KLOHN-CRIPPEN

May 7, 1997

Ministry of Environment, Lands and Parks
Water Management Division
765 Broughton Street
Victoria, British Columbia, V8V 1X5

Mr. R.W. Nichols, P.Eng.
Head, Floodplain Mapping Section, Hydrology Branch

Dear Mr. Nichols:

Floodplain Mapping Program, Fraser and Nechako Rivers at Prince George
Design Brief

Enclosed please find:

- 12 bound copies of the Design Brief and one unbound copy;
- one set of prints and mylars of Drawings 93-3-1 to 93-3-12;
- one CD ROM with all Drawings and HEC-2 files;
- one CD ROM with Drawings for the City of Prince George; and
- one copy of the Study File containing HEC-2 Cross Sections and output tables.

It has been a pleasure working on this interesting project.

Yours truly,

KLOHN-CRIPPEN CONSULTANTS LTD.

Richard F. Rodman, P.Eng.
Project Manager, P.Eng.

PW 7490 0101
970115

Klohn-Crippen Consultants Ltd., 10200 Shellbridge Way, Richmond, B.C., Canada, V6X 2W7 • Tel. (604) 273-0311 • Fax (604) 279-4300

Province of British Columbia

Ministry of Environment Lands & Parks

FLOODPLAIN MAPPING FRASER AND NECHAKO RIVERS AT PRINCE GEORGE

DESIGN BRIEF

PW 7490 01

APRIL 1997

COVER PHOTO

Nechako River at Foothills Bridge
during ice jam flood of November 1996.

Klohn-Crippen

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS
(continued)

TABLES

APPENDICES

TABLE OF CONTENTS
(continued)

DRAWINGS

1. INTRODUCTION

This report describes the floodplain mapping study carried out by Klohn-Crippen for the Fraser and Nechako Rivers at Prince George under the joint Federal/Provincial Floodplain Mapping Agreement. The purpose of the study is to delineate the limits of the 200-year floodplain and display flood elevations on topographic base maps. This study was carried out in accordance with specifications outlined in the Ministry of Environment, Land and Parks, Water Management Division Request for Proposal, dated June 27, 1996.

The scope of this study includes:

- review of available river survey data to confirm that it meets with the Ministry's requirements for floodplain mapping;
- determination of the 20-year and 200-year return period daily and instantaneous discharges for Fraser and Nechako Rivers;
- set up and calibration of a HEC-2 backwater model for Fraser and Nechako Rivers;
- delineation of the 200-year floodplain on topographic maps supplied by the BC Ministry of Environment; and
- documentation of the study in this comprehensive Design Brief.

A study file, which contains the HEC-2 output for all runs, has also been produced as part of this study. To ensure compliance with study specifications and procedures, discussions were held throughout the study with Mr. Richard W. Nichols, P.Eng., Ministry of Environment, Lands and Parks, Water Management Division, Victoria. Mr. Glen Davidson, of the Water Management Division in Prince George was also consulted and provided assistance for this study.

The floodplain maps, Drawings 91-3-1 to 91-3-12 listed in Appendix II, replace Drawings 5419-1 to 5419-4, issued in 1983, and extend to the limits of the City of Prince George. Drawings 91-3-1 to 91-3-5 and Drawings 91-3-11 and 91-3-12 are based on digital mapping prepared for the City of Prince George by Triathalon Mapping Corp. in April 1993. These maps were provided to BC Environment by the City to assist in the floodplain mapping study. The remaining map sheets are based on provincial topographic mapping based on 1979 air photography. A digital overlay for the digital maps has also been produced and BC Environment will provide the approximate extent of the floodplain, in digital form, to the City for planning purposes once the area is designated under the Federal/Provincial Floodplain Mapping Agreement.

2. STUDY AREA

The study area is located at the confluence of the Fraser and Nechako Rivers, see Drawing B-1001. Catchment areas of interest are listed in Table 1 below.

Table 1 Catchments of Interest

LOCATION	CATCHMENT AREA (km^2)
Nechako Reservoir at Skins Lake Spillway (WSC Gauge 08JA013)	13,933
Nechako River at Isle Pierre (WSC Gauge 08JC002)	42,500
Nechako River at confluence with Fraser River	47,100
Fraser River at Shelley (WSC Gauge 08KB001)	32,400
Fraser River at South Fort George (WSC Gauge 08KE018) (located immediately downstream of the confluence with the Nechako River)	79,500

The Fraser River has its headwaters in the Rocky Mountains along the BC/Alberta border. The highest elevations are in the order of El. 3000 m to El. 4000 m. The Salmon, Bowron and McGregor Rivers are major tributaries upstream of Prince George. The Nechako River has its headwaters in the Interior Plateau as far west as the Coast and Hazelton Mountains. Alcan's Nechako Reservoir releases water into the Nechako River via Cheslatta Lake. Major unregulated tributaries entering the Nechako River include the Francois and Fraser Lakes and Stuart River.

3. DATA USED FOR STUDY

Due to the presence of the City of Prince George at the confluence of the Fraser and Nechako Rivers flood events have been monitored and documented by the Ministry of Environment for quite some time. In addition to the survey information listed below, the Ministry of Environment working files from Victoria and Prince George were available for this study. Within these files were Ministry memos, reports and newspaper articles discussing flooding. The key references and data sources are listed below.

BC Ministry of Environment, Lands and Parks, River Survey

- Fraser/Nechako Rivers 1979 Cross Sections at Prince George - Project 79FDC04.
- Fraser/Nechako Rivers 1995 Cross Sections at Prince George - Project 9503F019.
- Fraser/Nechako Rivers 1990 High Water Marks at Prince George - Project 9017F054.
- Bridge drawings for bridges in the study area.
- Surveyed cross-section data on diskette in HEC-2 GR card format.

BC Ministry of Environment, Lands and Parks, Correspondence and Background Information

- Floodplain Mapping sheets 91-3-5 through 91-3-10.
- City of Prince George topographic mapping.
- Preliminary documentation of high water marks from the November 29 1996 ice jam flooding on the Nechako River.
- "Nechako River Water Management Plan, Appendix 2.5 - Hydrological Changes in the Nechako System Following Regulation; Appendix 2.6 -

Tributary Inflow to the Nechako River; and Appendix 2.7 - Flooding and Erosion Problems, Northern Region and Policy Planning Branch." Final Draft, February, 1990.

- "Flood Frequencies in the Fraser Basin", R. Wyman, Water Management Branch, May 24, 1985.
- Annual Reports, Omineca-Peace Region, 1968 to 1973.
- "Fraser-Nechako Rivers - 200-Year Profile at Prince George", Memo to J.H. Doughty-Davies, Head, Planning Subsection Inventory and Engineering Branch from R.W. Nichols, Senior Hydraulic Engineer, Planning Subsection, December 1, 1980, file 0305030-14.
- Discharge and observed high water marks for June 15, 1972 flood on the Fraser River.

Environment Canada, Water Survey of Canada, HYDAT CD ROM (Version 4.94), Stream Flow and Water Level Data

The stations listed in Table 2 below were used:

Table 2 List of Stations

STATION NAME	STATION NUMBER
Nechako Reservoir at Skins Lake Spillway	08JA013
Nechako River below Cheslatta Falls	08JA017
Nechako River at Vanderhoof	08JC001
Nechako River at Isle Pierre	08JC002
Fraser River at Shelley	08KB001
Fraser River at South Fort George	08KE018

4. HISTORICAL FLOODING

Flooding in this northern area can occur due to spring runoff events or due to ice jamming events. Both the Fraser and Nechako Rivers have had significant flood events due to both mechanisms. Recent historical flooding accounts and high water levels were found in several references. The major recent flood events of record were June 1972, June 1990 and November 1996. The summer floods of 1972 and 1990 affected both the Fraser and Nechako Rivers and had discharges as follows:

Table 3 Daily Flood Estimates for Historical Floods (m^3/s)

	1972	1990
Fraser River upstream of Nechako River	4980	4800
Fraser River downstream of Nechako River	5781	5203
Nechako River at Prince George	801	403

Newspaper clippings and photographs of these floods and others are included in Appendix I. It should be noted that the 1972 and 1990 floods on the Fraser River exceeded the estimated 20-year return period discharge presented in Table 11.

The 1996 ice jam flood affected only the Nechako River, resulting in estimated flood levels higher than any others, summer or winter, experienced on the Nechako River at Prince George. These reported levels are only preliminary and will be confirmed when the snow cover has melted and the high water marks can be accurately surveyed. A list of historical ice jam flood events was compiled from the files and is divided into Nechako River and Fraser River events, Tables 4 and 5. Included in these tables is the river discharge, where available. It is interesting to note that these discharges are quite small when compared to the estimated 200-year flood events presented in Section 5.

Table 4 Nechako River Ice Jams at Prince George

Approximate Date	Discharge Rate[1] (m^3/s)	Maximum Water Level (m) G.S.C.[2]	Comments
Dec. 1917	Not available	min. 569.8[3]	Flooding "similar to 1933"[5]
"early 1920s"[4]	Not available	min. 569.8[3]	"swept across the railway yards and covered the entire eastern section of the city with up to 6 ft of water"[5]
Late 1920s	Not available	572.1[6]	File notation of uncertain origin
Dec. 1933	Not available	min. 570.4[3]	"Railway yards submerged... two feet over tracks"[5]
Jan. 1937	Not available	min. 570.4[3]	Water at least two feet over the railway tracks (from photographs)
Feb. 1956	55	Not available	River Road area flooded[7]
Mar. 1957	311	min. 569.4	Highest reading occurred at beginning of available record
7 Mar. 1960[8]	212	570.7	Mills, homes flooded[5]
5 Feb. 1961	142	569.6	
22 Jan. 1953	143	569.4	
15 Dec. 1964	171	568.9	
3 Jan. 1968	140	568.9	
27 Dec. 1968	219	568.8	Flooding in Island Cache. "Several basements are just blocks of ice."[5] Level at Pulp Mill water intake[9] 568.2
26 Jan. 1970	233	min. 570.4[10]	Mills, homes flooded[5]. Level at Pulp Mill water intake 568.1
10 Dec. 1970	143	569.6	
22 Dec. 1971	193	569.1	
3 Apr. 1972	205	567.5[11]	Homes "threatened"[5]
18 Dec. 1972	182	570.0	
22 Jan. 1974	107	569.0	
15 Jan. 1975	139	569.4	
12 Jan. 1976	162	569.8	Basements flooded[5]
19 Nov. 1996	190	570.9	Preliminary level to be confirmed in 1997

See following page for notes.

Table 4 Nechako River Ice Jams at Prince George (Continued)

Notes to Table

[1]As recorded at W.S.C. Gauge 8JC002, Nechako at Isle Pierre.

[2]Unless otherwise stated, the elevations are as recorded at a former City of Prince George recording gauge, located at their water intake just upstream from the Cameron Street Bridge also known as the old Nechako Bridge (Cross Section 11).

[3] Elevations estimated at the CN Railway Station on First Avenue, about 2.2 km downstream from the City gauge. Archive photographs indicate that the elevation at the old Nechako Bridge was similar to that of the late 1920's event.

[4] Incident thought to have occurred in 1921 or 1922.

[5] From newspaper reports, in some cases written long after the event.

[6] The file notation states that this elevation may have been taken on top of the ice jam; it was observed at the old Nechako Bridge (near the City gauge used 1957-76) in "the winter of 1928, 29 or 30 or thereabouts". This reading has not been used in the present study since it is probably the top of ice.

[7] This comment comes from a 1960 reference to "the big 1956 flood", which may, however, be a mistaken reference to the March 1957 event. 1956 newspaper reports refer to a flood "threat".

[8] This and subsequent dates refer to the occurrence of peak recorded water level, or to the first of several days at the highest level.

[9] This water intake is located on the north shore of the Nechako, opposite Cottonwood Island, about 2.4 km downstream from the City gauge.

[10]Recorder did not print elevations for the previous eight days.

[11]A "dramatic 8-foot rise in water level" recorded at the Pulp Mill intake gauge, as reported in the contemporary press, was not reflected in the City gauge records at this time.

Table 5 Fraser River Ice Jams at Prince George

Date	Flow[1] (m^3/s)	Level[2] (m)	Comments
28 Dec. 1969	300	561.8	Choked confluence. Cottonwood Island homes flooded[5]
16 Dec. 1971	283	563.2	Confluence jammed. No problems[3]
13 Dec. 1972	200	563.3	Confluence jammed. Flooding and evacuation of Cottonwood Island[3]
10 Dec. 1973	328	561.5	Damage in industrial area and Cottonwood Island[3]
18 Dec. 1980	200	565.4	Flooding of Penny. Cars underwater at boat access. About 3.5 m rise in one day[4]
28 Dec. 1989	625	562.5	4 km log jam at Shelley. No damage[5]

Notes:

[1]Fraser at Shelley.

[2] At South Fort George gauge (cross section 19)

[3] Annual Report

[4] Newspaper

[5] 31 Dec. 1989 memorandum.

5. FLOOD FREQUENCY ANALYSIS

5.1 General

This section describes the hydrological analyses carried out to estimate the 20-year and 200-year return period discharges on the Fraser and Nechako Rivers at Prince George. These discharges were used for the floodplain mapping of the study area. Catchment areas and Water Survey of Canada Gauges of interest are listed in Table 6 below.

Table 6 Catchments of Interest

LOCATION	CATCHMENT AREA (km^2)	PERIOD OF RECORD
Nechako Reservoir at Skins Lake Spillway (WSC Gauge 08JA013)	13,933	39
Nechako River at Isle Pierre (WSC Gauge 08JC002)	42,500	45
Nechako River at confluence with Fraser River	47,100	-
Fraser River at Shelley (WSC Gauge 08KB001)	32,400	45
Fraser River at South Fort George (WSC Gauge 08KE018) (located immediately downstream of the confluence with the Nechako River)	79,500	27

For the reach of the Fraser River upstream of the confluence, the Water Survey of Canada (WSC) gauge, Fraser River at Shelley (08KB001), was used for the flood frequency analysis. There are 45 years of daily and instantaneous peak flow data available from this gauge which is a reasonably good data set for flood frequency analysis. For the Nechako River upstream of the confluence, the WSC gauge, Nechako River at Isle Pierre (08JC002) also has a long data set of 45 years of daily and instantaneous peak flow data. However, the flows at this gauge and downstream of Prince George on the Fraser River are influenced by operation of the Nechako Reservoir. In flood years, the BC Water Comptroller can order flow releases, from the Nechako Reservoir via Skins Lake Spillway, in the early spring and reductions in spillway

flows when the Fraser River is in flood, to mitigate flood levels on the Fraser. An estimate of 20- and 200-year flows on the Nechako River requires consideration of the current flood operation of the Nechako Reservoir.

5.2 Fraser River Analyses

The Fraser River, upstream of the Nechako River confluence, is unregulated. Due to regulation of the Nechako River, the Fraser River flows, downstream of the confluence with the Nechako River, are affected by the Skins Lake Spillway releases, Alcan's spill release facility for the Nechako Reservoir. Regulated flows on the Nechako River began in the fall of 1952, with the completion of the Kenney Dam and the filling of the Nechako Reservoir. Regulated releases from the Skins Lake Spillway commenced in 1956. At this time the WSC gauge, 08JA013, was established to record the releases from Skins Lake Spillway.

To ensure hydrologically consistent periods of record, flood frequency analyses have been carried out for the period 1956 to 1994. For Fraser River discharges upstream of the confluence with the Nechako River, the WSC gauge at Shelley (08KB001) was used. Downstream of the confluence with the Nechako River, coincident regulated discharges, prorated from the WSC gauge Nechako River at Isle Pierre (08JC002), were added to the annual maximum Shelley discharges. The coincident Isle Pierre discharges were prorated by catchment area to account for the additional local catchment between the gauge and the confluence with the Fraser River. A flood frequency analysis was then carried out on this data set to obtain the return period discharges on the Fraser River downstream of the confluence with the Nechako River. Usage of the coincident regulated Isle Pierre flows accounts for the reduction of Nechako Reservoir releases during high flows on the Fraser River.

The computer program, CFA, was used for these analyses. Although the Generalized Extreme Value (GEV), Three Parameter Lognormal and Log Pearson Type III all fit both data sets

reasonably well, the GEV distribution was selected for this study since it resulted in slightly higher discharge values. The resulting return period discharges are presented in Table 7 below and graphical output on Drawings A-1002 and A-1003.

Table 7 Fraser River Peak Daily Flow Estimates (m^3/s)

	20-YEAR	200-YEAR
Fraser River at Shelley (upstream of Nechako River)	4470	5560
Fraser River downstream of Nechako River	5180	6200

5.3 Nechako River Analyses

5.3.1 General

To account for the regulation of the Nechako River, the return period discharges have been determined for the unregulated inflows downstream from the Skins Lake Spillway. Separate reservoir routings were then carried out for the Nechako Reservoir to estimate the spill discharge which would occur when the unregulated Nechako River flows are peaking. The unregulated inflows and Nechako Reservoir releases were then combined to obtain the design discharge for floodplain mapping on the Nechako River at Prince George. Maximum flows on the Nechako River at Prince George occur in late June or July, with a few instances in May and August.

5.3.2 Unregulated Inflows

Inflows between the Skins Lake Spillway and Prince George were estimated by subtracting the Skins Lake Release from the Nechako River recorded discharge at Isle Pierre. The period 1956 to 1994 was used, consistent with the analyses on the Fraser River. The travel time for releases from Skins Lake Spillway to Prince George is approximately one week. Releases which occurred approximately one week prior to the maximum annual recorded discharge at

Isle Pierre were subtracted from the Isle Pierre discharge. In some cases the daily releases were varying significantly and therefore preference to selecting lower release values was done to maximize the unregulated inflow component. Flood frequency analysis was carried out on the estimated unregulated inflows. The Generalized Extreme Value distribution was selected. The results are presented in Table 8 and on Drawing A-1004.

Table 8 Peak Flow Estimates for Unregulated Inflows on the Nechako River (m^3/s)

	20-YEAR	200-YEAR
Nechako River at Isle Pierre	651	815
Nechako River at Prince George	723	905

5.3.3 Nechako Reservoir Routing

To estimate the releases from the Nechako Reservoir corresponding to 20-year and 200-year return period events, characteristic inflow hydrographs (Klohn Leonoff, 1992) were routed through the reservoir. The routings were commenced on April 1 since prior to that the Nechako River can be ice covered. An increase in flows when an ice cover is present may result in ice jams and flooding. Inflow forecasting is currently used to determine the spill quantities from the Nechako Reservoir. Discussions are held between Ministry of Environment, Fisheries and Alcan to determine the spill schedule each year. If large inflows are predicted a pre-spill is released to lower the reservoir level and to allow reduction of spill releases when the Fraser River at Prince George is in flood, generally in June or July.

To ensure that release flows were not underestimated, conservative operating procedures were assumed as follows:

- spill releases from April 1 to the end of May matched the historical releases for 1972 and 1976 when conditions approximated a 20- and a 200-year inflow event respectively;
- releases from the powerhouse assumed seven out of eight units were operating;
- after June 01, releases from Skins Lake Spillway were adjusted to ensure that the reservoir level did not exceed the Maximum Normal Level (MNL), El. 853.44 m;
- the releases from the spillway were assumed to remain constant over the monthly intervals of June and July; and
- the April 01 reservoir level was based on the maximum recorded level of El. 851.8 m for April 01.

This analysis gave the following outflow estimates at Skins Lake spillway.

Table 9 Nechako Reservoir Peak Daily Flow Estimates (m^3/s)

	20-YEAR	200-YEAR
Inflow Peak	1230	1540
Routed Outflow	300	460

The peak flow estimates for the Nechako River at Prince George were derived by combining the outflow estimates for the Nechako Reservoir with the unregulated inflow estimates as shown in Table 10. Since releases from Skins Lake Spillway were assumed to be constant for monthly intervals, they would then coincide with the peak daily unregulated inflows presented in Table 10.

Table 10 Nechako River Peak Daily Flow Estimates (m^3/s)

	20-YEAR	200-YEAR
Nechako Reservoir	300	460
Unregulated Inflow	723	905
Total at Prince George	1023	1365

5.4 Summary

Because the methodology for both the Fraser and Nechako Rivers has required flow summations, it is unlikely peak instantaneous flows will occur concurrently. In addition the Fraser River flood events are a result of extreme hydrological conditions over a very large catchment resulting in gradually increasing flood hydrographs, not "flashy" flood events. The difference between maximum mean daily discharge and maximum instantaneous discharge is negligible. Similarly the Nechako River is not "flashy" either. Flood releases from the Nechako Reservoir, once they reach the confluence with the Fraser River, tend to be gradual. We therefore based our floodplain mapping on peak daily flow estimates presented in Table 11 below.

