FLOODPLAIN MAPPING INVESTIGATION

FRASER AND QUESNEL RIVERS AT QUESNEL DESIGN BRIEF

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SUMMARY

Floodplain mapping was carried out along the Fraser and Quesnel Rivers and Baker Creek. The study area included a 16.4 km reach of the Fraser River, through the City of Quesnel, an 8.4 km reach of the Quesnel River and a 3.7 km reach along Baker Creek. Flood profiles for the 20- and 200-year instantaneous and daily floods were computed using the HEC-2 backwater program. Model calibration was performed using high water marks from the flood in 1990. Sensitivity analyses were conducted to verify the reliability of the estimated flood profiles. The flood levels and floodplain limits have been presented on five 1:5000 scale, 2 m contour interval floodplain mapping sheets (map sheets 89-43-1 through 89-43-5).

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1.0 INTRODUCTION

1.1 Purpose of Study

The British Columbia Ministry of Environment is undertaking floodplain mapping under a joint federal/provincial agreement covering various watercourses in the province, including the Fraser River near Quesnel. The purpose of a floodplain mapping study, as defined by the Ministry, is to determine the 200-year floodplain. Floodplain maps display the limits of the 200-year flood boundaries and the flood elevations (freeboard included). The maps are then utilized to assist in the administration of local bylaws, official community plans, the Land Title Act and in other aspects of floodplain management to mitigate the potential damage caused by flooding (Reference 1).

1.2 Authority and Acknowledgements

Hydrologic and hydraulic analyses for preparation of the 200-year floodplain maps, were carried out by Northwest Hydraulic Consultants Ltd (NHC) for the Ministry of Environment (MOE). The work was authorized by an agreement dated July 15, 1991.

The study was conducted under the direction of V. Galay, Project Manager, by M. Mannerstrom, Project Engineer. D. McLean and K. Rood provided technical advice and B. Hunter assisted in the study.

The guidance and suggestions offered by the contract manager, P.J. Woods, Water Management Branch, MOE and by R.W. Nichols, also of the Water Management Branch are greatly appreciated. Mr. W.S. Klopp, MOE Williams Lake and Mr. J. Marsh, Municipal Superintendent, City of Quesnel, assisted by providing information on local ice and flood conditions.

2.0 GENERAL DESCRIPTION OF STUDY AREA

2.1 Scope of Study

The floodplain mapping investigation involved detailed hydrologic and hydraulic analyses of the Fraser and Quesnel Rivers and Baker Creek. The study area comprises a 16.4 km reach of the Fraser River, through the City of Quesnel, an 8.4 km reach of the Quesnel River and a 3.7 km reach along Baker Creek. (All these river channels are shown in Photo No. 1.)

The Fraser River drainage area at Quesnel is about 100 000 km^2. The river originates in the Rocky Mountains and flows in a northwesterly direction to just north of Prince George, where it turns to the south. At the City of Quesnel, the Quesnel River flows into the Fraser River from the east. Baker Creek, a minor tributary to the Fraser, enters from the west at a point a few hundred meters upstream of the Quesnel River confluence. The three drainage basins are shown on the Watershed Map (Figure 1), and the extent of the study area is shown on the Location Map (Figure 2).

2.2 Historic Flooding

Maximum flows in the Fraser and Quesnel Rivers and in Baker Creek occur in late spring or early summer as a result of snowmelt. Annual mean, maximum and minimum flow hydrographs are shown in Figures 3 to 5. The four highest flows on record at Marguerite, downstream of the Quesnel River confluence, occurred in 1967, 1972, 1976 and 1990 and ranged from 5790 to 6510 m^3/s. Other known high floods occurred in 1948 and 1894. A list of annual peak flows at Marguerite are provided in Table 1 and the mean, maximum and minimum stage level for the Fraser River at Quesnel is shown in Figure 6. The four largest events on record are reviewed below along with limited information of the two earlier floods.

2.2.1 The 1990 Flood

Flooding occurred in the beginning of June after a sudden spell of very warm weather, which resulted in rapid snow melt. A maximum daily discharge of 5790 m^3/s was recorded at Marguerite, corresponding roughly to the 10-year flood. The maximum stage at Quesnel was 470.65 m (gauge reading = 8.92 m) and the high water levels lasted for about a week. The Riverfront Walk and a portion of Legion Drive were inundated by about 0.5 m of water at the Fraser/Quesnel confluence (See Photos 2 and 3 and Figure 7 for views of the flooding). The walkway was cracked in a few locations. On the right bank of the Fraser River, in the area just upstream of the bridges, sump pumps were used in several basements to pump water seeping through the dyke which protects the area. The trailer park immediately to the north, where dyking is absent was within inches of being flooded.

On the Quesnel River some flooding occurred on the left bank just upstream of the Highway 97 bridge,in a former trailer park area now owned by Cariboo Pulp and Paper. The discharge in the Quesnel River during the peak flow in the Fraser was 820 m^3/s and the high levels on the Quesnel were the result of backwater from the Fraser River. Some of the debris in the Quesnel River was trapped on the Davie Street bridge piers.

During the peak flow in Baker Creek, corresponding to a return period of just less than 10 years, a large amount of debris was the main problem. The bridge opening at Marsh Drive was nearly plugged several times and logs and debris had to be removed continuously. A berm was built along the left bank, just upstream from the bridge, to prevent the creek from changing its course into a light industrial/residential area on the left bank.

According to Mr. J. Marsh, municipal superintendent, who provided the above information, the overall damage caused in 1990 was minimal.

2.2.2 The 1976 Flood

On May 13, a maximum daily discharge of 5950 m^3/s was recorded at Marguerite, a flow with roughly a 15 year return period. The water level at Quesnel rose to 470.73 m, but the duration of the flood was relatively short, with the peak lasting about four days. Flood damage was limited and again log jams and debris caused the main problems in Baker Creek (Cariboo Observer).

2.2.3 The 1972 Flood

Following extreme snow accumulation over the winter and warm weather in the spring, a discharge of 6510 m^3/s was recorded at Marguerite on June 15. This corresponded to a 50-year return period flood. Water levels at Quesnel exceeded 470.75 m for three days, subsided for a week but then rose to a level of 471.77 m and remained high for over a week. Flood damage was worse in the West Quesnel area on the right bank of the Fraser River (See Photo No. 4). Several families were evacuated and homes were severely damaged. An apartment building near the Baker confluence experienced 1 m of water and vehicles were submerged. Marsh Drive remained dry, but the area to the south of it was flooded except for an area built up for a future shopping center, now in place. The West Quesnel area upstream of the Fraser bridge crossings was also flooded. The worst hit area on the Quesnel River was near the confluence, by the left bank at the Davie Street bridge. (Cariboo Observer and oblique air photography, MOE Special Projects Section).

2.2.4 The 1967 Flood

Water levels rose sharply by about 2 m in April, prompting flood preparations. Dyking work was carried out at the upper end of Funn Street, on the right bank of the Fraser upstream of the bridge crossings. Man holes were plugged and conditions by the Baker Creek bridge were monitored. On June 5, a daily flow of 6120 m^3/s was recorded at Marguerite, corresponding to about the 20-year flood. The maximum level at Quesnel was 471.03 m and

the water level remained above 470.75 m for over a week. Again, flooding occurred in the flood prone areas in West Quesnel along Baker Creek.

2.2.5 The 1948 Flood

The extent of flooding in the Quesnel area caused by the 1948 flood has been mapped (Reference 2) and is reproduced in Figure 8. According to this map, a large area was inundated on the left bank of the Fraser River, next to the Quesnel River confluence and also along the Quesnel River as shown in Photo No. 5. On the right bank, by Baker Creek, extensive flooding also occurred. The 1948 flood is estimated to be of the same magnitude as the 1972 flood. More extensive flooding occurred in 1948 since by 1972 some of the flood prone land had been raised. The maximum stage recorded in 1948 was 471.56 m.

2.2.6 The 1894 Flood

Very limited flood information is available. The maximum water level has been approximated as 2 feet higher than the 1948 level, or about 472.2 m. In the lower Fraser River the 1894 flood has a return period in the order of 200 years. However, as outlined in Section 5.1 the event may have been less severe in the Quesnel area.

3.0 DATA SOURCES

3.1 Hydrologic Information

The hydrometric stations operated by Water Survey of Canada and used in this investigation are listed in Table 2.

The "Fraser River at Quesnel" gauge provides stage records only, starting in 1941. The gauge near Marguerite has been in operation since 1950 and has 41 years of discharge data. It is located about 50 km downstream of Quesnel. The tributary area between the downstream end of the Fraser River study reach and the gauge is about 2000 km^2, small compared to the drainage area at the gauge, and adjustment of the recorded flow is not necessary to describe the reach downstream of the Quesnel River.

The "Quesnel River near Quesnel" gauge has been in operation since 1939 and is located approximately 30 km upstream of the City of Quesnel. The drainage basin at the confluence is about 2% larger than at the gauge and a factor of 1.02 was applied to the computed flood estimates to account for local inflows. Flow through the Quesnel River study reach is assumed to be constant.

"Baker Creek at Quesnel" has a record of 27 years, starting in 1964. The gauge is located near the confluence and no areal adjustment was required for the study reach.

Previous reports and notes on flood levels in the Quesnel area were reviewed. Reference 3 provides data on the frequencies, elevations and durations of flooding from the Fraser and Quesnel Rivers in the Quesnel area. The report includes a "naturalized" rating curve for the Fraser River stage observations at the Quesnel gauge, based on natural flow conditions in the Nechako River prior to the construction of Kenney Dam. Unregulated peak flows were produced for the period 1952 to 1972 and were then combined with recorded flows from 1929 to 1941 into a single rating curve. Corresponding stage levels were derived and

a frequency analysis of these yielded a 200-year flood level at the "Fraser River at Quesnel" gauge of 472.8 m. For present regulated conditions this level would be high.

Reference 4 summarizes a stage frequency analysis for the Fraser River at Quesnel for the period 1953 to 1985, giving a 200-year flood level of 471.92 m. This was compared to a revised estimate of 472.35 m based on the same method as outlined in the above 1973 report. A recommended preliminary flood level of 473.12 m was presented based on a 200-year flood of 8240 m^3/s and the rating curve given in the 1973 report. It was recognized that this value may be an over-estimate.

Reference 5, describing preliminary floodplain mapping for the Quesnel area, adopted a flood level at Quesnel of 473.1 m. However, the freeboard allowance was adjusted to match the existing flood level of 473.4 m including freeboard.

Reference 6 provided 20- and 200-year flood estimates for the Fraser River, upstream and downstream of the Quesnel River confluence, and for the Quesnel River. The estimates were based on the limited time period from 1967 to 1982 and were therefore not adopted for the present study.

3.2 Hydraulic Information

The study reaches, as outlined on the Location Map (Figure 2), were surveyed in 1989 by MOE. Additional surveys were not required. Floodplain topography was obtained from 1:5000 scale, 2 m contour interval maps (Sheets 89-43-1 through 89-43-5). Additional supplementary data, including high water mark information and site photography were also provided. Table 3 lists the hydraulic data sources.

The discharge rating curves for both the Marguerite and Quesnel stations show scatter as indicated in Figures 9 to 11. The reasons for this scatter will be discussed later in the section dealing with hydraulic analysis. NHC results from the study on the proposed Fraser River bridge (Reference 7) were also incorporated where applicable.

4.0 FIELD INSPECTION

Two field trips were conducted within the study area, one by Dr. Galay on September 27, 1991 and one by M. Mannerstrom on October 4, 1991.

During the first field trip an aerial reconnaissance with a fixed wing airplane was conducted in order to assess the geomorphic characteristics of the rivers, the conditions along the river banks, the status of bridges and types of materials on the river bed. Thereafter, site visits were taken to each bridge site and to specific erosion sites along the rivers. Also, visits were paid to the local newspaper, the Cariboo Observer, to collect information on historical flooding as well as to a photographic shop (Perry's Picture Place) that had taken photos during flood events.

During the second field trip, M. Mannerstrom obtained information regarding hardships encountered by local residents and interviews were conducted with Mr. J. Marsh, municipal superintendent, and other residents. The location of delineated floodplain boundaries was reviewed.

The findings from these field inspections were incorporated into the following sections of this report.

5.0 HYDROLOGIC ANALYSES

Available flow records were reviewed and adjusted as required. Frequency analyses were carried out and the 200-year and 20-year instantaneous and daily discharges for the Fraser and Quesnel Rivers and Baker Creek were determined.

5.1 Adjustments to Hydrometric Records

After 1941, only stage records are available for the Fraser River gauge at Quesnel. In order to compute the Fraser River flood flows above the Quesnel River confluence, daily flow estimates were derived by subtracting concurrent daily flows on the Quesnel River near Quesnel (Sta. 08KH006) from the daily flows at the Fraser River near Marguerite (Sta. 08MC018). Flood frequency analysis for Fraser River flows at Quesnel was then carried out on the calculated 41 year record of annual maximum discharges.

The Kenney Dam has regulated flows in the Nechako River starting in 1952. The operating regime has changed over the years but the reservoir has often been operated to reduce peak flows in the Fraser, particularly in years of high snow pack. The reduction in the 200-year Fraser River flood estimate due to the operating regime of the Nechako Reservoir since 1980 was evaluated. However, the present reservoir operating procedures may not be adhered to in the future, and the estimated flood flows were therefore not adjusted.

5.2 Frequency Analyses

Flood estimates, for 20- and 200-year return periods based on the Gumbel, Normal, Lognormal, Three Parameter Lognormal and Log-Pearson Type III distributions were calculated with a PC version of the Water Survey of Canada CFA-88 program. Estimated 20-year and 200-year mean daily flows are summarized in Table 4 and were calculated as an average of all the estimates (Table 4). The estimates based on the Gumbel distribution were consistently higher than the other estimates. It is recognized that the Gumbel

distribution may not fit the data as well as the log-normal or log-Pearson distributions. However, in view of the Fraser River flood level variations discussed in Section 6.3, further refinement of the flow estimates was not considered warranted.

The available records are sufficiently long to provide reasonable estimates of the 200-year flood by a single station analysis, except for Baker Creek. The 200-year floods on Baker Creek were compared to a regional analysis for the Prince George area (Reference 8).

The standard error of estimate for the different distributions at the 200-year level average about 5% for the Fraser River and Quesnel River and about 20% for Baker Creek. Log-Normal frequency distributions are shown in Figures 12 to 15.

The magnitude of the large floods in 1948 and 1894 was reviewed. The maximum recorded stage for the Fraser River at Quesnel in 1948 was 471.56 m. This is less than the water level recorded at the same location in 1972 of 471.78 m. A corresponding 1948 flow record at Marguerite is unavailable. The 1894 level has been approximated as 2 feet (0.67 m) higher than the 1948 level, or about 472.2 m. In the lower Fraser the 1894 flood has a return period in the order of 200 years. However, when plotted on the "naturalized" stage frequency curve included in Reference 3, a stage of 472.2 m would have a return period of less than 80 years. Since reliable estimates of these two historic events were not achievable, they were omitted from the flood analysis.

5.3 Instantaneous Flows

At the "Fraser River near Marguerite" gauge, the average ratio between the recorded instantaneous maximum discharge and the daily maximum discharge was computed for 23 years and found to be 1.01, with the ratio ranging between 1.00 and 1.02. Instantaneous 20-year and 200-year flows were calculated by multiplying the daily flows by 1.01 (Table 5).

There are no instantaneous discharge records at the "Quesnel River near Quesnel" gauge. Maximum instantaneous flow records are available for two upstream tributaries. The "Horsefly River above McKinley Creek", provides the average ratio between the maximum instantaneous and daily flows of 1.06, with a range from 1.02 and 1.12 (15 years of record). At the "Cariboo River below Kangaroo Creek", the average ratio is 1.01 (10 years of record). The ratio of instantaneous to daily maximum flows at Quesnel is small due to the regulating effects of large lakes in the basin. Therefore, a ratio of 1.05 was used to calculate instantaneous 20- and 200-year flows.

No instantaneous records are available for Baker Creek. A review of local gauges yielded instantaneous/daily flow ratios of 1.02 at nearby "Nazko River above Michelle Creek" and 1.01 for "West Road River near Cinema". These ratios are low for the relatively small and steep Baker Creek basin. A wider regional analysis (Reference 9), suggested a ratio of 1.3 between instantaneous and daily maximum flows. On the recommendation of MOE, a ratio of 1.15 was adopted for Baker Creek and the corresponding instantaneous flows are tabulated in Table 5.

6.0 HYDRAULIC ANALYSES

Backwater computations were carried out for the Fraser River, Quesnel River and Baker Creek to estimate the 20- and 200-year daily and instantaneous flood profiles. Standard procedures were followed for model development, calibration and sensitivity assessment. Separate HEC-2 backwater models were assembled for the Fraser River, Quesnel River and Baker Creek. Water levels in the lower reaches of the Quesnel River and Baker Creek are influenced by backwater from the Fraser River and to a lesser extent, water levels in the Fraser River just upstream of the Quesnel River confluence are affected by the Quesnel River flows. The Baker Creek outflow has essentially no effect on the Fraser River levels, as the peak flow amounts to less than 1 % of the Fraser flows.

6.1 Model Development

The 1990 microcomputer version of the HEC-2 computer program (Reference 10) was used to compute the water surface profiles. Required input data are the river channel and floodplain geometry, roughness coefficients and descriptions of hydraulic structures.

The river channel and floodplain geometry was described by cross-sections perpendicular to the flow and by reach lengths measured between sections. MOE, Water Management Branch, surveyed 28 sections on the Fraser River, 33 sections on the Quesnel River and 23 sections on Baker Creek. NHC extended the channel sections across and beyond the floodplain using 1:5000 scale 2 m contour interval topographic mapping provided by MOE. CAD-plots of each channel/floodplain section were prepared as shown in Appendix B. The channel reach lengths between sections were provided by MOE and overbank distances were scaled off the topographic maps.

Channel and floodplain roughness values, represented by Manning's roughness coefficient "n", were used in the hydraulic computations. Initial values were selected by engineering judgement based on field inspection and photo documentation, and by reference to

recognized publications (References 11 and 12). The initial channel values ranged from 0.027 to 0.035 for the Fraser River, from 0.030 to 0.038 for the Quesnel River and from 0.035 to 0.040 on Baker Creek. Overbank roughness coefficients varied between 0.6 and 0.12.

Two bridges across the Fraser River, four bridges across the Quesnel River and one bridge across Baker Creek were included in the models. Drawings of each bridge were provided by MOE, along with excellent photographs. All seven bridges are supported by piers and therefore the Special Bridge Method of HEC-2 was used, which incorporates pier losses.

6.2 Model Calibration and Verification

The models were calibrated against two sets of recorded profiles. MOE surveyed the high water marks corresponding to the 1990 peak flows and the water surface levels at the time of the profile survey in July, 1990. Water surface elevations were obtained at 16 cross-sections on the Fraser River, 13 cross-sections on the Quesnel River and at 12 cross-sections on Baker Creek. Calibration flows are summarized in Table 6. The Fraser River flows below the Quesnel River confluence were estimated by WSC from their Marguerite rating curve for the period March 1990 to present.

Water surface profiles were initially computed for the higher 1990 flows in Table 6 using the backwater models and compared to the recorded profiles. Initial roughness coefficients were adjusted slightly and the final calibrated coefficients are summarized in Table 7, along with the recorded and computed water surface elevations. The differences between the recorded and computed elevations are given and the mean absolute error for each water course is computed. Calibration profiles are shown in Figures 16 to 19.

The profiles at the time of the survey (lower discharges) were subsequently computed as shown in Table 8. For both the Fraser River and the Quesnel River the computed low-discharge profiles appear slightly high. The Baker Creek low discharge profile, computed

using the flood calibrated roughness values, falls below the recorded low discharge profile. This is typical of small water courses where boulders and debris provide a higher relative roughness at low flows. For modelling low Baker Creek flows, the roughness values would need to be increased. However, for the flood conditions considered in this report, the roughness coefficients calibrated based on the 1990 flood were adopted.

The agreement between recorded and computed profiles was considered acceptable. The calibrated roughness coefficients varied gradually between sections as shown in Table 7. Typically, the coefficients would be identical through- out uniform river reaches. The gradual variation in n-values forced the computed profiles to match the recorded ones more closely, by taking into account other losses such as those due to turbulence, bends etc. For comparison, the 1990 flood profile for the Fraser River was also computed on a reach mean roughness basis, as outlined in Table 9.

The Fraser River model was further verified by reviewing historic stage levels at the "Fraser River at Quesnel" gauge. A rating curve was plotted showing the recorded annual maximum stage against the concurrent computed discharge (Figure 10). The figure showed a wide band of scatter over the entire discharge range, with a high and a low envelope curve spaced by about 0.8 m. The 1990 calibration levels coincided roughly with the low envelope and therefore any computed profile based on the calibrated roughness values would also fall on the low envelope.

In general, the years near the high envelope curve corresponded to proportionately high discharges in the Quesnel River and the years near the low envelope curve to proportionately low Quesnel River flows. This trend, indicating backwater effects from the Quesnel River, was not consistent for all years.

A similar rating curve was plotted for the Fraser River at Marguerite (Figure 9). Unfortunately, most of the stage readings have not been tied to GSC datum and the figure showed even more extensive scatter than at Quesnel. For the few years when the gauge

readings were tied to datum some scatter persisted. Figure 11 shows the peak stage at Quesnel against the discharge at Marguerite. The rating curve from Reference 3 is also shown. The river cross section at the Marguerite gauge is unstable (Reference 13 and Figure 20). Bed levels recorded in 1971 fluctuate by over 3 m. A gradual bed build-up is reported during the low flow period of the year, followed by degradation during the freshet. Water Survey of Canada frequently adjusts the rating curve for the gauge, with over 19 curves produced over a period of 38 years.

The scatter observed in Figure 10 is likely caused by a combination of Quesnel backwater effects and bed forms moving through the Fraser River study reach. The overall increase in roughness values required to match the high envelope curve was computed by trial and error to be just over 20 per cent. This roughness increase, together with an 0.8 m higher starting level, raised the water surface elevations by approximately 0.8 m through the entire reach, matching the high envelope rating curve at Quesnel.

It is recommended that the model be calibrated to the more conservative upper envelope. The Manning's n roughness coefficients for the entire Fraser River study reach were therefore increased by about 20 percent to range from 0.040 at the downstream end to 0.033 at the upstream end. The accuracy of this roughness increase over the full length of the study reach cannot be verified without a calibration profile matching the high envelope curve. With the revised model, the 200-year daily flood level at the "Fraser River at Quesnel" gauge then becomes 472.5 m without freeboard and 473.1 m with freeboard. This is 0.3 m lower than the level used in the previous floodplain mapping.

6.3 Sensitivity Tests For Starting Conditions

A synthesized rating curve was developed for Section 1 on the Fraser River, by transferring the high envelope rating curve for the "Fraser River at Quesnel" gauge at Section 11 to Section 1. Different starting levels, for a particular discharge, were used in the model and adjusted until the water level at Section 11, 6.6 km upstream, matched the high envelope rating curve at the gauge. The water level drop between Section 11 and Section 1 was approximately 4 m over the discharge range.

The sensitivity of the Fraser River model to the starting level was evaluated at the 200-year maximum daily flood and found to be low. The starting level at Section 1 was raised and lowered by 0.5 m. About 2.5 km upstream the variation from the base profile had diminished to 0.25 m and after an additional 6 km the profiles matched within 0.05 m (Table 10).

The water levels in the lower Quesnel River are governed by the Fraser River. Flood peaks on the Fraser and Quesnel Rivers generally occur within a few days of each other. However, a linear regression of flood peaks shows poor correlation with an r-squared value of 0.62 (Reference 14). The sensitivity of the Quesnel River flood profiles to the Fraser River stage was investigated by reviewing three different flow conditions:

1. Quesnel River 200-year daily flood (1330 m^3/s) with a Fraser River 200-year stage level of 472.4 m at the confluence;

2. Quesnel River 200-year daily flood with a Fraser River stage of 471.0 m, corresponding to a return period between 5 and 10 years; and

3. Quesnel River 10-year flood (980 m^3/s) with the Fraser River 200-year stage.

The Quesnel River flood profiles were found to be governed by the Fraser River stage up to approximately Section 12, 2 km from the confluence. Downstream of this point the profiles in case 1 and 3 coincided closely. Upstream of Section 13 the profiles of cases 1 and 2 were roughly identical (Table 10). Combining a 200-year event on the Fraser River with a 200-year event in the Quesnel River is therefore not overly conservative.

A similar analysis was carried out on Baker Creek, with the following flow cases:

1. Baker Creek 200-year daily flood (112 m^3/s) with a Fraser River 200-year stage level of 472.43 m at the confluence;

2. Baker Creek 200-year daily flood with a Fraser River stage of 470.0 m, corresponding to the average maximum Fraser River level in May; and

3. Baker Creek 10-year flood (65 m^3/s) with the Fraser River 200-year stage.

Flood levels in the lower Baker Creek were found to be entirely governed by the Fraser River, with cases 1 and 3 matching downstream of Section 6, 600 m from the confluence (Table 10). Roughly upstream of Section 7, the profiles in cases 1 and 2 were identical and the 200-year events on Baker Creek and in the Fraser River were combined.

6.4 Sensitivity Studies

The sensitivity of computed water surface profiles to variations in channel roughness and design discharge was evaluated. The 200-year daily discharge was assumed to be the base flood profile. The discharge and roughness values were altered and each resulting profile compared to the base condition and the average variation computed. (Reference 15).

