.46
4	823.34	823.63	0.29
3	824.58	824.38	-0.20
2	825.21	825.20	-0.01
1	826.69	826.37	-0.32
24	827.09	827.05	-0.04

The discharge of 818 m^3/s in 1986 gave an anomalous calibration with an "n" value of 0.025. This anomaly can be explained by the degradation of the river in the vicinity of the gauge between 1986 and 1989-1990. All of the stage-discharge measurements used in the calibrations were made in 1989 or 1990, except for the 818 m^3/s reading. B.C. Hydro studied the specific discharge at the gauge by comparing rating curves used during the period of record; they found that major drops in the curve have been associated with high floods, and intervening years of low flows have resulted in increases of the curve.

Figure 1 shows the relationship between discharge and channel Manning's "n" for the calibration range of flows. By extrapolating this relationship to the estimated 200-year and 20-year daily and instantaneous flows, the channel Manning's "n" was estimated to be as high as 0.030 for these flows. This value of Manning's "n" was used in the flood profile calculations.

Most cross sections' overbanks were defined to be on the gravel bars and islands adjacent to the main channel; a Manning's "n" of 0.040 was used for these overbanks. The "island" between the main channel and side channel upstream from the bridge was identified to be inundated at the flood flows under study; consequently, it was decided to include the main and side channels and the island in singular cross sections rather than making separate input files for each channel. The rough growth and irregular topography of the island were reflected in the selection of a Manning's "n" of 0.200 for over-island flow calculations.



Note: Measured gauge elevation (GSC) shown at each data point.

FIGURE 1

4.1.1 Columbia Lake Levels

The 200-year still-water level (water surface elevation without wave action) of Columbia Lake was estimated by two methods: the derived stage-outflow relationship for the lake and a HEC-2 river profile model for the Columbia River. Derivation of the stage-outflow relationship is explained in Appendix I, and the HEC-2 model was produced by the Ministry of Environment under the Columbia Lake to Windermere Lake Floodplain Mapping Program.

The instantaneous 200-year outflow estimate for Columbia Lake is 113 m^3/s. From the stage-outflow relationship, the still-water level (SWL) of the lake would be 810.3 m at this outflow. By running the HEC-2 model with a discharge of 113 m^3/s the calculated water surface elevation at Columbia Lake is 810.4 m. The results of the two methods are almost identical - a difference of only 10 cm. The higher estimate, 810.4 m, was used for the Columbia Lake flood level estimate.

A 200-year lake level due to an extreme wind was estimated (refer to Section 4.3). This estimate required calculation of the normal SWL during periods of extreme winds, July and August, to which wind setup and wave runup would be added. Both methods of SWL calculation yielded the same result: a normal SWL of 809.0 m GSC during July, the month of highest recorded wind speeds.

4.2 SENSITIVITY ANALYSIS

4.2.1 Kootenay River

The sensitivity of the river profile model to variations in roughness at the 200-year daily flow was investigated. Manning's "n" values of the channel and overbank were varied by +10% and -10% from the base case, and differences in the calculated flood level were noted. Table 2 lists the results of the analysis.

TABLE 2

KOOTENAY RIVER
SENSITIVITY TO CHANNEL MANNING'S "n"

Cross Section No.	Calculated Water Surface Elevation (m)		
	"n" = 0.027	"n" = 0.030	"n" - 0.033
19	811.52	811.64	811.74
18	812.30	812.38	812.47
17	813.44	813.52	813.60
16	814.65	814.73	814.80
15	816.29	816.40	816.49
14	816.91	817.09	817.25
13	817.46	817.53	817.62
12	817.62	817.69	817.77
11	818.01	818.07	818.15
10	818.54	818.63	818.72
9	819.23	819.34	819.43
8	820.99	821.12	821.23
7	821.73	821.83	821.94
6	822.66	822.84	822.99
5	824.17	824.28	824.40
4	824.90	825.06	825.20
3	826.07	826.14	826.21
2	826.47	826.58	826.69
1	827.78	827.90	828.00
24	828.75	828.88	829.98

A multiple profile run was made to examine the sensitivity of the model to discrete variations of discharge above the 200-year daily flow. Discharges at the 200-year instantaneous flow (995 m^3/s) and 10% above this flow (1095 m^3/s) were used to compare with the base case of 939 m^3/s. The Manning's "n" of the profile model was unchanged for this run. Results of the discharge sensitivity analysis are listed in Table 3.

Increases of the water profile at any one cross section in these sensitivity cases were well within the 0.6 m freeboard which was added to the base case water levels.

4.2.2 Columbia Lake

The sensitivity of the lake's SWL estimates to variations in outflow was studied. The 200-year outflow estimate of 113 m^3/s was varied by +10% and the differences in the calculated lake level were noted. The results of the investigation, listed in Table 4, show that for both methods the calculated increase in lake level is similar. The estimated increase in lake level at the higher outflow is well within the freeboard added to the SWL.

4.3 COLUMBIA LAKE WAVE RUNUP AND WIND SETUP

The flood level for Columbia Lake must include sufficient freeboard above the design SWL so that waves cannot damage shoreline structures. Freeboard for the lake includes wind setup and wave runup. Wind setup is caused by movement of water toward the leeward shore by the wind. Wave runup is the vertical extent to which waves will run up the shore.

TABLE 3

KOOTENAY RIVER
SENSITIVITY TO FLOW

Cross Section No.	Calculated Water Surface Elevation (m)		
	939 m^3/s	995 m^3/s	1095 m^3/s
19	811.63	811.70	811.81
18	812.38	812.43	812.53
17	813.52	813.57	813.65
16	814.73	814.77	814.85
15	816.40	816.45	816.53
14	817.09	817.15	817.27
13	817.53	817.64	817.86
12	817.69	817.80	817.94
11	818.07	818.21	818.40
10	818.63	818.76	818.96
9	819.34	819.40	819.49
8	821.12	821.22	821.43
7	821.83	821.92	822.08
6	822.84	822.92	823.05
5	824.28	824.37	824.52
4	825.06	825.13	825.24
3	826.14	826.21	826.34
2	826.58	826.65	826.77
1	827.90	827.96	828.07
24	828.88	828.93	829.01

TABLE 4

SENSITIVITY ANALYSIS - COLUMBIA LAKE RESULTS

METHOD	OUTFLOW (m^3/s)	SWL ESTIMATE (m, GSC)
Stage-Outflow Relationship	113	810.3
	124	810.5
HEC-2 Model	113	810.4
	124	810.6

NOTE: 200-year maximum instantaneous outflow estimate = 113 m^3/s; 110% of this estimate = 124 m^3/s.

Freeboard was calculated for two scenarios: a normal spring high wind coincident with the 200-year still-water lake level, and an extreme high wind coincident with a normal lake level. Over-land wind data from Cranbrook and Kimberly was used in the calculations. Over-water wind speeds were estimated using general ratios of wind speed over land to those over water; over-water wind speeds tend to be greater than those over land. The 93 km/h wind is greater than the maximum gust speed recorded at Cranbrook or Kimberly; therefore, this provides an overly conservative estimate of an extreme high wind, but this was done to determine if a frequency analysis of wind data was required. Further study showed that the former scenario provided the highest flood level; therefore, a wind frequency analysis was unnecessary.

Wind setup and wave runup were estimated to be 0.6 m for 22 km/h, and 1.3 m for 93 km/h. Combining the estimates with their respective still-water estimates provided the following 200-year lake level estimates:

- scenario 1: 811.0 m GSC
- scenario 2: 810.3 m GSC

Scenario 1, a 200-year SWL coincident with a normal high spring wind, provides the higher 200-year estimate.

The 200-year lake level estimate of 811.0 m GSC is conservative because:

- the SWL was based on an instantaneous outflow estimate input to the HEC-2 model;
- the stage-outflow relationship for the lake provided slightly less SWL estimates than the HEC-2 model; and
- winds at speeds and directions used in the wave runup and wind setup calculations are infrequent; therefore, they may not coincide with the SWL conditions.

As the estimate is conservative and freeboard allowance for setup and runup has been included, it is considered that additional freeboard is not required. This Columbia Lake flood level estimate should be used to revise Floodplain Mapping Drawing A5286.

5. FLOOD HAZARDS

5.1 DESIGNATED FLOOD LEVELS

As stated in the Terms of Reference, the designated river flood level generally consists of the 200-year instantaneous peak profile plus 0.3 m of freeboard or the 200-year daily peak profile plus 0.6 m of freeboard, whichever is higher. The computed profiles for the Kootenay River at the 200-year instantaneous and mean daily discharges are very similar; therefore, the 200-year mean daily peak profile plus 0.6 m of freeboard will be the designated flood level along the river. The highway bridge provides ample clearance at this flood discharge. Table 5 lists the 200-year daily instantaneous levels with and without freeboard. Drawing B-1002 shows the profiles of the 200-year daily peak and calibration flow.

TABLE 5

KOOTENAY RIVER
200-YEAR RETURN PERIOD PROFILES
WITH AND WITHOUT FREEBOARD

Cross Section No.	Calculated Water Surface Profile (m)		Profile with Freeboard Included (m)	
	200-year daily	200-year instantaneous	200-year daily	200-year instantaneous
19	811.63	811.70	812.23	812.00
18	812.38	812.43	812.98	812.73
17	813.52	813.57	814.12	813.87
16	814.73	814.77	815.33	815.07
15	816.40	816.45	817.00	816.75
14	817.09	817.15	817.69	817.45
13	817.53	817.64	818.13	817.94
12	817.69	817.80	818.29	818.10
11	818.07	818.21	818.67	818.51
10	818.63	818.76	819.23	819.06
9	819.34	819.40	819.94	819.70
8	821.12	821.22	821.72	821.52
7	821.83	821.92	822.43	822.22
6	822.84	822.92	823.44	823.22
5	824.28	824.37	824.88	824.67
4	825.06	825.13	825.66	825.43
3	826.14	826.21	826.74	826.51
2	826.58	826.65	827.18	826.95
1	827.90	827.96	828.50	828.26
24	828.88	828.93	829.48	829.23

NOTE: Freeboard is 0.60 m for daily discharge, and 0.30 m for instantaneous discharge.