Table 11 Design Daily Flood Estimates (m^3/s)

	20-YEAR	200-YEAR
Fraser River upstream of Nechako River	4470	5560
Fraser River downstream of Nechako River	5180	6200
Nechako River at Prince George	1023	1365

The previous floodplain mapping study used a discharge of 6,200 m^3/s for the 200-year return period discharge on the Fraser River and 850 m^3/s for the 200-year return period discharge on

the Nechako River (Memo to Watts, Head Planning and Surveys Section, Inventory and Engineering Branch, Ministry of Environment, from R. Nichols, dated March 25, 1981).

The Fraser River flood flows remain unchanged from the previous study. The estimate of 1365 m^3/s for the 200-year flow on the Nechako River at Prince George from the present study is greater than the value of 850 m^3/s used in 1981. However, in the 1981 study, sensitivity studies indicated that a flow of 1,275 m^3/s would not exceed the flood levels shown on the mapping (includes an allowance for hydraulic and hydrologic uncertainty) due to the influence of Fraser River flood levels. Therefore, open water flood levels would not be expected to increase significantly over those used in 1981. However, as described in Section 7, accounting for the effects of ice jamming is much more significant than the variation in the open water flood flows.

6. HYDRAULIC ANALYSIS

6.1 General

Water surface profiles were estimated with the HEC-2 computer program. Input to this program includes cross-section geometry, reach lengths, discharges, ineffective flow areas and estimates of energy loss coefficients. Calibration of the computer model with known flows and corresponding river elevations is required to model river levels at various flows. Caution must be used when modelling beyond calibration events.

Cross-section geometry and reach lengths were obtained from detailed surveys which were carried out by the Ministry of Environment in 1979 and 1995. Locations of all cross sections are shown on the floodplain maps listed in Appendix II. The cross-section data was provided to Klohn-Crippen along with topographic maps showing their locations and a set of photographs at each cross section showing the banks and views looking upstream and downstream. A site visit was made by Mr. Richard Rodman of Klohn-Crippen, on September 17 and 18, 1996 , to assist in determining the correct modelling coefficients and cross-section configurations. Areas of flooding during extreme events were also inspected during the site visit and the Ministry of Environment, Prince George office, flood files were reviewed.

A second site visit was made by Mr. Richard Rodman on February 24, 1997 to review the initial floodplain limits which had been identified on the maps. Areas of particular concern included the Northwood Pulp Mill area, on the Fraser River, and the Heritage River Trail and Hudson Bay Slough areas near downtown Prince George.

The following sections describe the river profile model and model calibration.

6.2 HEC-2 River Model Setup and Calibration

The cross sections provided by the Ministry of Environment were imported into HEC-2. Back channel sections were connected to main channel sections to span the valley from side to side. Based on cross section photographs, field observations and the survey data file, overbank locations were identified and marked as such. Extensions to the cross-sections were made, where required, based on the topographic maps provided by the Ministry of Environment and the City of Prince George.

The bridges located on the Fraser and Nechako Rivers induce headlosses primarily because causeways for the Northwood Bridge, on the Fraser River, and the John Hart Bridge, on the Nechako River, restrict overbank flow. The standard bridge routine and standard step backwater routine were used to model the losses due to the constructions and bridge piers.

Two major open water flood events were used for calibration: June 1972 and June 1990. The discharges for these events are as follows:

Table 12 Calibration Event Flood Estimates (m^3/s)

	1972	1990
Fraser River upstream of Nechako River	4980	4800
Fraser River downstream of Nechako River	5781	5203
Nechako River at Prince George	801	403

The profiles for the calibration events are shown on Drawing A-1005 and A-1006 along with the surveyed high water marks. Also included on Drawing A-1006 are the preliminary ice jam flood levels for the Nechako River.

For overbank areas which are densely treed a Manning's "n" of 0.15 was used, while for open or sparsely vegetated overbank areas an "n" value of 0.05 was used. As part of the calibration process main channel "n" values of 0.029, for the Fraser River, and 0.028, for the Nechako River, were derived. The standard contraction and expansion loss coefficients of 0.1 and 0.3 were used.

Drawing A-1005 shows the Fraser River HEC-2 calibration runs. The 31 1990 high water marks and the 17 1972 high water marks were generally well replicated in the runs, with a few exceptions. Between chainage 5,000 m and 10,000 m the observed 1972 high water marks were higher than the calculated levels. This may have been due to temporary debris jams or interpretation of high water marks in the field. Drawing A-1006 shows the Nechako River HEC-2 calibration runs. The 9 1996 ice jam water levels, 10 1990 high water levels and the 12 1972 high water levels are plotted along with the calculated levels from HEC-2. The 1972 flood is slightly overestimated while the 1990 levels are reasonably well modelled. It can be seen that the 1996 ice jam water levels are well below the open water high water marks near the mouth of the river and well above the open water high water marks in the upstream reach. The influence of the Fraser River level can be seen from chainage 0 m to 4,000 m. In general the open water calibrations for both the Fraser and Nechako Rivers are reasonable.

7. FLOOD LEVELS

7.1 General

Due to their northern location, the Fraser and Nechako Rivers are not only subject to spring snowmelt flood events, but also winter ice jam flood events. These two flooding mechanisms are described separately below.

7.2 Calculated Open Water Conditions

The daily flood discharges described in Section 5 were input into the HEC-2 model for the Fraser and Nechako Rivers resulting in the 20-year and 200-year flood levels presented in Tables 14 and 15 in Section 7.5. Due to the expected long duration of the flood events on both rivers, it has been assumed that the flood events are coincident. As shown in Table 15 the lower 4 km of the Nechako River is affected by the water level on the Fraser River. This can also be seen on the calibration events shown on Drawing A-1006.

7.3 Sensitivity Analysis

Sensitivity analyses were done to estimate the effect of modelling data assumptions on calculated design 200-year water levels. Manning's "n" and discharge were varied for the analyses and the results are shown in Table 13. A plus or minus 10% variation in Mannings' "n" resulted in a maximum variation on both rivers of plus or minus 0.5 m. Discharge was varied plus or minus 10% resulting in a maximum variation of plus or minus 0.5 m.

Table 13 - Sensitivity Analysis Results

Reach Description	Cross Section	Water Level Variation from Design Levels (m)							
		200-year Flood				20-year Flood			
		Manning's "n"		Discharge		Manning's "n"		Discharge	
		Plus 10%	Minus 10%	Design Discharge Plus 10%	Design Discharge Minus 10%	Plus 10%	Minus 10%	Design Discharge Plus 10%	Design Discharge Minus 10%
Fraser River Downstream of Confluence	Downstream Extent of Study								
	1	0.4	-0.4	0.4	-0.4	0.4	-0.4	0.4	-0.4
	2	0.4	-0.5	0.4	-0.4	0.4	-0.4	0.4	-0.4
	3	0.4	-0.5	0.4	-0.4	0.4	-0.4	0.4	-0.4
	4	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.4
	5	0.4	-0.5	0.4	-0.5	0.4	-0.4	0.4	-0.4
	6	0.4	-0.5	0.4	-0.5	0.4	-0.4	0.4	-0.4
	7	0.4	-0.4	0.4	-0.4	0.4	-0.4	0.4	-0.4
	8	0.4	-0.4	0.4	-0.5	0.4	-0.4	0.4	-0.4
	9	0.4	-0.5	0.4	-0.5	0.4	-0.4	0.4	-0.4
	10	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	11	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.5
	12	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	13	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	14	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	15	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.4
	Simon Fraser Bridge (Highway 97)								
	16	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	17	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	18	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.4
	19	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	20	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.4
	20.3	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	Yellowhead Bridge (Highway 16)								
	21	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	21.5	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	22	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	23	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	CN Bridge								
	24	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	25	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	26	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
Confluence with Nechako River									

Table 13 - Sensitivity Analysis Results (continued)

Reach Description	Cross Section	Water Level Variation from Design Levels (m)							
		200-year Flood				20-year Flood			
		Manning's "n"		Discharge		Manning's "n"		Discharge	
		Plus 10%	Minus 10%	Design Discharge Plus 10%	Design Discharge Minus 10%	Plus 10%	Minus 10%	Design Discharge Plus 10%	Design Discharge Minus 10%
Fraser River Upstream of Confluence	27	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	28	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	29	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	BCR Bridge								
	30	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.5
	31	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.5
	32	0.5	-0.5	0.5	-0.5	0.4	-0.4	0.5	-0.5
	33	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	34	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.5	-0.5
	35	0.5	-0.5	0.5	-0.5	0.4	-0.4	0.5	-0.5
	36	0.5	-0.5	0.5	-0.5	0.4	-0.4	0.5	-0.5
	37	0.4	-0.5	0.5	-0.6	0.4	-0.4	0.5	-0.5
	38	0.4	-0.5	0.5	-0.6	0.4	-0.4	0.5	-0.5
	39	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.5	-0.5
	40	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.5	-0.5
	41	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.4
	42	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.5
	43	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.5
	44	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.5
	45	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.5
	46	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.4
	47	0.4	-0.5	0.5	-0.5	0.4	-0.4	0.4	-0.4
	48	0.5	-0.5	0.4	-0.5	0.4	-0.4	0.4	-0.4
	49	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	50	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	51	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	52	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	Northwood Bridge								
	52.5	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	52.7	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	53	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.5
	54	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	55	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	56	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	57	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	58	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	59	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	60	0.4	-0.4	0.4	-0.5	0.4	-0.4	0.4	-0.4
	61	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	Upstream Extent of Study								

Table 13 - Sensitivity Analysis Results (continued)

Reach Description	Cross Section	Water Level Variation from Design Levels (m)							
		200-year Flood				20-year Flood			
		Manning's "n"		Discharge		Manning's "n"		Discharge	
		Plus 10%	Minus 10%	Design Discharge Plus 10%	Design Discharge Minus 10%	Plus 10%	Minus 10%	Design Discharge Plus 10%	Design Discharge Minus 10%
Confluence with Fraser River									
Nechako River	1	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	2	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	3	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	4	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.5	-0.5
	5	0.4	-0.4	0.5	-0.5	0.4	-0.4	0.4	-0.4
	6	0.4	-0.4	0.5	-0.5	0.4	-0.3	0.4	-0.4
	7	0.4	-0.4	0.4	-0.4	0.3	-0.3	0.4	-0.4
	8	0.3	-0.4	0.4	-0.4	0.3	-0.3	0.3	-0.3
	9	0.3	-0.3	0.4	-0.3	0.3	-0.3	0.3	-0.3
	10	0.3	-0.3	0.4	-0.3	0.3	-0.3	0.3	-0.3
	Cameron Street Bridge (Old Nechako River Bridge)								
	11	0.3	-0.3	0.3	-0.3	0.3	-0.3	0.3	-0.3
	12	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.3	-0.2
	13	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	14	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	John Hart Bridge (Highway 97)								
	15	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	16	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	17	0.2	-0.2	0.3	-0.3	0.2	-0.2	0.2	-0.2
	18	0.2	-0.2	0.3	-0.3	0.2	-0.2	0.2	-0.2
	19	0.2	-0.2	0.3	-0.3	0.2	-0.2	0.2	-0.2
	20	0.2	-0.2	0.2	-0.2	0.2	-0.2	0.2	-0.2
	21	0.2	-0.2	0.2	-0.2	0.2	-0.2	0.2	-0.2
	22	0.2	-0.2	0.2	-0.2	0.2	-0.2	0.2	-0.2
	Foothills Bridge								
	23	0.2	-0.2	0.2	-0.3	0.2	-0.2	0.2	-0.2
	24	0.2	-0.2	0.2	-0.3	0.2	-0.2	0.2	-0.2
	25	0.2	-0.3	0.2	-0.3	0.2	-0.2	0.2	-0.2
	26	0.3	-0.3	0.2	-0.3	0.2	-0.2	0.2	-0.2
	27	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	28	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	29	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	30	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	31	0.3	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	32	0.2	-0.3	0.2	-0.2	0.2	-0.2	0.2	-0.2
	33	0.2	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	34	0.2	-0.3	0.3	-0.3	0.2	-0.2	0.2	-0.2
	Upstream Extent of Study								

7.4 Ice Jam Conditions

Tables 4 and 5, presented in Section 4, Historical Flooding, document most of the major flooding events resulting from ice jams. The scope of the present study did not include hydraulic modelling of ice jam flood events, but only compilation, review and interpretation of historical events. Although ice jam flooding events do occur on the Fraser River, those that have been documented near the South Fort George Gauge are 3 or more metres lower than estimated open water flood levels. Based on this information, ice jam flooding on the Fraser River does not govern the flood levels, but rather open water flooding.

On the other hand the Nechako River ice jam flood events are similar to and higher than the open water flood levels. This is due to the variability of winter flows on the Nechako River and the channel geometry. Disruption of the upstream ice cover and formation of frazil ice, when the air temperature is very low, results in ice jamming of the relatively narrow and shallow Nechako River near its confluence with the Fraser River. If the Fraser River has a stable ice cover then the mobilized ice on the Nechako River cannot discharge downstream and ice jams are formed. With sufficient ice supply from upstream, ice jam flooding could occur throughout the study area on the Nechako River.

The ice jam flood levels at the former City of Prince George recording gauge, located just upstream from the Cameron Street Bridge, also known as the old Nechako Bridge (XS- 11), are listed in Table 4. These levels were plotted on probability paper using a plotting position based on an 80 year period of record, as shown on Drawing A-1007. The resulting 200-year return period level was El. 571.2 m, slightly higher than the estimated flood level of El. 570.9 m, for the 1996 ice jam flood event. The estimated open water 200-year return period flood level at this location, of El. 570.3 m, not including contingency allowance, is 0.6 m below the 1996 estimated ice jam flood level and 0.9 m

below the estimated 200-year return ice jam flood level. Further upstream from this point, the estimated ice jam flood levels for 1996 are approximately 1.5 m above the calculated open water 200-year flood levels. This indicates that ice jam flooding is far more significant than open water flooding on the Nechako River.

7.5 Design River Flood Levels

The design river flood levels, including contingency allowances are discussed below and presented in Table 14, for the Fraser River, and Table 15 for the Nechako River. These levels were used to delineate the floodplain limits shown on the floodplain maps, Drawings 91-3-1 to 91-3-12. The profiles for the design water levels are shown on Drawings A-1008 and A-1009.

The digital floodplain maps will be provided by BC Environment to the City of Prince George for planning purposes once the area is designated under the Federal/Provincial Floodplain Mapping Agreement. All flood level information and notes have been excluded from these maps and only the extent of the 200-year return period floodplain will be included on the maps provided to the City.

An appropriate contingency allowance, commonly known as "freeboard", must be added to the calculated water levels to obtain the flood levels shown on the drawings. The sensitivity analyses indicated that the usual 0.3 m of allowance on top of the flood levels derived using mean daily discharges is not sufficient. For the Fraser River a contingency allowance of 0.6 m will be sufficient to encompass variation in levels indicated by the sensitivity analyses. The resulting flood levels, including contingency allowance, used for the floodplain mapping for the Fraser River are presented in Table 14. A frequency analysis of the maximum annual water levels at the WSC gauge Fraser River at South Fort George (Cross Section 19), see Drawing A-1010, resulted in a 200-year level of El. 569.0 m and a 20-year level of

Table 14 - Design Fraser River Flood Profiles

Reach Description	Cross Section	200-Year Design Level (m) [1]	20-Year Design Level (m) [1]
Fraser River Downstream of Confluence	Downstream Extent of Study		
	1	563.3	562.5
	2	563.5	562.8
	3	563.9	563.2
	4	564.6	563.8
	5	565.1	564.3
	6	565.6	564.8
	7	566.1	565.4
	8	566.5	565.8
	9	567.2	566.4
	10	567.5	566.7
	11	567.7	566.8
	12	567.9	567.0
	13	567.9	567.1
	14	568.1	567.3
	15	568.4	567.6
	Simon Fraser Bridge (Highway 97)		
	16	568.4	567.6
	17	568.4	567.6
	18	568.7	567.9
	19	569.3	568.5
	20	569.6	568.8
	20.3	569.9	569.1
	Yellowhead Bridge (Highway 16)		
	21	569.9	569.1
	21.5	569.9	569.1
	22	570.1	569.2
	23	570.1	569.2
	CN Bridge		
	24	570.1	569.2
	25	570.1	569.2
	26	570.1	569.2
Confluence with Nechako River			

Table 14 - Design Fraser River Flood Profiles (continued)

Reach Description	Cross Section	200-Year Design Level (m) [1]	20-Year Design Level (m) [1]
Fraser River Upstream of Confluence	27	570.1	569.2
	28	570.2	569.4
	29	570.3	569.4
	BCR Bridge		
	30	570.3	569.5
	31	570.3	569.5
	32	570.5	569.6
	33	571.0	570.1
	34	571.3	570.3
	35	571.4	570.4
	36	571.5	570.5
	37	571.8	570.8
	38	571.9	570.9
	39	572.0	571.0
	40	572.1	571.1
	41	572.2	571.3
	42	572.6	571.6
	43	572.9	571.9
	44	573.0	572.0
	45	573.2	572.2
	46	573.4	572.5
	47	573.7	572.7
	48	573.7	572.8
	49	574.4	573.4
	50	574.4	573.4
	51	574.6	573.6
	52	574.6	573.6
	Northwood Bridge		
	52.5	574.6	573.6
	52.7	574.6	573.6
	53	574.8	573.8
	54	575.0	574.0
	55	575.2	574.2
	56	575.4	574.4
	57	575.5	574.6
	58	576.0	575.0
	59	576.1	575.2
	60	576.4	575.5
	61	576.8	575.9
	Upstream Extent of Study		

Note: *1. Contingency allowance, commonly known as "freeboard", of 0.6m was used*

Table 15 - Design Nechako River Flood Profiles

Cross Section	200-Year Design Levels (m)			20-Year Design Levels (m)		
	Open Water Level (m) [1]	Ice Jam Level (m) [2]	Design Level (m) [3]	Open Water Level (m) [1]	Ice Jam Level (m) [4]	Design Level (m) [3]
Confluence with Fraser River						
1	570.2	565.4	**570.2**	569.3	565.2	**569.3**
2	570.2	566.9	**570.2**	569.3	566.6	**569.3**
3	570.2	567.6	**570.2**	569.3	567.3	**569.3**
4	570.2	568.9	**570.2**	569.3	568.5	**569.3**
5	570.3	569.7	**570.3**	569.4	569.2	**569.4**
6	570.4	570.1	**570.4**	569.5	569.6	**569.6**
7	570.5	570.7	**570.7**	569.7	570.1	**570.1**
8	570.7	571.1	**571.1**	569.9	570.6	**570.6**
9	570.9	571.6	**571.6**	570.2	571.2	**571.2**
10	570.9	571.6	**571.6**	570.2	571.2	**571.2**
Cameron Street Bridge (Old Nechako River Bridge)						
11	570.9	571.7	**571.7**	570.2	571.2	**571.2**
12	571.3	572.3	**572.3**	570.7	571.7	**571.7**
13	571.5	572.5	**572.5**	570.9	572.0	**572.0**
14	571.6	572.6	**572.6**	571.0	572.1	**572.1**
John Hart Bridge (Highway 97)						
15	571.6	572.6	**572.6**	571.0	572.1	**572.1**
16	571.8	572.9	**572.9**	571.2	572.4	**572.4**
17	572.2	573.3	**573.3**	571.6	572.7	**572.7**
18	572.6	573.7	**573.7**	571.9	573.1	**573.1**
19	572.9	574.1	**574.1**	572.3	573.5	**573.5**
20	573.3	574.5	**574.5**	572.7	573.9	**573.9**
21	573.9	575.1	**575.1**	573.3	574.5	**574.5**
22	574.2	575.4	**575.4**	573.6	574.8	**574.8**
Foothills Bridge						
23	574.7	575.9	**575.9**	574.1	575.3	**575.3**
24	575.1	576.3	**576.3**	574.4	575.6	**575.6**
25	575.4	576.6	**576.6**	574.8	576.0	**576.0**
26	575.8	577.0	**577.0**	575.2	576.4	**576.4**
27	576.2	577.4	**577.4**	575.5	576.7	**576.7**
28	576.7	577.9	**577.9**	576.0	577.2	**577.2**
29	577.3	578.5	**578.5**	576.6	577.8	**577.8**
30	577.7	578.9	**578.9**	577.0	578.2	**578.2**
31	578.2	579.4	**579.4**	577.5	578.7	**578.7**
32	578.9	580.1	**580.1**	578.3	579.5	**579.5**
33	580.0	581.2	**581.2**	579.3	580.5	**580.5**
34	580.4	581.6	**581.6**	579.7	580.9	**580.9**
Upstream Extent of Study						

Note: *1. 200-year discharge on Fraser + Nechako Rivers with 0.6 contingency allowance*
2. Average winter discharge on Fraser R and 200yr discharge on Nechako R with 1.8m contingency allowance
3. Maximum of open water and ice jam levels used for mapping
4. Average winter discharge on Fraser R and 20yr discharge on Nechako R with 1.8m contingency allowance

El. 567.7 m. These levels indicate that the design flood levels in Table 14, including the contingency allowance, are adequate.