The backwater models' sensitivity to changes in the roughness coefficients was evaluated by adjusting the channel "n" values, as calibrated against the 1990 flood, by a factor of 1.1, 1.2

and 0.9. The corresponding profiles were compared with the base profile. The average variation for the Fraser River was 0.35 m, 0.68 m and -0.36 m for corresponding increases of 10 percent and 20 percent and a 10 percent decrease in channel "n" values. The equivalent variations for the Quesnel River were 0.13 m, 0.26 m and -0.14 m and for Baker Creek 0.09 m, 0.19 m and -0.09 m. Results are summarized in Table 11.

The sensitivity of the computed water surface profiles to variations in design discharge was evaluated. For the Fraser River, Quesnel River and Baker Creek the discharge was increased by 10 and 20 percent and decreased by 10 percent. When compared to the 200-year base profile, the mean absolute difference ranged from 0.37 m to 0.74 m for the Fraser River, from 0.14 m to 0.28 m for the Quesnel River and from 0.10 m to 0.19 m for Baker Creek. Table 12 summarizes the results of the discharge sensitivity analysis.

6.5 Flood Profiles

Flood profiles were prepared to show the computed water surface elevations for the 20- and 200-year daily and instantaneous events. The river thalweg, bridges and high water marks are also indicated on the flood profiles. The water surface profiles as shown, do not include an allowance for freeboard.

The hydraulic analyses for this study are based on unobstructed flow in the channel and at the bridges. The computed flood elevations are valid if the channels remain unobstructed. Also, the flood models are only valid for the rivers in their present state.

The Fraser River flood profiles are shown in Figures 21 and 22, the Quesnel River profiles in Figure 23 and Baker Creek in Figure 24.

6.6 Designated Flood Level

The recommended designated flood level is the water surface elevation computed for the 200-year maximum daily flood plus 0.6 m of freeboard or the 200-year instantaneous flood plus 0.3 m of freeboard, whichever is higher. For the Fraser and Quesnel Rivers the daily flood levels plus 0.6 m are higher than the instantaneous profiles plus 0.3 m, typically by 0.2 m. The computed profiles for the Fraser River include a roughness adjustment to account for possible variations in water levels due to the movement of bed forms through the reach.

For Baker Creek, the maximum daily and maximum instantaneous flow profiles including freeboard are nearly the same, the maximum daily profile being slightly higher.

6.7 Ice Conditions

The designated flood levels may be affected by ice jams. According to Reference 7 the mean freeze-up date on the Fraser River near Quesnel is January 1st and the mean ice free date is April 1st to 15th. However, local residents report that the Fraser River may only freeze over completely once in every three years. Sudden sharp rises in water levels during ice conditions have been observed but flooding due to ice jams has not occurred.

Ice jams have also been observed on the Quesnel River, with massive ice blocks being pushed up on the shores (pers. comm. with Mr. Klopp, MOE, Williams Lake). Damage to structures due to ice has not been reported.

7.0 FLOODPLAIN BOUNDARIES

Floodplain maps (Map Sheets 89-43-1 through 89-43-5) at a scale of 1:5000 and contour intervals of 2 m were prepared to show the outline of the 200-year floodplain. This floodplain is the area inundated by the 200-year maximum daily event plus freeboard. The floodplain limits assume the absence of all dykes, railway embankments and road fills. In addition to the floodplain boundary, the maps depict the following:

- location of river cross-sections, monuments and gauging stations;
- interpolated flood levels for the 200-year designated flood and the 20-year flood (freeboard included) are shown along the river thalweg;
- flood level isograms showing approximate lines of equal 200-year flood level to the edge of the floodplain.

8.0 GEOMORPHOLOGY AND FLOODING

The changes to the boundaries such as width, depth and channel pattern will slowly influence flood levels throughout the rivers being studied and these changes will generally be a reflection of the rate of sediment movement (bed-material load) through this system.

The following comments pertain to prominent river/geomorphological processes that specific river reaches are undergoing and their influence on the floodplain boundaries will be discussed.

8.1 The Effect of Sediment Deposition at the Confluence

A study of historic aerial photographs and of recent oblique photographs indicates a steady build-up of bars and islands at or near the confluence of the Fraser and Quesnel Rivers with Baker Creek. Photo No. 1 shows former bars now emerging as islands on the Quesnel River and the development of new bars. Photo No. 6 shows deposits at the B.C. Railway bridge upstream from the Highway 97 bridge. This deposition is primarily caused by the high flow levels on the Fraser - this large river at high flow, basically serves as a reservoir into which the Quesnel River and Baker Creek flow. The sediment moving along these two tributaries drops out at the upstream end of the backwater limit and eventually moves further downstream as the Fraser levels recede. The effect of this deposition, on both the Quesnel and the Baker, will be a gradual extension upstream of the backwater limit. In other words, the deposition will cause the flood levels in these two tributaries to slowly rise with time in an upstream direction. The extent of deposition at the confluence of Baker Creek has grown substantially as shown in Photo No. 7. The deposition generally begins at the upper limit of the backwater as shown in Photo No. 8 which indicates a requirement for flood dykes on the left bank of Baker Creek upstream from the Marsh Drive bridge.

The Fraser River, however, appears capable of moving sediment out of the confluence reach since there are no gravel bars along this relatively straight stretch of river (see Photo No. 9).

The sediment that enters from the tributaries, therefore, moves downstream once it enters the Fraser River. As noted from the discharge rating curve (Figure 10) there is evidence of scatter which may be caused by the movement of submerged gravel bars through the reach. Further upstream on the Fraser, just outside of the study reach, several meander loops are undergoing extensive bank erosion resulting in an increased bed load to the river (see Photo No. 10). This sediment load moves further down the river, past the confluence and should not cause any long term trends in water level, except for the rising and lowering of the rating curve as gravel bars move through.

As stated previously, the long term trend on the Quesnel and Baker Creek is for a rising flood level as deposits (bars) work their way upstream as the backwater limit is extended with time. On the Quesnel River, there is evidence of some recent erosion of steep banks (see Photo No. 11), so the process of aggradation near the confluence is expected to continue. The rate of aggradation will, however, probably not be extremely rapid.

8.2 Long Term Trends Regarding Floods on the Fraser River

A recent review of the water supply in the Fraser River Basin makes the following observation (Reference 16):

> "The warmest and coldest decades were 1938-47 and 1963-72, respectively.... both maximum and minimum daily flows (at Hope) are higher during the cold decade. The timing of minimum flows is about the same for both decades, but maximum flows occur earlier in the spring during the warmer decade. If these decades represent valid analogues of the differences between the present climate and a future enhanced-greenhouse-effect climate, then it appears that Fraser River floods would be decreased and occur earlier in the spring, and low flows would also be decreased, but would occur at about the same times of year as at present."

The figure showing these trends is presented as Figure 25 (Figure 2.17 in the original document).

The climatic trend, therefore, may result in reduced flood levels in the future but the geomorphic trend of deposition near the confluence may cause levels to rise - possibly these trends will offset each other resulting in only minor changes in the future.

9.0 CONCLUSIONS AND RECOMMENDATIONS

1. The comparisons between recorded and computed water levels, as well as, the sensitivity analyses demonstrate that the HEC-2 backwater computations performed in this study are adequate for defining the 200-year flood levels and floodplain limits on the Quesnel River and Baker Creek.

2. The Fraser River HEC-2 backwater model was initially calibrated to the 1990 flood flow. A review of recorded Fraser River water levels at Quesnel indicated large variations in the stage-discharge relation. Model roughness values were increased by approximately 20 percent in order for the model to match the high envelope rating curve at Quesnel.

3. It is recommended that the flood levels and floodplain limits shown on Map Sheets 89-43-1 through 89-43-5 be interim designate pursuant to the terms of the Canada British Columbia Floodplain Mapping Agreement.

REFERENCES

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TABLE 1

Fraser River Annual Peak Flows at Marguerite (Sta. 08MC018)

Year	Date	Maximum Daily Discharge (m^3/s)
1950	JUN 21	5440
1951	MAY 19	4530
1952	MAY 23	4590
1953	MAY 21	3650
1954	JUL 5	4250
1955	JUN 28	5550
1956	JUN 8	4560
1957	MAY 23	4980
1958	JUN 1	4700
1959	MAY 22	4280
1960	JUL 2	5040
1961	MAY 29	4560
1962	JUN 29	4620
1963	JUN 14	4250
1964	JUN 15	5640
1965	JUN 5	4840
1966	MAY 12	4900
1967	JUN 5	6120
1968	JUN 14	4930
1969	JUN 7	3370
1970	JUN 7	5320
1971	JUN 17	4500
1972	JUN 16	6510
1973	JUN 27	4620
1974	JUN 25	5010
1975	JUL 9	3600
1976	MAY 13	5950
1977	JUN 11	4300
1978	JUN 8	3280
1979	JUN 7	5410
1980	JUN 21	3230
1981	MAY 28	4330
1982	JUN 5	4700
1983	JUN 22	3220
1984	JUL 2	3970
1985	MAY 27	5120
1986	JUN 3	5570
1987	JUN 15	3770
1988	MAY 16	4280
1989	JUN 17	3550
1990	JUN 3	5790

TABLE 2
Key Hydrometric Stations

Station Name	Station Number	Drainage Area Sq. km	Period of Record	Years of Annual Maximum	Status
Fraser River near Marguerite	08MC018	114000	1950–1990	41	Regulated
Quesnel River near Quesnel	08KH006	11500	1939–1990	52	Natural
Baker Creek at Quesnel	08KE016	1570	1963–1990	27	Natural
Fraser River at Quesnel	08KE002	97900	1941–1990	45	Regulated
Nechako River at Isle Pierre	08JC002	42500	1950–1979	41	Regulated
Horsefly River above McKinley Creek	08KH010	785	1955–1988		Natural
Cariboo River below Kangaroo Creek	08KH003	3260	1926–1988		Natural
Nazko River above Michelle Creek	08KF001	3240	1965–1988		Natural
West Road River near Cinema	08KG001	12400	1952–1988		Natural

TABLE 3

HYDRAULIC DATA SOURCES

Ministry of Environment; Water Management Branch:

River Survey, Volumes 1 to 3, Floodplain Survey at Quesnel, Project #89 12 F027 Fraser River XS 1-28, Quesnel River XS 1-33, Baker Creek XS 1-23, July 1989.

Fraser/Quesnel Rivers and Baker Ck, High Water Marks, Project 90 16 F 027

Floodplain Mapping, Fraser and Quesnel Rivers at Quesnel, 1:5000 scale, 2m contour interval. Mapsheets 89-43-1 to 5.

TABLE 4
Flood Frequency Estimates

Location	Return Period (Years)	Discharge (m^3/s) Based on:						Mean Daily Flood (m^3/s)
		Gumbel	Normal	Log-Normal	3-Param. Lognormal	Log Pearson III		
						Max.Like.	Moments	
Fraser River near Marguerite	20	6490	6000	6160	6030	5990	6060	6120
	200	8240	6760	7280	6850	6710	6910	7130
Fraser River at Quesnel	20	5530	5110	5250	5140	5110	5160	5220
	200	7050	5770	6240	5870	5750	5910	6100
Quesnel River near Quesnel	20	1090	1030	1050	1070	1060	1060	1060
	200	1400	1180	1280	1330	1320	1310	1300
Baker Creek at Quesnel	20	77.2	69.4	88.2	73	–	77	77
	200	115	87	155	100	–	105	112

TABLE 5
Estimated Flood Flows

Location	20–yr Flood (m^3/s)		200–yr Flood (m^3/s)	
	Daily	Instant.	Daily	Instant.
Fraser R. below Quesnel R. confluence	6100	6200	7100	7200
Fraser R. above Quesnel R. confluence	5200	5300	6100	6200
Quesnel River	1080	1140	1330	1400
Baker Creek	77	89	112	129

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TABLE 6
Estimated Calibration Flows

Location	Date	Discharge (m^3/s)	Date	Discharge (m^3/s)
Fraser R. below Quesnel R. confluence	June 3,1990	5840	July 4,1990	3460
Fraser R. above Quesnel R. confluence	June 3,1990	4910	July 4,1990	2630
Quesnel River	June 14,1990	967	July 4–5,1990	763–739
Baker Creek	June 13,1990	60	July 4–5,1990	13.8

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TABLE 7

Recorded and Computed Water Levels Based on 1990 High Water Marks

FRASER RIVER

Cross Section	Recorded Water Level (m)	Calculated Water Level (m)	Error (m)	Roughness Coefficient
1	466.48	466.48	0	0.035
2	467.14	467.09	-0.05	0.035
3		467.64		0.032
4		468.16		0.030
5	468.63	468.72	0.09	0.030
6		469.19		0.030
7	469.42	469.61	0.19	0.030
8	469.96	469.99	0.03	0.030
9	470.5	470.49	-0.01	0.030
10		470.73		0.029
11	470.65	470.73	0.08	0.028
12		470.76		0.028
13		470.76		0.027
14		470.78		0.027
15	470.69	470.81	0.12	0.027
16	471.06	471.05	-0.01	0.028
17	471.53	471.57	0.04	0.028
18		471.94		0.028
19	472.29	472.32	0.03	0.028
20	472.62	472.7	0.08	0.028
21		473.13		0.028
22	473.78	473.8	0.02	0.029
23		474.13		0.032
24		474.69		0.032
25	475.23	475.09	-0.14	0.032
26		475.68		0.028
27	476.06	476.1	0.04	0.028
28	476.53	476.49	-0.04	0.028
Mean Absolute Error=			0.06	

QUESNEL RIVER

Cross Section	Recorded Water Level (m)	Calculated Water Level (m)	Error (m)	Roughness Coefficient
1		470.6		0.036
2		470.63		0.036
3	470.64	470.63	-0.01	0.036
4		470.65		0.036
5		470.69		0.036
6		470.74		0.036
7		470.77		0.036
8		470.8		0.036
9	470.78	470.81	0.03	0.036
10	470.85	470.9	0.05	0.036
11		471.35		0.037
12	472.29	472.24	-0.05	0.037
13		472.74		0.030
14		472.78		0.030
15	472.46	472.81	0.35	0.030
16		472.84		0.030
17		473.15		0.030
18		473.14		0.030
19	473.01	473.21	0.2	0.030
20		473.36		0.030
21		473.7		0.030
22	474.05	474.2	0.15	0.030
23		475.08		0.038
24	475.85	475.8	-0.05	0.038
25		476.79		0.032
26	477.18	477.34	0.16	0.030
27		477.77		0.030
28	478.09	478.17	0.08	0.030
29	478.71	478.51	-0.2	0.035
30		479.59		0.033
31		480.5		0.033
32	480.92	481.04	0.12	0.033
33	481.85	481.79	-0.06	0.034
Mean Absolute Error=			0.12	

BAKER CREEK

Cross Section	Recorded Water Level (m)	Calculated Water Level (m)	Error (m)	Roughness Coefficient
1		470.37		0.035
2	470.39	470.39	0	0.035
3	470.5	470.56	0.06	0.035
4	470.84	470.96	0.12	0.035
5	470.91	470.98	0.07	0.035
6		471.56		0.035
7	472.13	472.3	0.17	0.035
8		473.13		0.040
9	474.56	474.54	-0.02	0.040
10		475.29		0.035
11	475.97	476.02	0.05	0.035
12		477.38		0.037
13		478.35		0.039
14		479.52		0.040
15	480.28	480.22	-0.06	0.040
16		481.86		0.035
17		483.38		0.032
18	484.21	484.3	0.09	0.032
19	485.83	485.8	-0.03	0.032
20	487.39	487.61	0.22	0.032
21		488.83		0.032
22		490.16		0.032
23	491.39	491.63	0.24	0.030
Mean Absolute Error=			0.1	

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TABLE 8

Recorded and Computed Water Levels

July 4-5, 1990

FRASER RIVER				
Cross Section	Recorded Water Level (m)	Computed Water Level (m)	Error (m)	Roughness Coefficient
1	464.49	464.49	0	0.035
2	465.1	465.13	0.03	0.035
3		465.67		0.032
4		466.19		0.030
5	466.59	466.69	0.1	0.030
6		467.12		0.030
7	467.31	467.49	0.18	0.030
8	467.74	467.96	0.22	0.030
9	468.12	468.43	0.31	0.030
10		468.79		0.029
11	468.61	468.8	0.19	0.028
12		468.82		0.028
13		468.82		0.027
14		468.85		0.027
15	468.62	468.86	0.24	0.027
16	468.91	469.06	0.15	0.028
17	469.4	469.51	0.11	0.028
18		469.88		0.028
19	470.19	470.28	0.09	0.028
20	470.51	470.58	0.07	0.028
21		470.86		0.028
22	471.71	471.43	-0.28	0.029
23		471.92		0.032
24		472.83		0.032
25	473.05	473.32	0.27	0.032
26		473.73		0.028
27	473.88	474.15	0.27	0.028
28	474.45	474.61	0.16	0.028
Mean Absolute Error =			0.18	

QUESNEL RIVER				
Cross Section	Recorded Water Level (m)	Computed Water Level (m)	Error (m)	Roughness Coefficient
1		468.4		0.036
2		468.61		0.036
3	468.59	468.7	0.11	0.036
4		468.73		0.036
5		468.79		0.036
6		468.89		0.036
7		469.01		0.036
8		469.18		0.036
9	468.97	469.19	0.22	0.036
10	469.25	469.42	0.17	0.036
11		470.72		0.037
12	471.64	471.94	0.3	0.037
13		472.42		0.030
14		472.46		0.030
15	471.89	472.48	0.59	0.030
16		472.51		0.030
17		472.81		0.030
18		472.8		0.030
19	472.35	472.85	0.5	0.030
20		472.97		0.030
21		473.29		0.030
22	473.53	473.83	0.3	0.030
23		474.76		0.038
24	475.2	475.5	0.3	0.038
25		476.43		0.032
26	476.71	476.95	0.24	0.030
27		477.33		0.030
28	477.55	477.75	0.2	0.030
29	478.11	478.13	0.02	0.035
30		479.17		0.033
31		480.06		0.033
32	480.35	480.58	0.23	0.033
33	481.1	481.29	0.19	0.034
Mean Absolute Error =			0.26	

BAKER CREEK				
Cross Section	Recorded Water Level (m)	Computed Water Level (m)	Error (m)	Roughness Coefficient
1		469.24		0.035
2	469.26	469.25	-0.01	0.035
3	469.78	469.51	-0.27	0.035
4	470.22	470.15	-0.07	0.035
5	470.34	470.21	-0.13	0.035
6		470.88		0.035
7	471.55	471.51	-0.04	0.035
8		472.25		0.040
9	474.02	473.82	-0.2	0.040
10		474.47		0.035
11	475.42	475.13	-0.29	0.035
12		476.55		0.037
13		477.52		0.039
14		478.63		0.040
15	479.54	479.43	-0.11	0.040
16		481.22		0.035
17		482.63		0.032
18	483.58	483.42	-0.16	0.032
19	485.35	485.14	-0.21	0.032
20	486.93	486.81	-0.12	0.032
21		488.18		0.032
22		489.48		0.032
23	490.96	490.91	-0.05	0.030
Mean Absolute Error =			0.15	

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TABLE 9

Fraser River Profile Computed using Mean Roughness

Cross Section	1990–Flood Calibrated Roughness	200–Year Profile Based on Calibrated Roughness	200–Year Profile Based on Mean Roughness	Difference in Water Levels (m)
1	0.035	467.90	467.90	0.00
2	0.035	468.37	468.23	0.14
3	0.032	468.84	468.61	0.23
4	0.030	469.25	469.03	0.22
5	0.030	469.79	469.60	0.19
6	0.030	470.25	470.08	0.17
7	0.030	470.67	470.52	0.15
8	0.030	471.01	470.86	0.15
9	0.030	471.50	471.37	0.13
10	0.029	471.69	471.58	0.11
11	0.028	471.69	471.58	0.11
12	0.028	471.73	471.62	0.11
13	0.027	471.73	471.62	0.11
14	0.027	471.74	471.64	0.10
15	0.027	471.78	471.68	0.10
16	0.028	472.01	471.97	0.04
17	0.028	472.53	472.55	–0.02
18	0.028	472.89	472.94	–0.05
19	0.028	473.25	473.34	–0.09
20	0.028	473.65	473.77	–0.12
21	0.028	474.14	474.29	–0.15
22	0.029	474.80	474.93	–0.13
23	0.032	475.11	475.20	–0.09
24	0.032	475.56	475.56	0.00
25	0.032	475.89	475.81	0.08
26	0.028	476.55	476.49	0.06
27	0.028	476.98	476.98	0.00
28	0.028	477.33	477.36	–0.03
Mean Roughness	0.0295			

TABLE 10

Sensitivity to Starting Conditions
Water Surface Elevations (m)

FRASER RIVER *			
Cross Section	Base Profile	0.5 m low Starting Level	0.5 m high Starting Level
1	467.90	467.40	468.40
2	468.37	467.98	468.78
3	468.84	468.53	469.19
4	469.25	469.01	469.53
5	469.79	469.60	470.02
6	470.25	470.10	470.43
7	470.67	470.55	470.83
8	471.01	470.90	471.14
9	471.50	471.41	471.61
10	471.69	471.61	471.79
11	471.69	471.61	471.79
12	471.73	471.65	471.83
13	471.73	471.65	471.82
14	471.74	471.67	471.84
15	471.78	471.70	471.87
16	472.01	471.95	472.09
17	472.53	472.48	472.60
18	472.89	472.85	472.94
19	473.25	473.22	473.30
20	473.65	473.62	473.68
21	474.14	474.12	474.17
22	474.80	474.79	474.82
23	475.11	475.10	475.13
24	475.56	475.55	475.57
25	475.89	475.88	475.90
26	476.55	476.55	476.56
27	476.98	476.98	476.99
28	477.33	477.33	477.34

QUESNEL RIVER			
Cross Section	200-Year Flood 200-Year Start Level	200-Year Flood 10-Year Start Level	10-Year Flood 200-Year Start Level
1	472.40	471.00	472.40
2	472.41	471.03	472.40
3	472.41	471.04	472.40
4	472.42	471.07	472.41
5	472.47	471.14	472.44
6	472.52	471.22	472.46
7	472.53	471.25	472.47
8	472.54	471.29	472.48
9	472.54	471.30	472.48
10	472.62	471.44	472.52
11	472.82	471.92	472.64
12	473.17	472.73	472.87
13	473.47	473.22	473.12
14	473.50	473.26	473.14
15	473.53	473.30	473.16
16	473.57	473.35	473.19
17	473.82	473.67	473.40
18	473.78	473.63	473.38
19	473.88	473.74	473.43
20	474.06	473.95	473.56
21	474.42	474.34	473.85
22	474.85	474.80	474.28
23	475.57	475.56	475.10
24	476.24	476.24	475.81
25	477.30	477.30	476.80
26	477.91	477.91	477.36
27	478.46	478.46	477.79
28	478.82	478.82	478.19
29	479.10	479.10	478.53
30	480.22	480.22	479.60
31	481.18	481.18	480.52
32	481.75	481.75	481.06
33	482.53	482.53	481.81

BAKER CREEK			
Cross Section	200-Year Flood 200-Year Start Level	200-Year Flood 10-Year Start Level	10-Year Flood 200-Year Start Level
1	472.43	470.00	472.43
2	472.43	470.27	472.43
3	472.44	470.89	472.43
4	472.47	471.51	472.44
5	472.59	471.56	472.48
6	472.73	472.13	472.53
7	473.01	472.86	472.67
8	473.69	473.71	473.17
9	475.12	475.12	474.61
10	475.83	475.83	475.35
11	476.65	476.65	476.10
12	478.03	478.03	477.45
13	478.87	478.87	478.41
14	480.16	480.16	479.59
15	480.81	480.81	480.28
16	482.34	482.34	481.91
17	483.92	483.92	483.44
18	484.95	484.95	484.37
19	486.30	486.30	485.86
20	488.12	488.13	487.67
21	489.18	489.18	488.89
22	490.76	490.76	490.22
23	492.06	492.06	491.68

* Sensitivity studies are based on model calibrated to the 1990 flood

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TABLE 11

Sensitivity to Channel Roughness Variations
Water Level Changes (m)

FRASER RIVER *				
Cross Section	Base Profile	90% Roughness Value	110% Roughness Value	120% Roughness Value
1	467.90	0.00	0.00	0.00
2	468.37	-0.09	0.10	0.20
3	468.84	-0.17	0.18	0.37
4	469.25	-0.22	0.23	0.46
5	469.79	-0.29	0.29	0.57
6	470.25	-0.33	0.31	0.63
7	470.67	-0.36	0.34	0.68
8	471.01	-0.38	0.36	0.71
9	471.50	-0.38	0.35	0.70
10	471.69	-0.38	0.37	0.72
11	471.69	-0.39	0.37	0.72
12	471.73	-0.38	0.36	0.71
13	471.73	-0.38	0.36	0.71
14	471.74	-0.38	0.36	0.72
15	471.78	-0.38	0.36	0.70
16	472.01	-0.39	0.37	0.73
17	472.53	-0.39	0.38	0.74
18	472.89	-0.41	0.38	0.75
19	473.25	-0.41	0.40	0.77
20	473.65	-0.44	0.41	0.80
21	474.14	-0.47	0.43	0.84
22	474.80	-0.39	0.37	0.74
23	475.11	-0.40	0.38	0.75
24	475.56	-0.39	0.37	0.72
25	475.89	-0.40	0.38	0.75
26	476.55	-0.38	0.37	0.73
27	476.98	-0.39	0.38	0.74
28	477.33	-0.37	0.36	0.71
	Average	-0.36	0.35	0.68

QUESNEL RIVER				
Cross Section	Base Profile	90% Roughness Value	110% Roughness Value	120% Roughness Value
1	471.00	0.00	0.00	0.00
2	471.03	-0.01	0.01	0.02
3	471.04	-0.01	0.01	0.03
4	471.07	-0.01	0.01	0.03
5	471.14	-0.01	0.02	0.04
6	471.22	-0.03	0.02	0.05
7	471.25	-0.03	0.04	0.07
8	471.29	-0.04	0.05	0.10
9	471.30	-0.04	0.05	0.10
10	471.44	-0.06	0.06	0.13
11	471.92	-0.12	0.12	0.24
12	472.73	-0.16	0.15	0.29
13	473.22	-0.17	0.16	0.32
14	473.26	-0.17	0.16	0.32
15	473.30	-0.16	0.16	0.30
16	473.35	-0.17	0.16	0.31
17	473.67	-0.18	0.16	0.33
18	473.63	-0.19	0.18	0.34
19	473.74	-0.16	0.16	0.31
20	473.95	-0.16	0.15	0.30
21	474.34	-0.17	0.17	0.33
22	474.80	-0.17	0.16	0.31
23	475.56	-0.16	0.16	0.30
24	476.24	-0.19	0.16	0.32
25	477.30	-0.16	0.16	0.31
26	477.91	-0.20	0.19	0.38
27	478.46	-0.22	0.20	0.40
28	478.82	-0.18	0.18	0.35
29	479.10	-0.21	0.20	0.39
30	480.22	-0.21	0.19	0.37
31	481.18	-0.22	0.20	0.40
32	481.75	-0.24	0.22	0.44
33	482.53	-0.26	0.24	0.47
	Average	-0.14	0.13	0.26

BAKER CREEK				
Cross Section	Base Profile	90% Roughness Value	110% Roughness Value	120% Roughness Value
1	470.00	0.00	0.00	0.00
2	470.27	-0.09	0.07	0.15
3	470.89	-0.10	0.09	0.17
4	471.51	-0.09	0.08	0.16
5	471.56	-0.07	0.07	0.15
6	472.13	-0.12	0.11	0.22
7	472.86	-0.11	0.11	0.21
8	473.71	-0.11	0.09	0.19
9	475.12	-0.13	0.10	0.20
10	475.83	-0.12	0.11	0.22
11	476.65	-0.13	0.12	0.24
12	478.03	-0.09	0.08	0.15
13	478.87	-0.12	0.11	0.21
14	480.16	-0.11	0.10	0.21
15	480.81	-0.14	0.14	0.26
16	482.34	-0.05	0.10	0.19
17	483.92	-0.14	0.08	0.17
18	484.95	-0.08	0.11	0.20
19	486.30	-0.03	0.11	0.22
20	488.13	-0.10	0.04	0.09
21	489.18	0.01	0.11	0.19
22	490.76	-0.16	0.05	0.12
23	492.06	-0.01	0.09	0.17
	Average	-0.09	0.09	0.19

* Sensitivity studies are based on model calibrated to the 1990 flood.