At Canal Flats the 200-year flood profile with freeboard is higher than the alluvial fan between the river and lake. The designated flood profile runs approximately 0.3 m to 1.0 m above the elevation of the right bank, and the land slopes down several metres to Columbia Lake.

The estimated 200-year flood level for Columbia Lake is 811.0 GSC. This is 7.2 m less than the designated flood level of the Kootenay River near the Highway 93/95 bridge.

The floodplain maps in Appendix III depict the following:

- the 200-year return period mean daily flood level plus 0.6 m freeboard for the Kootenay River;
- the extent of the alluvial fan which is subject to overflow and avulsions between the Kootenay River and Columbia Lake; and
- the 200-year return period SWL plus wave runup and wind setup for Columbia Lake.

The floodplain maps were checked by C. David Sellars, P.Eng., and Robert Baker, P.Eng., during a site inspection on October 10, 1990.

5.2 AVULSIONS

The extent of the floodplain is defined by the valley slopes upstream and downstream of Canal Flats. At Canal Flats, however, the alluvial fan, being of deposited material, is not a permanent boundary of the river. The fan slopes from the river bank to Columbia Lake with an elevation difference of up to 10 m. At high stages, the Kootenay River could overtop the river bank and flow over land to the lake, or the Kootenay River could switch channels by eroding through the fan at the sharp river bend upstream of the bridge. Although there is no record of over-land flow from the river to the lake, an extreme event such as the 200-year flood could cause over-land flow or a major avulsion.

Over-land flow or an avulsion could have severe consequences at Canal Flats and communities downstream along the Columbia River System. Bank protection along the alluvial fan, particularly at the sharp bend upstream from the highway bridge, could control erosion. Some riprap is currently in this location, but it is inadequate to provide erosion protection during extreme floods. A dyke with riprap could be an effective structure to train high flows of the Kootenay River away from the alluvial fan. Most of the community would be protected from the designated flood profile, and the most likely location for an avulsion would be protected by a dyke with riprap extending from the highway bridge to the eastern slope of the Rocky Mountain Trench. More extensive protection against flooding and an avulsion could be provided by a 3-km-long dyke along the right bank of the river adjacent to the fan.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

1. The designated flood levels of the Kootenay River and Columbia Lake would most likely occur in spring.

2. The designated flood level of the Kootenay River at Canal Flats is higher than the divide between the river and Columbia Lake.

3. Over-land flow and channel avulsion at Canal Flats is a possibility during extreme floods on the Kootenay River.

4. The designated flood level of Columbia Lake is 811.0 m GSC.

6.2 RECOMMENDATIONS

1. The floodplain and alluvial fan areas outlined on Maps 89-41-1 to 89-41-8 should be designated pursuant to the Canada-British Columbia Floodplain Mapping Agreement.

2. The flood profile should be reassessed if B.C. Hydro proceeds with a diversion from the Kootenay River to Columbia Lake.

3. Dyking and bank protection should be considered on the right bank upstream of the highway bridge to prevent flooding at Canal Flats and to guard against a channel avulsion at high river flows.

4. The computed flood level of 811.0 GSC for Columbia Lake should be used to revise Floodplain Mapping Drawing A5286.

KLOHN LEONOFF LTD.

Robert Baker

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
R. E. BAKER

Robert E. Baker, P.Eng.
Project Engineer

C. David Sellars, P.Eng.
Project Manager

REB/CDS:tp

APPENDIX I

PROGRESS REPORT ON FREQUENCY ANALYSES

PB 5450 0101
WP 554

August 8, 1990

FLOODPLAIN MAPPING PROJECT
KOOTENAY RIVER AT CANAL FLATS
RESULTS OF FREQUENCY ANALYSES

This progress report presents the results of frequency analyses carried out for the floodplain mapping project for the Kootenay River at Canal Flats. Flood frequency analyses were carried out to estimate the 20-year and 200-year return period discharges of the Kootenay River at Canal Flats and the Columbia River near Fairmont Hot Springs.

1. KOOTENAY RIVER AT CANAL FLATS

Water Survey of Canada (WSC) operates a streamflow gauge station at the highway bridge in Canal Flats. Annual maximum daily discharge data are available for 39 years (1939 to 1990, interrupted record). To extend the record, regression analyses were carried out using downstream gauges with longer periods of record.

Canal Flats discharge data were analyzed with discharge data from the Kootenay River near Skookumchuck (Station 08NG053) and at Wardner (Station 08NG005). The regression analyses showed a high correlation between the annual maximum daily discharges, in particular between Kootenay River flows at Canal Flats and at the gauge downstream at Skookumchuck. A comparison of synthetic data from the correlation and actual data is shown in Figure 3.1. Synthetic data from the regression with Skookumchuck were added to the Canal Flats data set, producing a total of 52 years of record.