As can be seen on Drawings A-1005 and A-1008, the slope of the Fraser River water surface profiles increases downstream of its confluence with the Nechako River. In this reach the Fraser River is confined by high banks, except in a few locations. In contrast, upstream of the confluence with the Nechako River, the Fraser River meanders and has a very wide floodplain. Field observations and historic accounts of flooding indicate that bank erosion does occur in this reach. Notes have been added to the floodplain maps in this reach regarding the possibility of debris and ice jamming and channel relocation. There are also some locations, noted on the maps, which are above the 200-year return period flood level but may be subject to flooding from upstream high water levels.

For the Nechako River the estimated ice jam flood levels for the 1996 event varied from 0.6 m to 1.5 m higher than the 200-year return period open water flood levels, see Drawing A-1009. In the light of this event, and the fact that four other ice jam flood events have produced flood levels at the old Nechako River bridge similar to the 1996 levels , the ice jam flood levels govern the flood construction levels on the Nechako River. To to account for ice jam flood events on the Nechako River, a contingency allowance of 1.8 m was added to the 200-year modelled flood levels.

The Fraser River levels govern the water levels on the lower reaches of the Nechako River. Applying a 1.8 m ice jam contingency allowance in the lower reaches of the Nechako River, which are directly influenced by the 200-year return period open water flood level on the Fraser River, would be overly conservative. To provide a transition from the open water contingency allowance of 0.6 m on the Fraser River to the ice jam contingency allowance of 1.8 m on the Nechako River two HEC-2 simulations were run: 200-year return period discharge on both

the Fraser and Nechako Rivers with a 0.6 m contingency allowance; and 200-year return period discharge on the Nechako River combined with the average winter discharge, 200 m^3/s, on the Fraser River with a 1.8 m contingency allowance. The results of these simulations for the Nechako River are presented in Table 15. In the lower reaches of the Nechako River the first HEC-2 run governs with the contingency allowance of 0.6 m, while for the remainder of the study area upstream, the second HEC-2 run governs with the contingency allowance of 1.8 m. The resulting highest levels, used for floodplain mapping, are presented in Table 15.

Based on the discussion presented above, detailed ice jam modelling is warranted on the Nechako River to thoroughly address the issue of flood construction levels. The methodology developed above is somewhat approximate, and in fact still requires confirmation of the 1996 ice jam flood levels when the snowcover has gone. In addition, the 1996 ice jam flood levels were only observed in the first 6 km of the Nechako River (see Drawing A-1009) and it is assumed that the same conditions could occur further upstream resulting in similar elevated ice jam flood levels.

There are some areas where detailed studies would be required to improve the estimate of the 200-year return period flood level because the level is affected by local structures, embankments and potential blockages. One of these areas is on Drawing 91-3-8 immediately south of Northwood Pulp Mill. There are two railway embankments and one road embankment with several culverts through each. Blockages could occur at any one of these embankments. For the purposes of the present mapping it has been assumed that the furthest downstream embankment is blocked.

The other area where detailed studies would be required to improve the estimate would be of the 200-year flood level in the Heritage River Trail and Hudson Bay Slough areas just south of downtown Prince George, see Drawing 91-3-3. These areas act as local

stormwater drainage areas into the Fraser River. A series of road embankments cross the area with either pipe arch or circular culverts. The flood levels shown on the mapping are based on evidence from the 1948 and 1972 floods and the assumption that partial blockage could occur at these embankments. Flood levels will be affected by the amount of incoming water, both from local runoff and from Nechako River flood water. The levels shown on the mapping are estimates only and have not been derived from detailed analysis of the expected flows and headlosses through this area.

8. CONCLUSIONS

1. This Design Brief presents an overview of the studies undertaken to produce the floodplain mapping sheets for the Fraser and Nechako Rivers.

2. The Nechako River floodplain in the study area has a documented history of ice jam flooding dating back to the early 1900s. To a lesser extent, ice jam flooding has also occurred on the Fraser River upstream of Prince George.

3. The floodplain maps are administrative tools which depict minimum elevations for floodproofing. They are not comprehensive floodplain management plans and do not provide solutions to site specific problems.

4. Flooding may occur outside of the designated floodplain. Tributaries, ice jamming, channel obstructions and larger flood events may cause flooding which exceeds the flood levels shown on the drawings. These limitations are noted on the floodplain mapping sheets under floodplain data.

9. RECOMMENDATIONS

1. The floodplain areas outlined on Drawings 91-3-1 to 91-3-12 for the Fraser and Nechako Rivers are recommended for designation pursuant to the Federal/Provincial Floodplain Mapping Agreement.

2. The floodproofing requirements contained in the appropriate bylaw(s) of the City of Prince George should take into account the information provided in this study.

3. Ice jam modelling of the Nechako River is recommended since the flood levels were determined based on historical ice jam flood events.

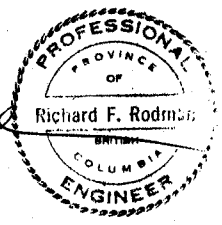
4. Any future significant changes to the operation of the Nechako Reservoir must be reviewed to ensure that the designated floodplain areas and levels are not affected.

5. The floodplain maps should be reviewed to maintain the adequacy, accuracy and usefulness of the information when significant flood events, erosion, floodplain development or other changes occur within the study area.

6. A floodplain management plan should be developed for the study area to define and determine solutions to the flood hazards.

KLOHN-CRIPPEN CONSULTANTS LTD.

Adriana Dinca, EIT
Project Engineer



Richard F. Rodman, P.Eng.
Project Manager

APPENDIX I

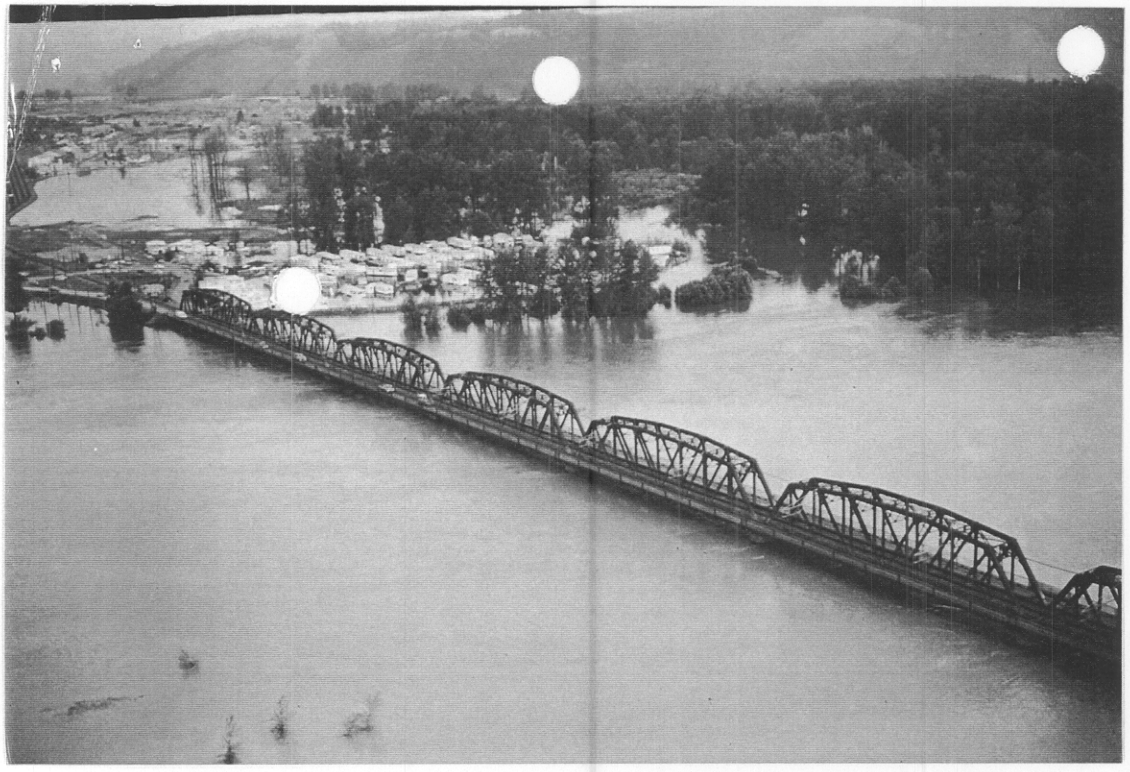
Historical Accounts of Flooding

Foothills Bridge

Cameron Street Bridge

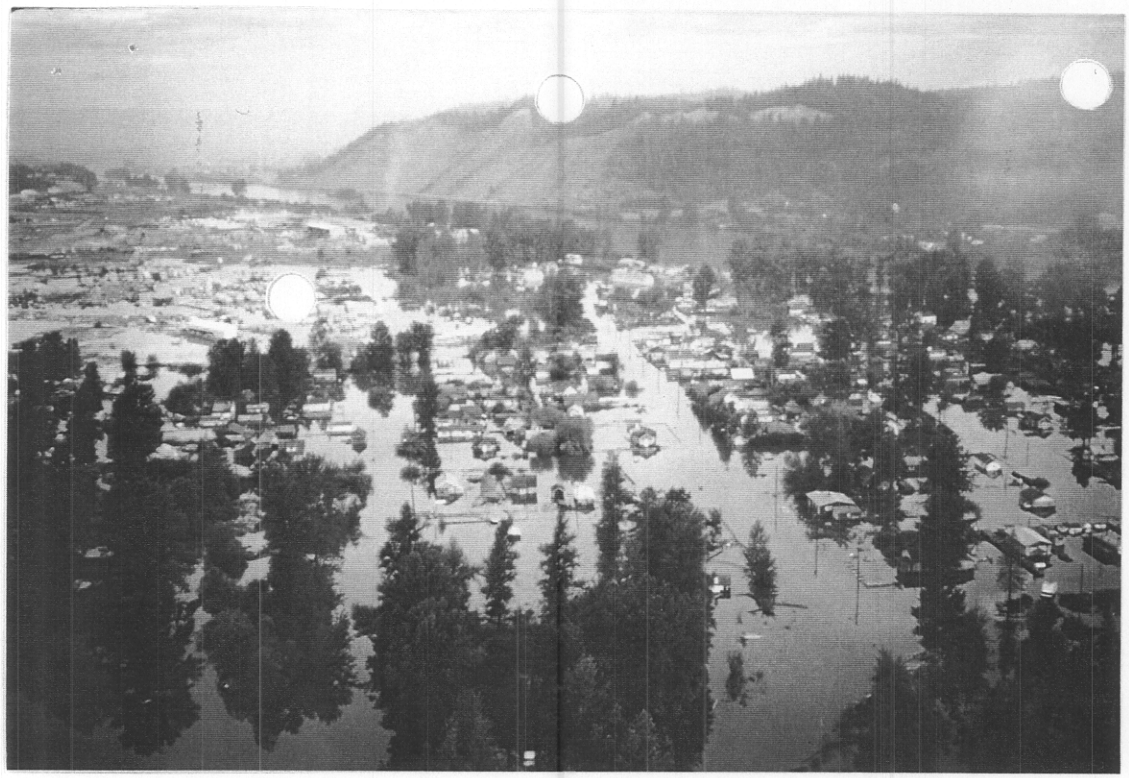
November 1996 Ice Jam Flood on Nechako River

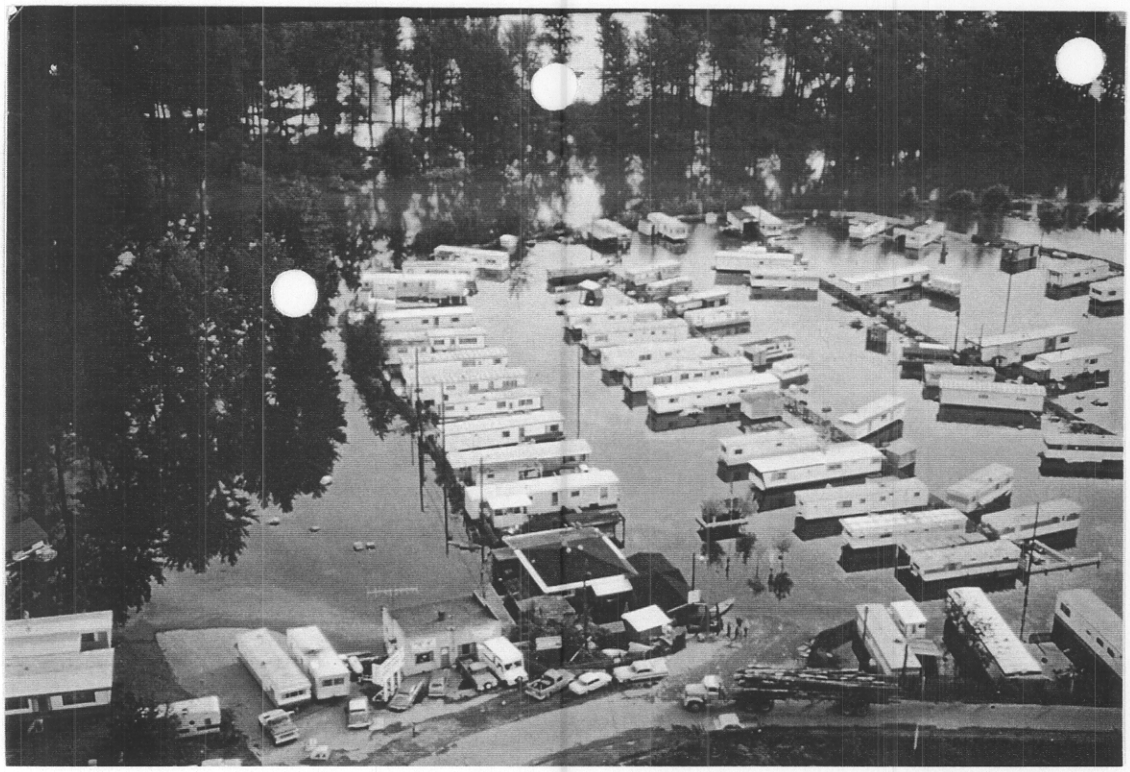
PW 7490 0101
970115



File Photos of June 15, 1972 Flooding

PW 7490 0101
970115



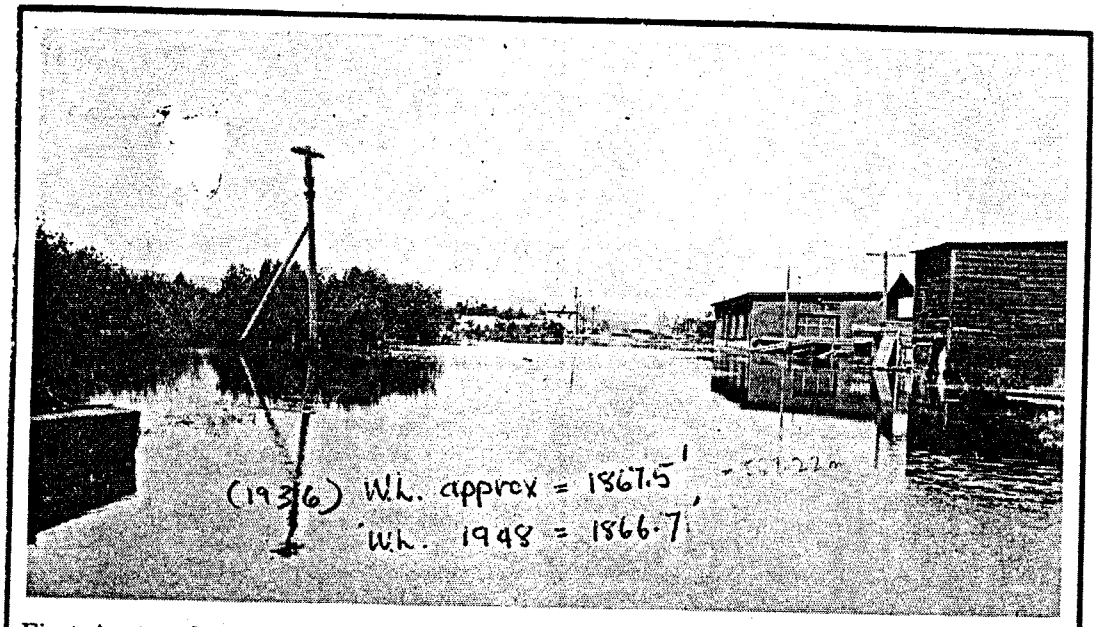


File Photos of June 15, 1972 Flooding

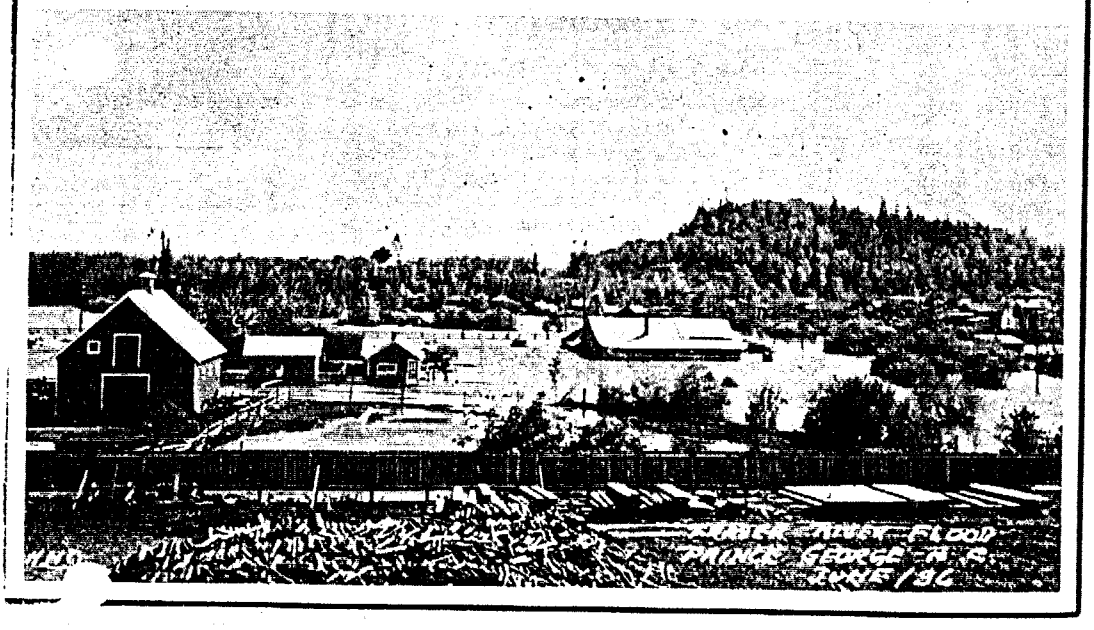
PW 7490 0101
970115

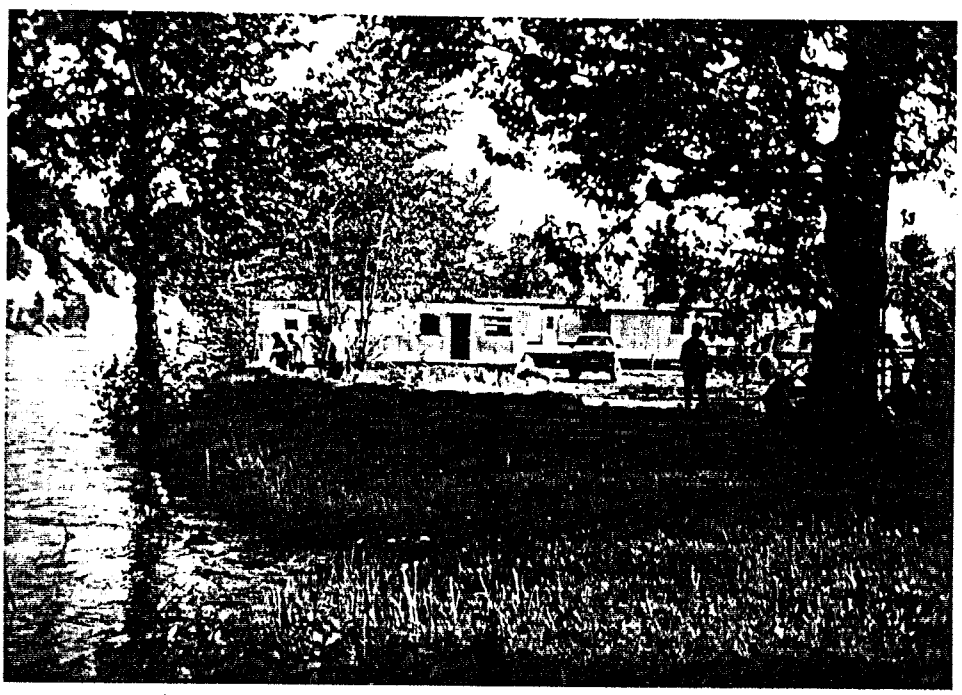
File Photo of June 15, 1972 Flooding

PW 7490 0101
970115



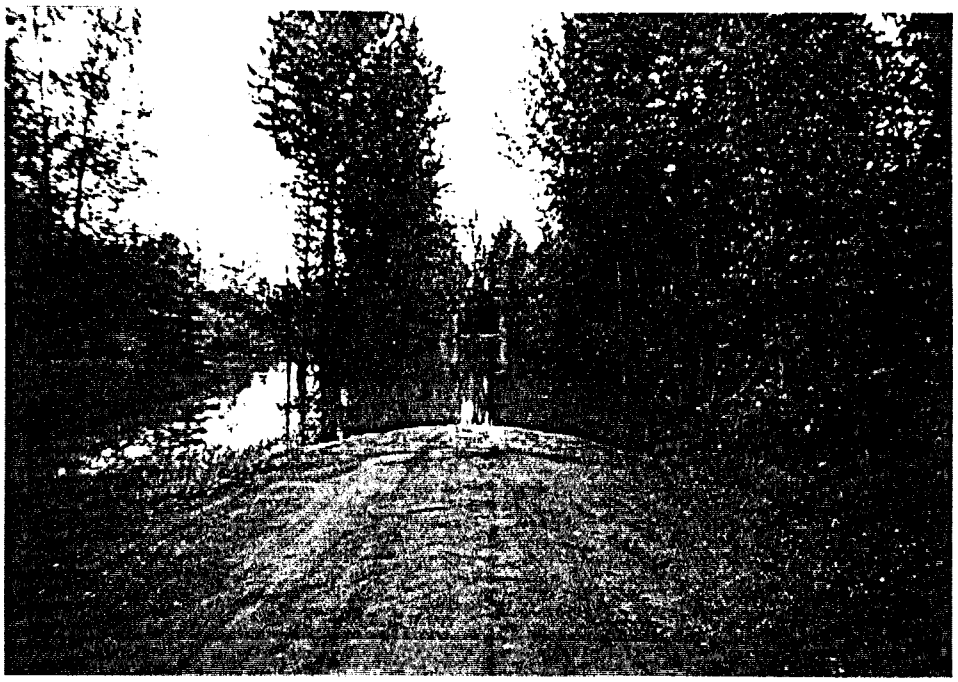
First Avenue became a placid sea of water during floods which swept Prince George in 1936. In the top picture the building at centre, right is the CNR freight shed. In the bottom photo the scene is looking across Second Avenue toward Connaught Hill with the old Catholic church in the centre of the horizon. The pictures were loaned to The Citizen by Doug Munro, 582 Winnipeg Street.