TABLE 12

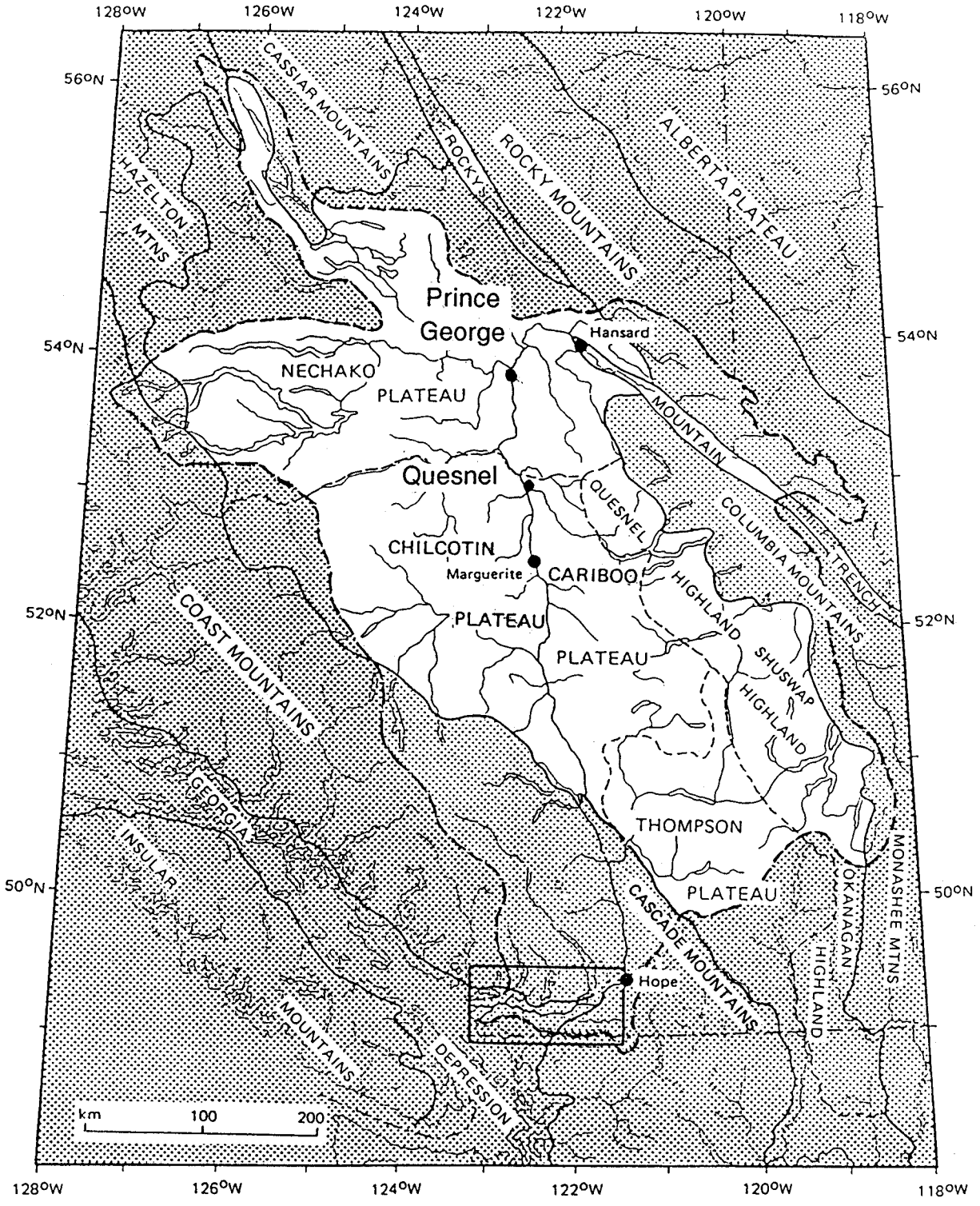
Sensitivity to Design Discharge Variations
Water Level Changes (m)

FRASER RIVER *				
Cross Section	Base Profile	90% Discharge	110% Discharge	120% Discharge
1	467.9	0.00	0.00	0.00
2	468.37	-0.09	0.10	0.21
3	468.84	-0.16	0.18	0.37
4	469.25	-0.21	0.22	0.44
5	469.79	-0.27	0.28	0.56
6	470.25	-0.32	0.32	0.63
7	470.67	-0.36	0.36	0.72
8	471.01	-0.38	0.37	0.73
9	471.5	-0.41	0.40	0.79
10	471.69	-0.41	0.40	0.79
11	471.69	-0.41	0.39	0.78
12	471.73	-0.41	0.40	0.79
13	471.73	-0.41	0.39	0.78
14	471.74	-0.41	0.40	0.78
15	471.78	-0.41	0.40	0.79
16	472.01	-0.42	0.40	0.80
17	472.53	-0.43	0.42	0.83
18	472.89	-0.44	0.42	0.82
19	473.25	-0.43	0.42	0.82
20	473.65	-0.44	0.42	0.83
21	474.14	-0.48	0.45	0.89
22	474.8	-0.48	0.45	0.89
23	475.11	-0.47	0.44	0.88
24	475.56	-0.43	0.41	0.81
25	475.89	-0.39	0.38	0.74
26	476.55	-0.43	0.42	0.82
27	476.98	-0.43	0.43	0.83
28	477.33	-0.41	0.41	0.80
	Average	-0.38	0.37	0.74

QUESNEL RIVER				
Cross Section	Base Profile	90% Discharge	110% Discharge	120% Discharge
1	471.00	0.00	0.00	0.00
2	471.03	0.00	0.01	0.02
3	471.04	-0.01	0.01	0.02
4	471.07	-0.01	0.02	0.04
5	471.14	-0.03	0.03	0.07
6	471.22	-0.04	0.05	0.10
7	471.25	-0.05	0.05	0.11
8	471.29	-0.05	0.06	0.12
9	471.30	-0.05	0.07	0.13
10	471.44	-0.08	0.08	0.18
11	471.92	-0.13	0.14	0.28
12	472.73	-0.16	0.15	0.29
13	473.22	-0.16	0.16	0.30
14	473.26	-0.16	0.15	0.30
15	473.30	-0.16	0.16	0.31
16	473.35	-0.17	0.16	0.32
17	473.67	-0.18	0.16	0.32
18	473.63	-0.17	0.16	0.31
19	473.74	-0.18	0.18	0.35
20	473.95	-0.21	0.19	0.38
21	474.34	-0.22	0.22	0.43
22	474.80	-0.21	0.21	0.41
23	475.56	-0.17	0.17	0.34
24	476.24	-0.16	0.14	0.29
25	477.30	-0.18	0.17	0.32
26	477.91	-0.20	0.19	0.36
27	478.46	-0.24	0.23	0.45
28	478.82	-0.23	0.22	0.43
29	479.10	-0.20	0.20	0.39
30	480.22	-0.21	0.18	0.36
31	481.18	-0.23	0.21	0.41
32	481.75	-0.24	0.23	0.45
33	482.53	-0.26	0.24	0.47
	Average	-0.15	0.14	0.28

BAKER CREEK				
Cross Section	Base Profile	90% Discharge	110% Discharge	120% Discharge
1	470.00	0.00	0.00	0.00
2	470.27	-0.06	0.05	0.11
3	470.89	-0.09	0.08	0.16
4	471.51	-0.11	0.08	0.16
5	471.56	-0.11	0.10	0.19
6	472.13	-0.12	0.11	0.23
7	472.86	-0.11	0.12	0.21
8	473.71	-0.11	0.09	0.18
9	475.12	-0.12	0.10	0.20
10	475.83	-0.10	0.10	0.19
11	476.65	-0.12	0.12	0.22
12	478.03	-0.14	0.12	0.24
13	478.87	-0.10	0.10	0.19
14	480.16	-0.13	0.11	0.22
15	480.81	-0.11	0.12	0.21
16	482.34	-0.09	0.11	0.20
17	483.92	-0.10	0.10	0.17
18	484.95	-0.12	0.13	0.24
19	486.30	-0.10	0.09	0.21
20	488.13	-0.10	0.08	0.15
21	489.18	-0.03	0.11	0.19
22	490.76	-0.15	0.08	0.17
23	492.06	-0.08	0.08	0.16
	Average	-0.10	0.10	0.19

* Sensitivity studies are based on model calibrated to the 1990 flood.



British Columbia Ministry of Environment

Boundary of the drainage basin

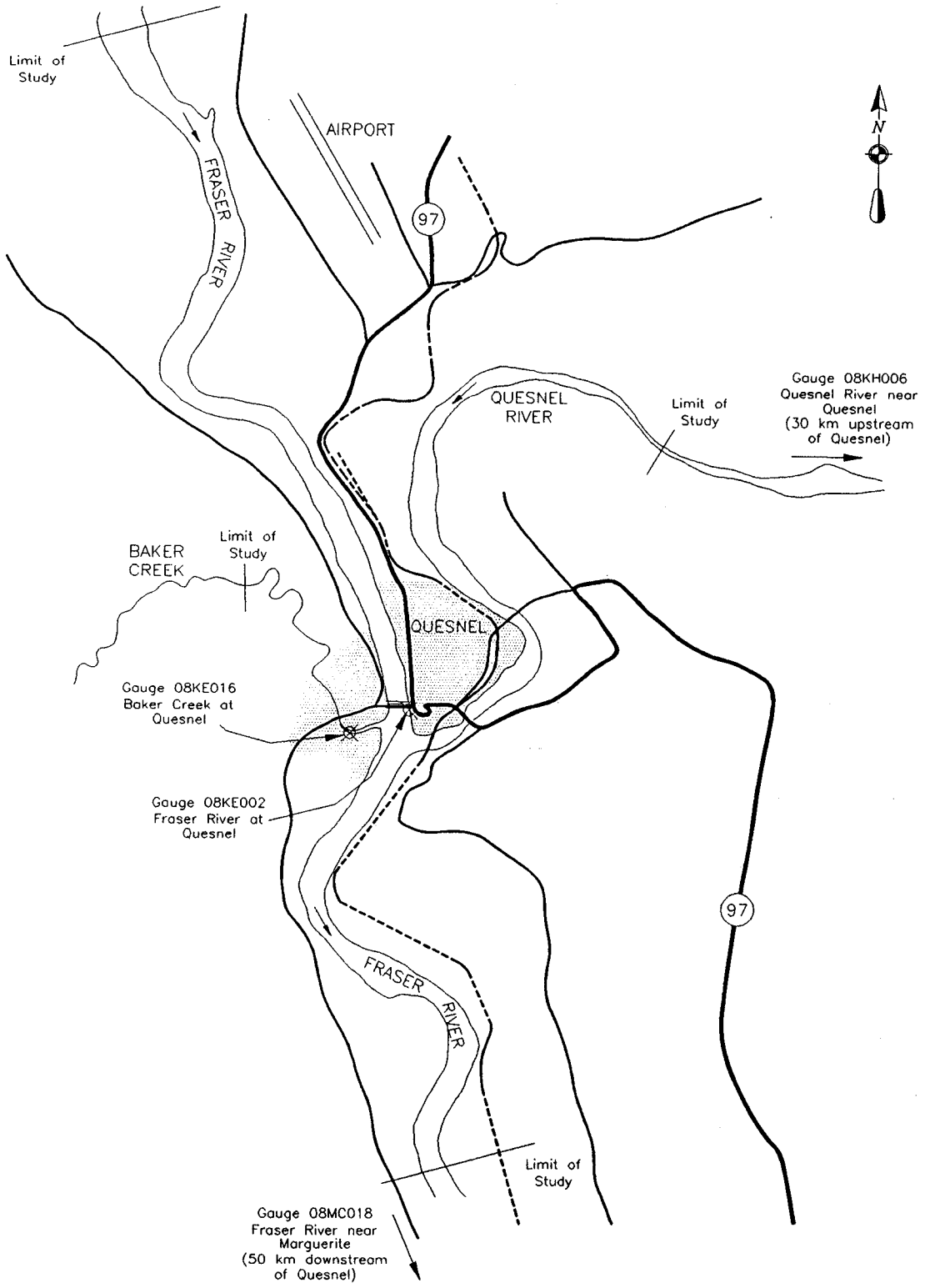
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Drainage Basin

northwest hydraulic consultants

NHCV1735-035

Figure 1



British Columbia Ministry of Environment

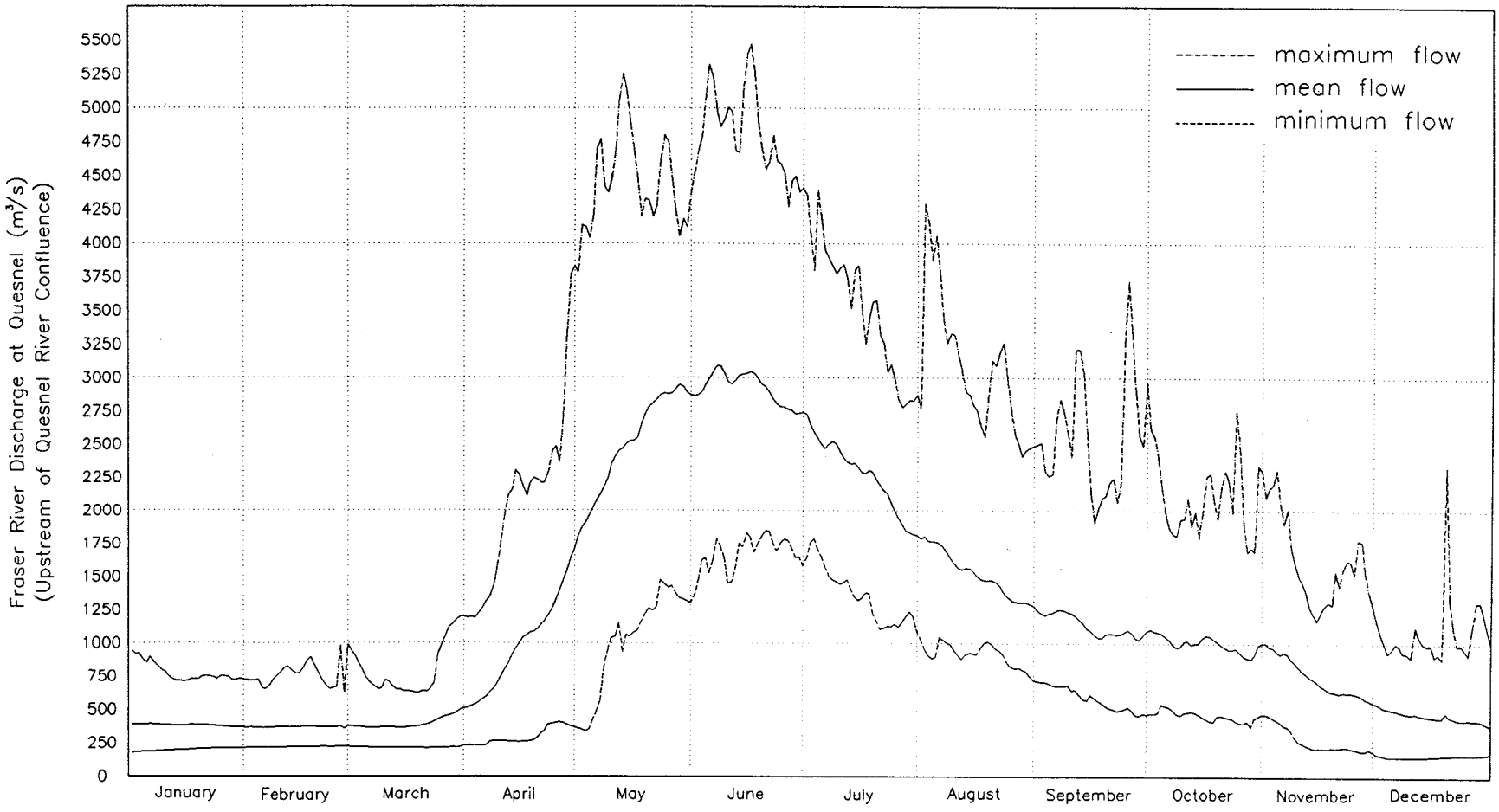
Floodplain Mapping Investigation
Fraser River at Quesnel

Study Area
Location Map

northwest hydraulic consultants

NHCV1735-044

Figure 2



Discharge calculated by subtracting daily readings on the Quesnel River (Gauge #08KH006) from daily readings from the Fraser River near Marguerite (Gauge #08MC018)

Period 1950–1988

British Columbia Ministry of Environment

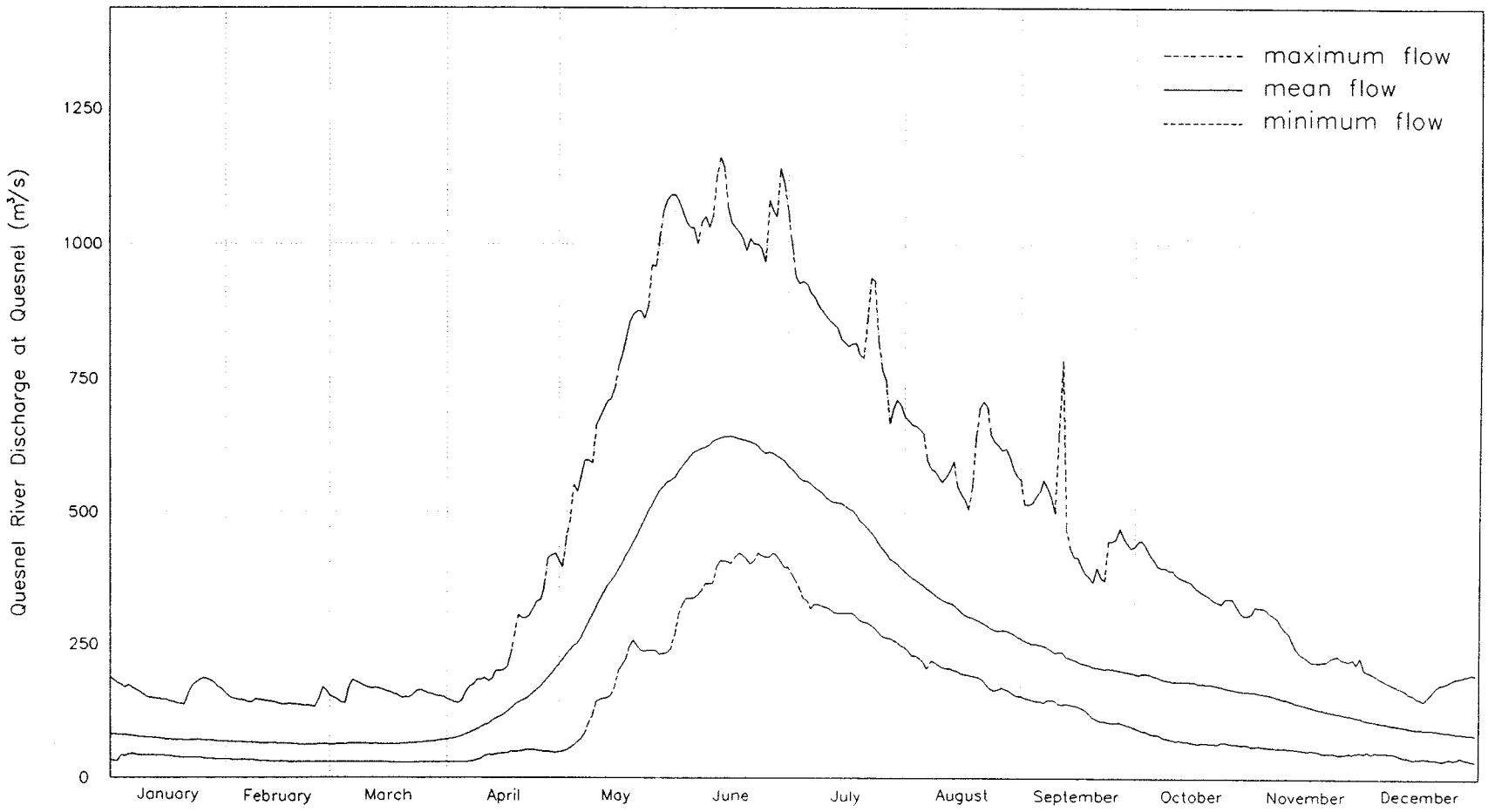
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River Discharge at Quesnel

northwest hydraulic consultants

NHCV 1735-036

Figure 3



Quesnel River (Gauge #08KH006)

Period 1939–1988

British Columbia Ministry of Environment

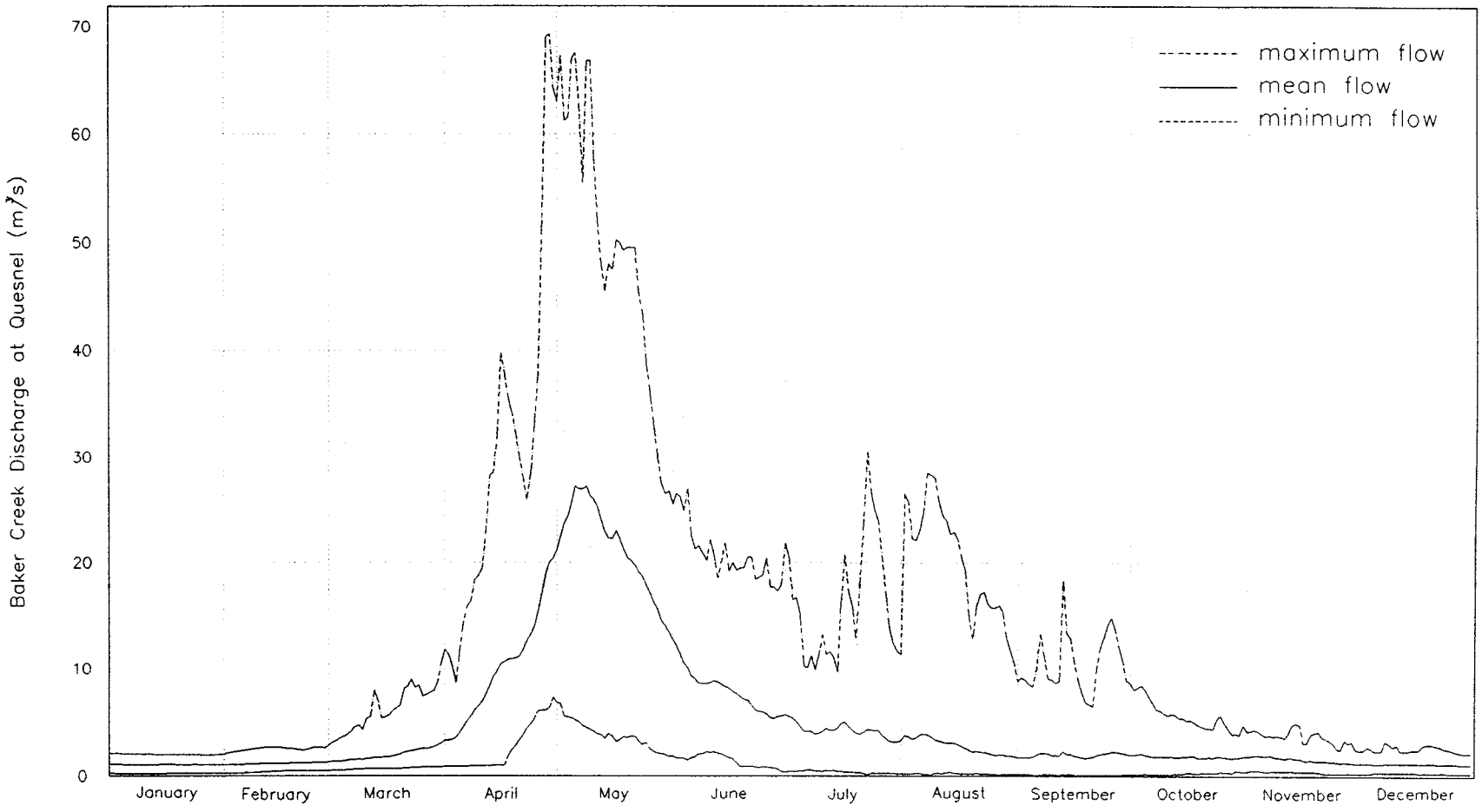
Floodplain Mapping Investigation
Fraser River at Quesnel