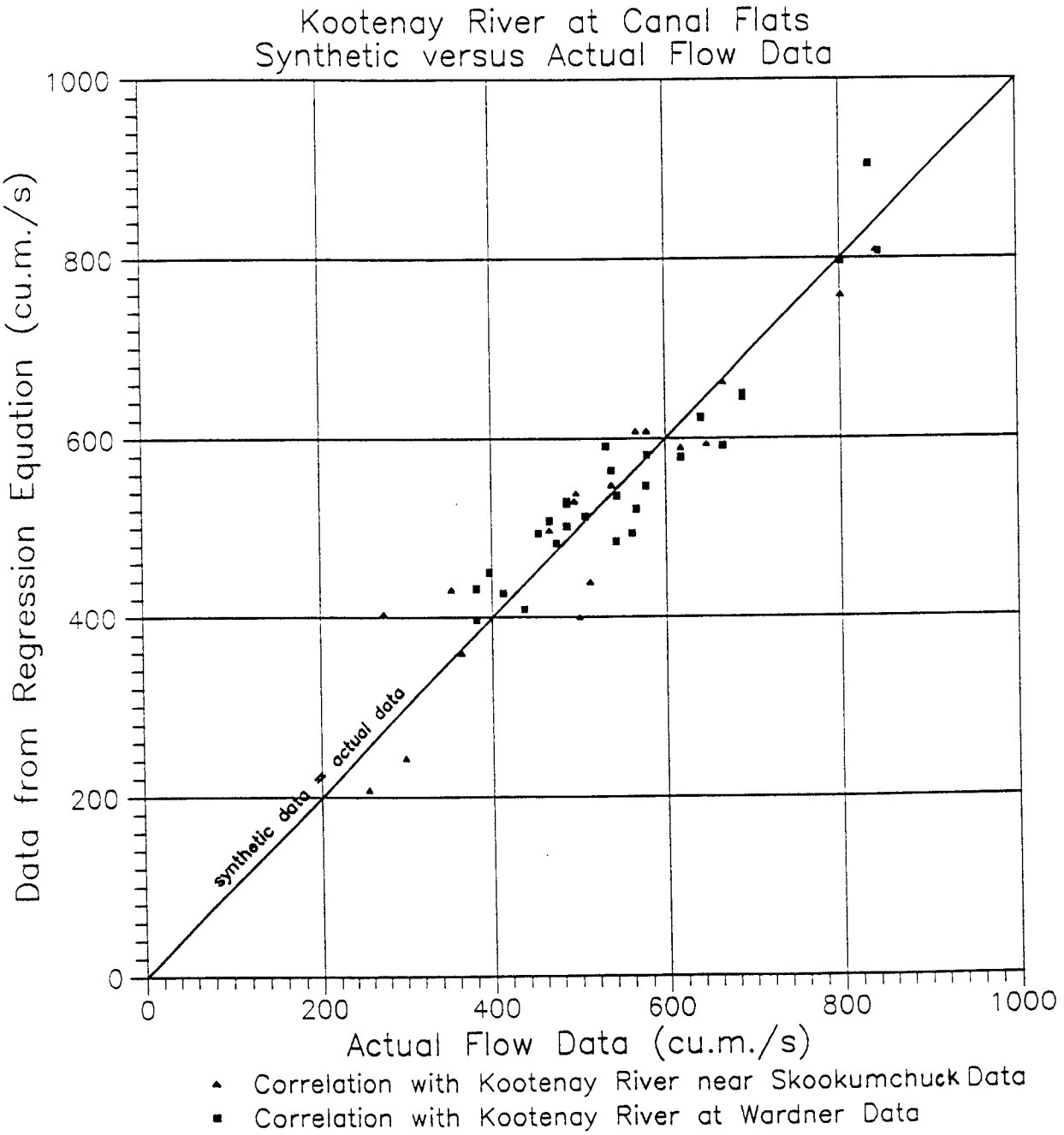


Figure 3.1 Comparison of Data Correlations for Kootenay River at Canal Flats

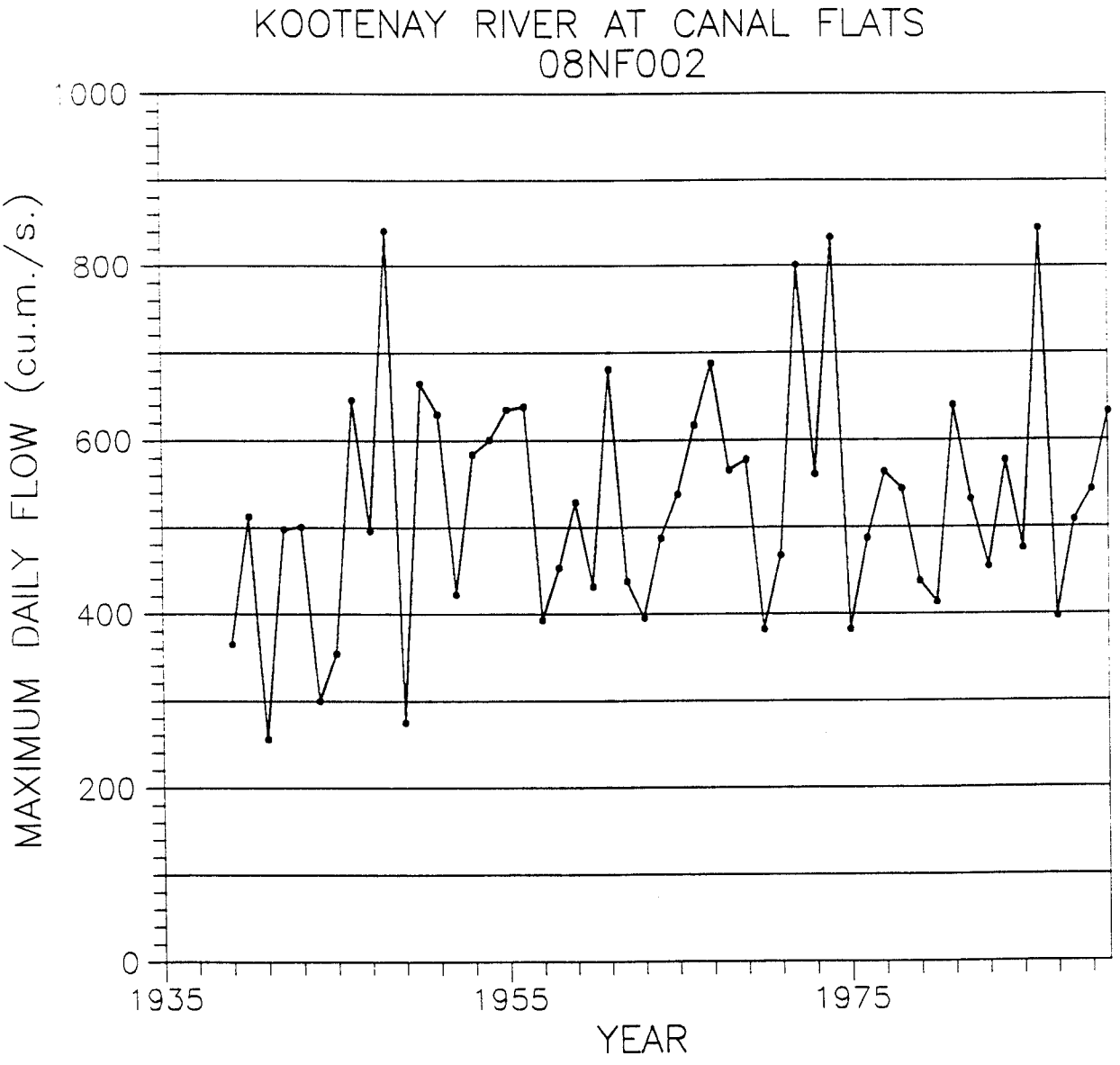


Figure 3.2 Maximum Daily Discharges for Kootenay River at Canal Flats. Includes actual data (1939-1950, 1963-1990) and synthetic data.

The annual maximum daily discharges are shown in Figure 3.2 The data does not display any trend, i.e. it is internally homogeneous.

A flood frequency analysis of the 52 maximum discharges was carried out using the WSC program, CFA88. Generalized Extreme Value (GEV), Three-Parameter Lognormal, and Log Pearson Type III distributions were used to analyze the data sample. Results for these three distributions are shown in Attachment 1. The frequency distributions were compared to identify the most suitable for use in predicting the one in 200-year discharge. Statistical restrictions of the distributions were used for this comparison. The three-Parameter Lognormal distribution fits the data set the best: the coefficients of skew and kurtosis are very close to their theoretical values of zero and 3, respectively. The GEV distribution was discounted because the upper bound, 1204, is close to the frequency curve in the range of interest; therefore, may influence the shape of the curve.

The Log Pearson Type III distribution was not of interest because the scale parameter and the coefficient of skew of the logarithm are negative.

Figure 3.3 shows the Three-Parameter Lognormal distribution for Canal Flats.

Frequency analyses with the Three-Parameter Lognormal distribution were carried out on discharge data from stream gauges in the region. Table 3.1 lists these gauge stations.

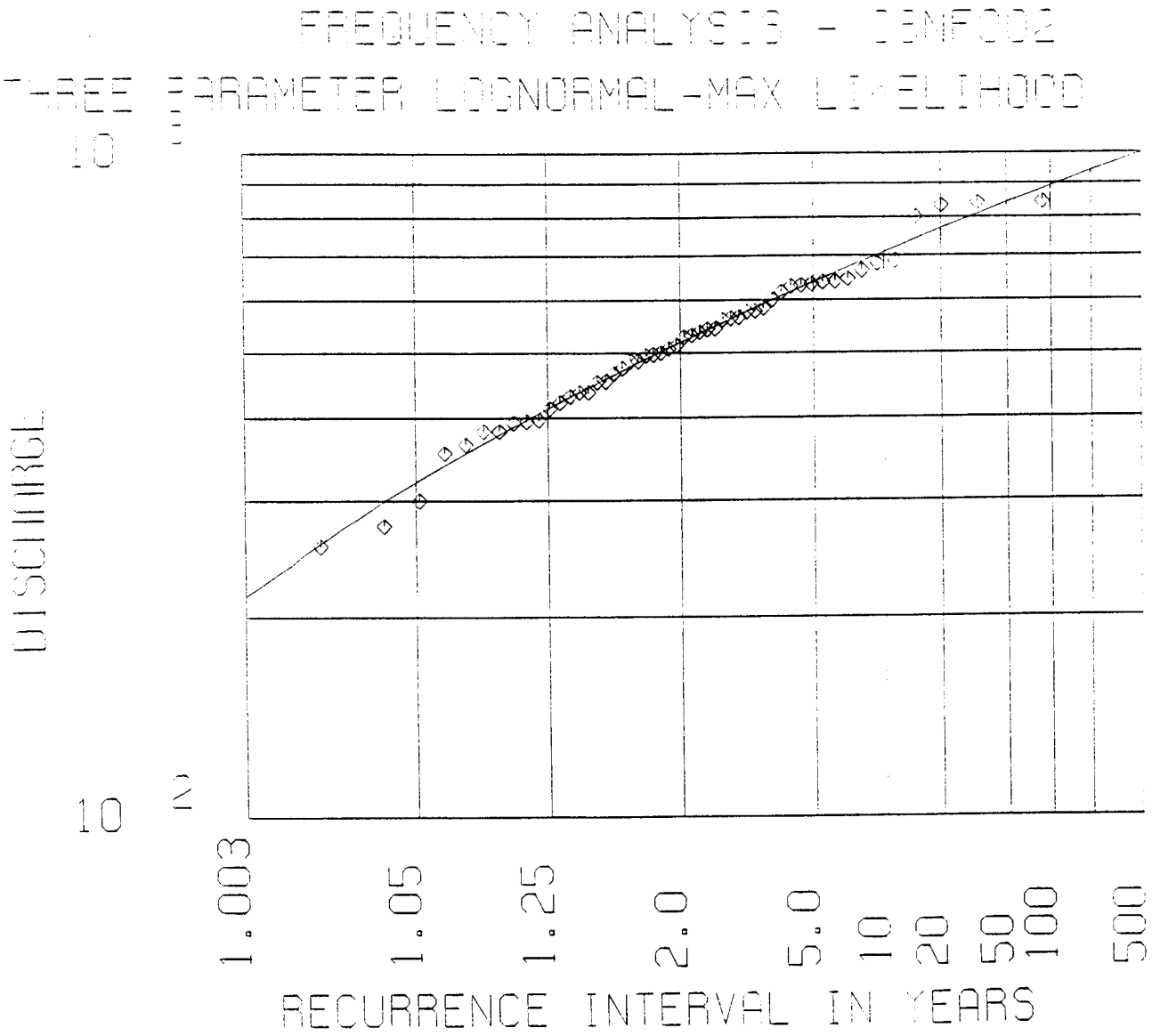


Figure 3.3 Three-Parameter Lognormal Distribution for Kootenay River at Canal Flats.

TABLE 3.1

STREAMFLOW GAUGES IN REGIONAL ANALYSIS

STATION NO.	STATION NAME	YEARS OF DATA
08NF002	Kootenay River at Canal Flats	52*
08NG005	Kootenay River at Wardner	59
08NG042	Kootenay River at Newgate	41
08NG053	Kootenay River near Skookumchuck	40
08NK005	Elk River at Phillips Bridge	65
08NK016	Elk River at Natal	38

* includes data from correlation with Station 08NG053.

Figure 3.4 shows that the results of the frequency analysis for the Kootenay River at Canal Flats is reasonably consistent with results from other stations in the region.