June 1990 Flood, South Fort George

PW 7490 0101
970115

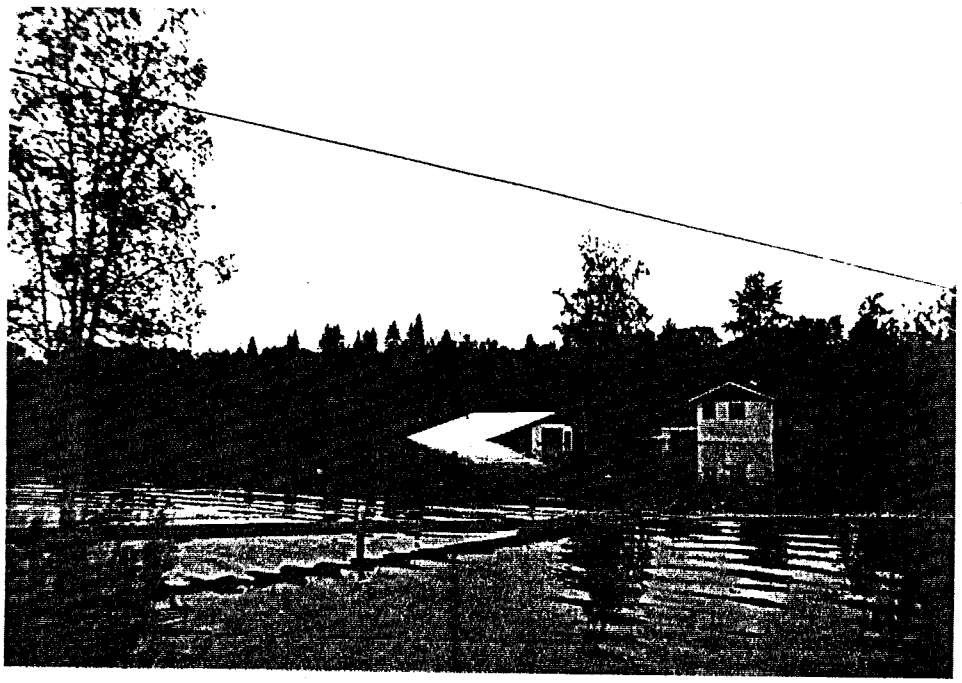


June 1990 Flood, Foreman Flats

PW 7490 0101
970115

June 1990 Flood, Foreman Flats

PW 7490 0101
970115



June 1990 Flood, Foreman Flats

PW 7490 0101
970115

PRINCE GEORGE - SOUTH FORT GEORGE

FILE PHOTOMOSAIC OF

JUNE 15, 1972 FLOODING

June 15, 1972 Flooding

PW 7490-01
N:\W\W7490\DESIGN\Photo.cdr

Heavy rain puts river levels up

The North Thompson River rose a foot at Barriere on Sunday as heavy weekend showers in central B.C. caused higher water levels throughout the province's major river systems.

But the river at Kamloops is already three feet below last week's peak reading, and the latest increase should only maintain the pressure on already strained dikes.

City civil defence co-ordinator Gerry Hutchinson said the river will move up today as the new crest flows the 40 miles south, but "it shouldn't create a dangerous situation" when it arrives.

He said around - the - clock patrolling of the serious spots along the dikes is continuing, but there have been no new breaks or major seepage.

Along the entire length of the Fraser River, however, levels continued a slow - but - sure drop Sunday, although officials predicted the river will remain high for a few more days.

Mission RCMP said the afternoon reading on the gauge was 22.85 feet, the first time the river had subsided below the 23-foot mark in slightly more than two days.

The river there peaked at 9:45 a.m. Saturday with a reading of 23.375 feet, highest level since 1950 and the fourth highest ever recorded.

DIKE MIGHT BREAK

Mission's civil defence co-ordinator Dick Davidson said there is no chance of the river going over the tops of the dikes, but the danger now is that a dike might break under the continued pressure of high water.

He said seepage through dikes is continuing and Chilliwack RCMP also reported heavy seepage through the west bank of the Vedder Canal, flooding some farm lands.

At Hope, RCMP said pumps are being employed to remove water from an undiked area where high water last week forced 10 families to evacuate their homes.

A police spokesman said it will be two more days at the earliest before residents can move back in.

CRISIS IS OVER

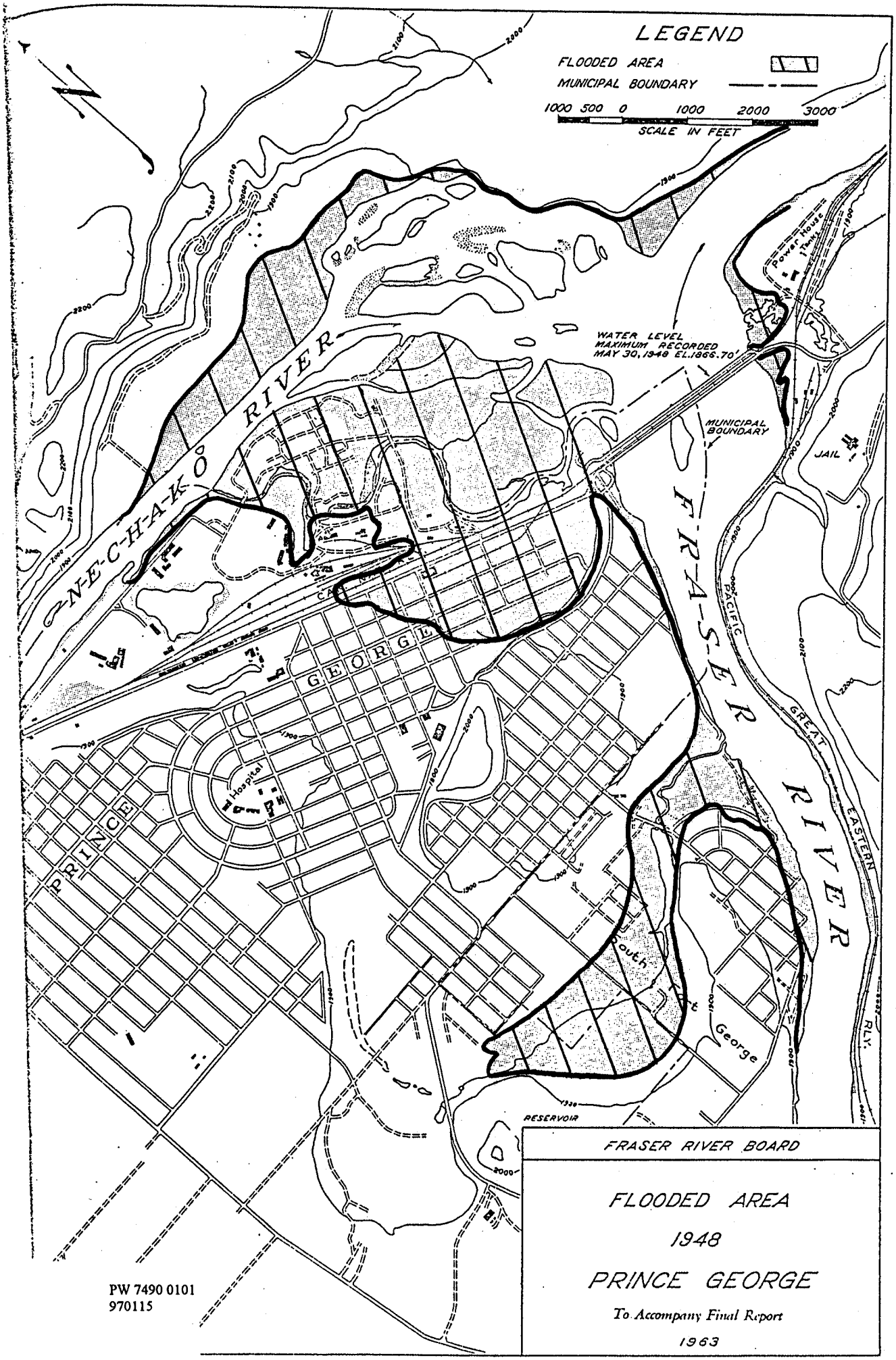
Cool temperatures and n rain at Prince George durin the weekend prompted water rights branch officia there to predict the crisis i over, for this year at least.

Mills Anderson said the Sun day reading of 30.35 feet wa a four-foot drop from las week's peak which caused flooding in the low lying Cottonwood Island and South Fort George areas.

He said, however, most of Cottonwood Island is still under water and it will likely be a week or two before the island's 200 residents are able to move back home.

They will be allowed to return only under restrictions, however, requiring a health inspection of their homes and an electrical inspection before B.C. Hydro restores power.

VANCOUVER PROVINCE
JUNE, 1972


LEGEND
FLOODED AREA
MUNICIPAL BOUNDARY
1000 500 0 1000 2000 3000
SCALE IN FEET
NECHAKO RIVER
FRASER RIVER
WATER LEVEL MAXIMUM RECORDED MAY 30, 1948 EL. 1868.70'
MUNICIPAL BOUNDARY
Power House
Tramway
JAIL
GEORGE
PRINCE
Hospital
PACIFIC
GREAT
EASTERN
RLY.
South Fork
George
RESERVOIR
FRASER RIVER BOARD
FLOODED AREA
1948
PRINCE GEORGE
To Accompany Final Report
1963
PW 7490 0101
970115

ICE JAM CAUSES FLOODS

DEC 18 1980

Hip-waders, canoes save day in Penny

by HAZEL ALLAN
Citizen Staff Reporter

Dressed in hip-waders and paddling canoes, residents of Penny helped evacuate several families whose homes were flooded due to ice floes in the Fraser River on Wednesday.

Most of the 40 residents of this small community, 90 km east of Prince George, were high and dry today, as the flooding did not reach the townsite, situated on higher ground.

Lisette Yokimas, a Penny school teacher, was one of those evacuated from her farm near the river.

"There were two families evacuated last night. The local people helped us get out with canoes and hip-waders — everyone was helping," Yokimas said.

She is staying with neighbors and has one of her cows with a newborn calf, sleeping on the front porch. The rest of the cattle are trapped on her farm but are safe.

Yokimas said some of the creeks around Penny are flooded, the Fraser has overflowed its banks and "everything is backed up."

"The whole river is covered with ice."

Most Penny residents have lost their cars and trucks on the other side of the Fraser. To reach the townsite, they park their cars on one side of the river and in the winter use an ice bridge to reach the town. In the summer they use canoes or boats.

Yokimas said residents realized their cars were in danger and "someone phoned search and rescue early in the morning."

"But they didn't come till 4 p.m. and by then it was too late. All the cars are frozen solid under the water."

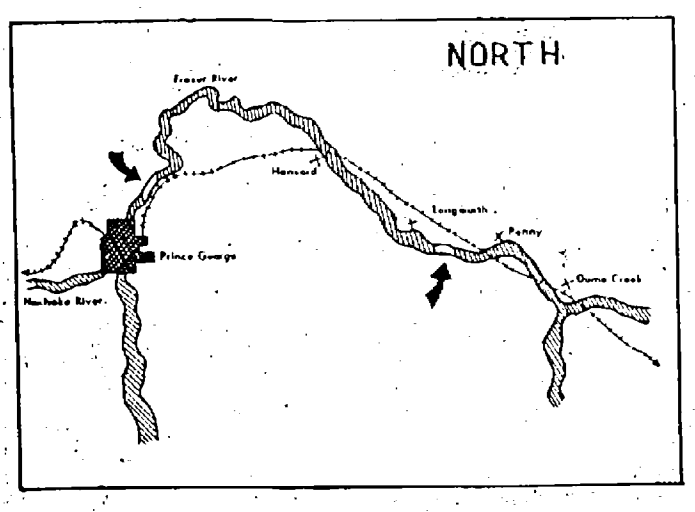
Despite all the upheaval and excitement at such an unusual occurance, Penny's children are in school today, being taught by a substitute teacher, as Yokimas is still waiting to be airlifted back to her farm.

Corp. Steven Hryciuk of the McBride RCMP says the water is receding and there wasn't much more to be done.

"I was in Dome Creek Wednesday and there were two houses with flooded basements. I spoke to the CN and they said about five or six Penny residents had managed to bring their cars out and park them in Dome Creek, and then got the freight back to Penny."

But Hryciuk said about 14 cars were under ice and water in Penny.

However, there is telephone communication between the townsites, and the CN freight line is in no danger, so anyone who needs to leave the two townsites can do so.



Arrows show areas of flooding

NORTHWOOD WORK DEC 18 1980

Dam damaged

Northwood Pulp and Timber Ltd. officials are hoping the worst of an unseasonal flood is over.

At the bridge construction site behind the mill, Fraser River flood waters have gone over the marks left by this spring's freshet, washing away unestimated manhours of work, materials and some tools. The coffer dam for the bridge's third pier has also been damaged and lies beneath the muddy water.

Bruce Pickett, woods administration manager, said, "It's many feet above the seasonal normal. We do our bridge construction in the winter so we don't have to contend with lots of water. This was completely unexpected."

He said he was turning misfortune to an asset: "I'm having this new level recorded. I want to know what the peak elevation for this river really is."

The bridge is to be used to cut the hauling distance from the logging areas to the mill, bypassing routes that now take trucks through city streets. About 16 km and almost an hour's travelling will be saved.

The worst damage done by the abnormal winter thaw came Tuesday, on the Herrick River 100 km east of Prince George. A tributary of the McGregor River, it went up about four feet, washed away parts of a bridge being built and dumped a crane into the water.

Pickett said the flooding in that district is, "being sorted out," and wherever possible logging and hauling is being resumed.

"Things are almost back to normal," he said.

DEC 18 1980

'Water rising like hell'

PENNY (Staff) -- Larry Siddler woke up early Wednesday and heard a tremendous noise from the Fraser River, just a few yards away from his cabin.

The Penny resident says "the water was rising like hell, and ice was flowing down the river."

He strapped on his skis and left his cabin at 3 that morning.

Another Penny couple had to evacuate their home as water was coming in through the floor boards.

The low-lying area around Penny is covered with ice as far as the eye can see, and the river appears to be solid ice for miles.

Penny residents say the water level is between 12 and 14 feet above normal, although it has receded about five inches today.

They say the flood level is approaching that of the 1936 flood which was the worst anyone can remember.

The problems started a couple of weeks ago, when during a heavy snowfall, more than five feet of snow fell. Then the weather turned warm, and the snow began to melt.

Nechako jumps banks

Ice jam spawns flooding on North Nechako and Pulp Mill roads

by PAUL STRICKLAND
Citizen Staff

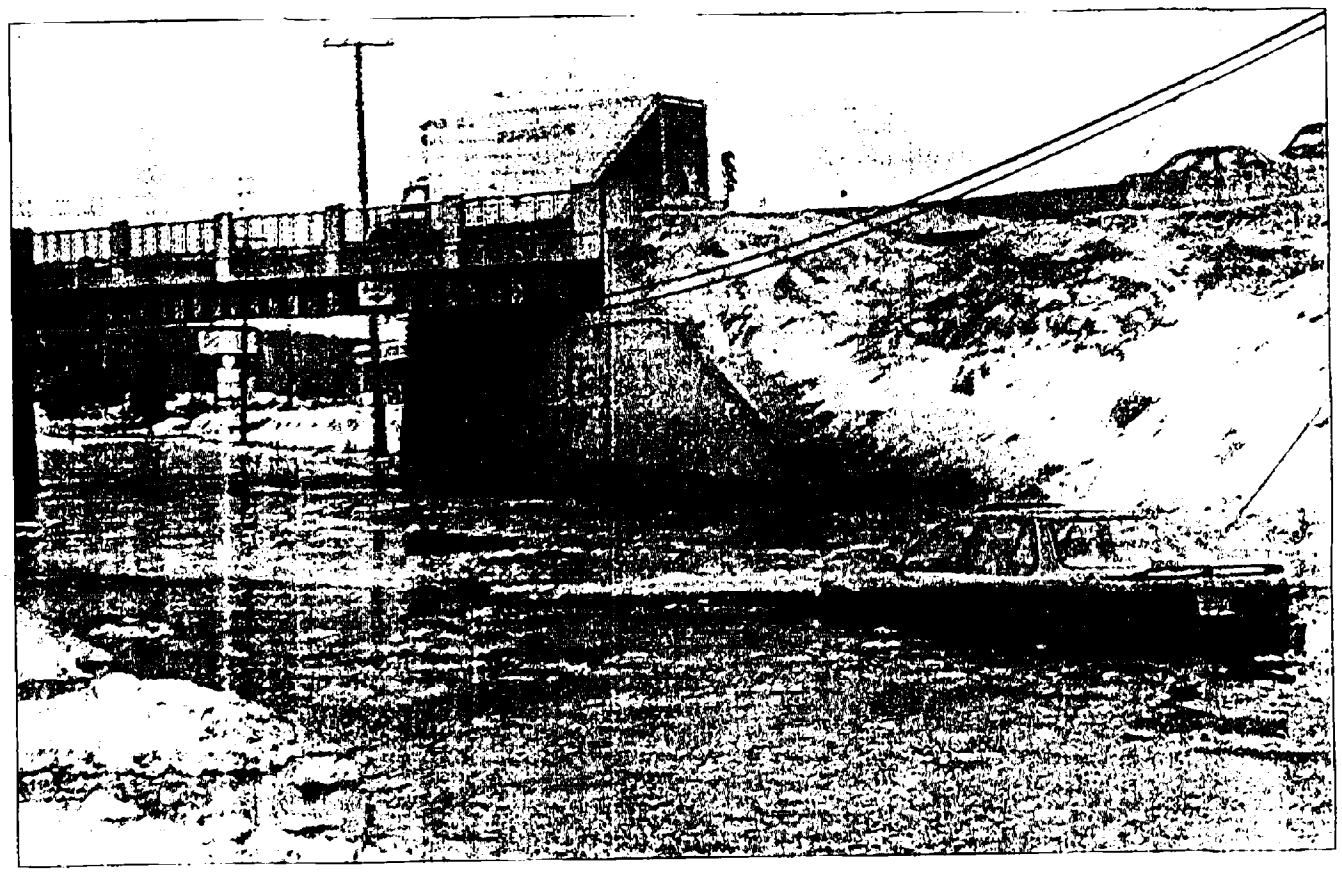
A massive ice jam on the Nechako River moved downstream from outlying western Prince George neighborhoods Thursday and caused significant flooding of low lying industrial and residential areas.