Quesnel River Discharge
at Quesnel

northwest hydraulic consultants

NHCV 1735-039

Figure 4



Baker Creek (Gauge #08KE016)

Period 1963-1988

British Columbia Ministry of Environment

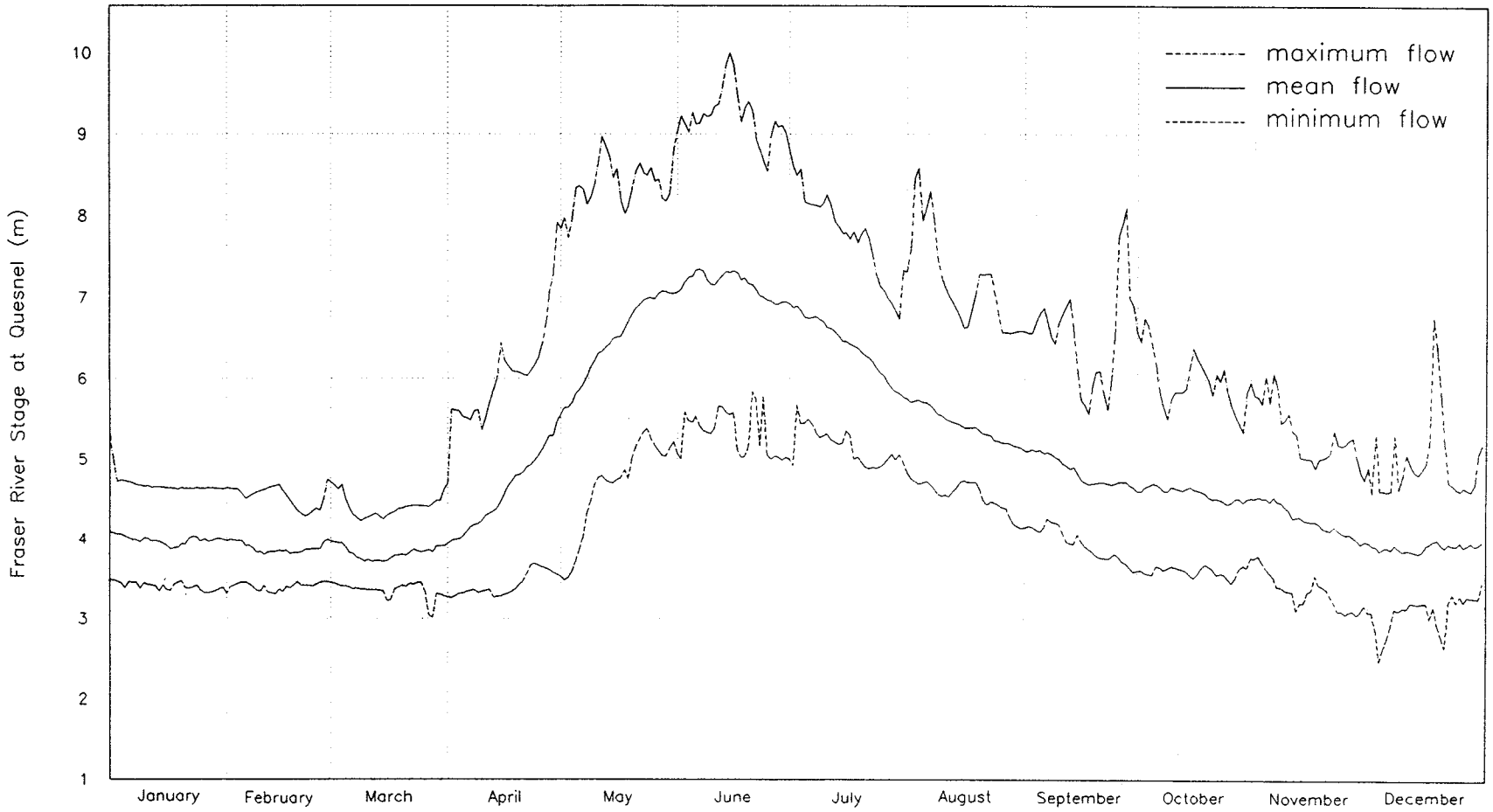
Floodplain Mapping Investigation
Fraser River at Quesnel

Baker Creek Discharge
at Quesnel

northwest hydraulic consultants

NHCV 1735-045

Figure 5



Fraser River (Gauge #08KE002)

Period 1950–1988

Add 461.77m to convert gauge heights to geodetic

British Columbia Ministry of Environment

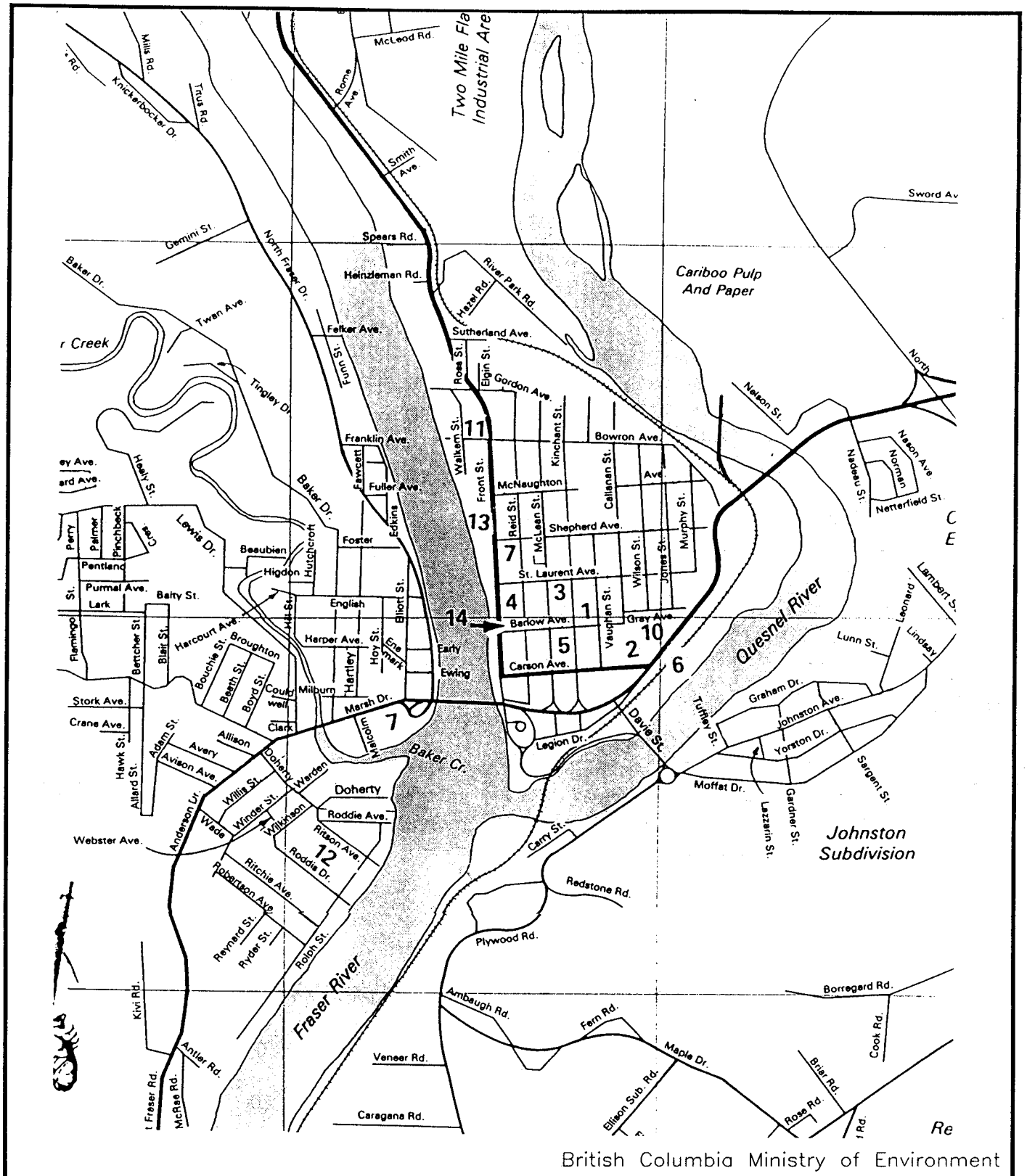
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River Stage
at Quesnel

northwest hydraulic consultants

NHCV 1735-037

Figure 6

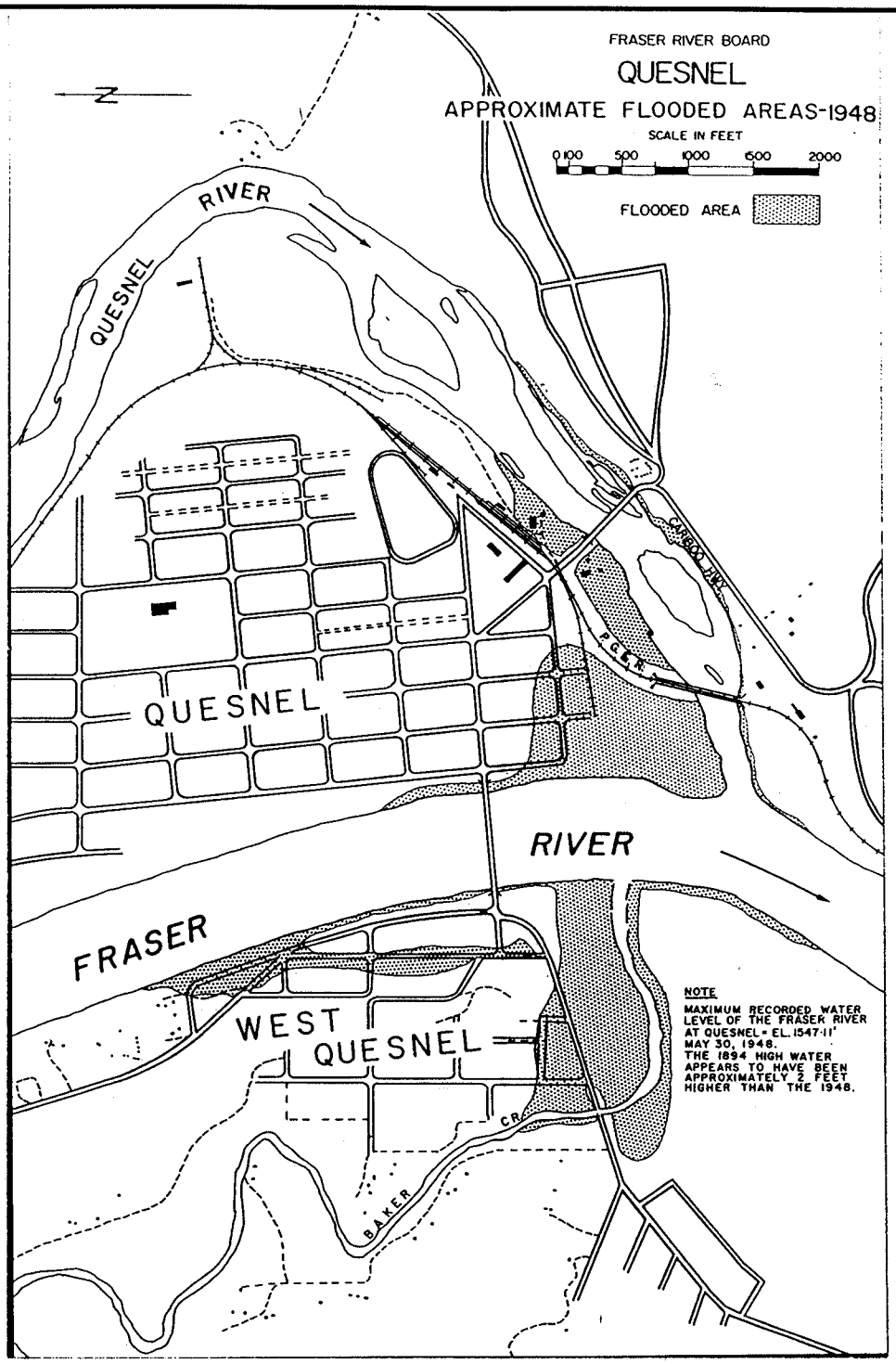


British Columbia Ministry of Environment

Floodplain Mapping Investigation Fraser River at Quesnel
City of Quesnel Street Map
northwest hydraulic consultants

NHCV1735-058

Figure 7

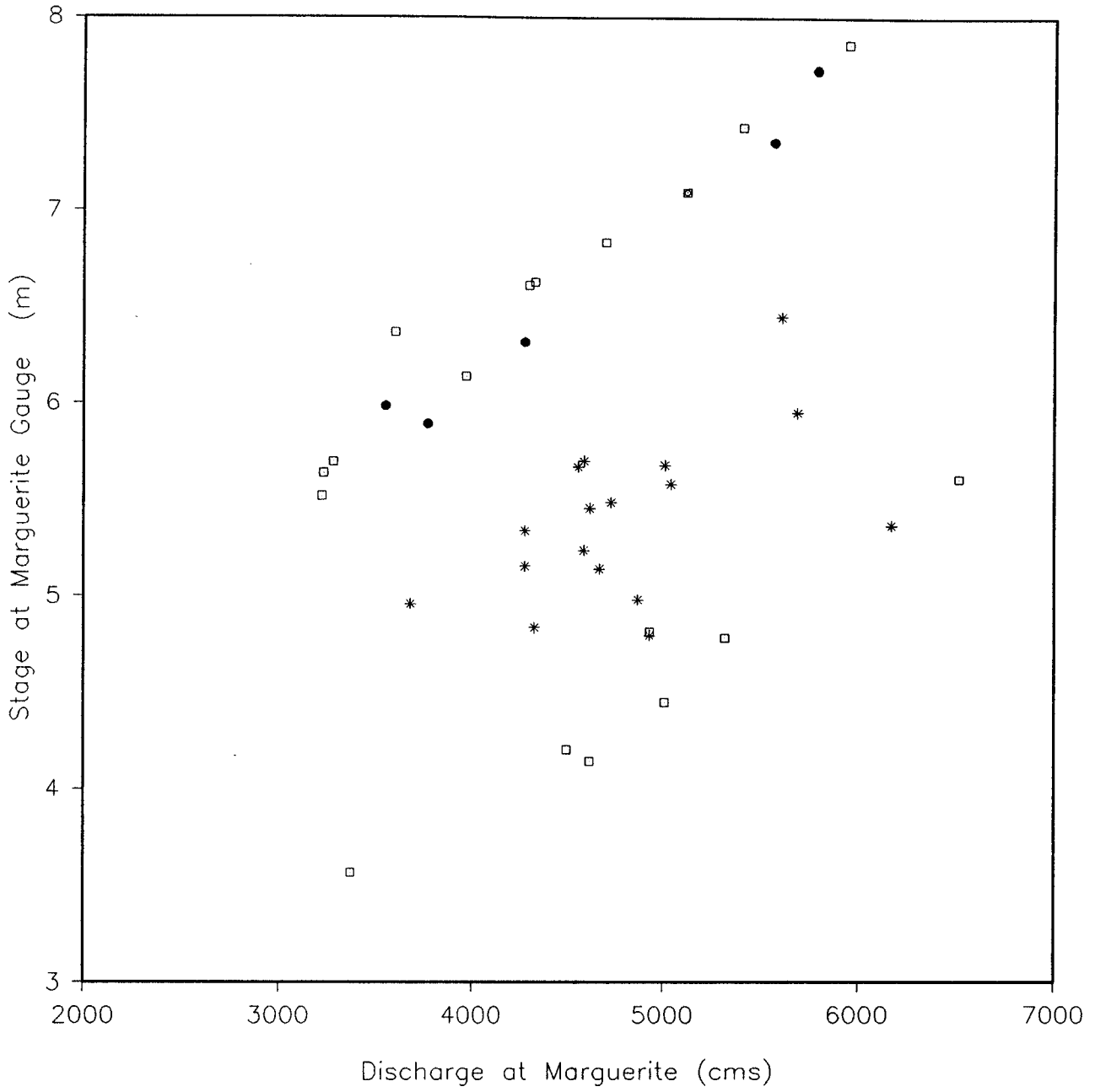


British Columbia Ministry of Environment

Floodplain Mapping Investigation Fraser River at Quesnel
City of Quesnel Extent of 1948 Flooding
northwest hydraulic consultants

NHCV1735-057

Figure 8



Notes:

Relation based on yearly maximum daily discharge and corresponding stage unless indicated.

No geodetic elevation supplied unless indicated.

* Data from 1951–1967. Stage correspondes to yearly maximum instantaneous discharge.

▣ Add 424.842 m to convert guage height to geodetic.

● Add 425.141 m to convert guage height to geodetic.

British Columbia Ministry of Environment

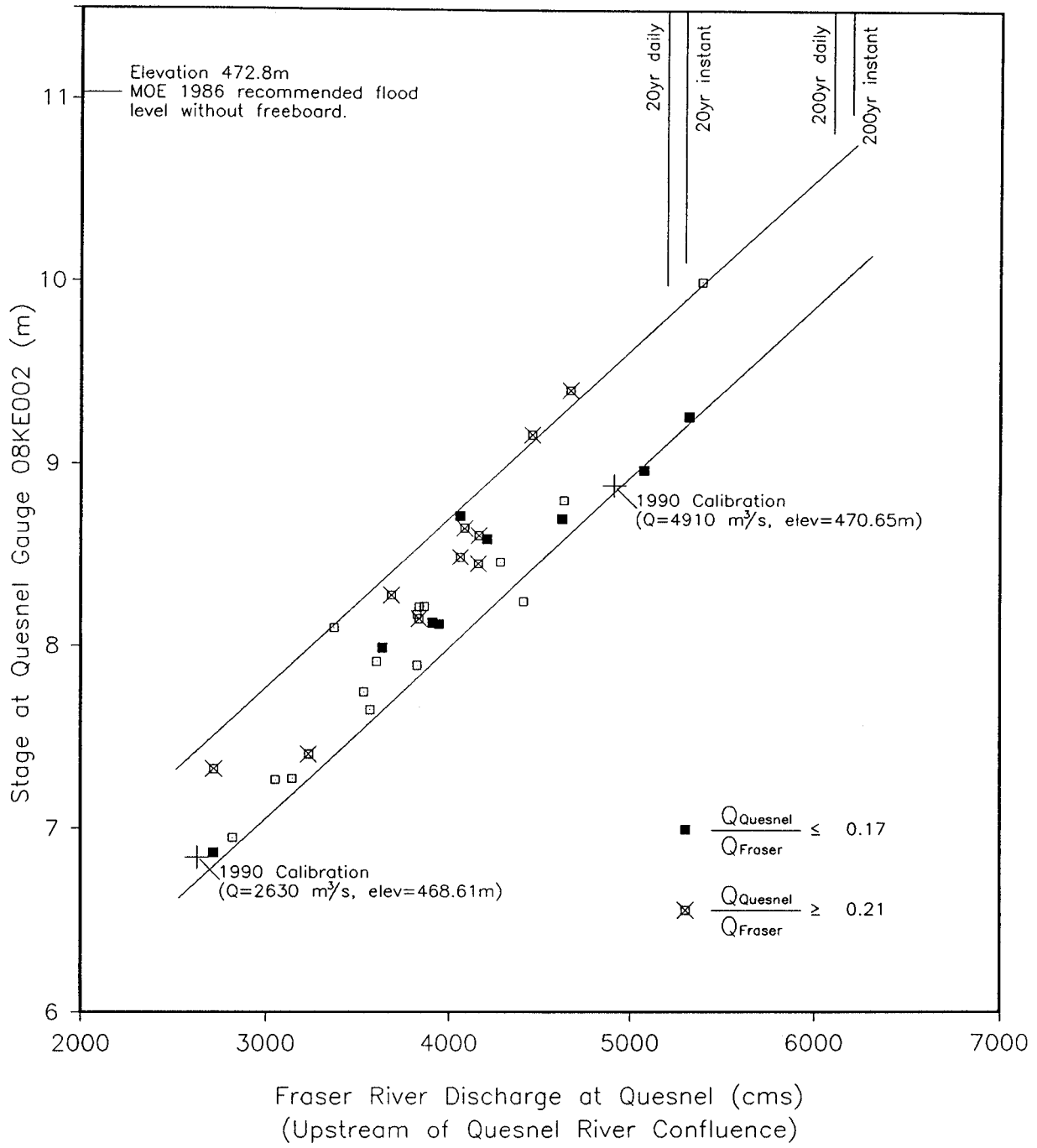
Floodplain Mapping Investigation
Fraser River at Quesnel

Stage – Discharge Relation
Fraser River near Marguerite

northwest hydraulic consultants

NHCV1735-034

Figure 9



Note: Add 461.77 m to convert gauge heights to geodetic.

Relation based on yearly maximum daily stage at Quesnel and corresponding discharge.

Discharge calculated by subtracting reading on the Quesnel River from reading on the Fraser River near Marguerite.

British Columbia Ministry of Environment

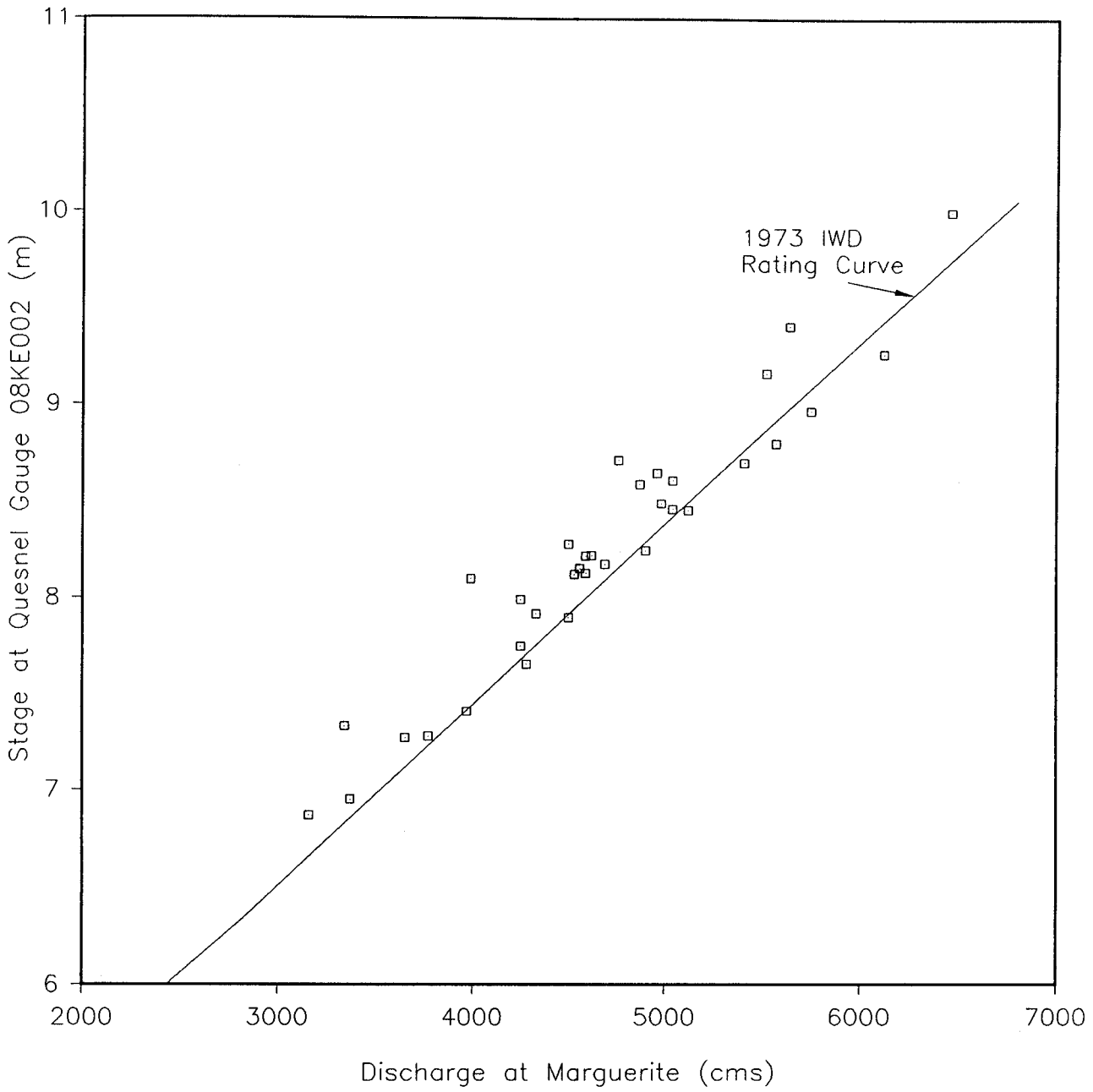
Floodplain Mapping Investigation
Fraser River at Quesnel

Stage – Discharge Relation
Fraser River at Quesnel

northwest hydraulic consultants

NHCV1735-029

Figure 10



Note: Add 461.77 m to convert gauge heights to geodetic.