Maximum instantaneous discharges for the Kootenay River were estimated from a correlation with maximum daily discharges: based on 10 years of instantaneous data from Canal Flats, maximum daily discharges are on average 94.4% of instantaneous discharges. From this correlation, the maximum instantaneous discharge estimates to be used in the flood profile analysis are:

one in 20 year magnitude: 815 m^3/s
one in 200 year magnitude: 995 m^3/s

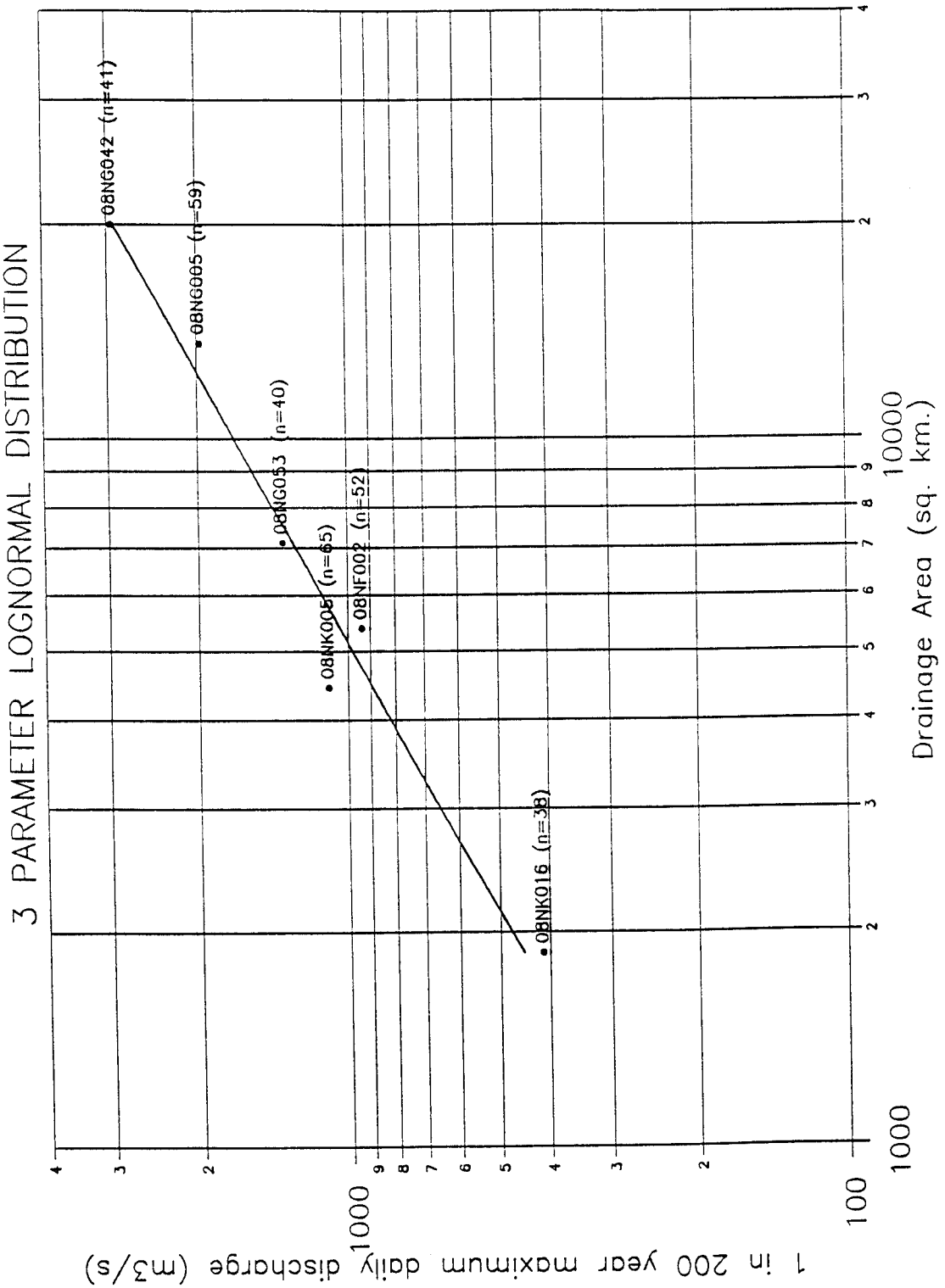


Figure 3.4 Regional Flood Frequency Analysis Curve

2. COLUMBIA RIVER NEAR FAIRMONT HOT SPRINGS

Discharge data from the WSC streamflow gauge located 3 km from the mouth of Columbia Lake was analyzed as part of an estimate of Columbia Lake flood levels.

A continuous set of discharge data from 1944 to 1990 is available from the station. Annual maximum daily discharges for the period of record are shown in Figure 3.5; a historic trend of decreasing annual maxima may be occurring, but the data set is too short to prove this conclusively. The entire data set was used in further analyses.

CFA88 was used to analyze the flood frequency of the data with Generalized Extreme Value (GEV), Three-Parameter Lognormal, and Log Pearson Type III distributions. Results of the analysis are shown in Attachment 2. A statistical comparison of the distributions showed that all of them fit the data well, and the estimates of flood events were almost identical (one in 200-year estimates were 101, 102 and 103 m^3/s). The GEV distribution, Figure 3.6, was selected to estimate the magnitude of flood events because of the marginally more conservative (i.e. higher) results.

A linear regression was carried out on the 42 years of maximum instantaneous and maximum daily discharges. From this correlation the following maximum instantaneous discharge estimates were calculated:

one in 20 year magnitude:	79 m^3/s
one in 200 year magnitude:	113 m^3/s

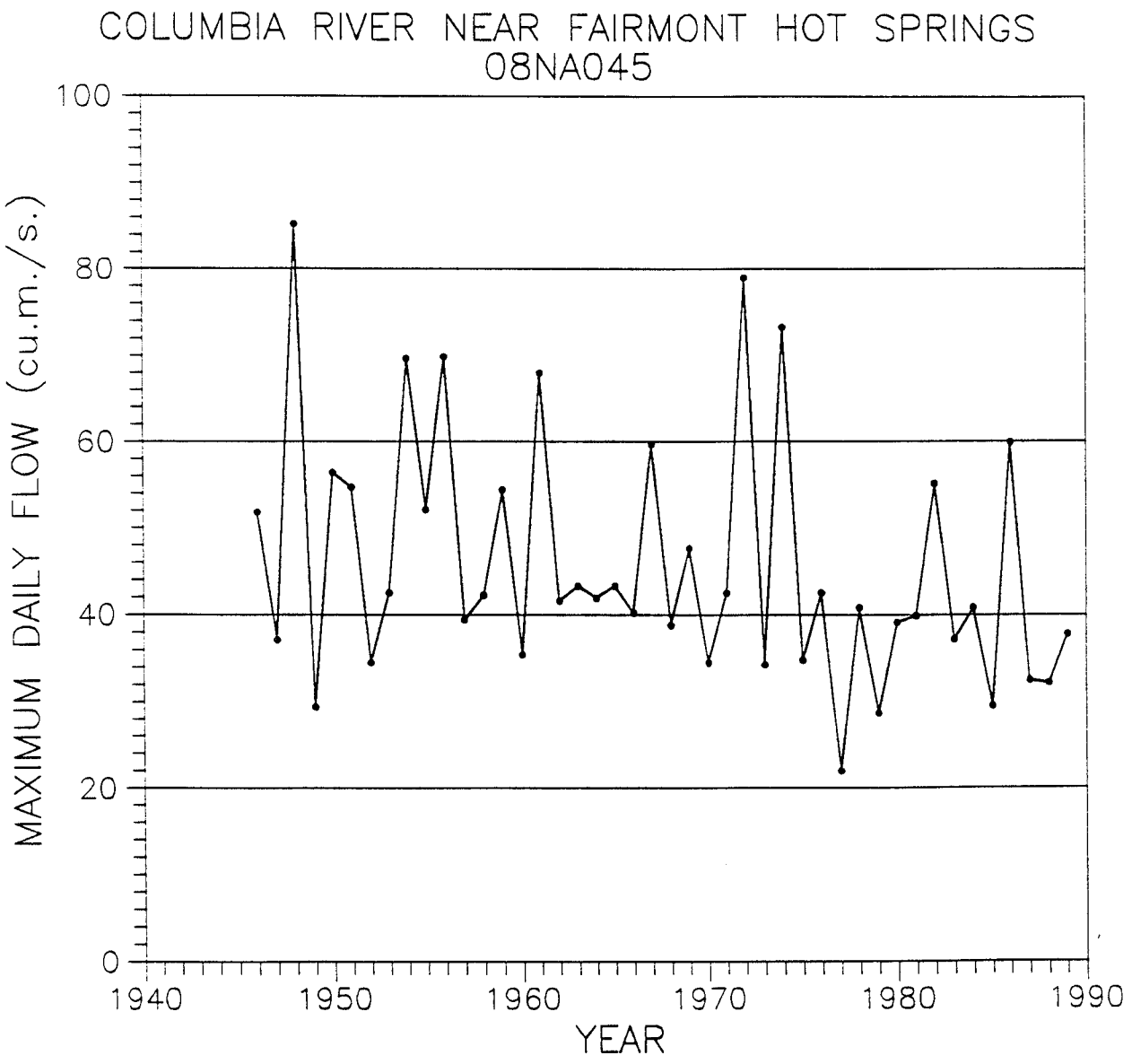


Figure 3.5 Maximum Daily Discharge for Columbia River near Fairmont Hot Springs.