For thousands of residents who use the Hart Highway for their morning commute, it meant traffic tieups and frayed nerves.

Most offramps from the Hart Highway at the John Hart Bridge were closed because a pool of water more than one metre deep forced the closure of an underpass on North Nechako Road after some vehicles stalled trying to get through during the night. One woman whose small car stalled in the water was rescued by the driver of a four wheel drive.

By 7:30 a.m., commuters heading into town on the Hart Highway were backed up to the Mohawk service station.

The water crested at 3:30 a.m. Thursday, said Egon Weger of the province's water management branch. By 2:30 p.m. Thursday, the water had receded by a foot, he said.



The driver of this sedan tried to push through the water in the underpass beneath the John Hart Highway. The car stalled and the driver was picked up by someone in a 4X4. It was pulled out later by a tow truck.

Flooding forced Pacific Western Brewery to shut down operations for the first time in 27 years. It won't reopen until Monday.

Environment Minister Paul Ramsey said he would tour the Nechako and the flooded areas of the city by helicopter today to get a look at the situation.

Thursday morning the ice jam that had caused the rise in Nechako River levels extended more than five kilometres, from about one kilometre west of the Foothills Bridge to the Spruce City Wildlife Association hatchery on River Road.

All Nechako River islands were under water except for the tallest trees.

The rising river was up to the backs of houses on Prince George Pulp Mill Road. River Road was closed and under water from just east of the Cameron Street Bridge to Foley Crescent.

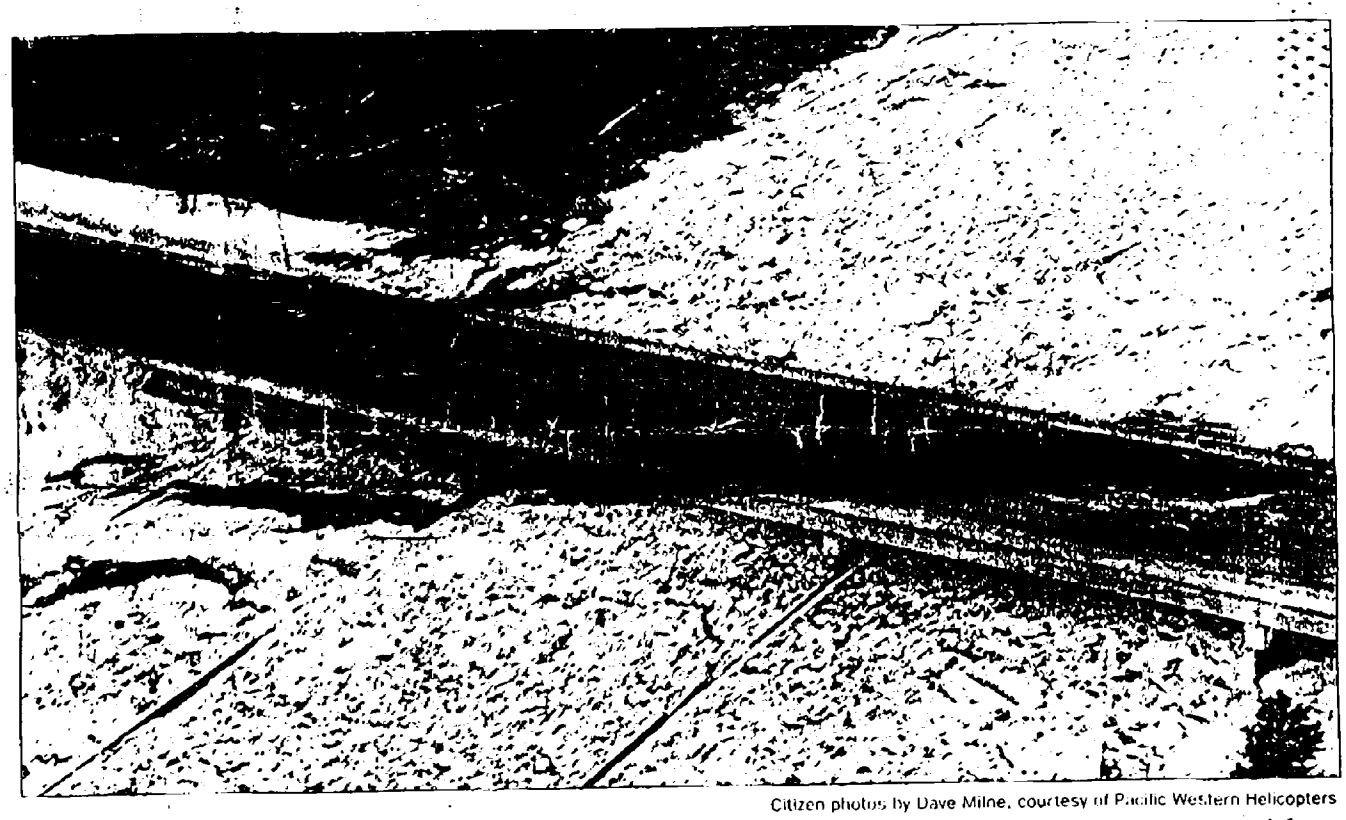
Parking lots and storage yards were flooded on both sides of the road. Cottonwood Island Park was half under water.

Flooding forced Pacific Western Brewery to shut down operations for the first time in 27 years. It won't reopen until Monday.

The nearby Cedars Christian School was closed for the day. Not far away, water had covered driveways and was lapping against the units of the Del Haven condominium project closest the riverbanks.

A gravel pit west of Wilson Park was under water, and industrial fuel tanks from it were floating downstream among the blocks of ice.

But residents of the Morning Place neighborhood, at the far western city limits on North Nechako Road, enjoyed a break Thursday from four days of fluctuating river levels that threatened flooding several times during the period.



Citizen photos by Dave Milne, courtesy of Pacific Western Helicopters

The pylons of Foothills Bridge cut neat lines into the ice jam that around midnight Wednesday moved from near the Morning Place neighborhood closer to downtown. The ice jam raised water levels early Thursday to a height older residents say has not been seen since the early '50s.

When the ice jam, which had been located just down from their neighborhood, moved further downstream overnight, the floodwaters receded and the riverbanks reappeared. Yet massive blocks of ice, some as thick as 10 feet, continued to hug the riverbanks.

Temperatures dipping to nearly -30 caused thick ice to form on the river while the big fall release of water from Alcan's Nechako Reservoir was still working its way downstream. Subsequent ice jams have caused notable river level fluctuations and intermittent flooding at Vanderhoof and Prince George.

There is no indication Alcan or any government agency is responsible for the ice jams and flooding, Ramsey said Thursday from Vancouver.

"First we had a cold snap that froze everything, and then all of a sudden it warmed up enough to cause the ice to break up and cause ice jams, leading to a crisis situation," he said.

Following one of the longest winters in recent years, the city had the fourth wettest summer on record, Ramsey said. Everyone is trying to cope with unusually heavy runoffs and river flows as best they can, he noted.

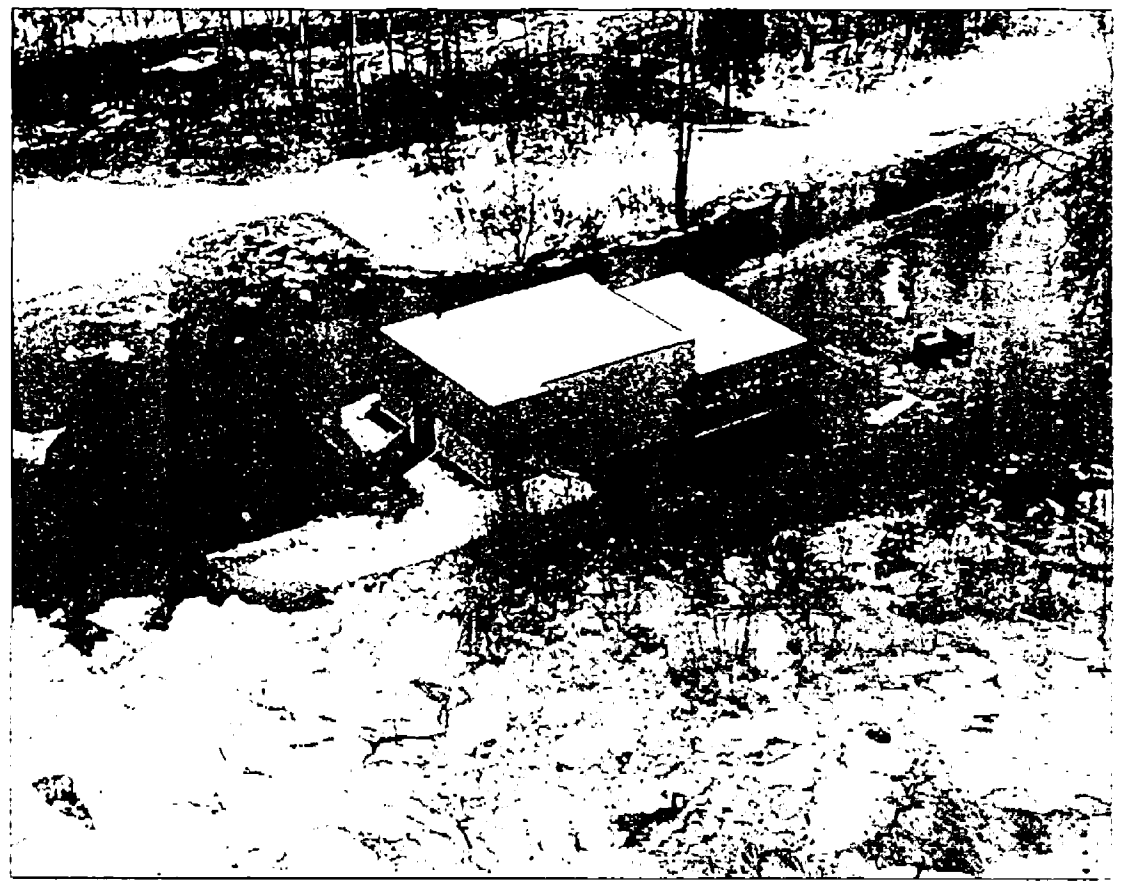
"The cause of the problem is Mother Nature. Sometimes she's kind; sometimes she's cruel."

One local oldtimer said it's the first time he's seen this type of winter flooding since 1953.

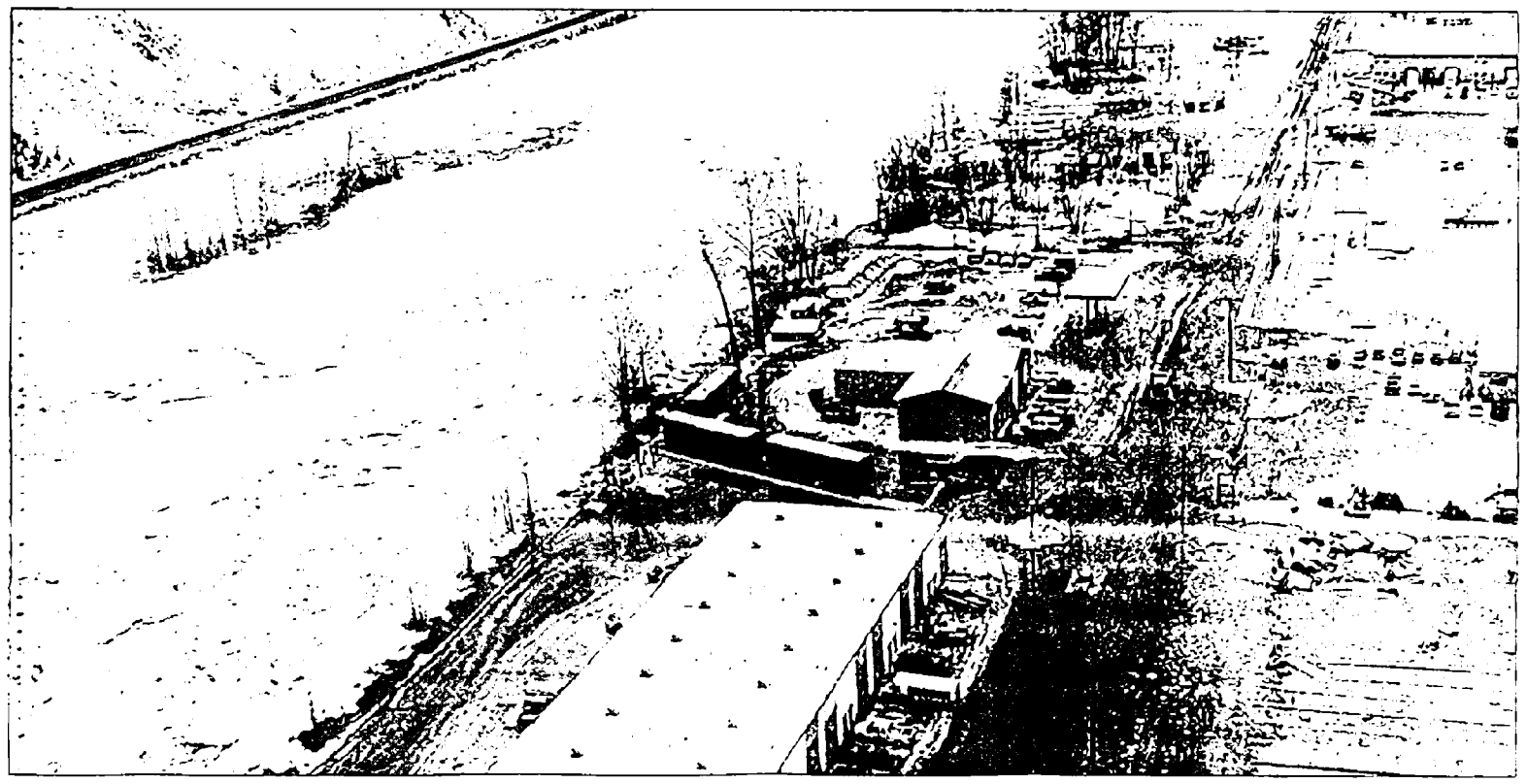
More photos, details pages 32,33.

NECHAKO FLOODING

Rod Harvey surveys the river trail near the Spruce City Wildlife Association fish hatchery. Only the fenceposts of the paved trail are visible.



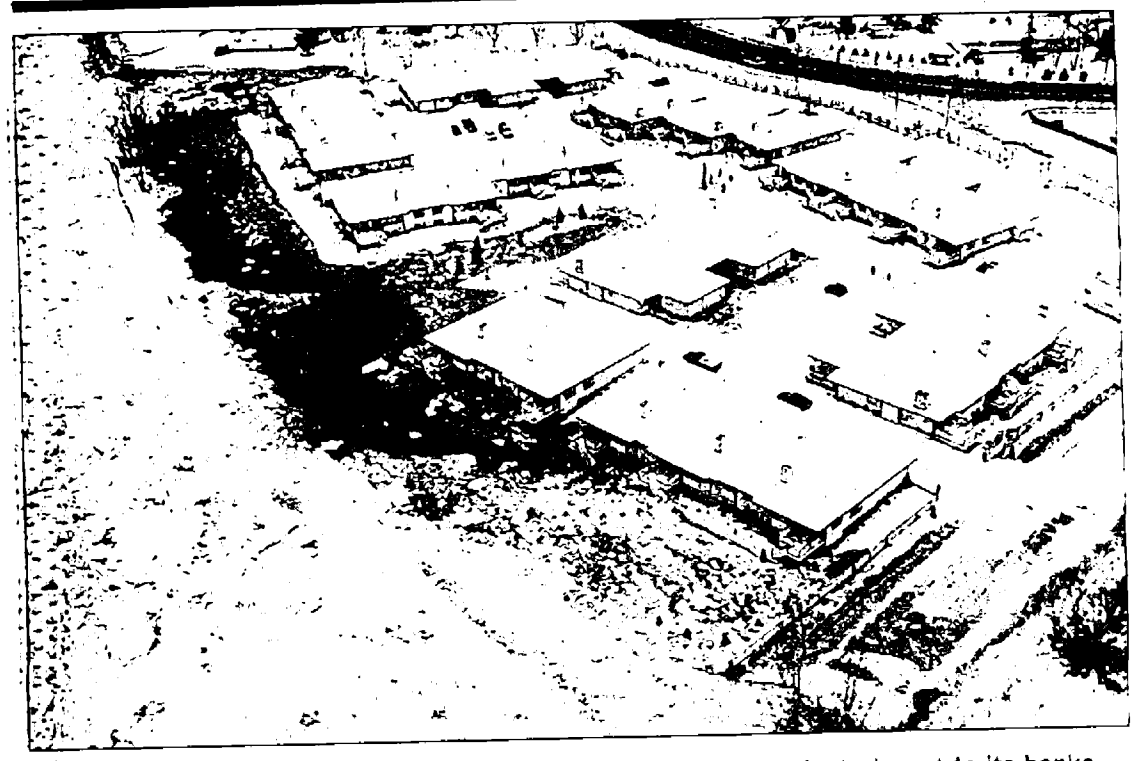
The new city water pumphouse in Wilson Park was engulfed by the flooding river.



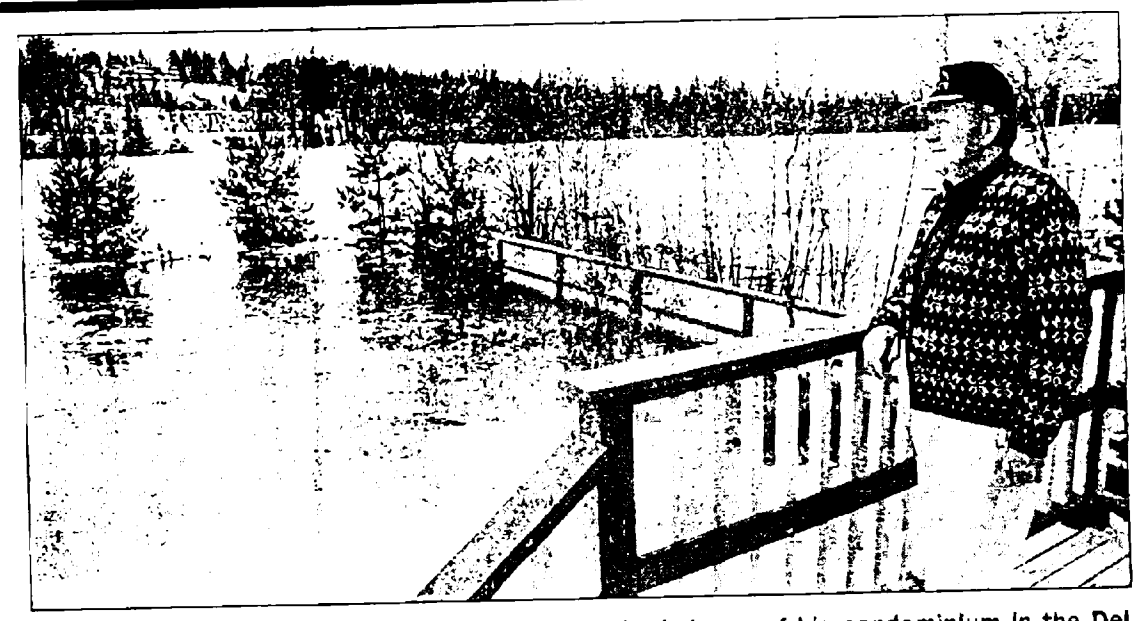
River Road was flooded and closed from the Cameron Street Bridge offramp to Foley Crescent. The river rose quickly, said

In the Del Haven condominium project, Janet Handford uses a wet vacuum on the soaked floor in

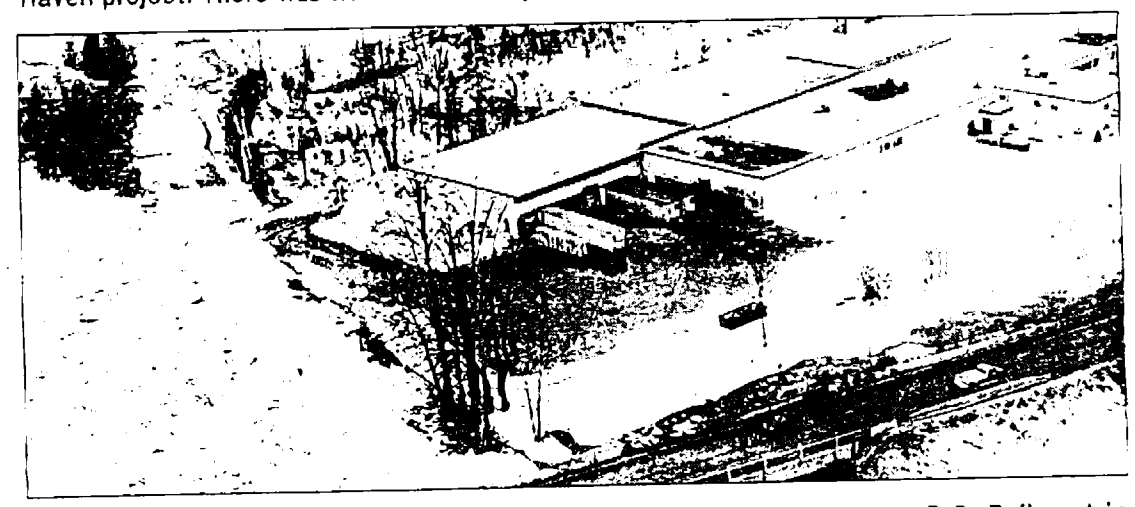
NECHAKO FLOODING



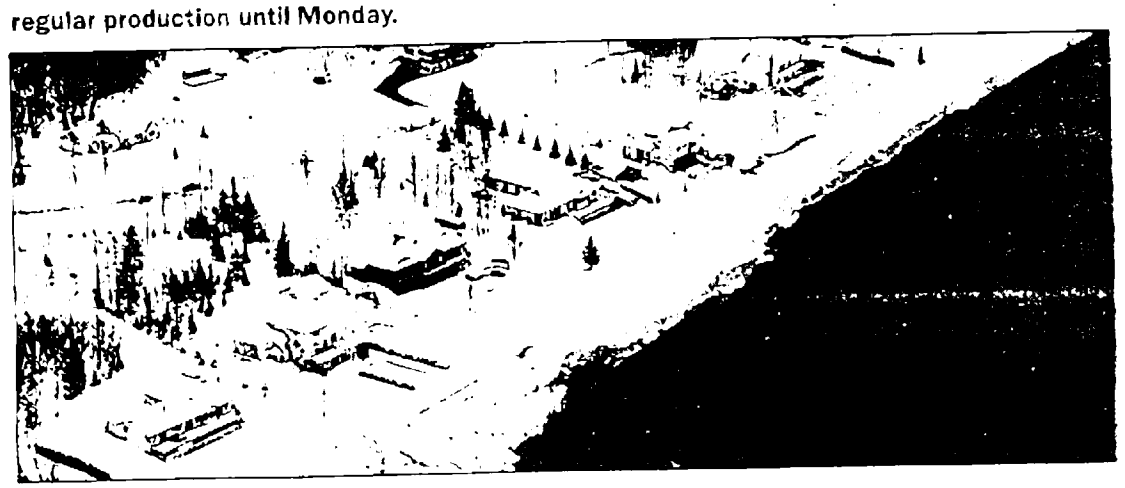
The Nechako flooded into units of Del Haven condominium project closest to its banks.