Relation based on yearly maximum daily stage at Quesnel and cooresponding discharge.

British Columbia Ministry of Environment

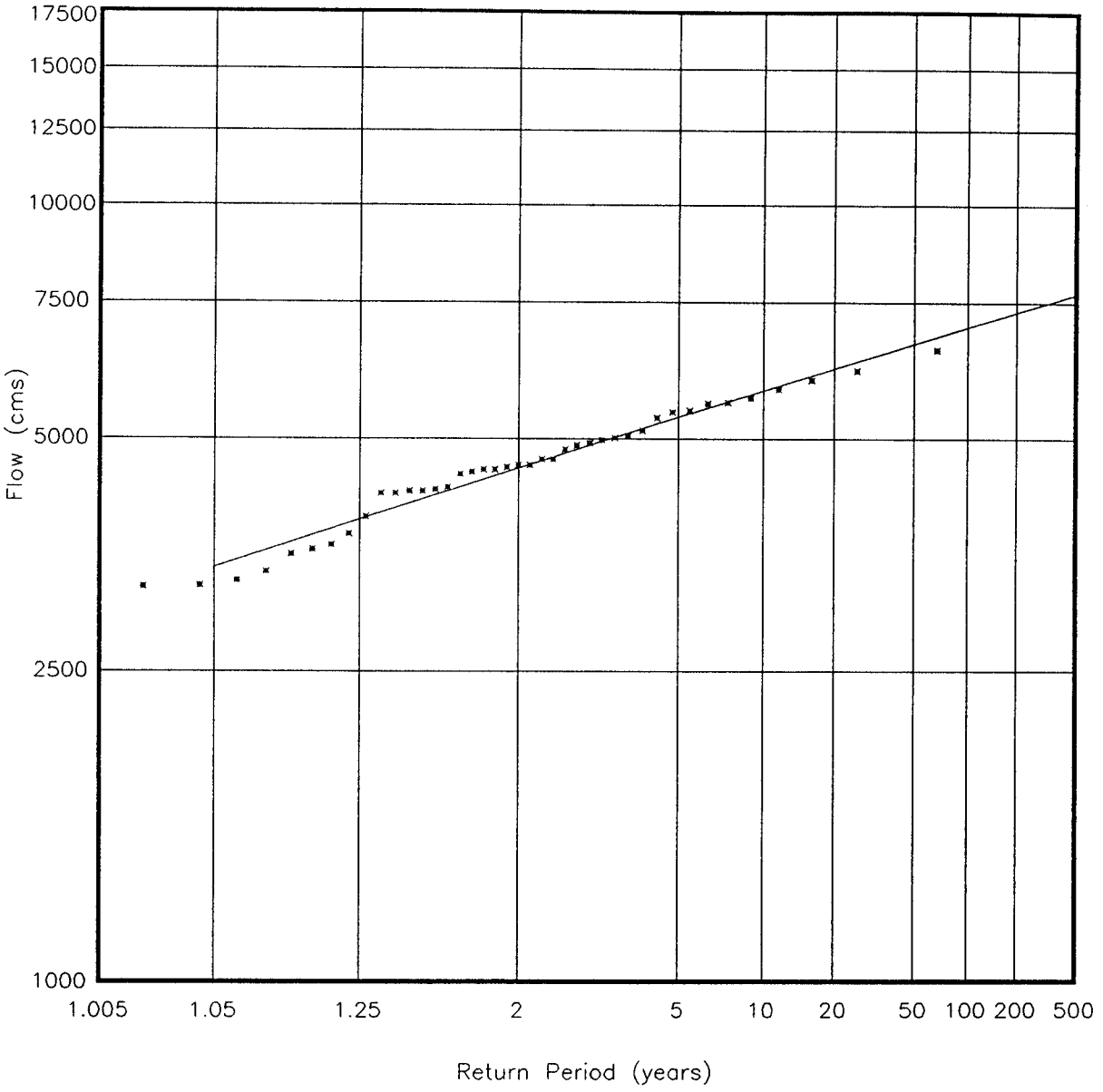
Floodplain Mapping Investigation
Fraser River at Quesnel

Stage – Discharge Relation
Fraser River at Quesnel/Marguerite

northwest hydraulic consultants

NHCV1735-028

Figure 11



British Columbia Ministry of Environment

Log–Normal Distribution

Gauging Station #08MC018

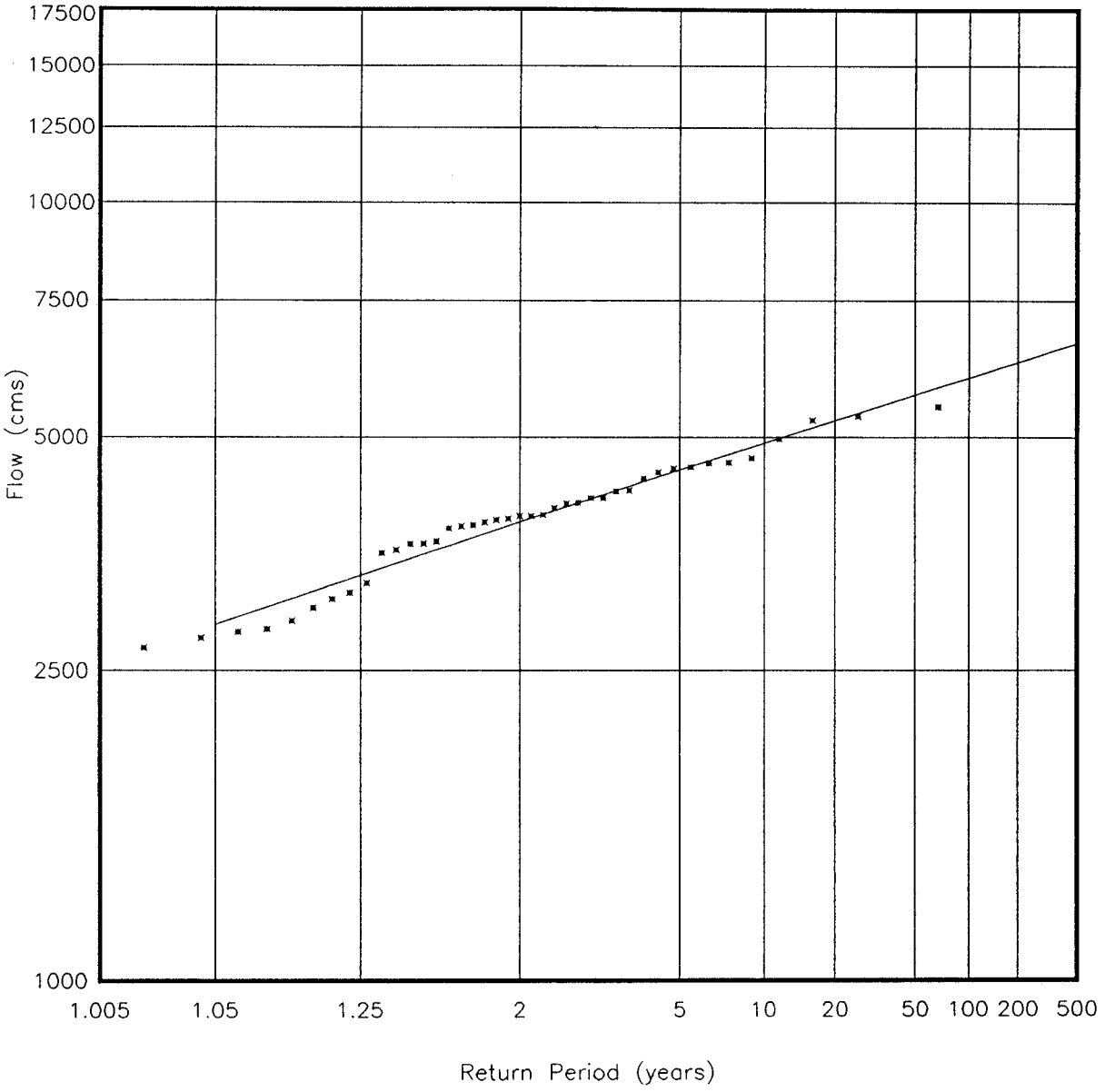
Floodplain Mapping Investigation
Fraser River at Quesnel

Flow Frequency Analysis
Fraser River at Marguerite

northwest hydraulic consultants

NHCV1735–022

Figure 12



Log–Normal Distribution

Discharge calculated by subtracting daily readings on the Quesnel River (Gauge #08KH006) from daily readings from the Fraser River near Marguerite (Gauge #08MC018)

British Columbia Ministry of Environment

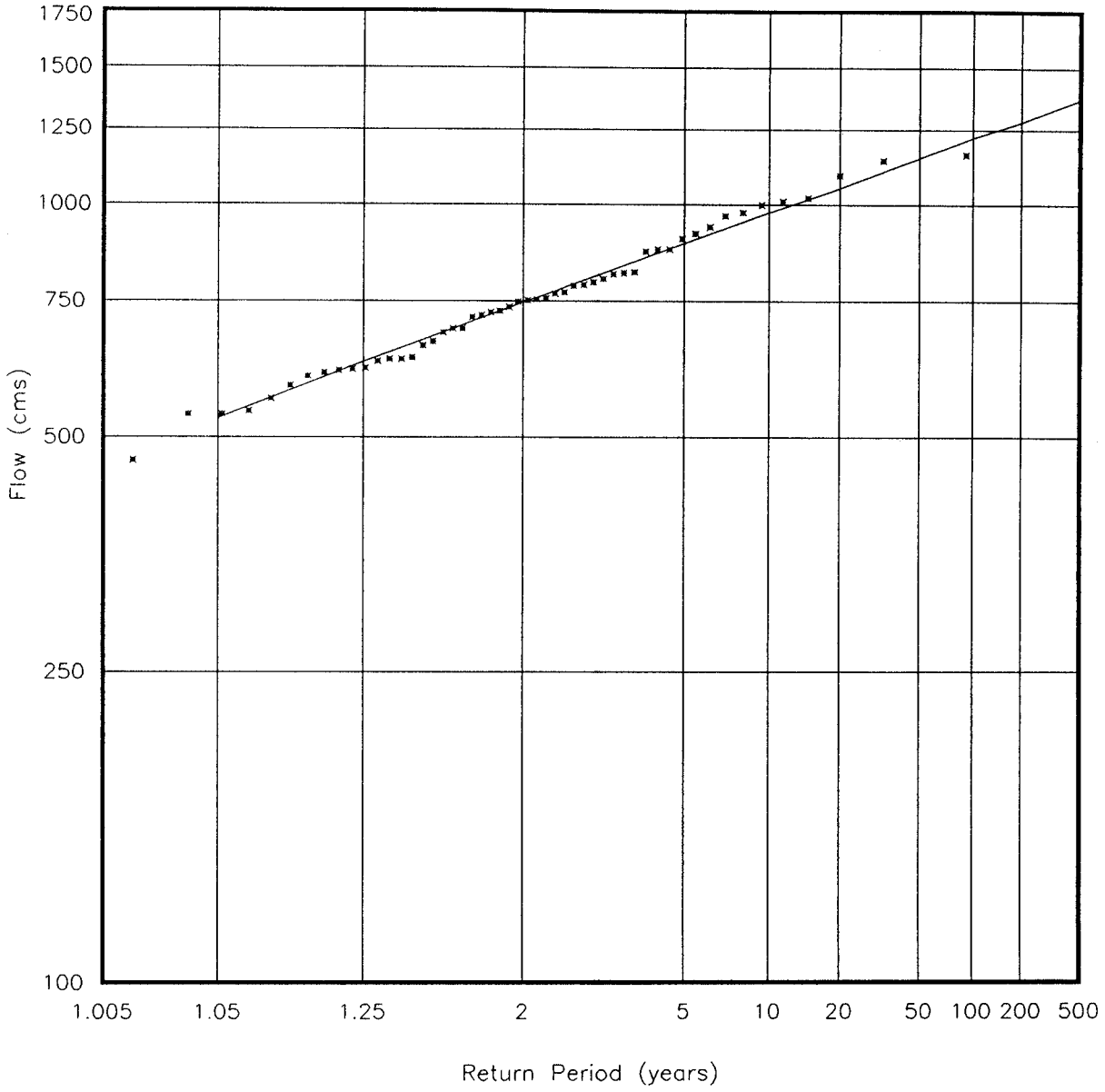
Floodplain Mapping Investigation
Fraser River at Quesnel

Flow Frequency Analysis
Fraser River at Quesnel

northwest hydraulic consultants

NHCV1735–017

Figure 13



Log–Normal Distribution

Gauging Station #08KH006

British Columbia Ministry of Environment

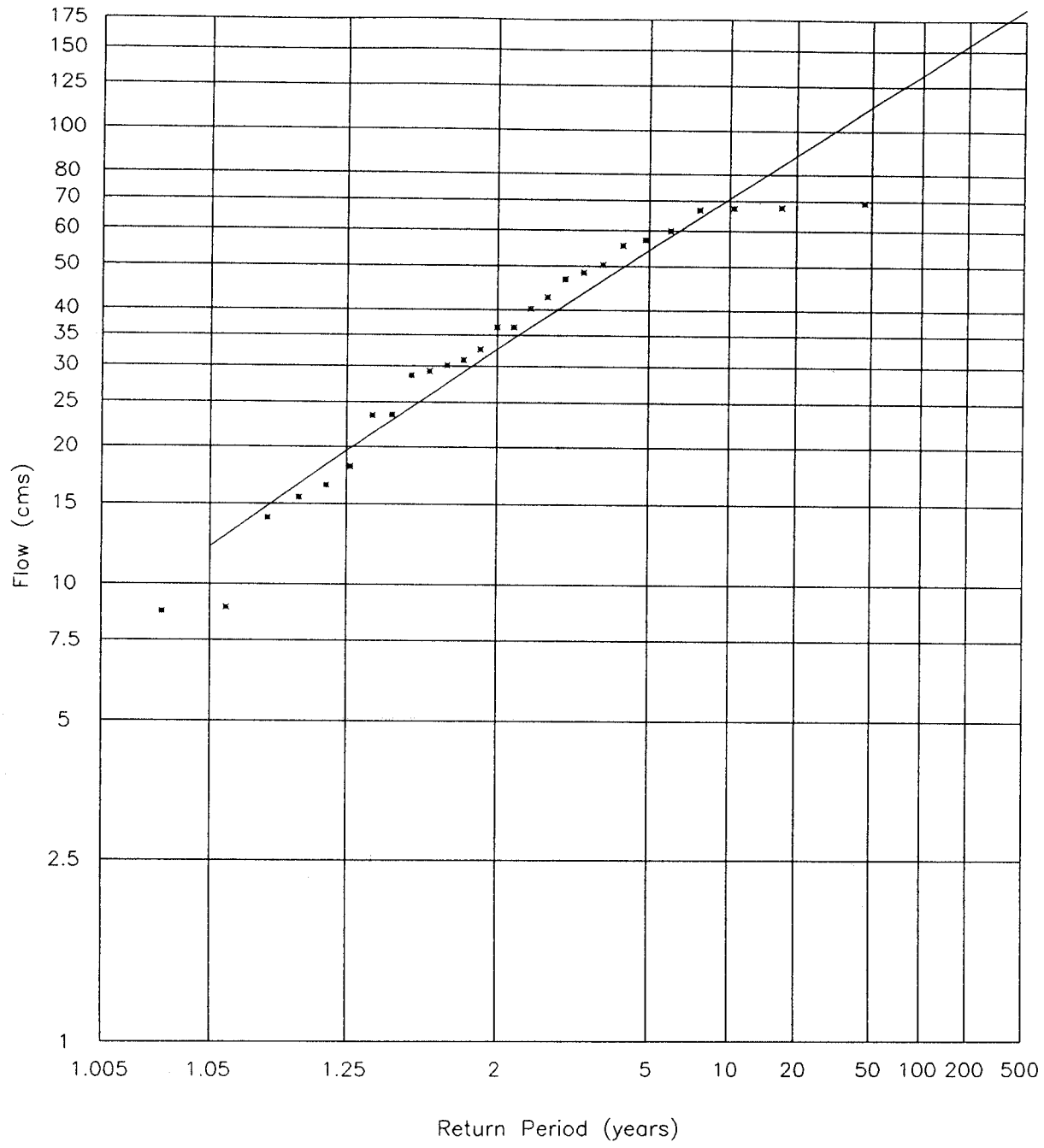
Floodplain Mapping Investigation
Fraser River at Quesnel

Flow Frequency Analysis
Quesnel River at Quesnel

northwest hydraulic consultants

NHCV1735–012

Figure 14



Log–Normal Distribution

Gauging Station #08KE016

British Columbia Ministry of Environment

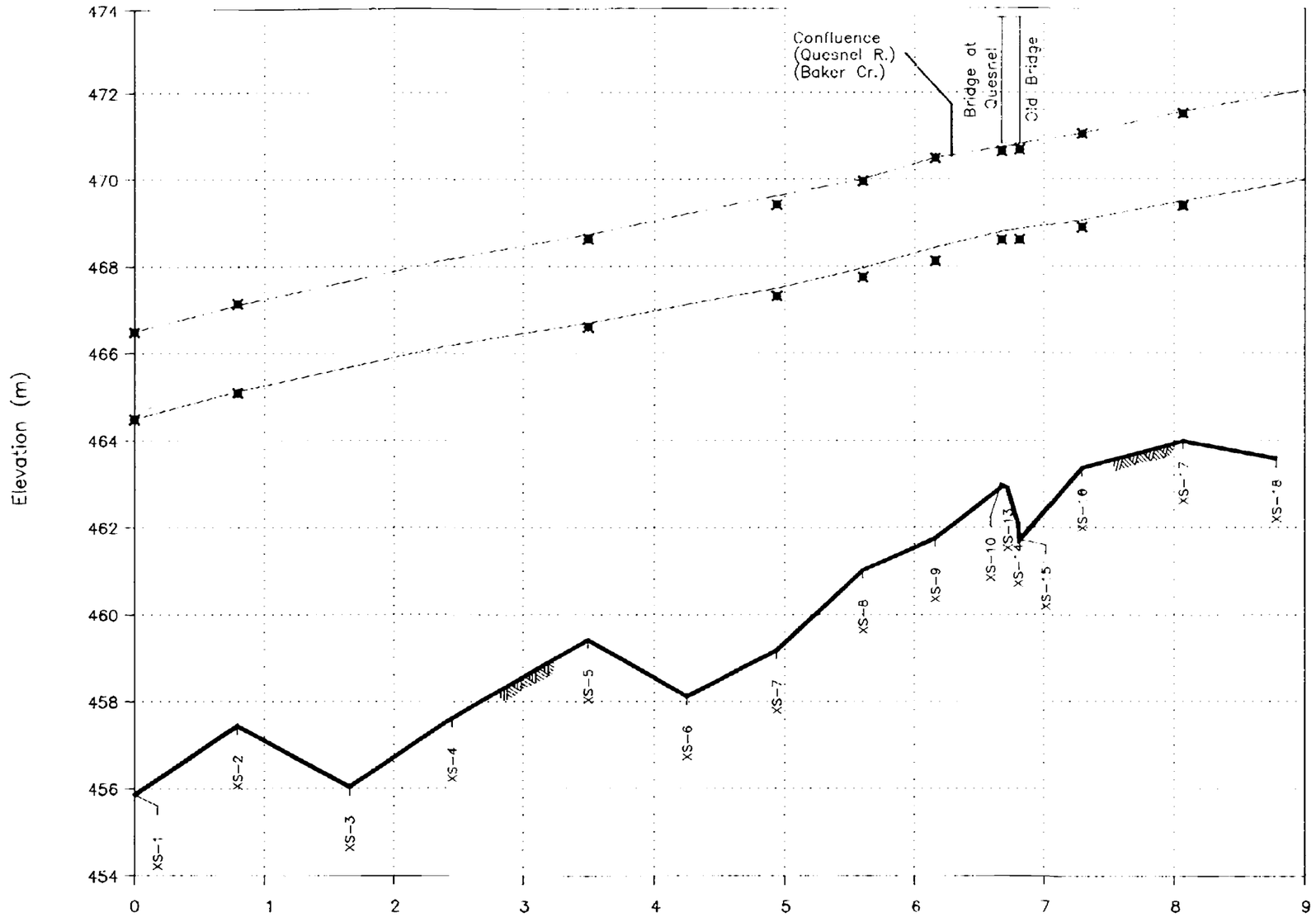
Floodplain Mapping Investigation
Fraser River at Quesnel

Flow Frequency Analysis
Baker Creek

northwest hydraulic consultants

NHCV1735-009

Figure 15



Notes

1. The water surface profiles were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface profiles do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-1 to 89-43-3

Legend

- Recorded Water Surface
- Calculated Water Surface June 3, 1990
- Calculated Water Surface July 4, 1990
- Thalweg
- Bridge

British Columbia Ministry of Environment

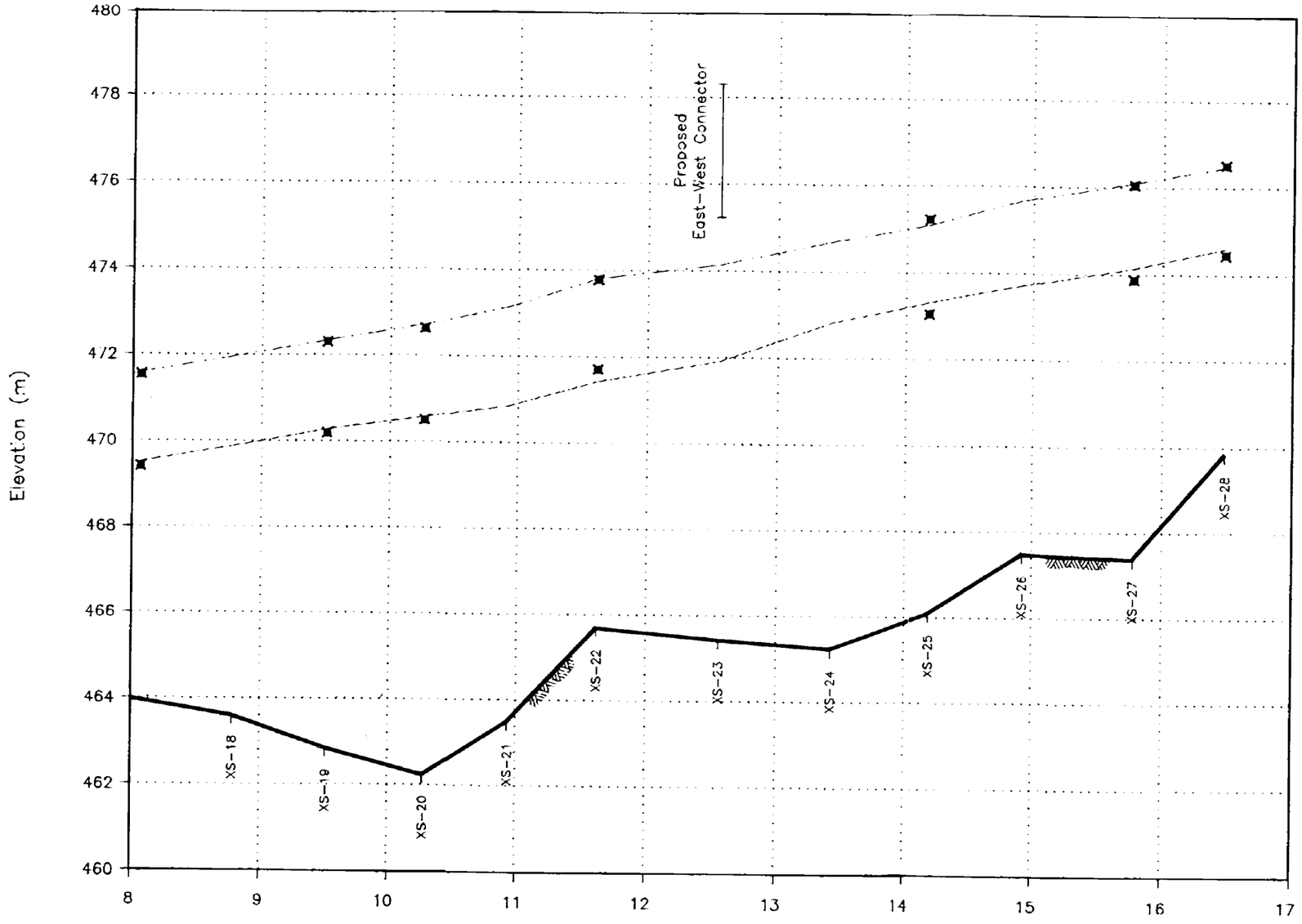
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Calibration Profiles (XS-1 to 18)

northwest hydraulic consultants

NHCV1735--030

Figure 16



Notes

1. The water surface profiles were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface profiles do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-3 to 89-43-5

Legend

- Recorded Water Surface
- Calculated Water Surface June 3, 1990
- Calculated Water Surface July 4, 1990
- Thalweg
- Bridge