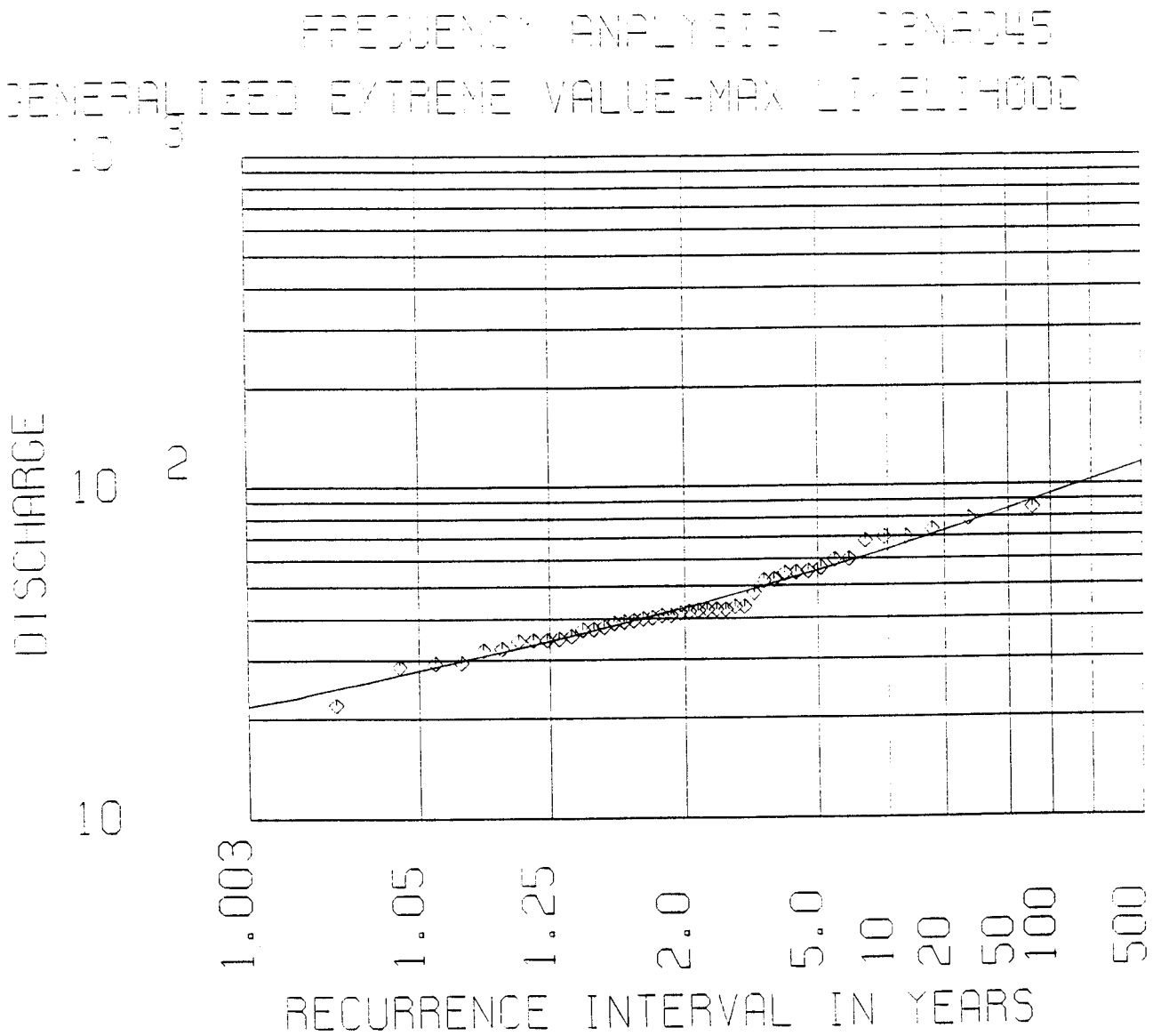


Figure 3.6 GEV Distribution for Columbia River near Fairmont Hot Springs.

3. COLUMBIA LAKE STAGE - DISCHARGE RELATIONSHIP

Levels of Columbia Lake were recorded approximately 10 times per year from 1966 to 1984 at the south end of the lake near Canal Flats. Average daily flow data from the Columbia River near Fairmont Hot Springs were correlated with these lake levels in order to produce a rating curve for lake discharges. The second-order polynomial equation of the rating curve was determined and the curve was extended to the magnitude of the maximum instantaneous one in 200-year return period discharge. Figure 3.7 shows the curve. The estimate of the one in 200-year lake level by this method is 810.3 m, not including an allowance for freeboard. An appropriate freeboard allowance is being evaluated at this time.

The flood level of Columbia Lake will also be estimated by using the Water Management Branch HEC-2 backwater model for the Columbia River. This estimate will be compared with the stage-discharge estimate.

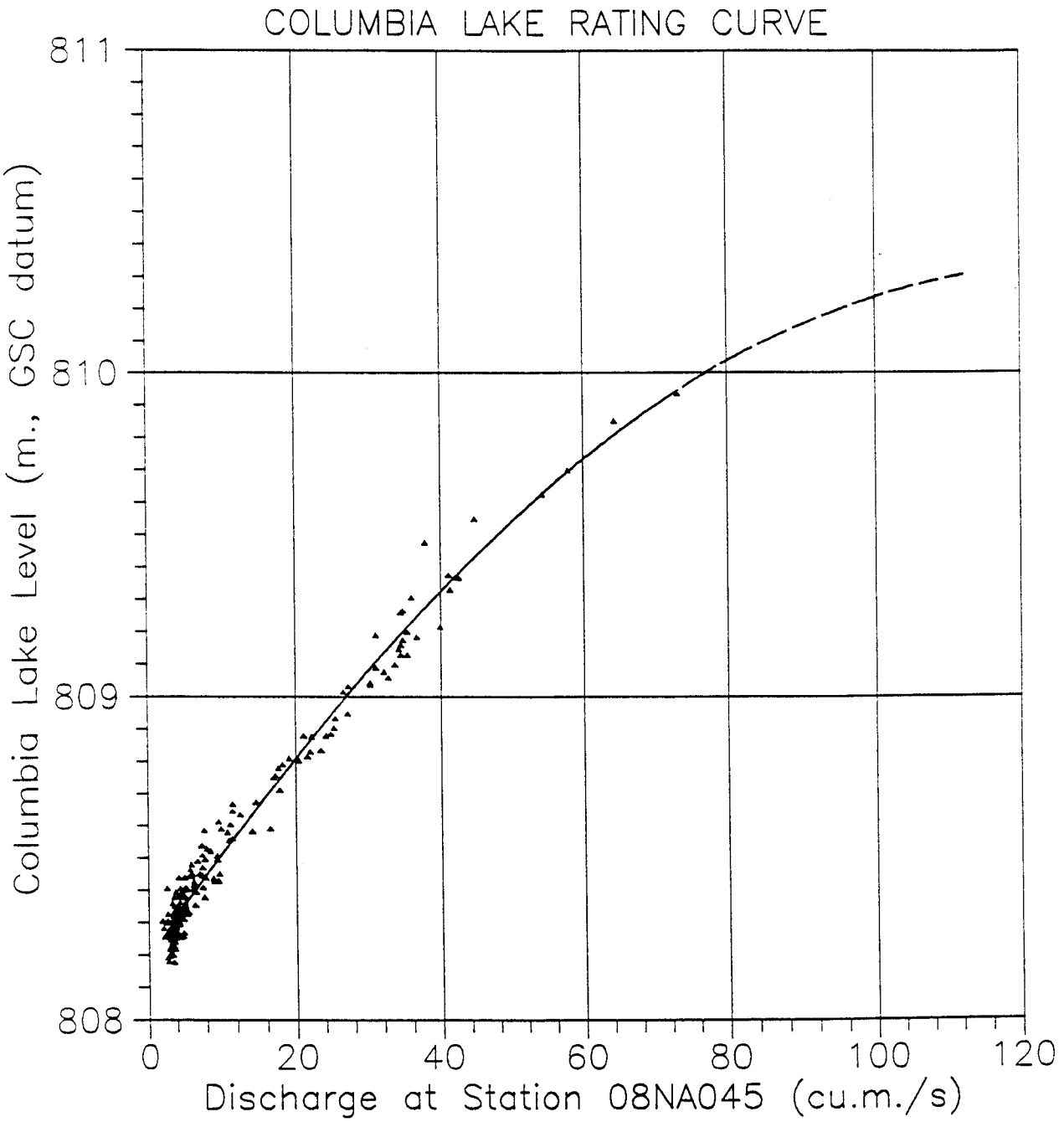


Figure 3.7 Lake Level - Outflow Curve for Columbia Lake.

ATTACHMENT I

CFA88 OUTPUT

FREQUENCY ANALYSIS

KOOTENAY RIVER AT CANAL FLATS

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
08NF002 KOOTENAY RIVER AT CANAL FLATS - ACT + SYN DATA

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	528.596	136.306	0.258	0.414	3.358
LN X SERIES	6.237	0.265	0.043	-0.364	3.466

X(MIN)= 256.000
X(MAX)= 844.000
LOWER OUTLIER LIMIT OF X= 244.170

TOTAL SAMPLE SIZE= 52
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= 0.1204E+04
GEV PARAMETERS: U= 474.79 A= 124.949 K= 0.171

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	218.00
1.050	0.952	322.00
1.250	0.800	413.00
2.000	0.500	519.00
5.000	0.200	640.00
10.000	0.100	708.00
20.000	0.050	766.00
50.000	0.020	830.00
100.000	0.010	872.00
200.000	0.005	910.00
500.000	0.002	953.00

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
08NF002 KOOTENAY RIVER AT CANAL FLATS - ACT + SYN DATA

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	528.596	136.306	0.258	0.414	3.358
LN X SERIES	6.237	0.265	0.043	-0.364	3.466
LN(X-A) SERIES	6.827	0.146	0.021	-0.005	3.195

X(MIN)= 256.000
X(MAX)= 844.000
LOWER OUTLIER LIMIT OF X= 244.170

TOTAL SAMPLE SIZE= 52
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= -403.307 M= 6.827 S= 0.146

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	215.00
1.050	0.952	320.00
1.250	0.800	413.00
2.000	0.500	519.00
5.000	0.200	639.00
10.000	0.100	708.00
20.000	0.050	769.00
50.000	0.020	841.00
100.000	0.010	891.00
200.000	0.005	939.00
500.000	0.002	999.00

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
08NF002 KOOTENAY RIVER AT CANAL FLATS - ACT + SYN DATA

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	528.596	136.306	0.258	0.414	3.358
LN X SERIES	6.237	0.265	0.043	-0.364	3.466

X(MIN)= 256.000
X(MAX)= 844.000
LOWER OUTLIER LIMIT OF X= 244.170

TOTAL SAMPLE SIZE= 52
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT M= 2203.
LP3 PARAMETERS: A=-0.4735E-01 B= 30.85 LOG(M)= 7.697
M = 2203.