Alf Nelson looks out at his yard Thursday from the balcony of his condominium in the Del Haven project. There was no water in the yard Wednesday.



The Nechako River flooded the loading area of Pacific Western Brewery. B.C. Rail sent in tractors to pull out all trailer units threatened by the floodwaters. The brewery shut down regular production until Monday.



The ice jam that had caused flooding at Morning Place moved further east around midnight Wednesday. While that caused problems closer to downtown, the change at least temporarily removed the threat of further flooding at the upscale neighborhood on the west side of North Nechako Road.

City public works dept. on 24-hour flood alert

by PAUL STRICKLAND
Citizen Staff

Thursday's flooding of the Nechako River behind a shifting ice jam prompted city officials to implement its emergency plan and establish an Emergency Operations Centre.

The city warned Thursday that owners and tenants of property next to the Nechako River were threatened by further flooding.

"Due to the nature of the problem, it is extremely hard to predict where problems may arise, and the public is warned that the situation could worsen in a matter of hours," Allan Chabot, the city's emergency public information officer, said in a release.

The city's public works department is on 24-hour alert and will deliver sandbags, free of charge, to anyone requiring them to floodproof their property, city officials said. The number to call is 561-7500.

"Owners and tenants of properties threatened by flood should take all measures possible to prevent or minimize damage by flooding," Chabot added. "A plan of action should be devised in case you must leave the area on short notice."

As of 4:30 p.m. flooding of low-lying areas continued, involving two main roads.

At nightfall North Nechako Road at the Highway 97 overpass remained closed, and so was turnoff and Foley Crescent.

Cameron Street Bridge remained open for traffic northbound to the Hart Highway. But North Nechako Road was closed to westbound traffic coming off the Cameron Street Bridge because its underpass under Highway 97 was flooded.

City officials advise commuters they still cannot connect with the Cameron Street Bridge when travelling south on Highway 97. They recommend Foothills Boulevard as an alternate route during rush hour for commuters travelling to and from the Hart.

At least one water pumping station in the flooded Wilson Park was shut down, Chabot said. Alternate pumps will continue to meet city water needs.

City officials warned people to stay well away from the banks of the Nechako River. "The shoreline of the Nechako is extremely hazardous due to the nature of the ice formations there," Chabot advised.

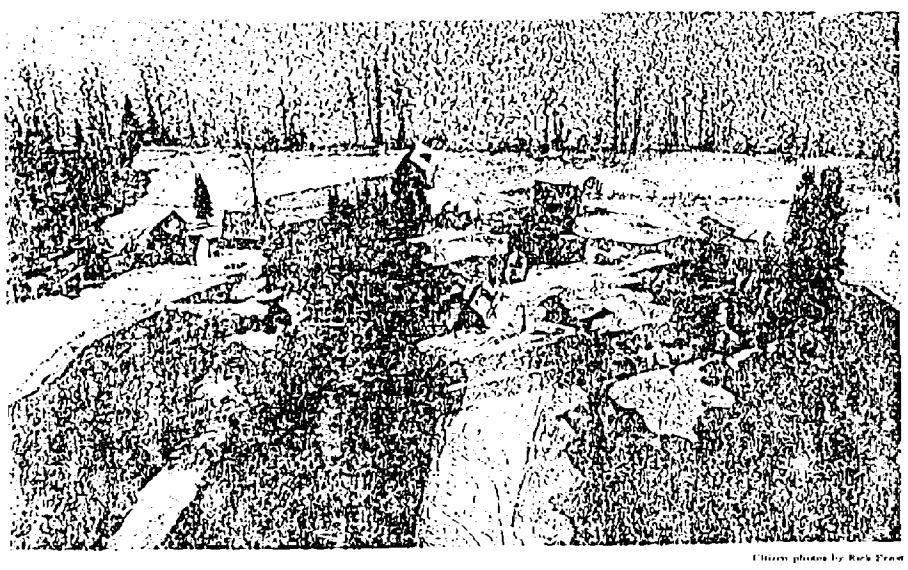
City officials said more information would be released from the Emergency Operations Centre as it arose.

Citizen photos by Dave Milne
Aerial photos courtesy
Pacific Western Helicopters

The Citizen
Friday, December 19, 1980 Prince George, British Columbia

Ice-packed Fraser River east of Prince George. Story, right.

Art Croy surveys ice and watches Fraser River level.



Citizen photos by Rick Frost

Penny farm on banks of Fraser River is isolated and surrounded by ice.

LEVEL WATCHED CLOSELY

Massive ice jams still block Fraser

At press time today, a Provincial Emergency Program official said the water level has dropped substantially in the Penny area. PEP will continue to monitor the levels, he added.

* * *

by JAN-UDO WENZEL
Citizen Staff Reporter

Residents of Penny are anxiously watching the level of the swollen Fraser River, which spilled over its banks this week and flooded low-lying areas of the community.

The river, blocked by ice jams both upstream and downstream from the town, was slowly dropping today. High water over the past few days forced evacuation of two families in the community of 40, about 100 kilometres east of Prince George.

About 13 cars and several boats owned by Penny residents were lost to river ice, and fields near the town were flooded.

A road near the community of Upper Fraser was also cut by the ice jams.

Heavy snow earlier this month, followed by a thaw and three days of rain, created the high-water situation along the banks of the river.

The cars were caught by the water on the south bank of the river, and their owners were unable to get to them.

At least one vehicle contains Christmas presents.

Today, an ice jam six kilometres long still plugged the river.

Larry Fiddler doesn't know where he'll spend the rest of the winter, but it won't be in his own cabin.

Art Croy will have to get another set of Christmas presents, and he is worried whether his truck carried comprehensive insurance.

'Most snow I've ever seen'

Clarence Boudreau is keeping an eye on the weather and on the safety of his fellow Penny residents.

All three agree this year's weather played a dirty trick on them.

About 10 days ago it snowed. In fact, it snowed until more than 1.5 metres covered the ground.

"It's the most snow I've ever seen coming down at one time," said Boudreau who lived in Penny all his life.

Then the weather changed. It thawed, then rained for three days.

The snow melted and it was more like a spring run-off than mid-December.

"Everything filled up with water," Croy said.

The sloughs were full and the river was rising.

Then it froze again. Ice floes drifted down the Fraser River, plugging sloughs and creeks. The ice flowed at a speed of at least 20 kmh, Fiddler said. It began to build up on gravel banks and the river's edges. Suddenly the flow stopped and the water backed up.

Creeks spilled over into fields and onto roads, then frost turned everything into a giant ice hockey rink.

At about 3 a.m. Wednesday, Fiddler was awakened by noise from the river. Ice was piling into ice, pushing it over the riverbank and creating more obstacles for the winter. The water found its way into the lower fields and Fiddler knew it was heading toward his cabin. He strapped on his skis left the cabin, and alerted others in the community.

Called for helicopter

By about 8 a.m. Wednesday, the river was still rising about 30 centimetres an hour, and Penny residents called for a helicopter to take some of them to the south shore of the Fraser, where their cars were parked.

Penny cannot be reached by road. The only way in and out is by railway or across the Fraser River by boat. Most people take a boat and park their vehicles on the other side.

The heaving ice precluded crossing by boat and people watched helplessly as their vehicles were slowly engulfed in water and ice.

"If a helicopter had come within an hour after we called, we could have saved the cars," Boudreau said.

But no helicopter was available in Prince George, and the vehicles will now sit until spring in their ice wrappings.

Art Croy had the family's Christmas gifts and his vehicle insurance papers in his small pickup truck.

It's now buried beneath the ice of the Fraser River.

Thursday, the people of Penny thought they had another worry -- one of the residents said she was having labor pains.

A helicopter was available, but it proved to be a false alarm.

The Provincial Emergency Program installed a portable telephone to ensure contact with the outside world.

By Thursday, the river was falling and the danger lessened.

Fiddler tried to ski back to his cabin, but was blocked by high water. A helicopter dropped him off and he checked his cabin.

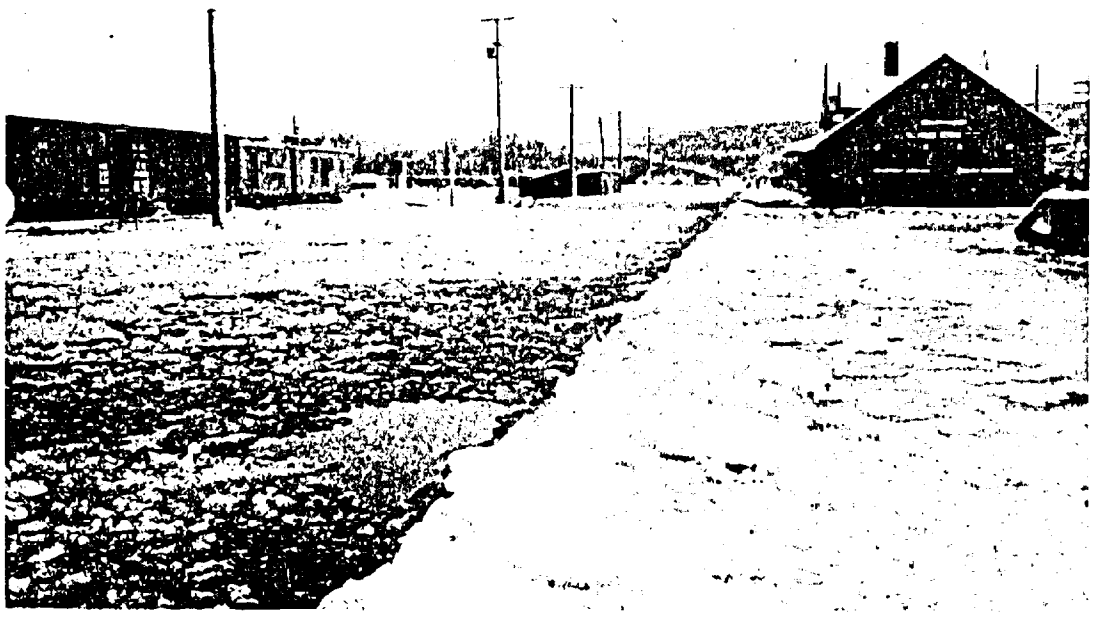
"There's no way I can live in it now," he said.

More flooding was reported west of Penny near Aleza Lake and the road to Upper Fraser was under water today. The people of Upper Fraser and Sinclair Mills will have to use the Bowron Forest Road to get to Highway 16 instead of the road to Giscome.

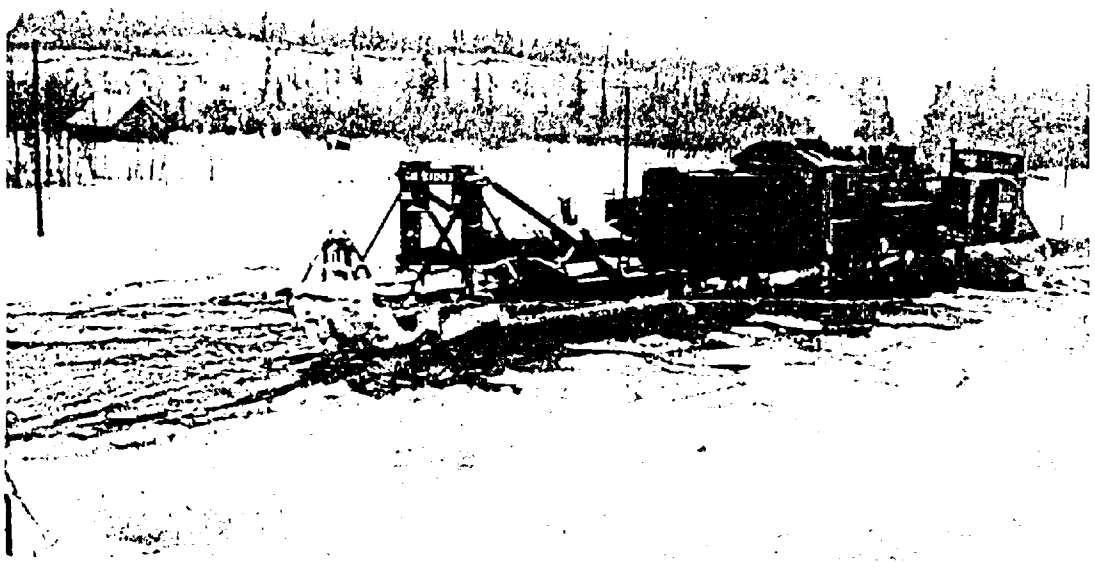
The Citize

The Only Daily Paper Serving B.C.'s Third Largest Market

Vol 13; No. 2 | 20 Pages | Forecast — Snowflurries | PRINCE GEORGE, BRITISH COLUMBIA, FRIDAY, JANUARY 3, 1969



CN station awash in 1936 flooding.



Work train looks like boat in 1936 flood.

Island Flood Refugees Maintain Uneasy Watch

By Jim Stirling
Citizen Staff Reporter

About 90 people are still refugees in downtown hotels while up to three times as many daily watch the temperature and the encroaching ice seeping into their Cottonwood Island homes.

The flood waters have receded about two feet but the water table in the gravel-bar island itself is higher now than floods of Dec. 30 that made the 16 families homeless.

The flood was caused by the ice-choked confluence of the Fraser and Nechako rivers. The icy waters built up until there was no where else for them to go but over the island.

Peter Hudson, social worker on the island, sees the weather conditions of the next few days as critical. He fears three times many homes would be in jpardy if conditions worsen and the water table continues to rise through the island.

"Everyone I have spoken to seems to shink that a slow thaw is the answer," said Hudson, "at the moment several basements of houses on the island are just blocks of ice."

Hudson said there was no measure of property damage yet.

He added, "The damage to homes is not so much in dollars and cents, but means a hell of a lot to people concerned. Some might not be habitable again."

Emery Wilson, district engineer for the B.C. Water Re- thinking and appraise the situation.

Hudson said they are hoping to see Resources Minister Ray Williston when he visits the city Monday.

He sees two alternatives open to residents.

They could ask for auxiliary help, he said, get thawed out and back in their homes and then discuss the feasibility of flood conservation methods.

The second alternative, he continued, was to get residents back in their homes and then think and study seriously the mass re-location of the island community.

Wilson agreed that re-location appeared the only long term solution to the annual flooding problems of the island.

"Engineering-wise," he said, "and that includes the economics of the situation, there is nothing to be done."

Short term solutions, added Wilson, could be dredging the Nechako close to the island confining the channel.

This would have the effect, he continued, of keeping a super-cool channel of rapidly flowing water which would not freeze as readily as the broad, slow waters at the point where the rivers meet.

Meanwhile, the fate of the island residents, rests as usual, on the fickle B.C. weather.

★ ★ ★

Williston Here Monday

Lands Forests and Water Resources minister, Ray Williston will be in Prince George Monday to discuss the stalled $10 million longe-range plan for extension to the regional hospital with the hospital's building committee.

He is making the visit in his capacity has MLA of the Fort George district.

MLA Williston has been invited as a courtesy to attend the meeting of city council Monday evening, city manager Arran Thomson said today.

The Fort George MLA will be approached by the Cottonwood Island refugees (see above), and undoubtedly will have some other petitioners from among the water-hungry Blackburn district residents.