British Columbia Ministry of Environment

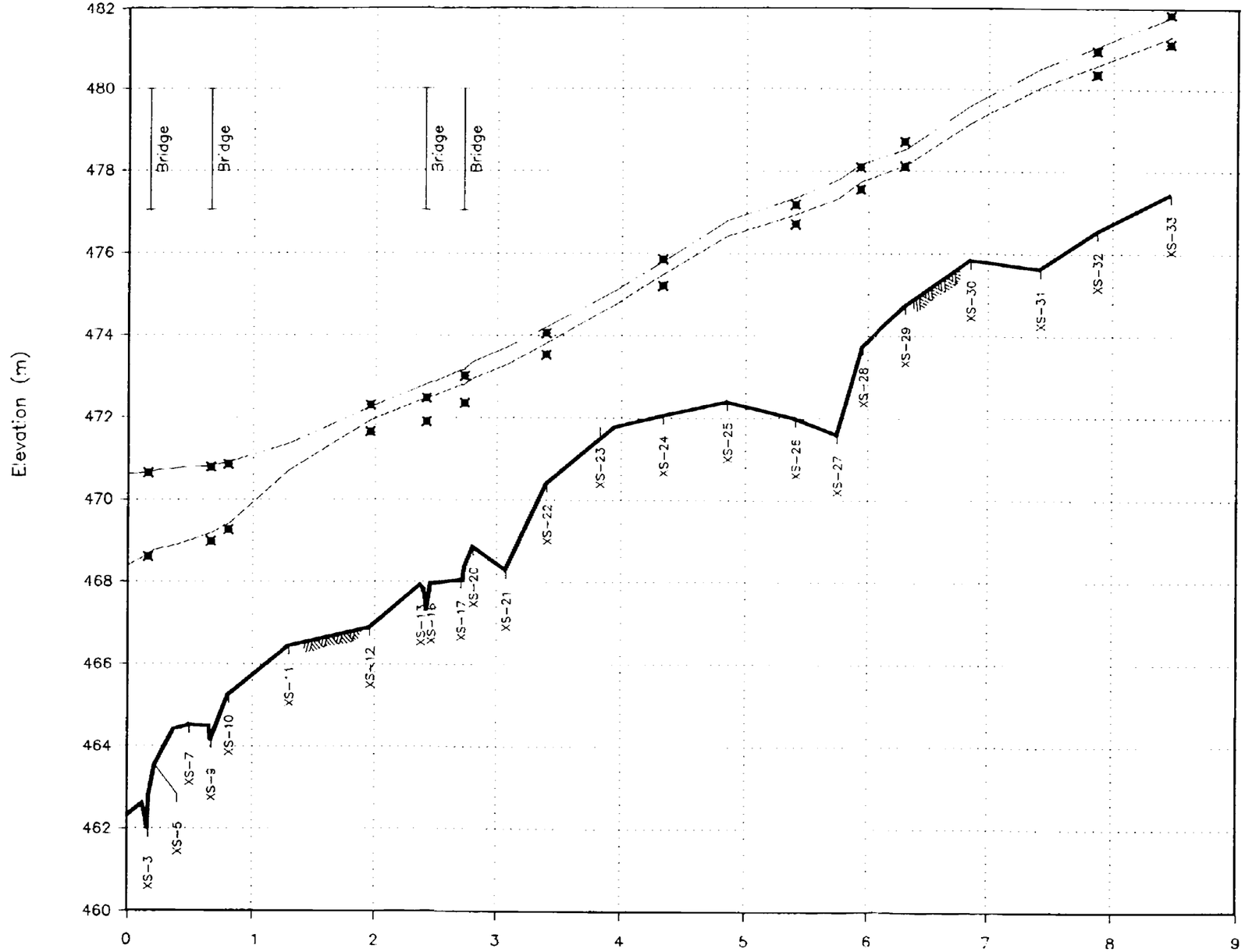
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Calibration Profiles (XS-18 to 28)

northwest hydraulic consultants

NHCV1735-031

Figure 17



Notes

1. The water surface profiles were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface profiles do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-2 to 89-43-3

Legend

- Recorded Water Surface
- Calculated Water Surface June 14, 1990
- Calculated Water Surface June 4, 1990
- Thalweg
- Bridge

British Columbia Ministry of Environment

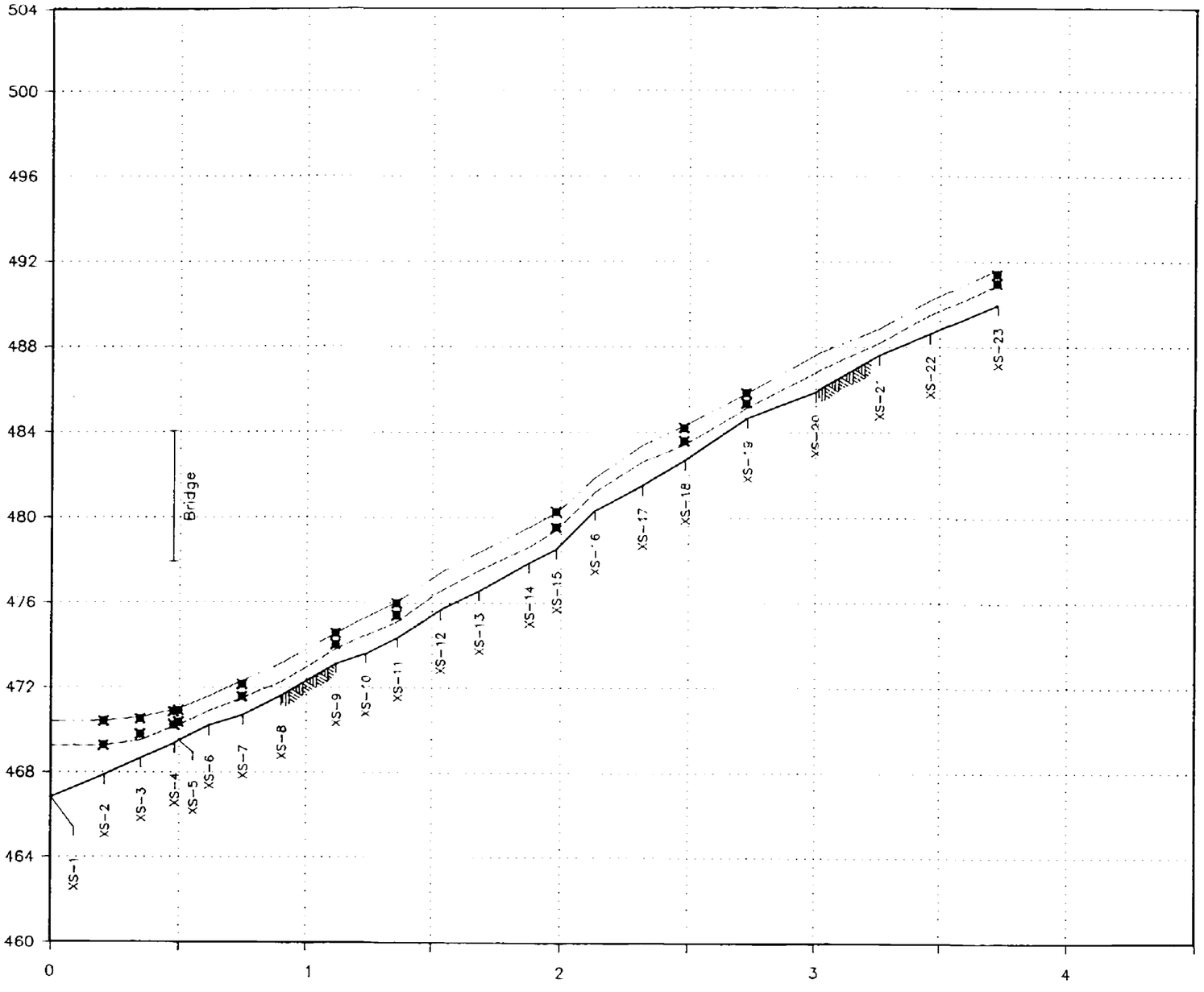
Floodplain Mapping Investigation
Fraser River at Quesnel

Quesnel River
Calibration Profiles (XS 1 to 33)

northwest hydraulic consultants

NHCV1735-032

Figure 18



Notes

1. The water surface profiles were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface profiles do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-2 to 89-43-3

Legend

- Recorded Water Surface
- Calculated Water Surface June 13, 1990
- Calculated Water Surface July 4-5, 1990
- Thalweg
- Bridge

British Columbia Ministry of Environment

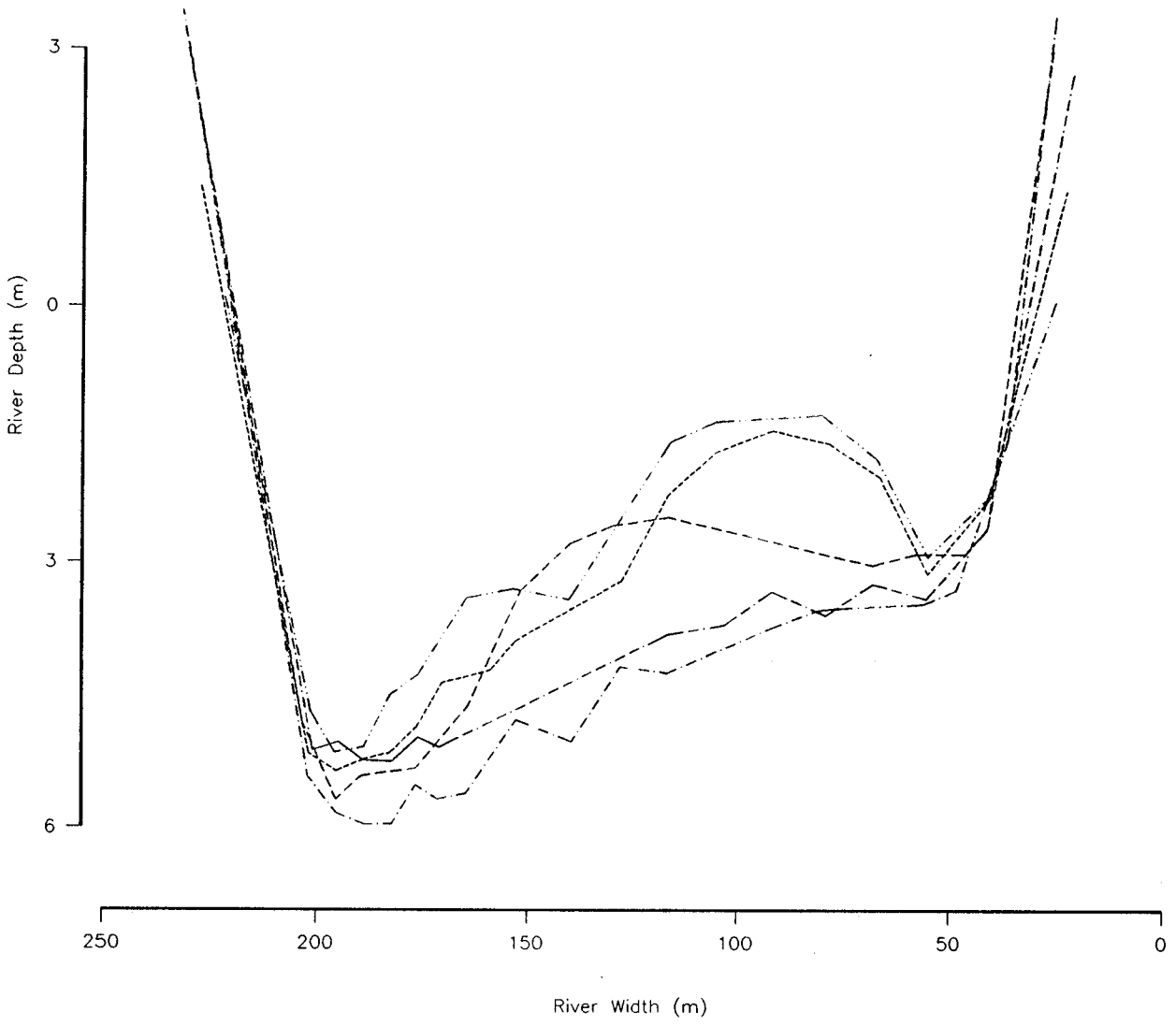
Floodplain Mapping Investigation
Fraser River at Quesnel

Baker Creek
Calibration Profiles (XS-1 to 23)

northwest hydraulic consultants

NHCV1735-033

Figure 19



British Columbia Ministry of Environment

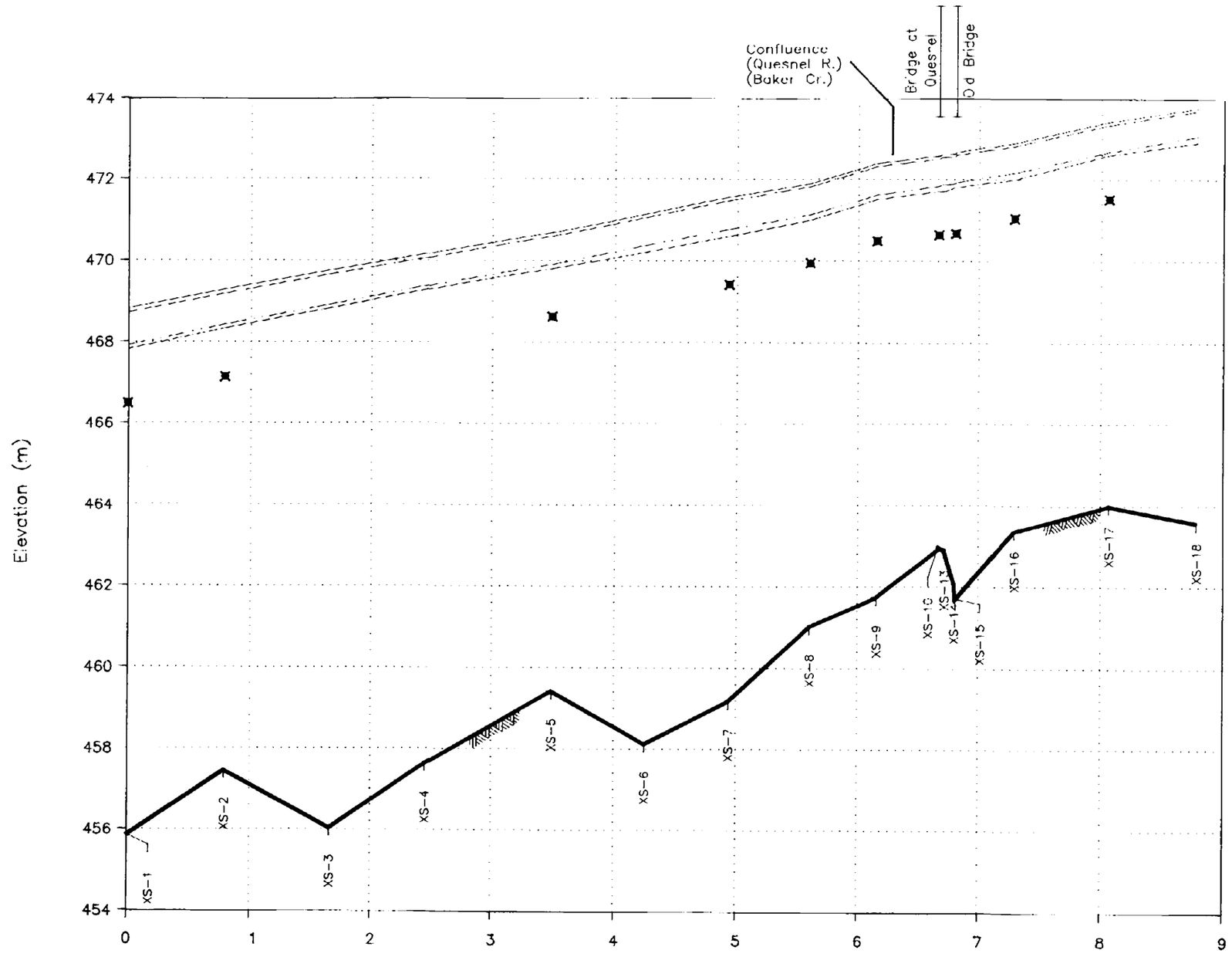
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River near Marguerite
Channel Geometry (1971)

northwest hydraulic consultants

NHCV1735-059

Figure 20



Notes

1. The water surface profiles were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface profiles do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-1 to 89-43-3

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20-Year Instantaneous Flood.
- 20-Year Daily Flood.
- Thalweg
- Bridge
- Highwater Mark recorded June 3, 1990

Flow Condition	U/S of Quesnel Discharge (m^3/s)	D/S of Quesnel Discharge (m^3/s)
20yr daily	5200	6100
20yr inst.	5300	6200
200yr daily	6100	7100
200yr inst.	6200	7200

British Columbia Ministry of Environment

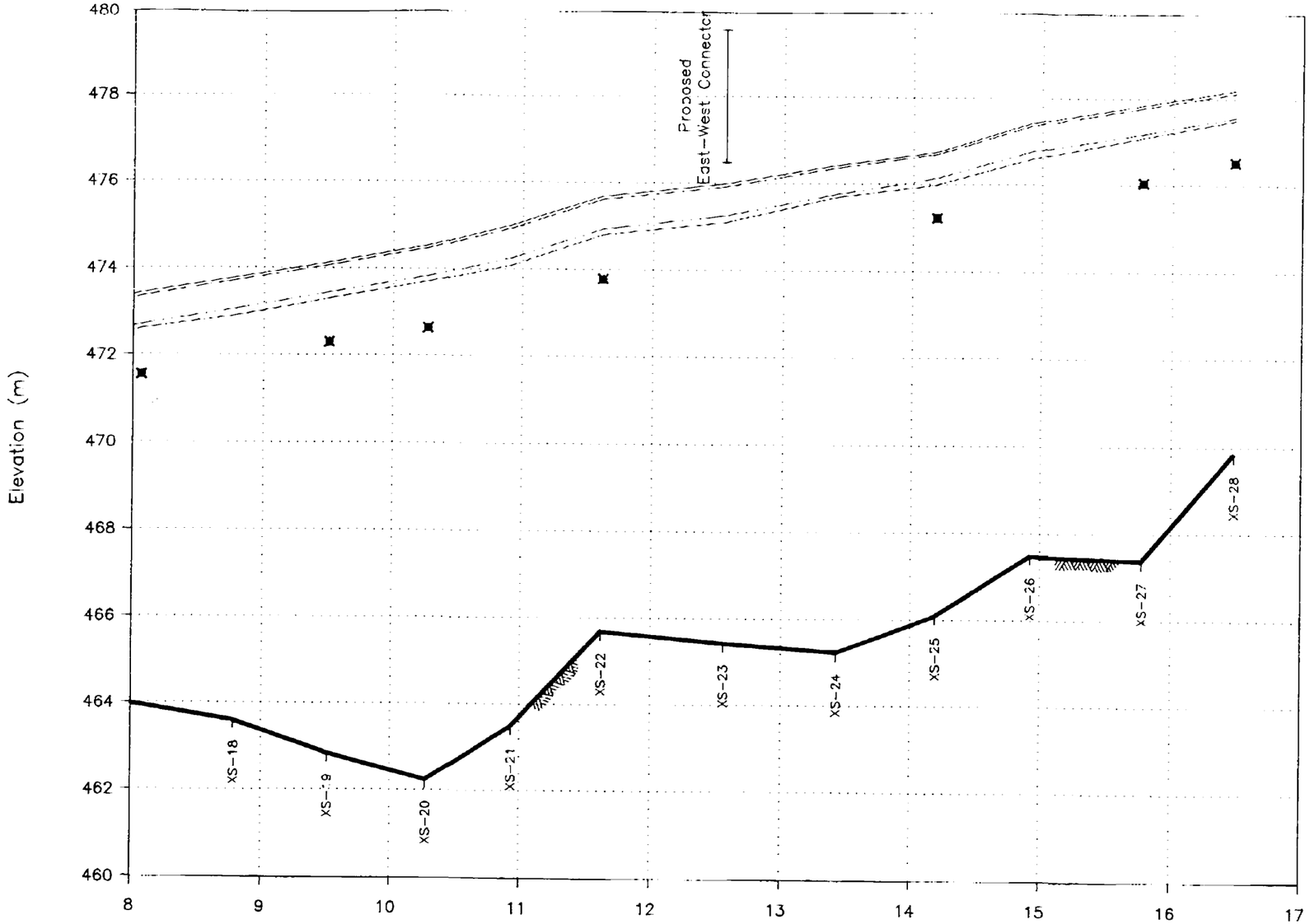
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Flood Profiles (XS-1 to 18)

northwest hydraulic consultants

NHCV1735-040

Figure 21



Notes

1. The water surface profiles were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface profiles do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-3 to 89-43-5

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20 Year Instantaneous Flood.
- 20 Year Daily Flood.
- Thalweg
- Bridge
- Highwater Mark recorded June 3, 1990

Flow Condition	U/S of Quesnel Discharge (m^3/s)	D/S of Quesnel Discharge (m^3/s)
20yr daily	5200	6100
20yr inst.	5300	6200
200yr daily	6100	7100
200yr inst.	6200	7200

British Columbia Ministry of Environment

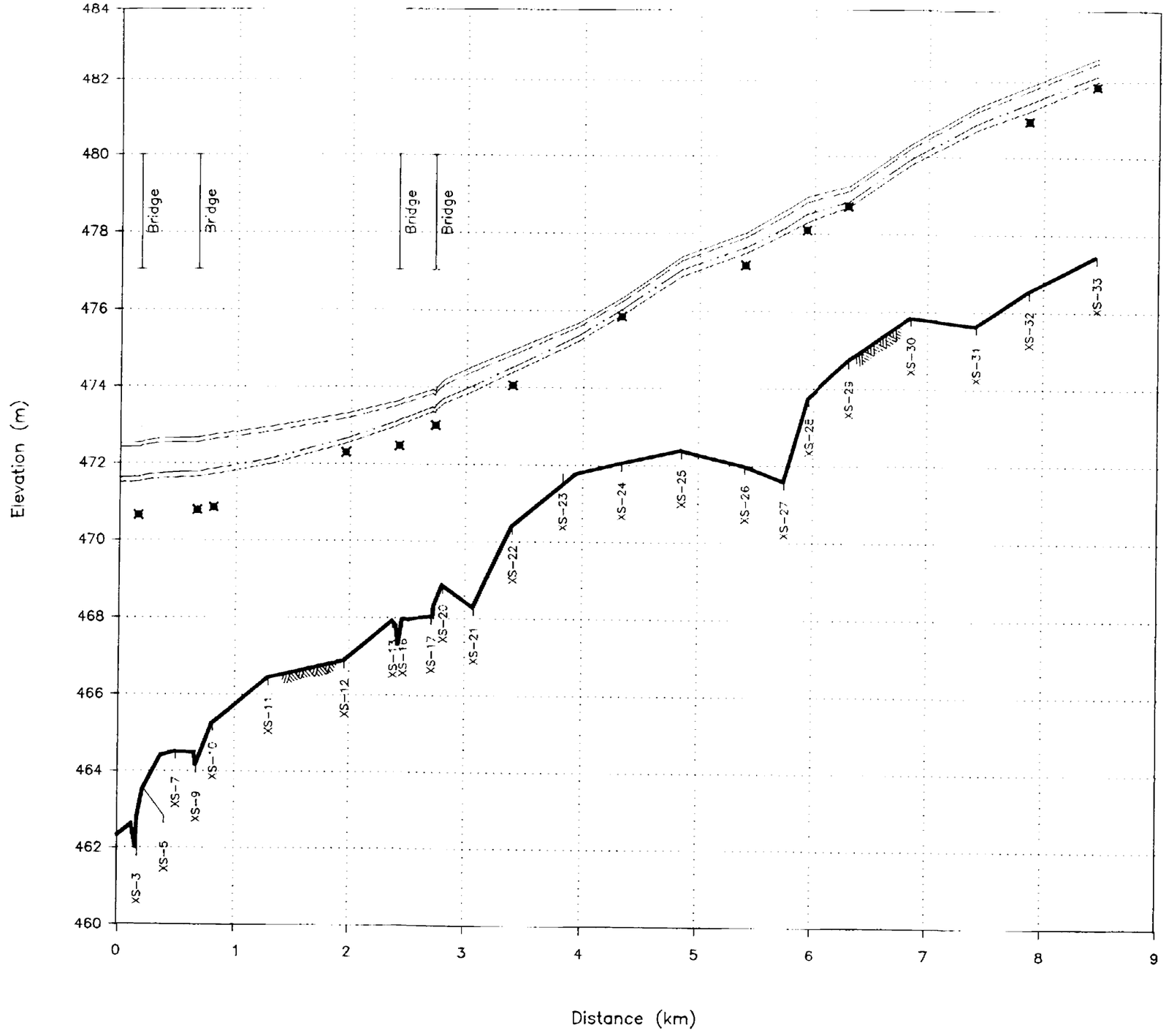
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Flood Profiles (XS-18 to 28)

northwest hydraulic consultants

NHCV1735-041

Figure 22



NHCV1735 042

Notes

1. The water surface profiles were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface profiles do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-2 to 89-43-3

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20-Year Instantaneous Flood.
- 20-Year Daily Flood.
- Thalweg
- Bridge
- Highwater Mark recorded June 14, 1990

Flow Condition	Discharge (m^3/s)
20yr daily	1080
20yr inst.	1140
200yr daily	1330
200yr inst.	1400