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	223.00
1.050	0.952	321.00
1.250	0.800	412.00
2.000	0.500	519.00
5.000	0.200	640.00
10.000	0.100	708.00
20.000	0.050	766.00
50.000	0.020	833.00
100.000	0.010	879.00
200.000	0.005	922.00
500.000	0.002	974.00

ATTACHMENT II

CFA88 OUTPUT

FREQUENCY ANALYSIS

COLUMBIA RIVER NEAR FAIRMONT HOT SPRINGS

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
08NA045 COLUMBIA RIVER NEAR FAIRMONT HOT SPRINGS

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	45.807	14.311	0.312	1.028	3.780
LN X SERIES	3.781	0.294	0.078	0.349	3.166

X(MIN)= 22.000
X(MAX)= 85.200
LOWER OUTLIER LIMIT OF X= 19.689

TOTAL SAMPLE SIZE= 44
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

GEV PARAMETERS: U= 39.18 A= 10.374 K= -0.055

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	21.80
1.050	0.952	28.00
1.250	0.800	34.30
2.000	0.500	43.00
5.000	0.200	55.40
10.000	0.100	64.00
20.000	0.050	72.70
50.000	0.020	84.40
100.000	0.010	93.50
200.000	0.005	103.00
500.000	0.002	116.00

08NA045 COLUMBIA RIVER NEAR FAIRMONT HOT SPRINGS

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	45.807	14.311	0.312	1.028	3.780
LN X SERIES	3.781	0.294	0.078	0.349	3.166
LN(X-A) SERIES	3.474	0.396	0.114	0.034	3.467

X(MIN)= 22.000
X(MAX)= 85.200
LOWER OUTLIER LIMIT OF X= 19.689

TOTAL SAMPLE SIZE= 44
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= 10.949 M= 3.474 S= 0.396

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	21.80
1.050	0.952	27.60
1.250	0.800	34.10
2.000	0.500	43.20
5.000	0.200	56.00
10.000	0.100	64.60
20.000	0.050	72.90
50.000	0.020	83.80
100.000	0.010	92.10
200.000	0.005	101.00
500.000	0.002	112.00

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
08NA045 COLUMBIA RIVER NEAR FAIRMONT HOT SPRINGS

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	45.807	14.311	0.312	1.028	3.780
LN X SERIES	3.781	0.294	0.078	0.349	3.166

X(MIN)= 22.000
X(MAX)= 85.200
LOWER OUTLIER LIMIT OF X= 19.689

TOTAL SAMPLE SIZE= 44
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

LP3 PARAMETERS: A= 0.4876E-01 B= 35.58 LOG(M)= 2.046
M = 7.735

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	21.90
1.050	0.952	27.80
1.250	0.800	34.20
2.000	0.500	43.10
5.000	0.200	55.70
10.000	0.100	64.20
20.000	0.050	72.60
50.000	0.020	83.90
100.000	0.010	92.60
200.000	0.005	102.00
500.000	0.002	114.00

APPENDIX II

PHOTOGRAPHS OF 1986 FLOOD

PHOTOGRAPHS ARE COURTESY OF:

MR. D. BOYER, P.ENG.,

HEAD ENGINEERING SECTION

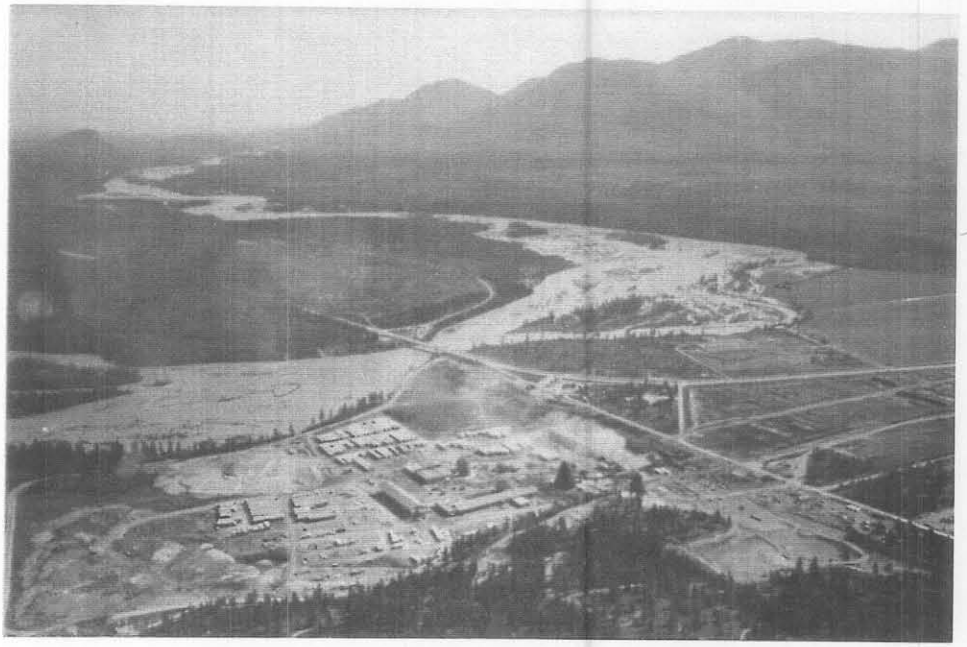
MINISTRY OF ENVIRONMENT

KOOTENAY REGION

Our file:

Date: May 29, 1986

Kootenay River
Canal Flats



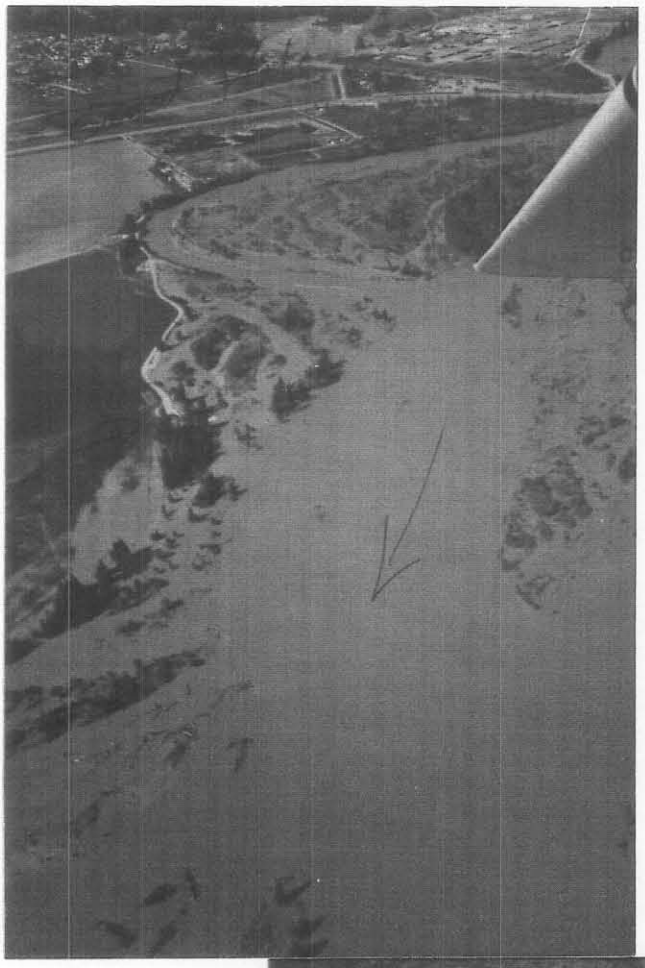
K-2 ranch house

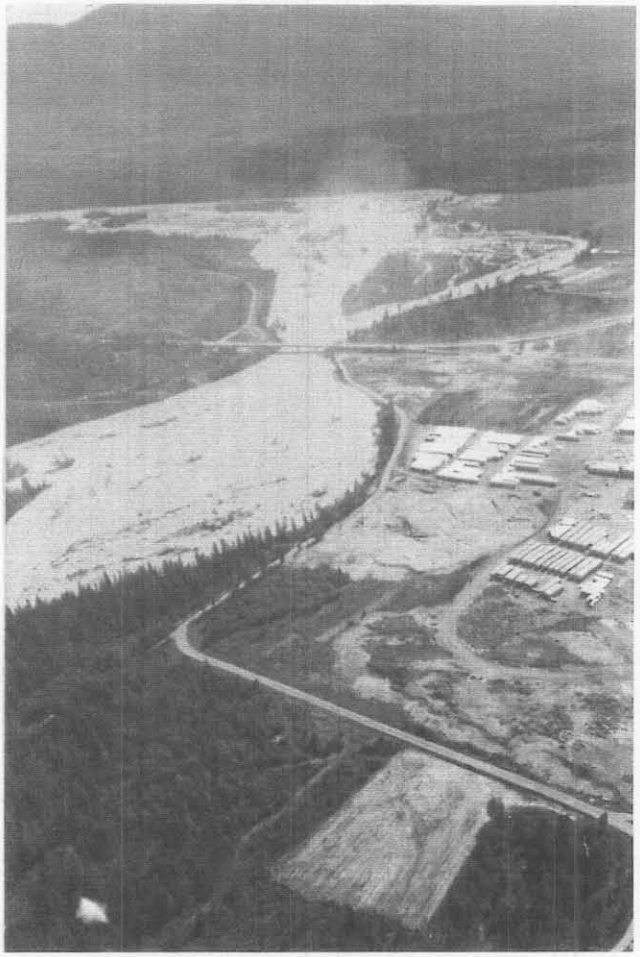


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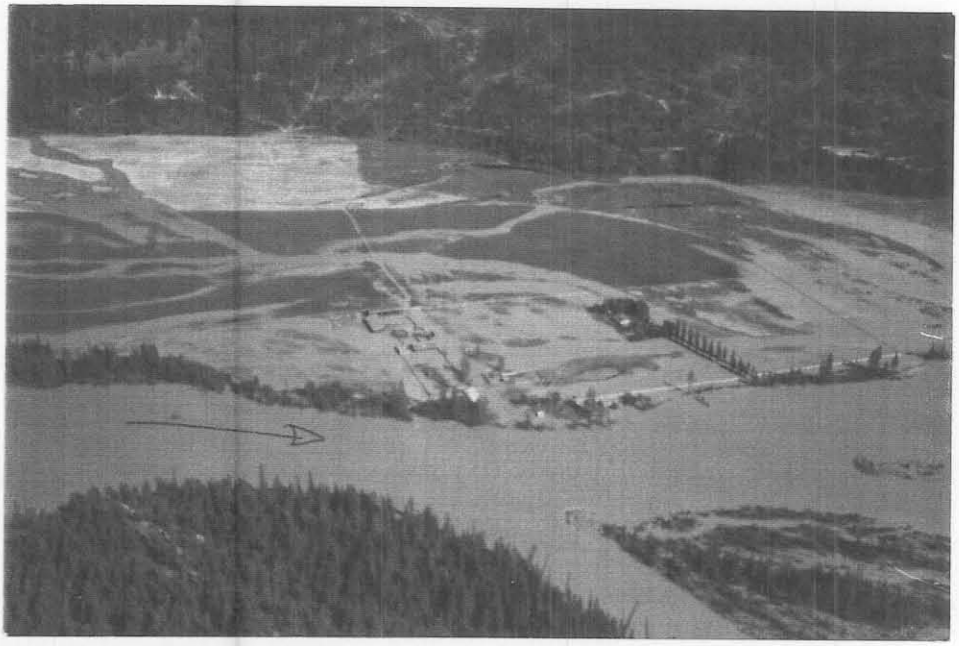
Kootenay River
Canal Flats

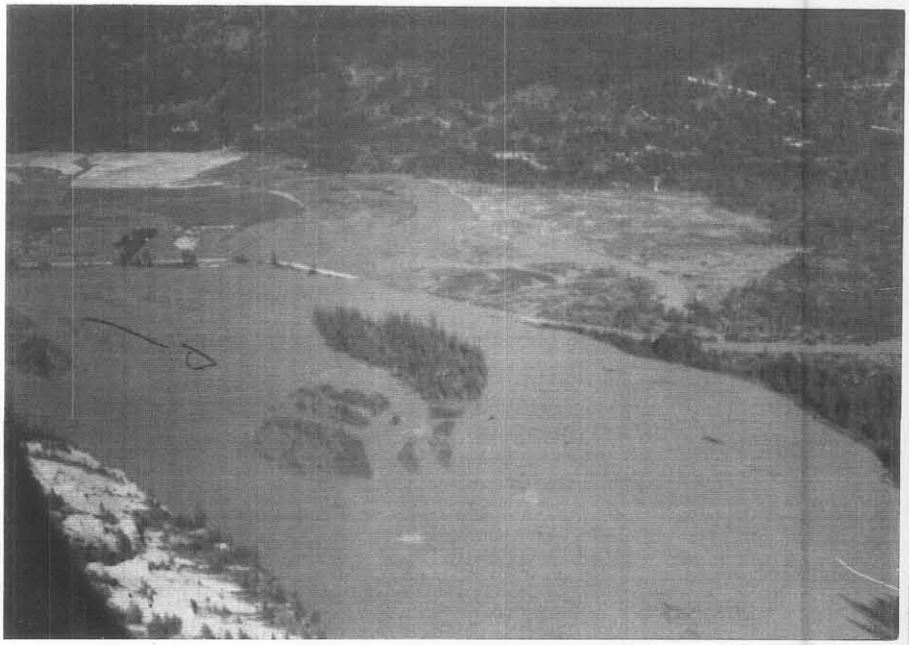


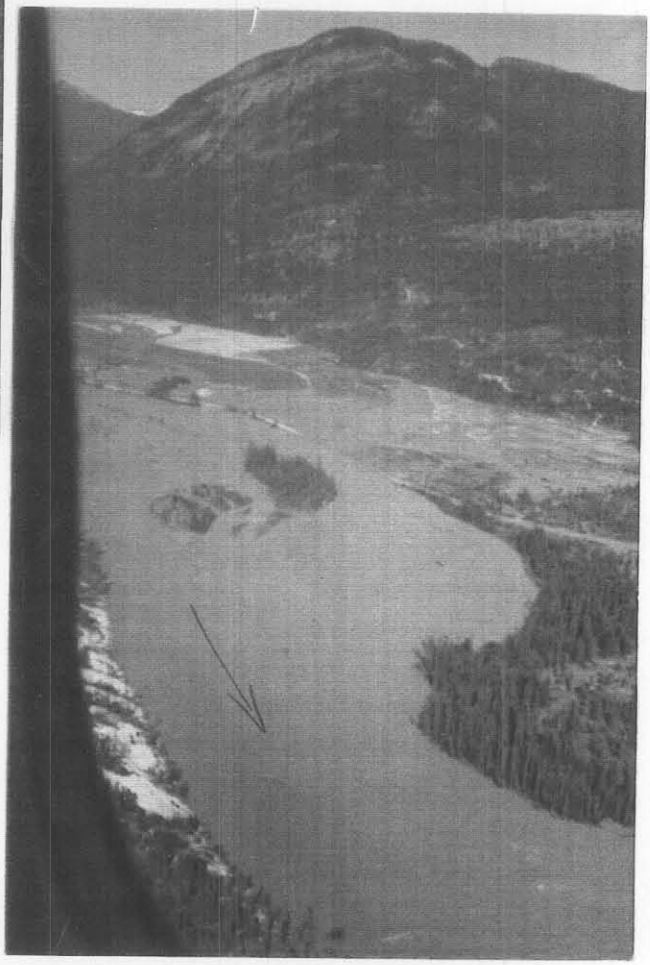




Arrow pts to ranch house on K-2 property d/s of Hwy bridge







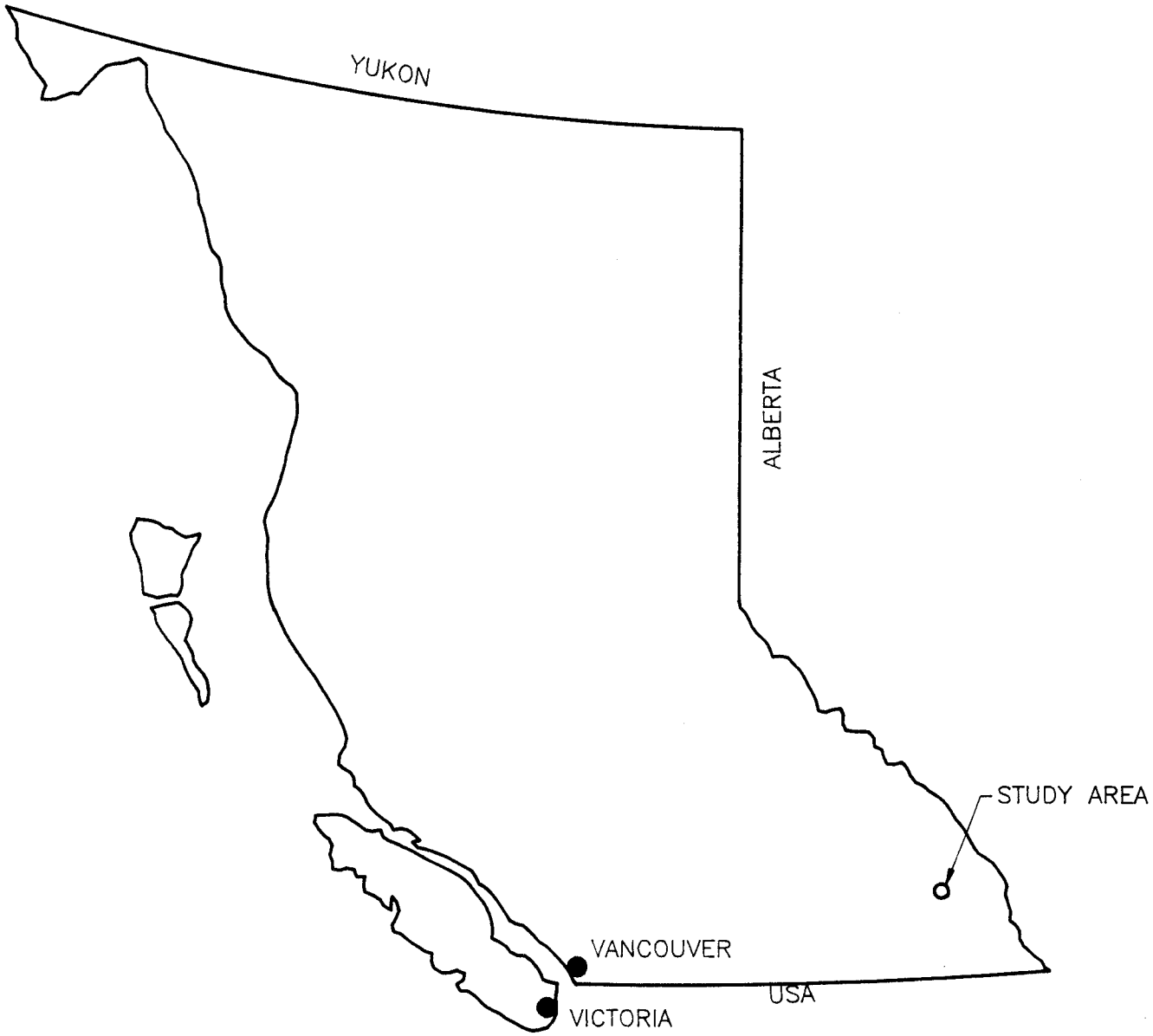
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APPENDIX III