APPENDIX II

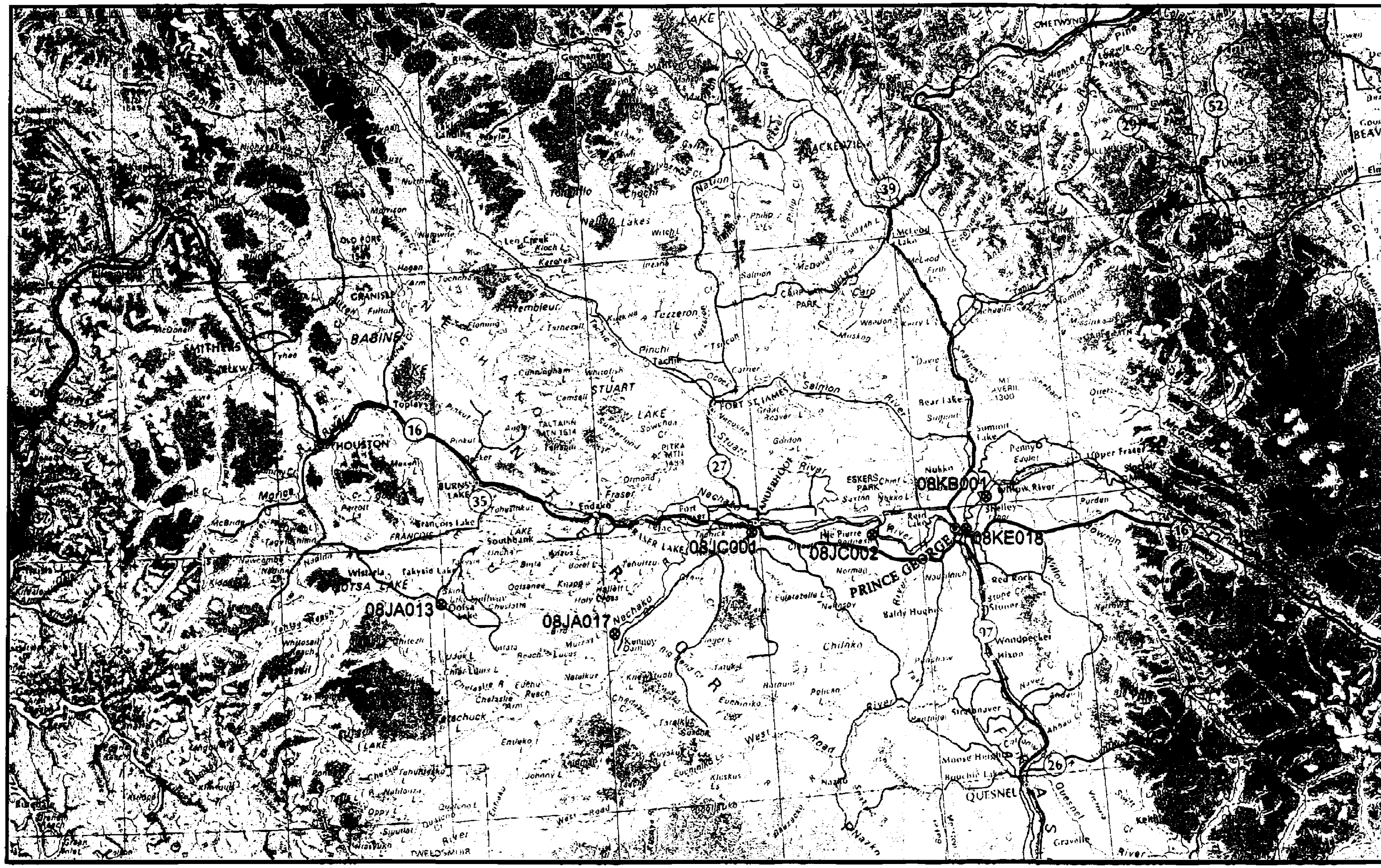
List of Floodplain Maps

List of Floodplain Maps

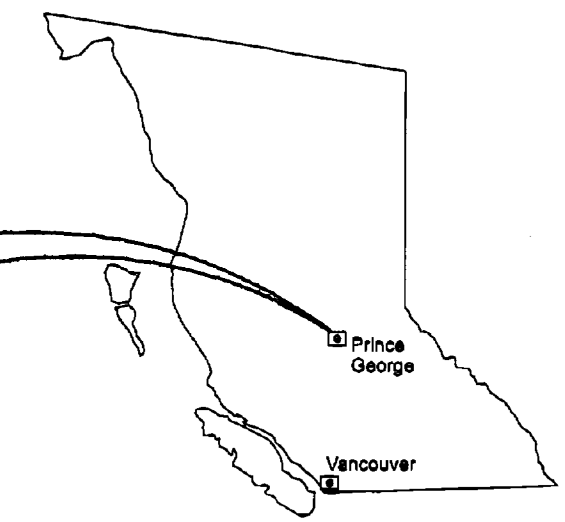
TITLE	DRAWING NUMBER	
Fraser and Nechako Rivers at Prince George	91-3-1	Sheet 1 of 12
Fraser and Nechako Rivers at Prince George	91-3-2, Rev. 1	Sheet 2 of 12
Fraser and Nechako Rivers at Prince George	91-3-3, Rev. 1	Sheet 3 of 12
Fraser and Nechako Rivers at Prince George	91-3-4, Rev. 1	Sheet 4 of 12
Fraser and Nechako Rivers at Prince George	91-3-5, Rev. 1	Sheet 5 of 12
Fraser and Nechako Rivers at Prince George	91-3-6	Sheet 6 of 12
Fraser and Nechako Rivers at Prince George	91-3-7	Sheet 7 of 12
Fraser and Nechako Rivers at Prince George	91-3-8	Sheet 8 of 12
Fraser and Nechako Rivers at Prince George	91-3-9	Sheet 9 of 12
Fraser and Nechako Rivers at Prince George	91-3-10	Sheet 10 of 12
Fraser and Nechako Rivers at Prince George	91-3-11	Sheet 11 of 12
Fraser and Nechako Rivers at Prince George	91-3-12	Sheet 12 of 12

DRAWINGS

Drawing B-1001	Location Plan
Drawing A-1002	Flood Frequency Plot of Fraser River at Shelley, Maximum Daily Discharge
Drawing A-1003	Flood Frequency Plot of Fraser River Downstream of Nechako River, Maximum Daily Discharge
Drawing A-1004	Flood Frequency Plot of Unregulated Nechako River Inflows to Isle Pierre, Maximum Daily Discharge
Drawing A-1005	Fraser River Calibration Profiles
Drawing A-1006	Nechako River Calibration Profiles
Drawing A-1007	Nechako River Ice Jam Flood Level Probability Plot at XS-11Drawing A-1008 Design Fraser River Flood Profiles
Drawing A-1009	Design Nechako River Flood Profiles
Drawing A-1010	Frequency Plot of Maximum Annual Fraser River Water Levels at South Fort George



Map Source: PROVINCE OF BRITISH COLUMBIA,RELIEF MAP, 1991



Map of British Columbia

50 0 100 km

SCALE

TO BE READ WITH KLOHN-CRIPPEN REPORT DATED January, 1997

KLOHN-CRIPPEN		DATE
DESIGNED	-	JAN. 97
DRAWN		
CHECKED		
RECOMMENDED		
APPROVED		

KLOHN-CRIPPEN

CLIENT

BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

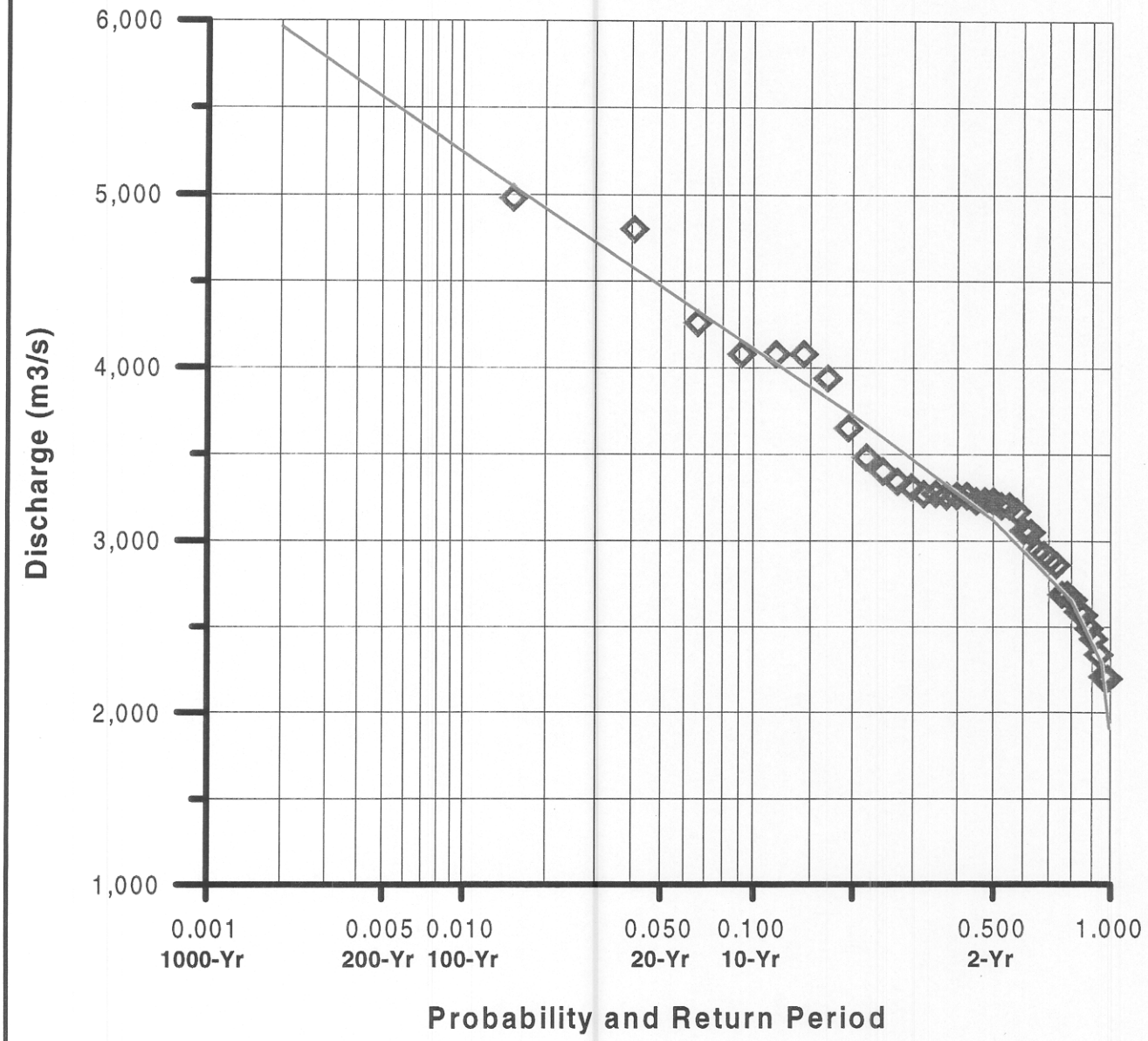
PROJECT

FLOODPLAIN MAPPING
FRASER AND NECHAKO RIVERS AT PRINCE GEORGE

TITLE

LOCATION PLAN

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
January, 1997	PW749001	B-1001	



KLOHN-CRIPPEN

CLIENT

BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

PROJECT

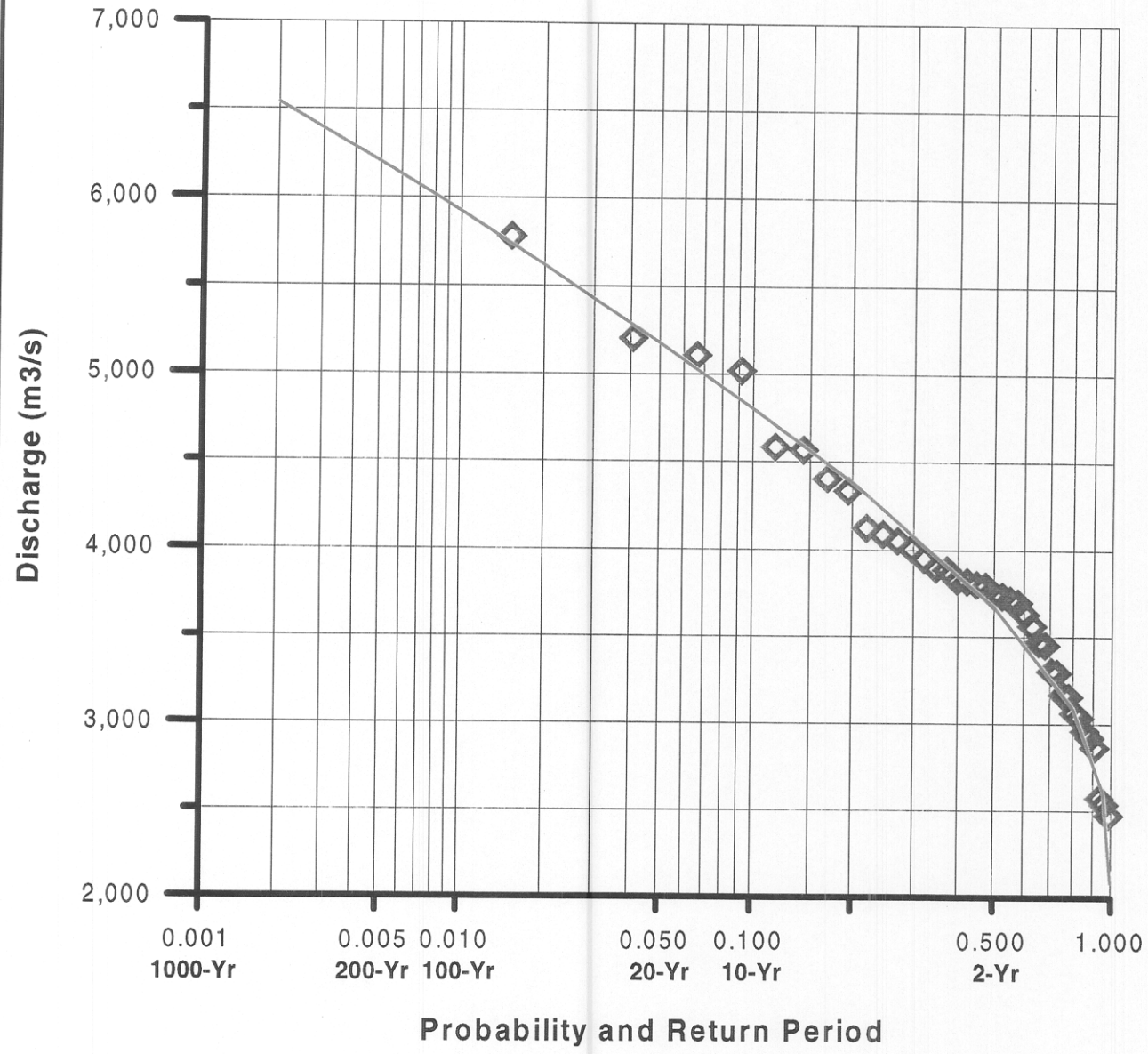
Floodplain Mapping, Fraser and Nechako Rivers at Prince George

TITLE

Flood Frequency Plot of Fraser River at Shelley, Maximum Daily Discharge

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
April 30, 97	PW 7490 01	A-1002	

Freqplts.xls - A-1002



KLOHN-CRIPPEN

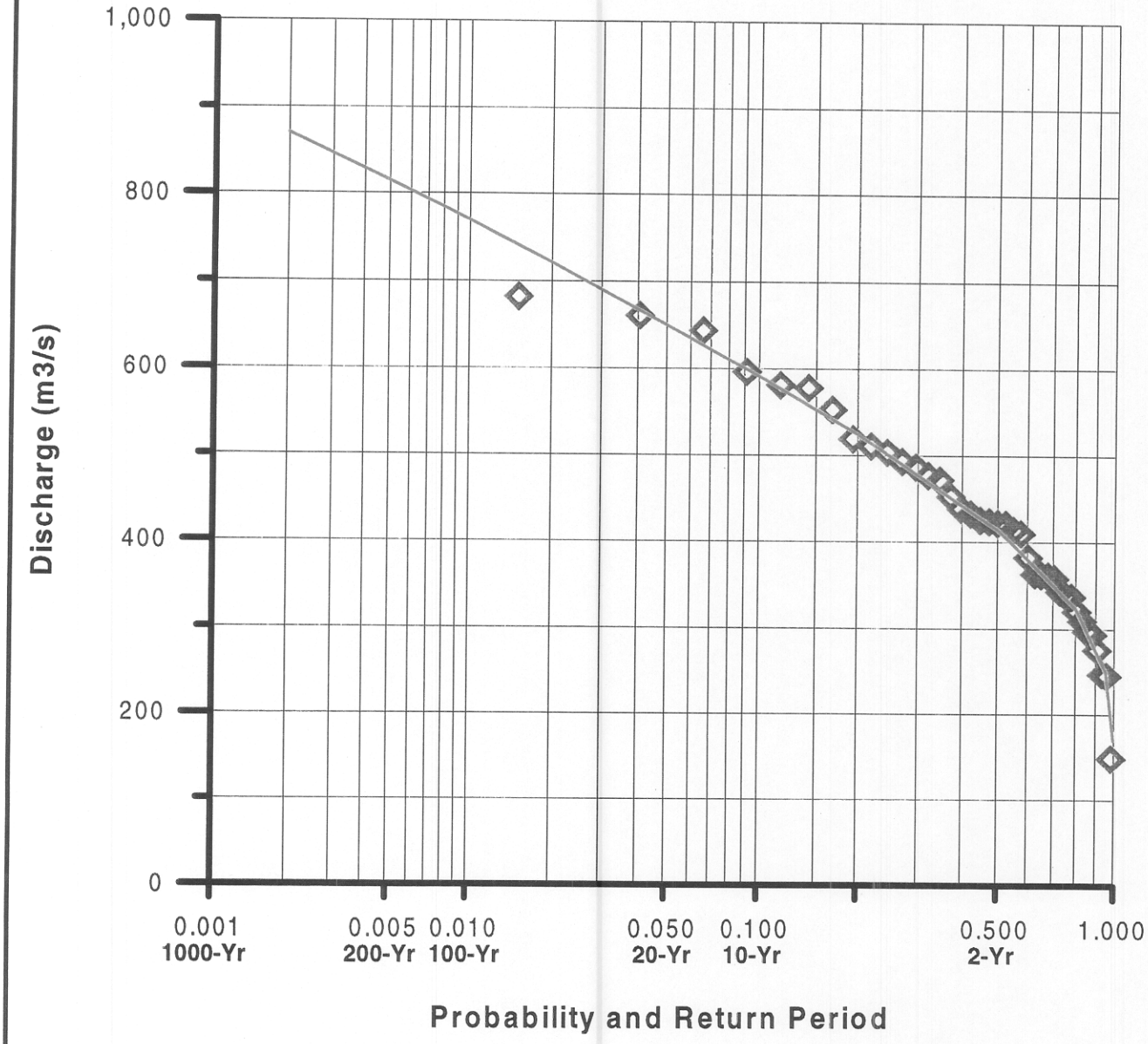
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

PROJECT: Floodplain Mapping, Fraser and Nechako Rivers at Prince George

TITLE: Flood Frequency Plot of Fraser River Downstream of Nechako River, Maximum Daily Discharge

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
January 15, 97	PW 7490 01	A-1003	

FREQPLTS.XLS - A-1003

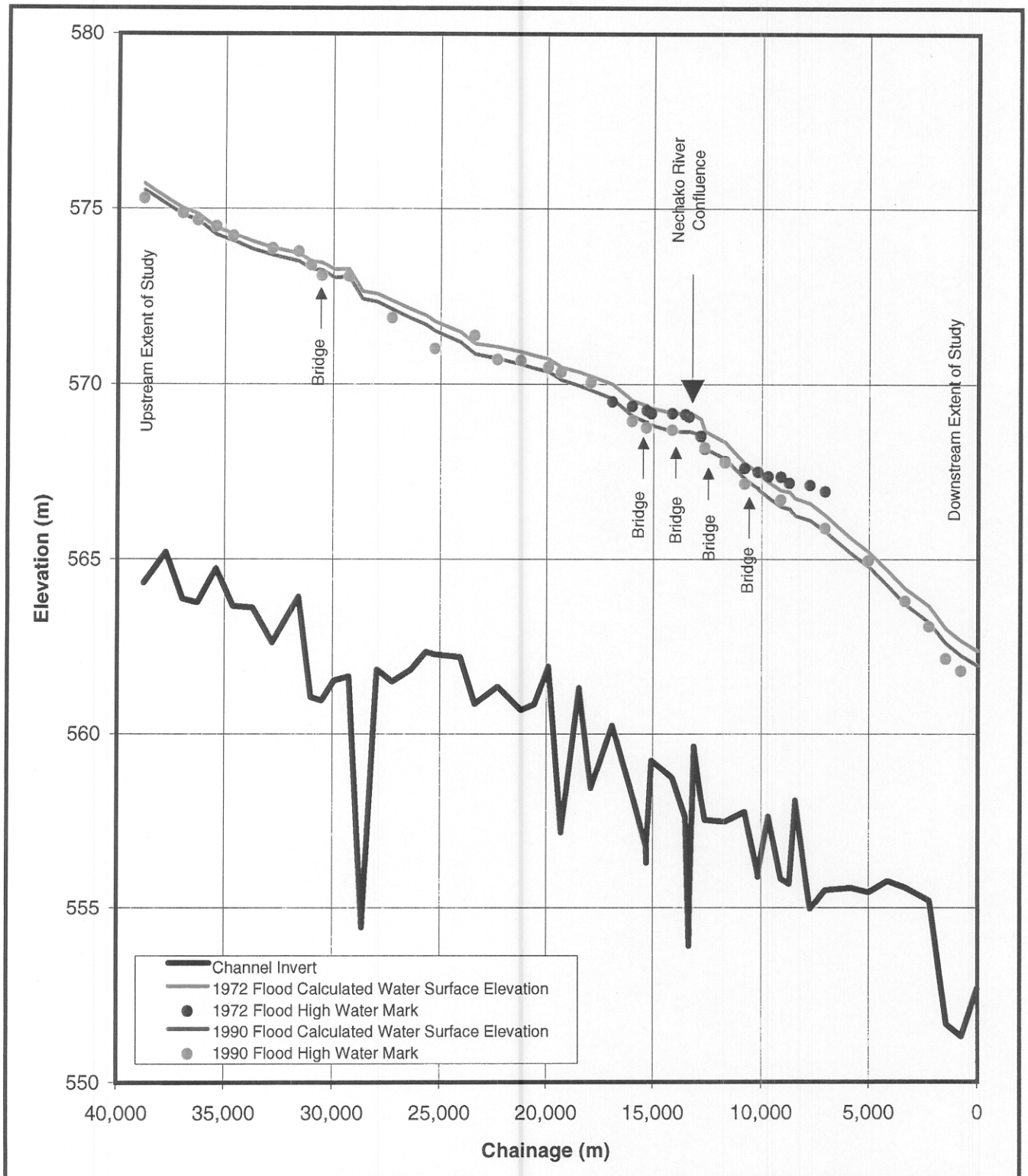


KLOHN-CRIPPEN

PROJECT	Floodplain Mapping, Fraser and Nechako Rivers at Prince George
TITLE	Flood Frequency Plot of Unregulated Nechako River Inflows to Isle Pierre, Maximum Daily Discharge
CLIENT	BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
January 15, 97	PW 7490 01	A-1004	