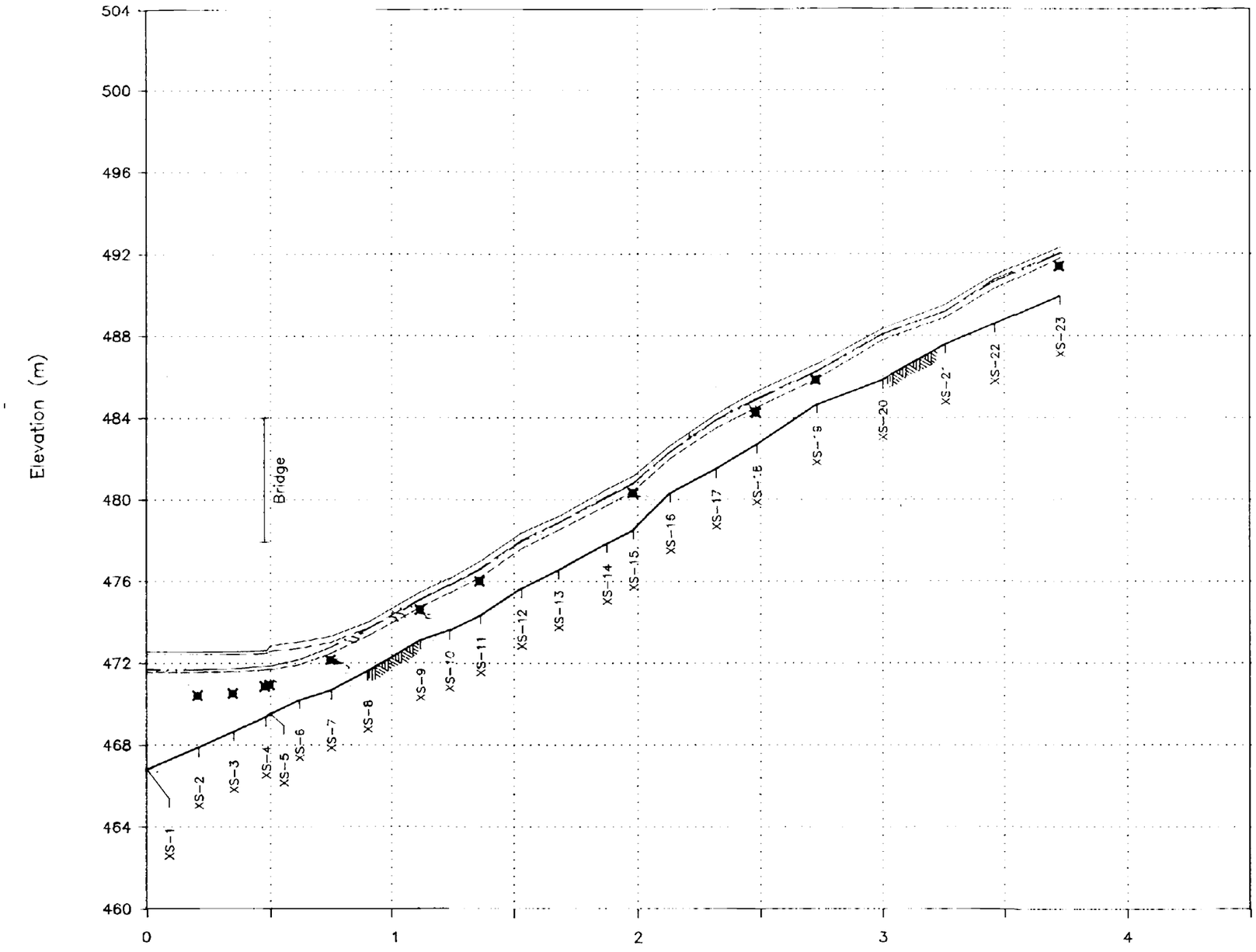
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Quesnel River
Flood Profiles (XS-1 to 33)

northwest hydraulic consultants

Figure 23



Notes

1. The water surface profiles were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface profiles do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-2 to 89-43-3

Legend

- 200-Year Instantaneous Flood.
- 200 Year Daily Flood.
- 20 Year Instantaneous Flood.
- 20 Year Daily Flood.
- Thalweg
- Bridge
- Highwater Mark recorded June 13, 1990

Flow Condition	Discharge (m^3/s)
20yr daily	77
20yr inst.	100
200yr daily	112
200yr inst.	146

British Columbia Ministry of Environment

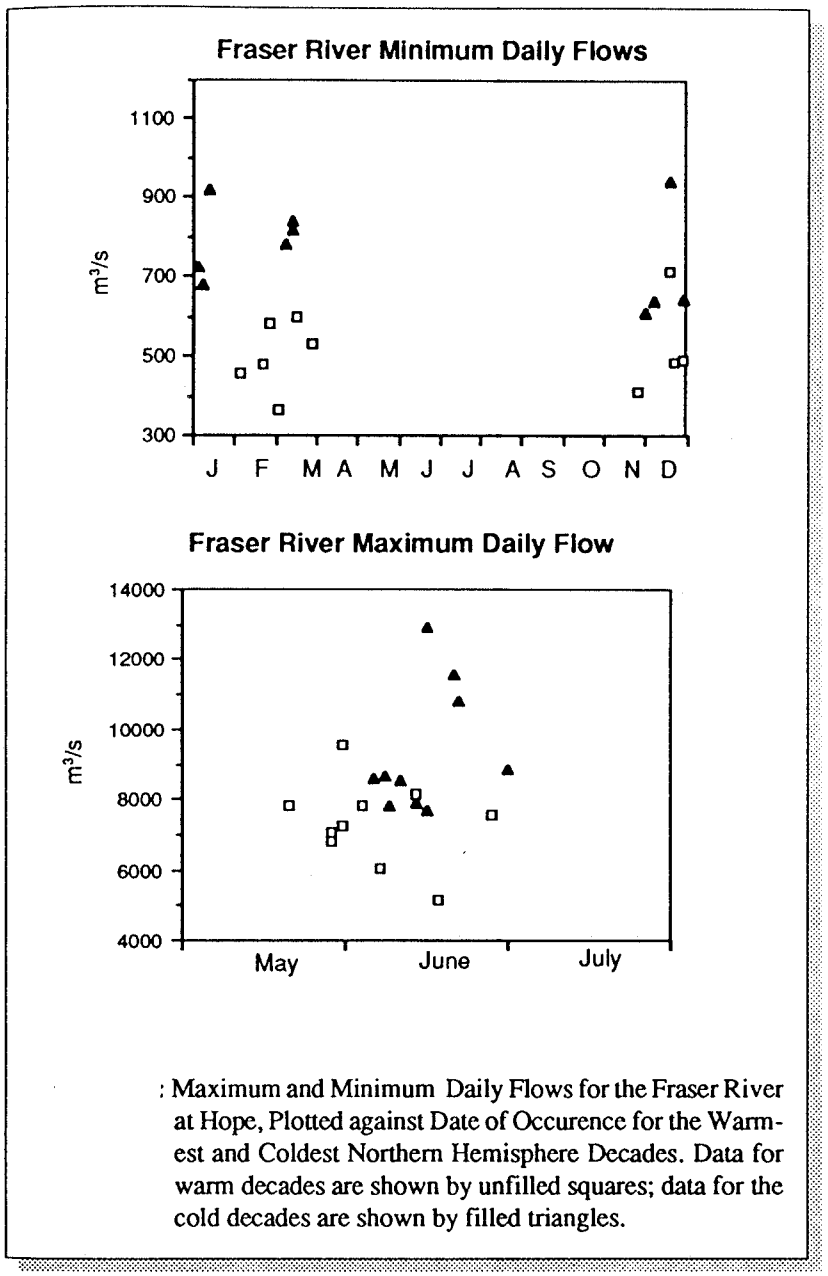
Floodplain Mapping Investigation
Fraser River at Quesnel

Baker Creek
Flood Profiles (XS-1 to 23)

northwest hydraulic consultants

NHCV1735-043

Figure 24



: Maximum and Minimum Daily Flows for the Fraser River at Hope, Plotted against Date of Occurence for the Warmest and Coldest Northern Hemisphere Decades. Data for warm decades are shown by unfilled squares; data for the cold decades are shown by filled triangles.

Note: Ref. "Water in a Sustainable Development"
by H.J. Dorcey and J.R. Griggs
Westwater Research Centre, UBC.

British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Flow Trends
Fraser River at Hope

northwest hydraulic consultants

NHCV1735-060

Figure 25

PHOTOGRAPHS

PHOTO NO. 1

Confluence of Fraser River, Quesnel River and Baker Creek at Quesnel, B.C.

The Fraser River is the largest one on the left, the Quesnel River traverses the entire photo (flowing from right to left) and Baker Creek is at the left of the photo just downstream from the two bridges.

September 27, 1991

PHOTO NO. 2

Flow near the Fraser - Quesnel - Baker confluence
on June 21, 1990.
Flow is left to right.

(Photo courtesy Perry's Picture Place, Quesnel)

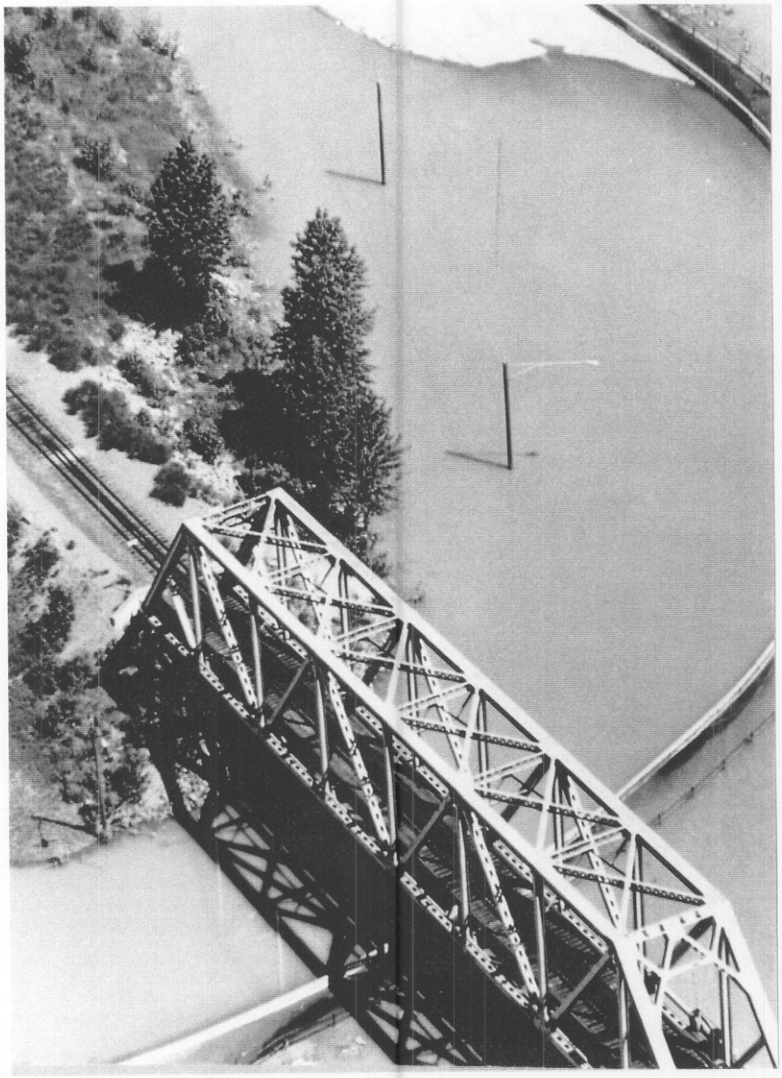


PHOTO NO. 3

High water at the B.C. Railway bridge
across Quesnel River
on June 21, 1990.

(Photo courtesy Perry's Picture Place, Quesnel)

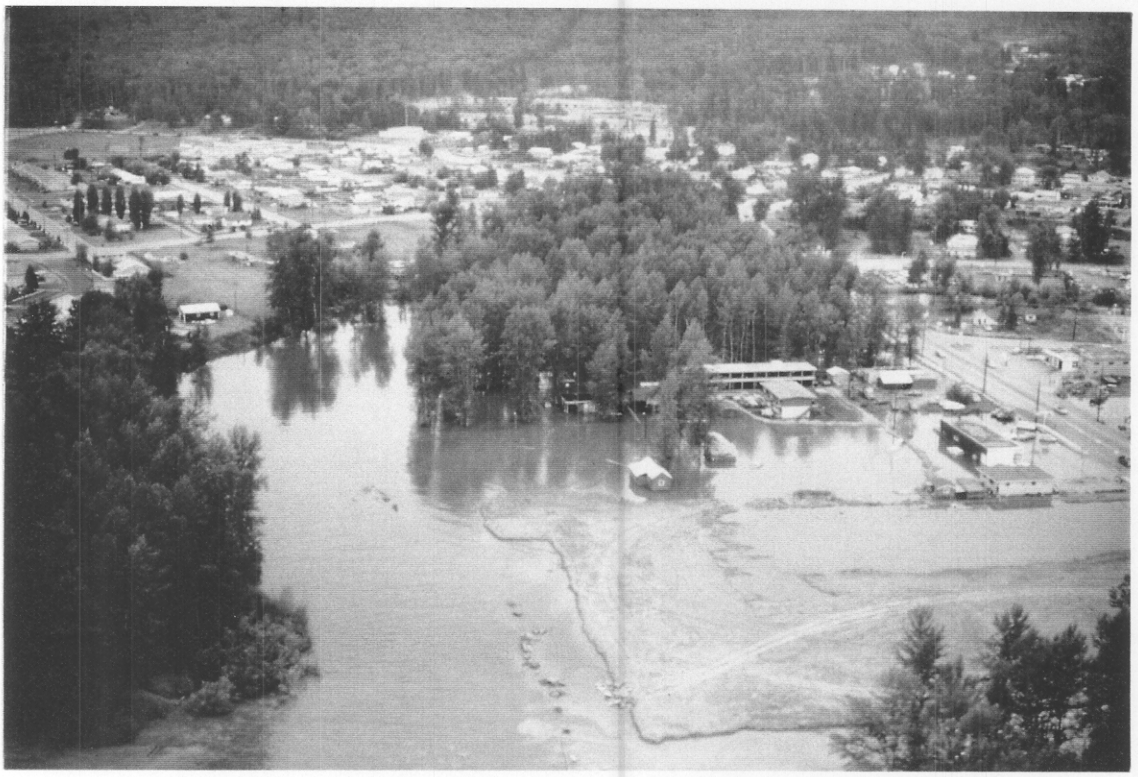


PHOTO NO. 4

Flooding at lower end of Baker Creek in 1972.
Several houses are inundated, but Marsh Drive
(on the right) is just above water.

(Photo courtesy B.C. Ministry of Environment)

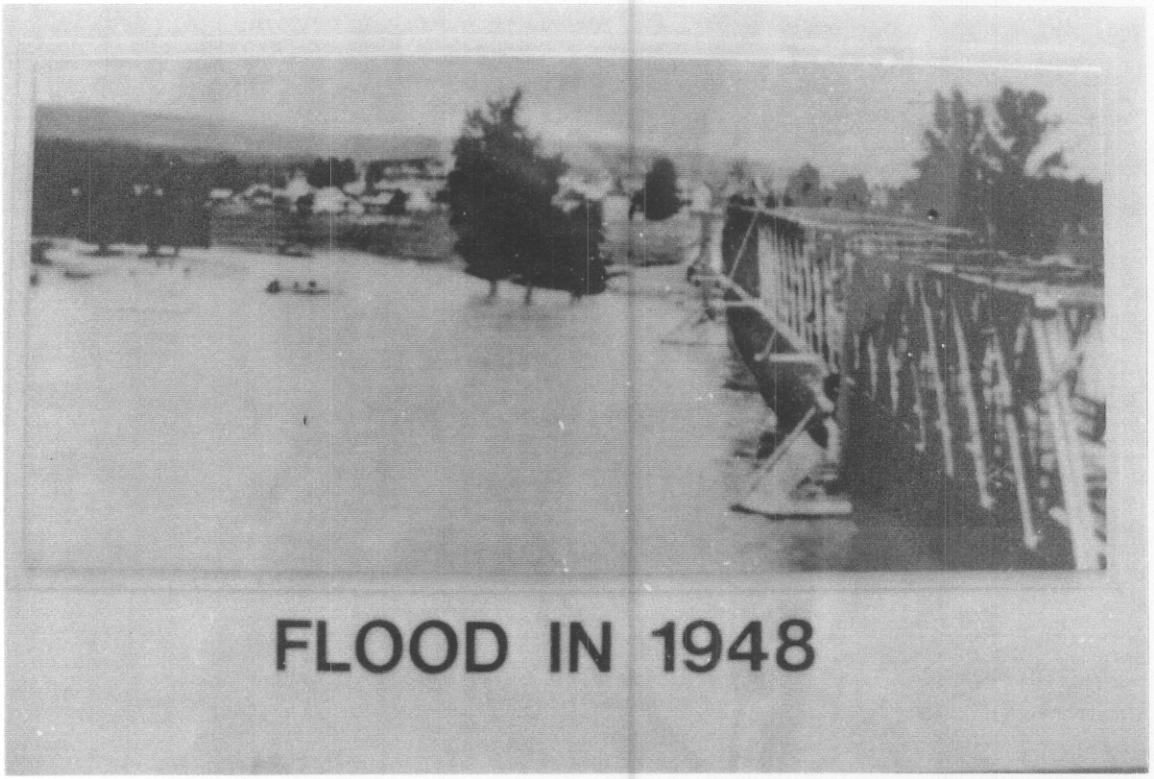


PHOTO NO. 5

Flooding along Quesnel River just upstream from
old Davie Street Highway Bridge.

(Photo posted along Riverfront Trail)

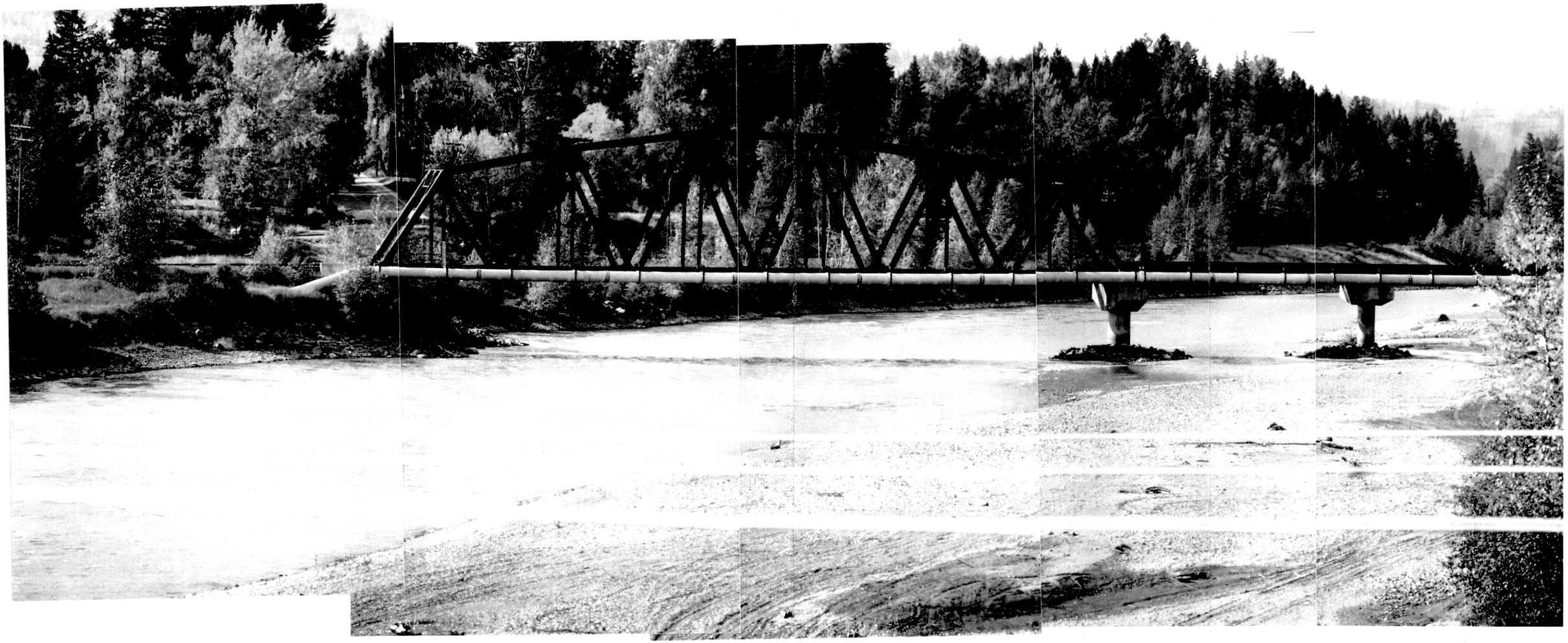


PHOTO NO. 6
Upstream view to B.C. Railway bridge just upstream from the Highway 97 bridge across the Quesnel River. Cross-sections 18 and 19 are located at this bridge. The 200 - year flood level would be below the deck level of the bridge. The point bar at the right of the photo has been growing with time.

(September 27, 1991)

PHOTO NO. 7

Downstream view of Baker Creek entering into Fraser River.
Extensive bars of sand and gravel are evident with
logs on top of the bars.

(Oct. 4, 1991)

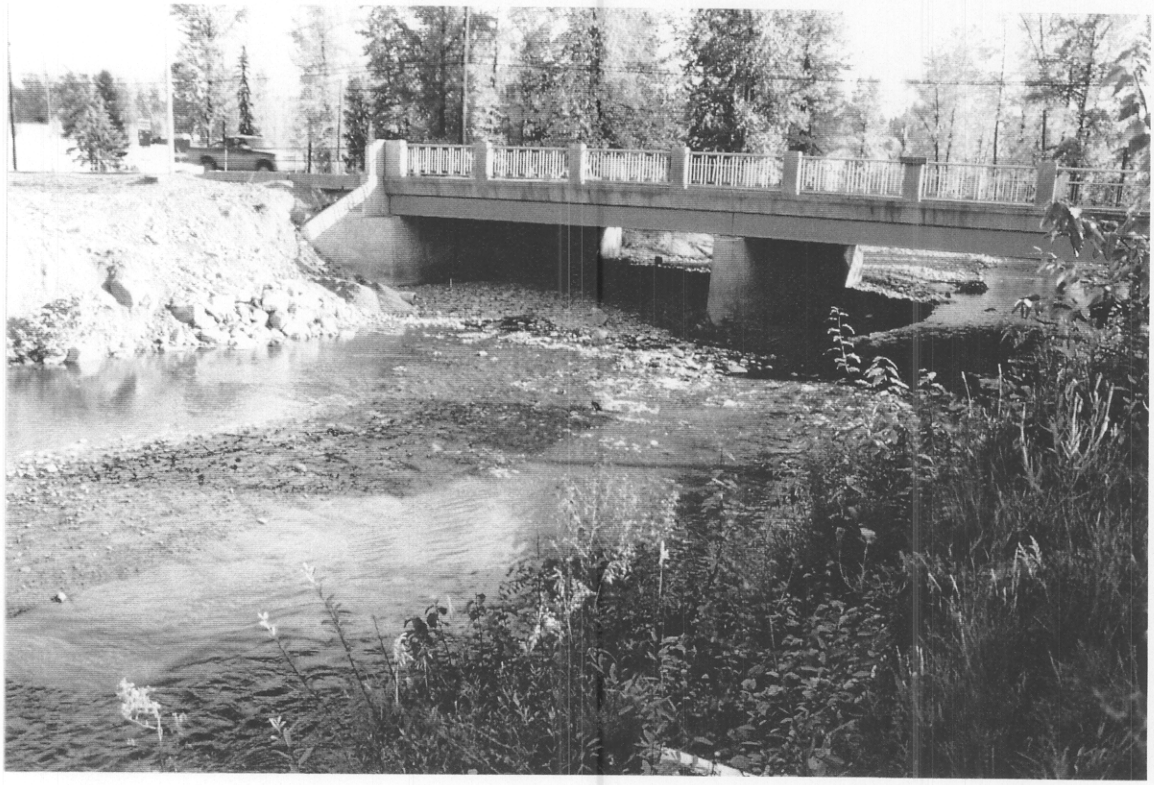


PHOTO NO. 8

Downstream view of Baker Creek at Marsh Drive bridge.
A dyke had to be constructed along the left bank to limit
flooding and to keep the river from developing a new course.
The bed of the river appears to be aggrading and this
phenomenon will probably continue.

(October 4, 1991)

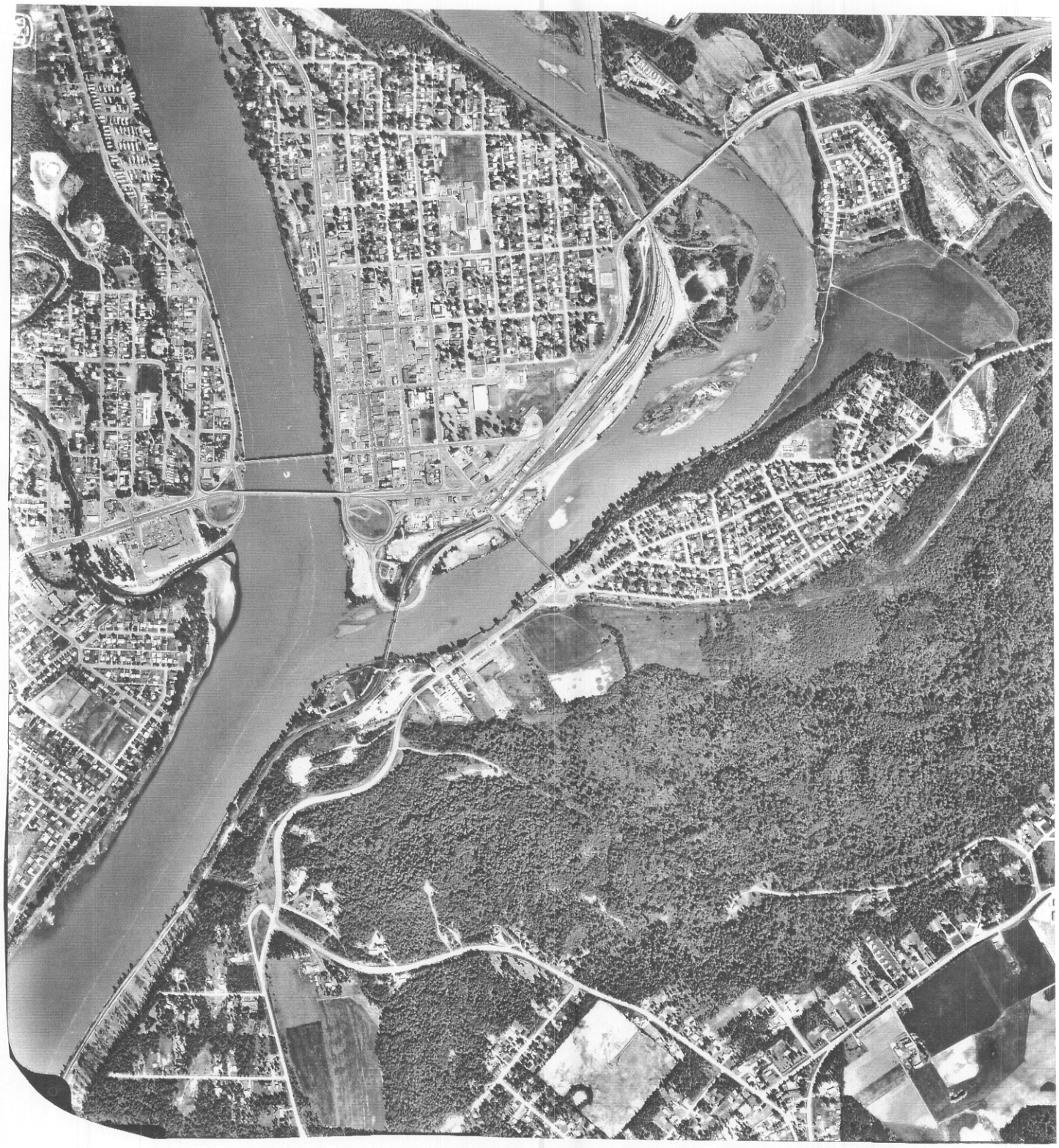


PHOTO NO. 9

Confluence of Fraser and Quesnel Rivers with Baker Creek.
Flow is from top to bottom with Quesnel river on the right.