FLOODPLAIN MAPS

LIST OF DRAWINGS

DRAWING A-1001	KEY PLAN
DRAWING A-1002	LOCATION PLAN
DRAWING B-1003	PLOT OF FLOOD PROFILE AND CALIBRATION POINTS - KOOTENAY RIVER



MAP OF BRITISH COLUMBIA

200Km 0 500Km

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SCALE

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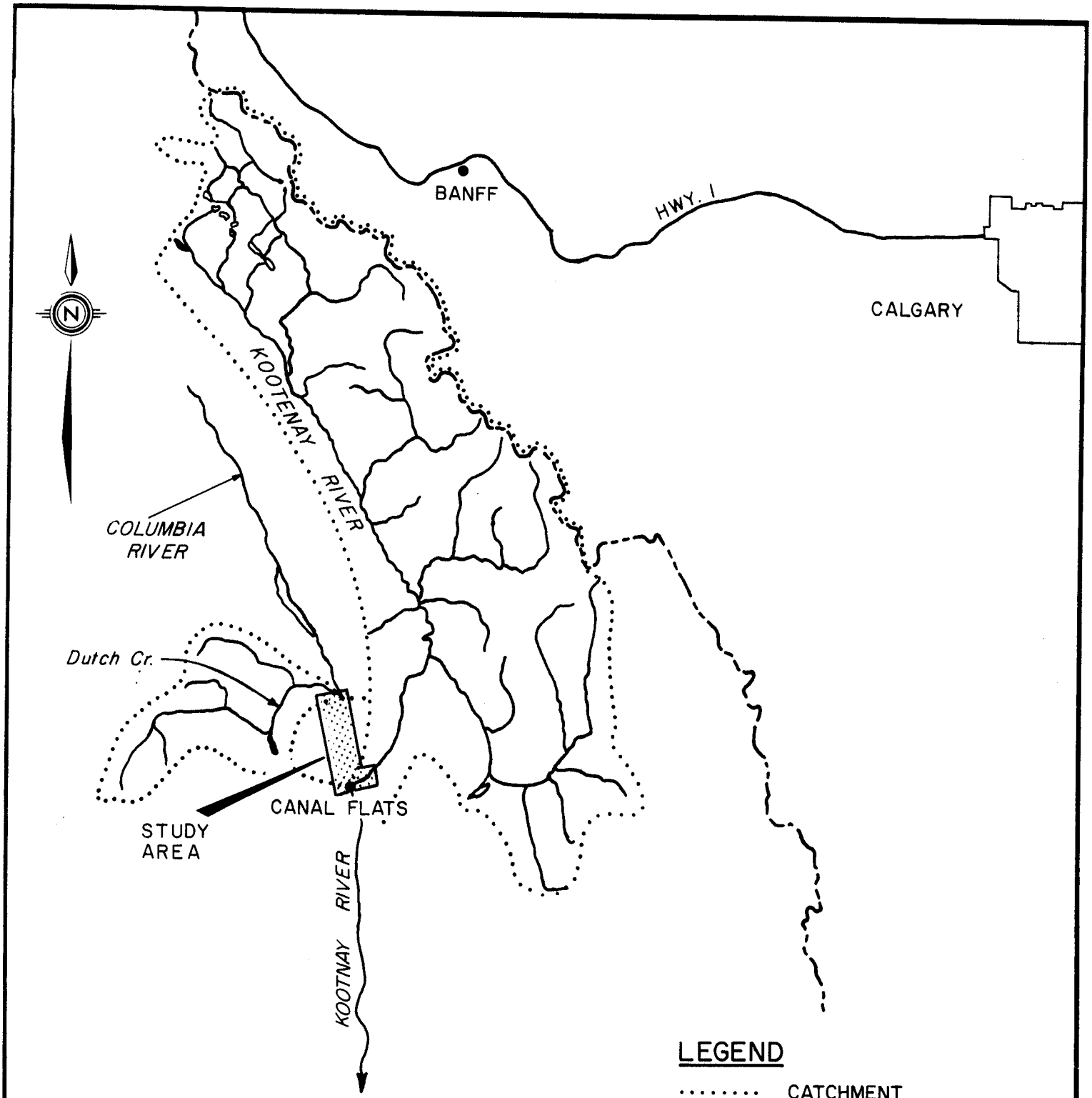
PROJECT: FLOODPLAIN MAPPING PROGRAM
KOOTENAY RIVER AT CANAL FLATS

TITLE: KEY PLAN

CLIENT: B.C. MINISTRY OF ENVIROMENT
ENVIRONMENT CANADA

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
OCT. 31, 1990	PB 5450 01	A-1001	

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SCALE

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CONSULTING ENGINEERS

PROJECT: FLOODPLAIN MAPPING PROGRAM
KOOTENAY RIVER AT CANAL FLATS

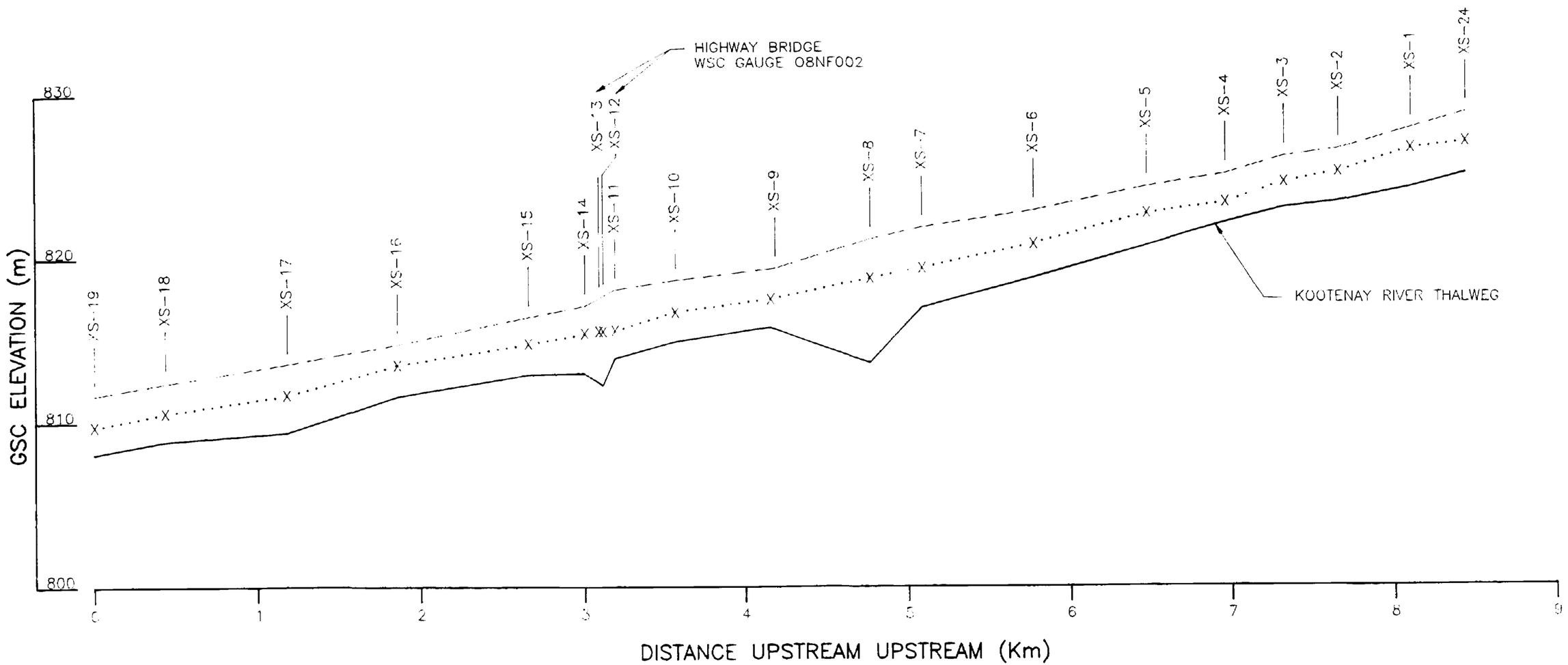
TITLE: LOCATION PLAN

CLIENT:
B.C. MINISTRY OF ENVIRONMENT
ENVIRONMENT CANADA

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
OCT. 31, 1990	PB 5450 01	A-1002	

APPROVED RB

NCI-760



LEGEND

200-YEAR DAILY PEAK (FREEBOARD NOT INCLUDED)

CALIBRATION PROFILE (25 MAY 1990 SURVEY)

TO BE READ WITH KLOHN LEONOFF REPORT DATED OCT. 31, 1990

SCALE AS SHOWN

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: B.C.MINISTRY OF ENVIRONMENT
ENVIRONMENT CANADA

PROJECT: FLOODPLAIN MAPPING PROGRAM
KOOTENAY RIVER AT CANAL FLATS

TITLE: PLOT OF FLOOD PROFILE AND
CALIBRATION POINTS – KOOTENAY RIVER

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
OCT. 31, 1990	PB 5450 01	B–1003	

APPROVED