FREQPLTS.XLS - A-1004



KLOHN-CRIPPEN

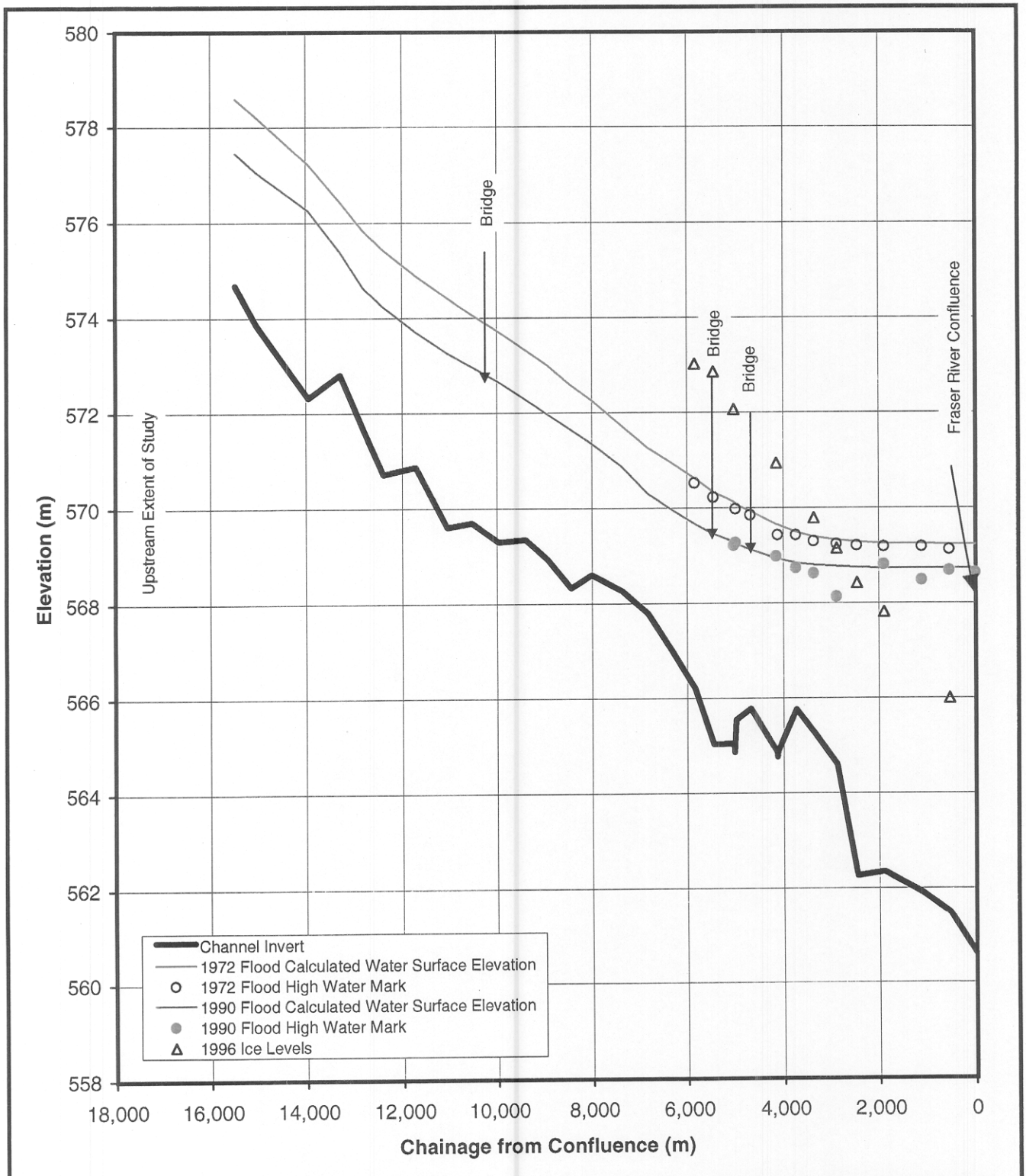
PROJECT: Floodplain Mapping, Fraser and Nechako Rivers at Prince George

TITLE: Fraser River Calibration Profiles

CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
January 15, 97	PW 7490 01	A-1005	

CALIB.XLS - A-1005



KLOHN-CRIPPEN

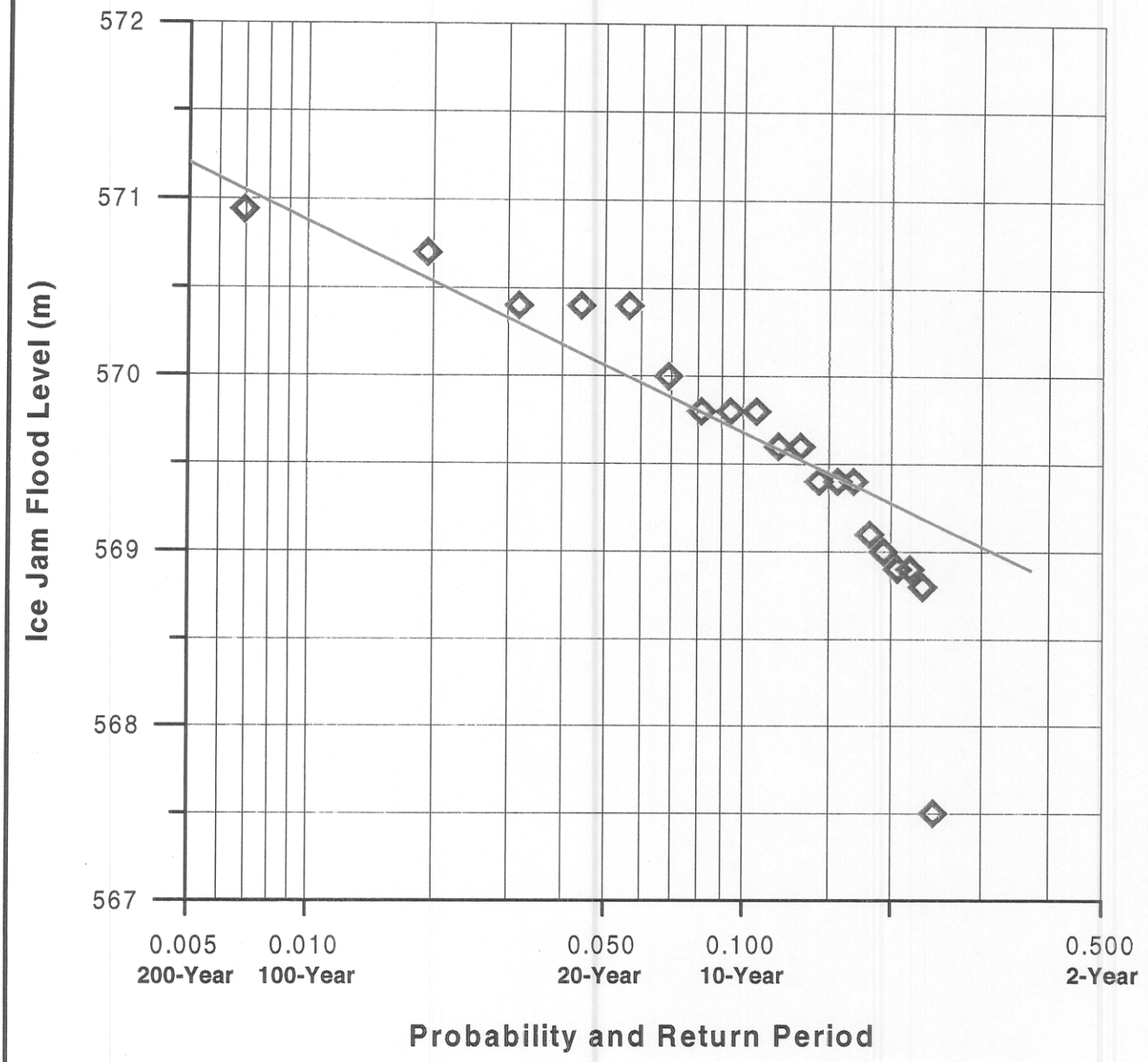
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

PROJECT: Floodplain Mapping, Fraser and Nechako Rivers at Prince George

TITLE: Nechako River Calibration Profiles

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
April 30, 97	PW 7490 01	A-1006	

Calib.xls - A-1006



KLOHN-CRIPPEN

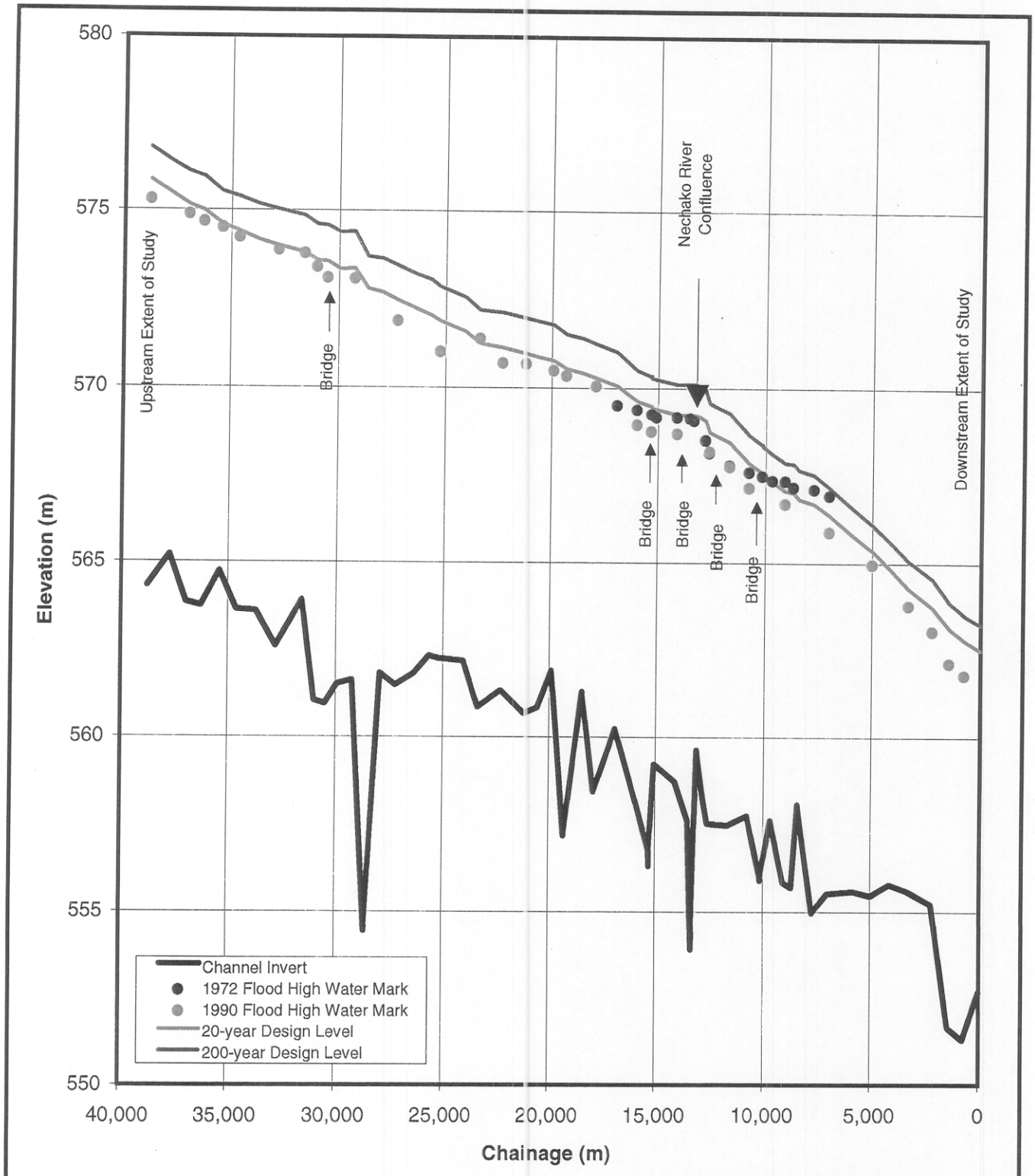
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

PROJECT: Floodplain Mapping, Fraser and Nechako Rivers at Prince George

TITLE: Nechako River Ice Jam Flood Level Probability Plot at Cross Section 11

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
April 30, 97	PW 7490 01	A-1007	

Calib.xls - A-1007



KLOHN-CRIPPEN

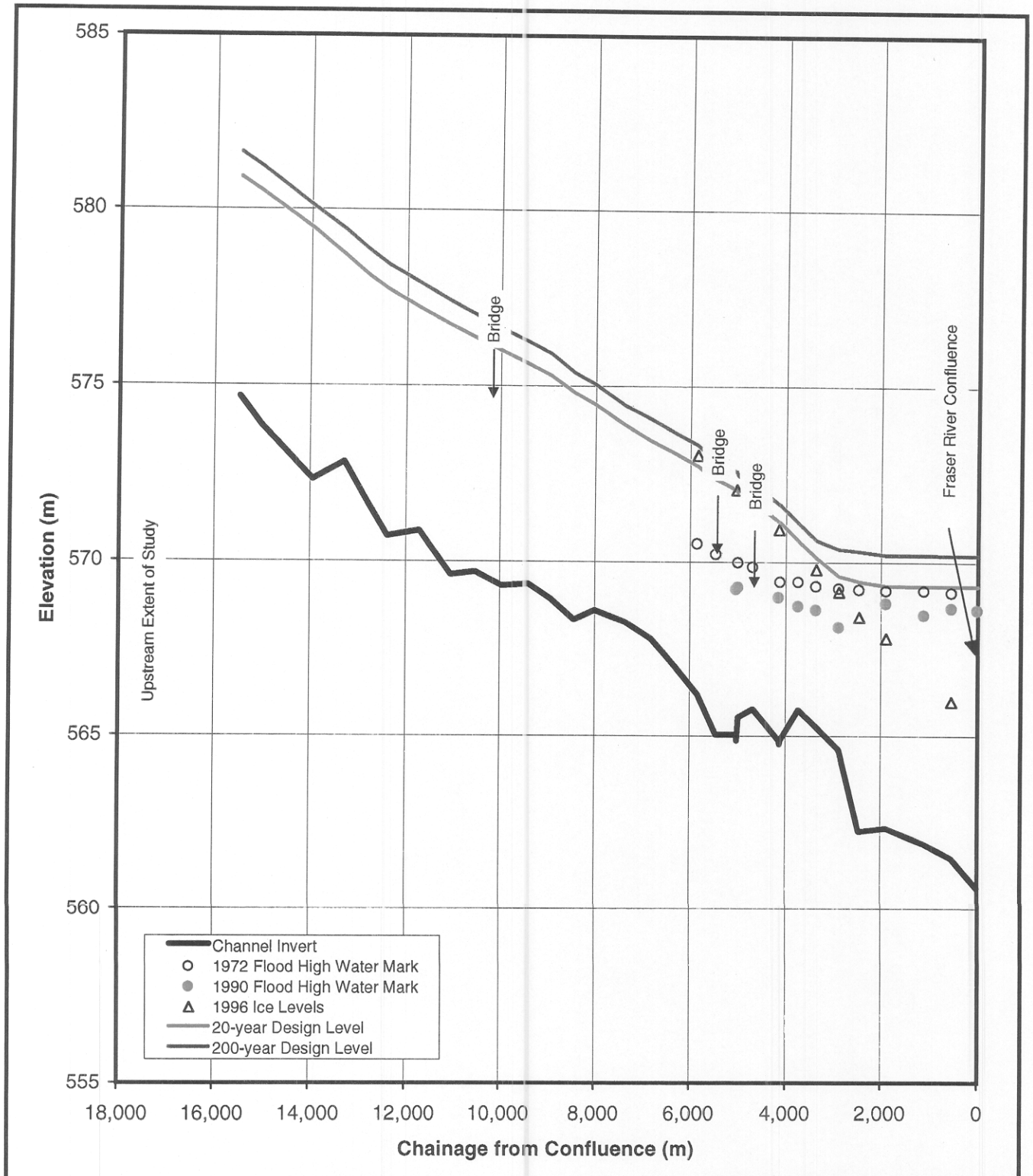
PROJECT: Floodplain Mapping, Fraser and Nechako Rivers at Prince George

TITLE: Design Fraser River Flood Profiles

CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
January 15, 97	PW 7490 01	A-1008	

CALIB.XLS - A-1008

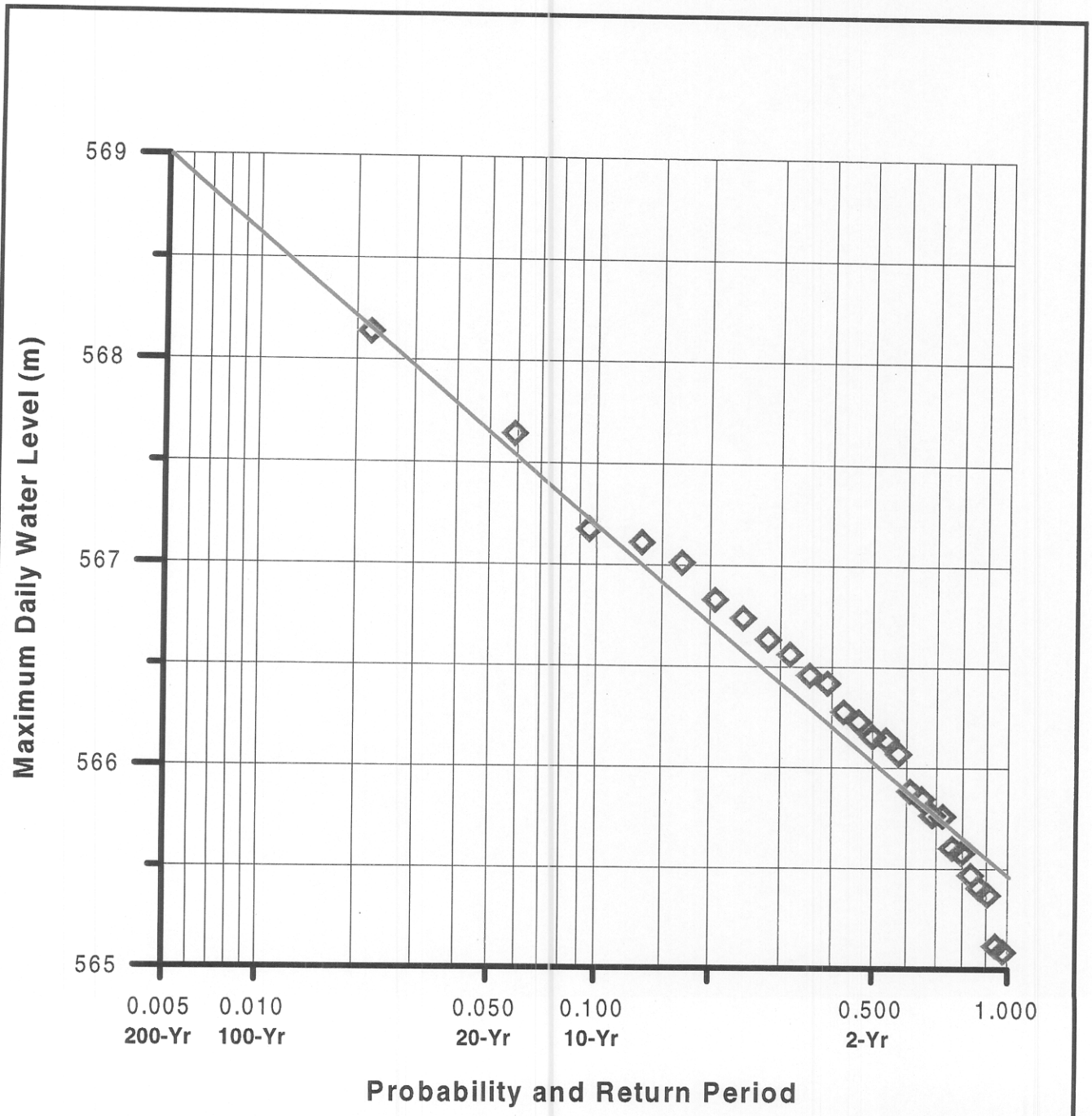


KLOHN-CRIPPEN

PROJECT	Floodplain Mapping, Fraser and Nechako Rivers at Prince George
TITLE	Design Nechako River Flood Profiles
CLIENT	BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
April 30, 97	PW 7490 01	A-1009	

Calib.xls - A-1009



KLOHN-CRIPPEN

CLIENT	BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS
PROJECT	Floodplain Mapping, Fraser and Nechako Rivers at Prince George
TITLE	Flood Frequency Plot of Maximum Annual Fraser River Water Levels at South Fort George

DATE OF ISSUE	PROJECT No.	DWG No.	REV.
January 15, 97	PW 7490 01	A-1010	

FREQPLTS.XLS - A-1010