(Date of photography = 1985)

PHOTO NO. 10

Eroding meander loops on Fraser River upstream from study search. The eroding banks are supplying bed material load to the river system. Some of the eroded material deposits to form point bars and side-channel bars while some moves further downstream.

(Photograph date 1977)

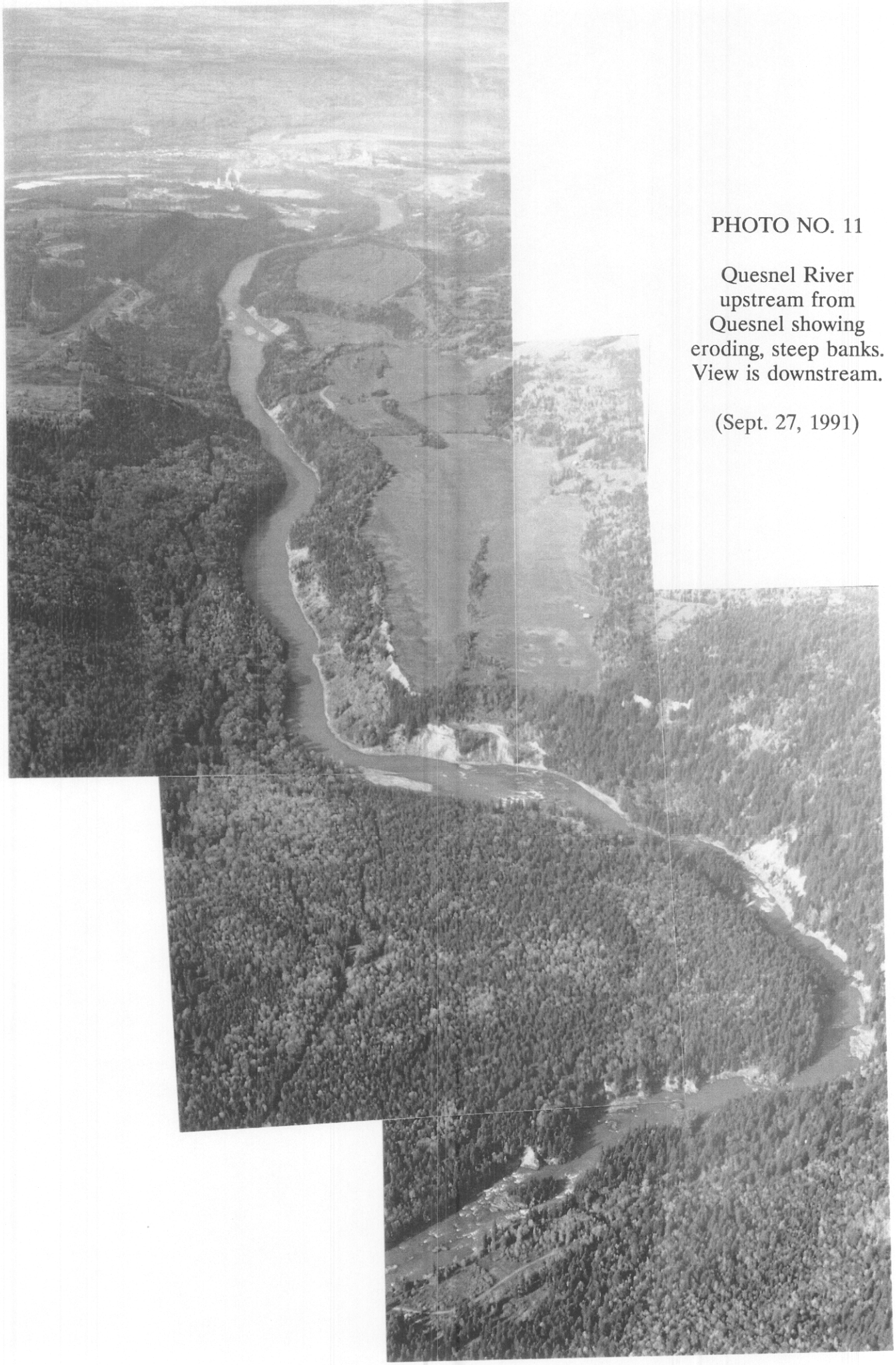


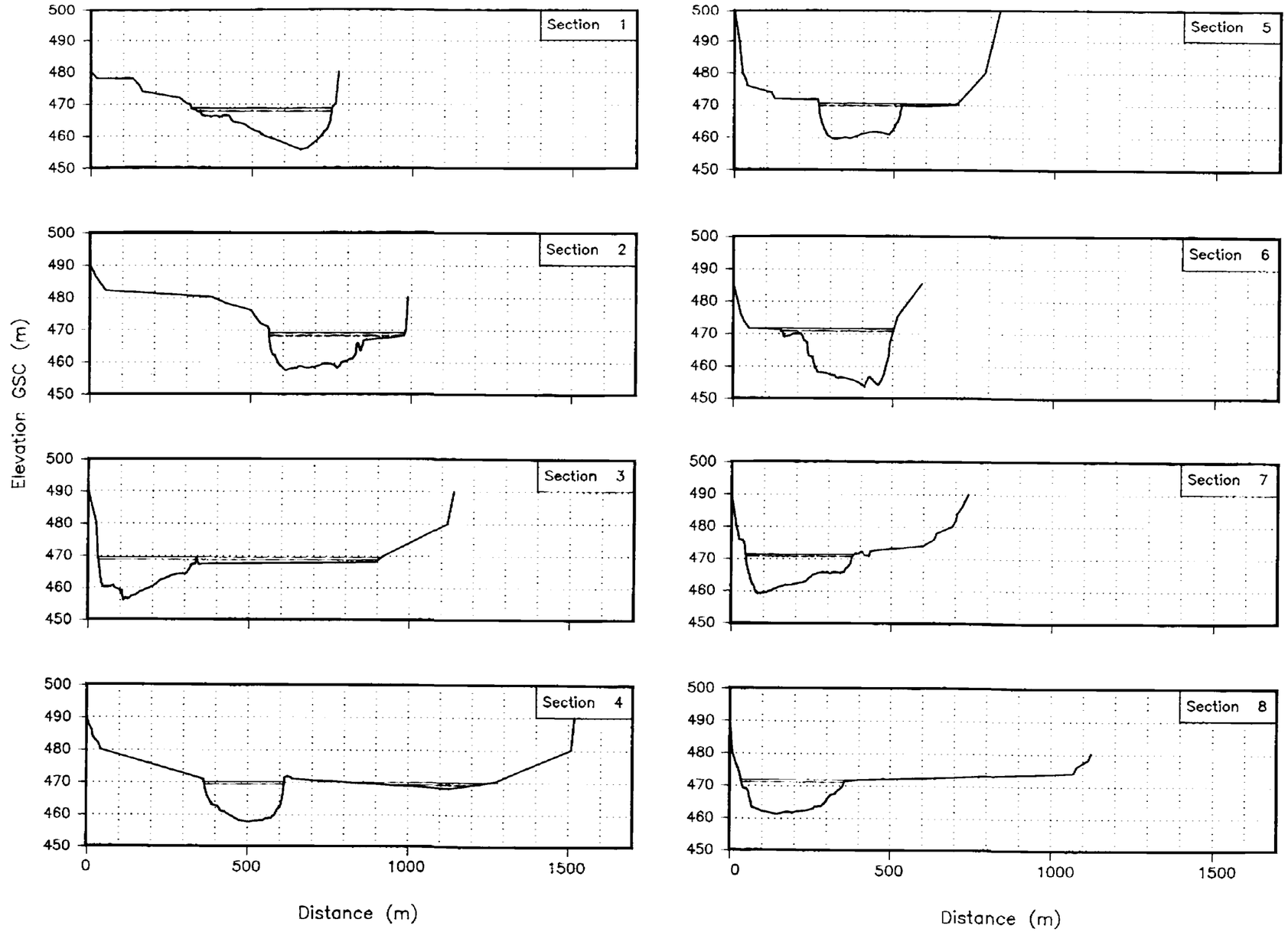
PHOTO NO. 11

Quesnel River upstream from Quesnel showing eroding, steep banks. View is downstream.

(Sept. 27, 1991)

APPENDIX A

Cross - section Plots for Fraser River, Quesnel River and Baker Creek



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89 43-1 and 89-43-2
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200 Year Instantaneous Flood.
- 200 Year Daily Flood.
- 20 Year Instantaneous Flood.
- 20 Year Daily Flood.

Flow Condition	U/S of Quesnel Discharge (m^3/s)	D/S of Quesnel Discharge (m^3/s)
20yr daily	5200	6100
20yr inst.	5300	6200
200yr daily	6100	7100
200yr inst.	6200	7200

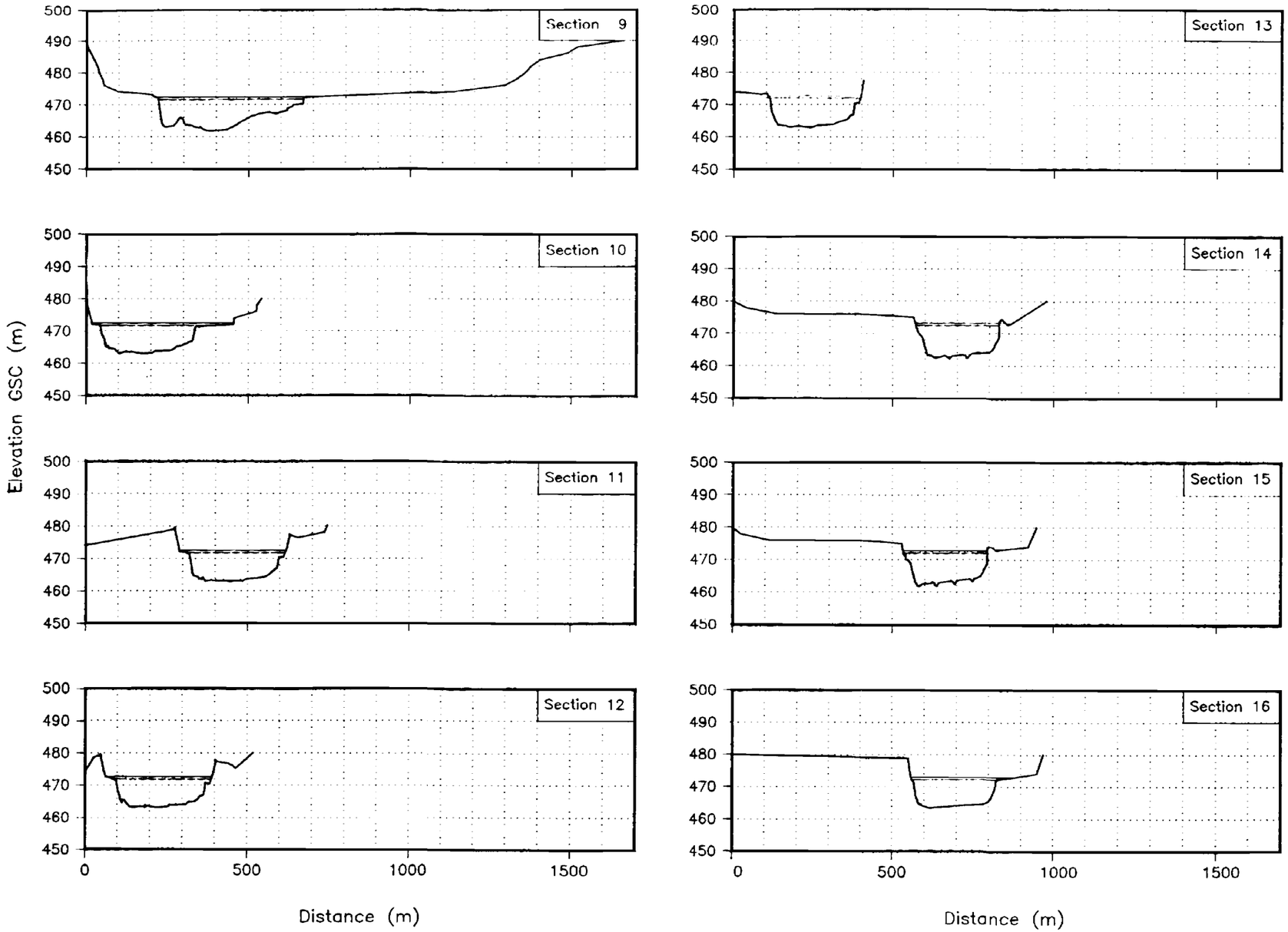
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Cross-sections (1-8)

northwest hydraulic consultants

NHCV1735-046



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawing 89-43-2
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20-Year Instantaneous Flood.
- 20-Year Daily Flood.

Flow Condition	U/S of Quesnel Discharge (m^3/s)	D/S of Quesnel Discharge (m^3/s)
20yr daily	5200	6100
20yr inst.	5300	6200
200yr daily	6100	7100
200yr inst.	6200	7200

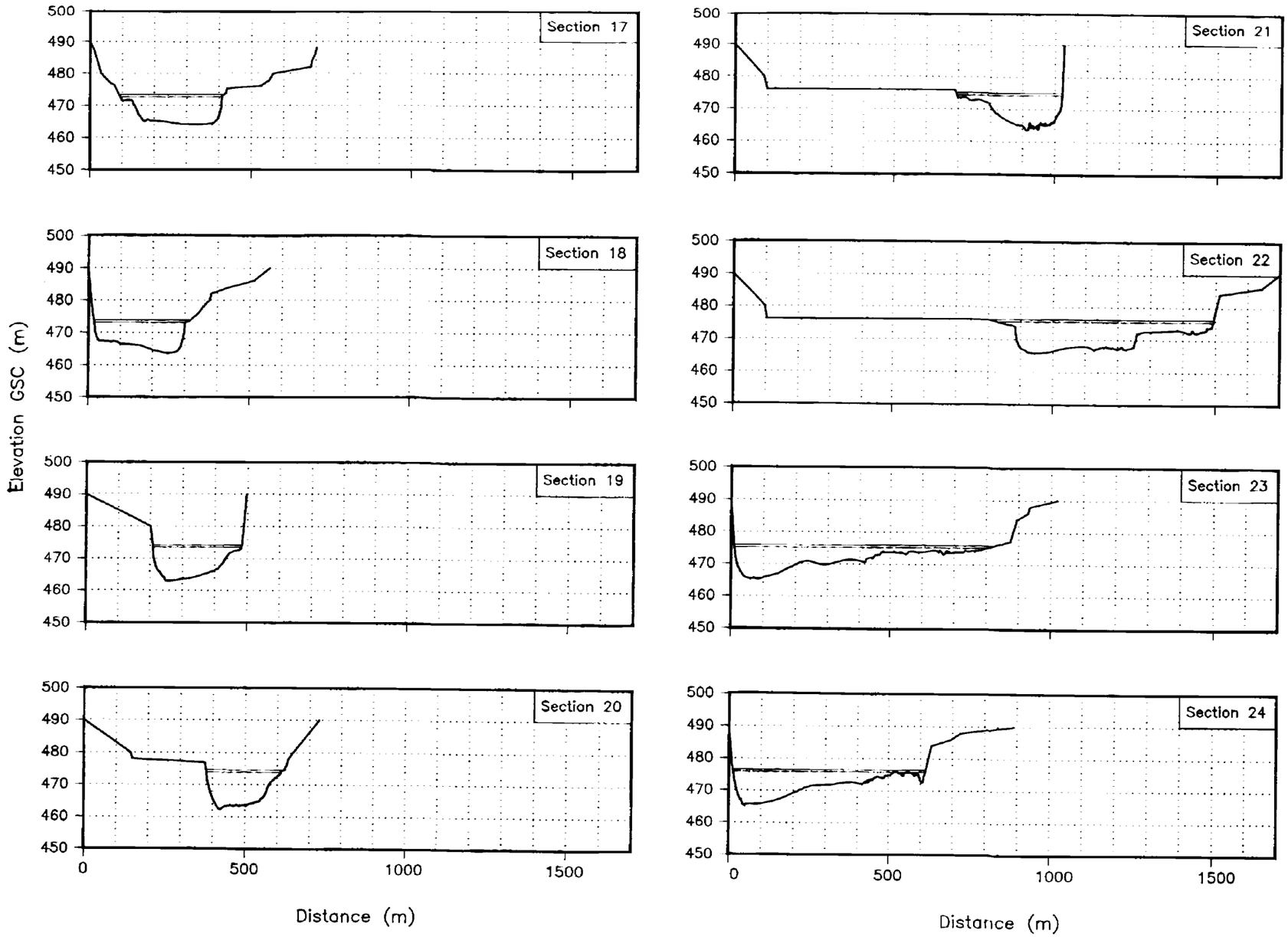
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Cross-sections (9-16)

northwest hydraulic consultants

\HCV1735-047



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawings 89-43-3 and 89-43-4
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20-Year Instantaneous Flood.
- 20-Year Daily Flood.

Flow Condition	U/S of Quesnel Discharge (m^3/s)	D/S of Quesnel Discharge (m^3/s)
20yr daily	5200	6100
20yr inst.	5300	6200
200yr daily	6100	7100
200yr inst.	6200	7200

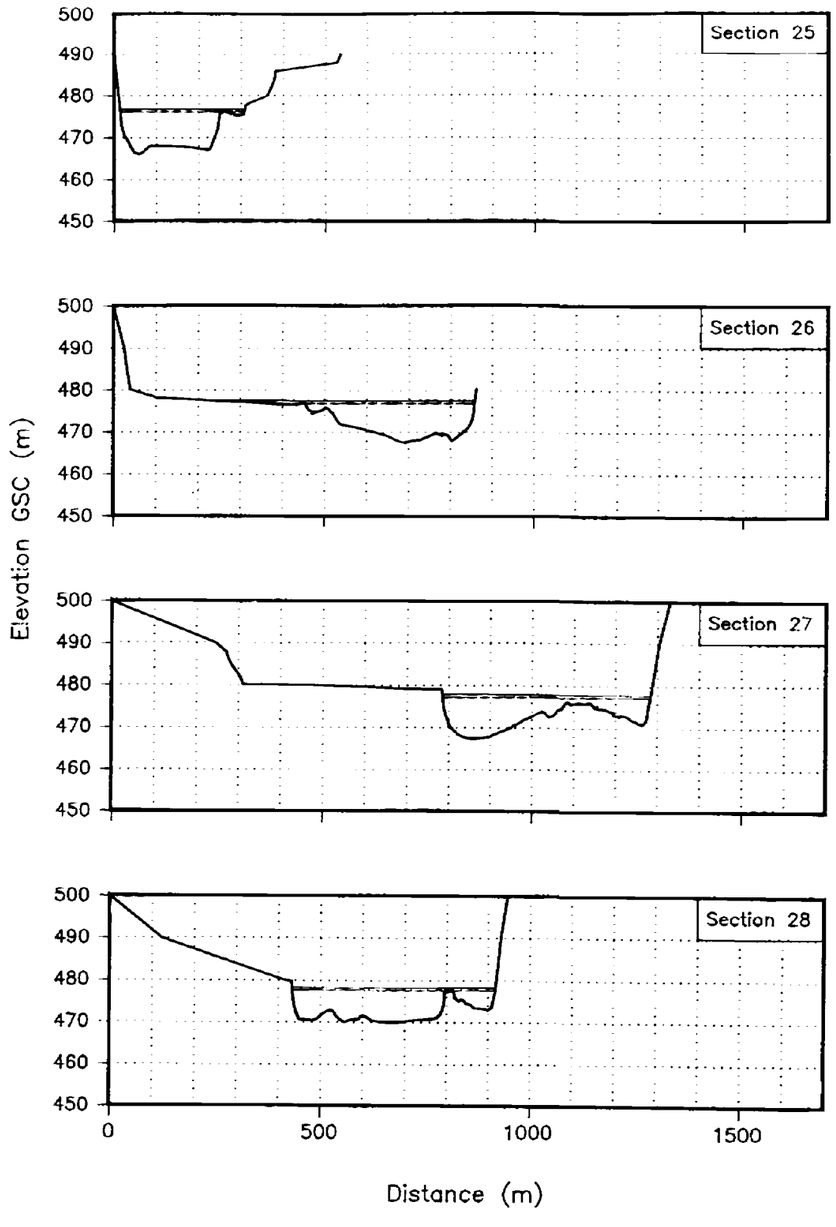
British Columbia Ministry of Environment

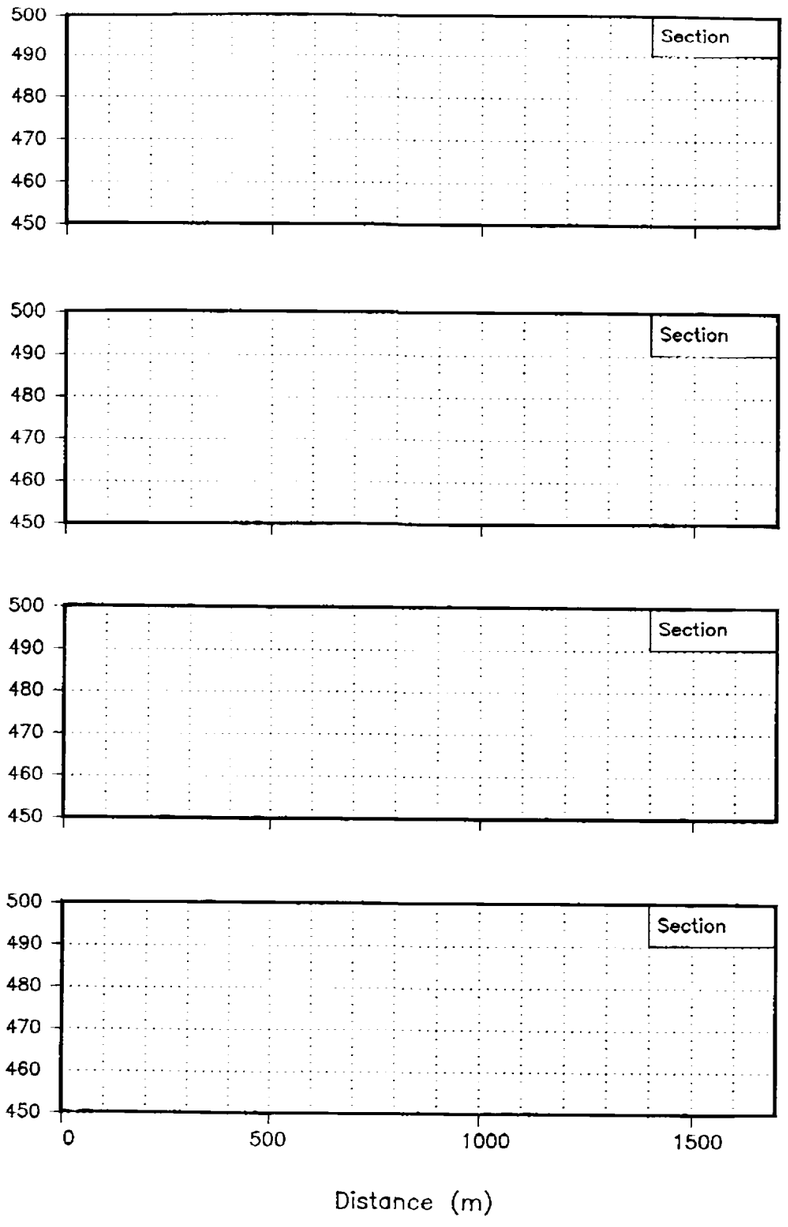
Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Cross-sections (17-24)

northwest hydraulic consultants

NHCV1735-048





Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawing 89-43-5
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20-Year Instantaneous Flood.
- 20-Year Daily Flood.

Flow Condition	U/S of Quesnel Discharge (m^3/s)	D/S of Quesnel Discharge (m^3/s)
20yr daily	5200	6100
20yr inst.	5300	6200
200yr daily	6100	7100
200yr inst.	6200	7200

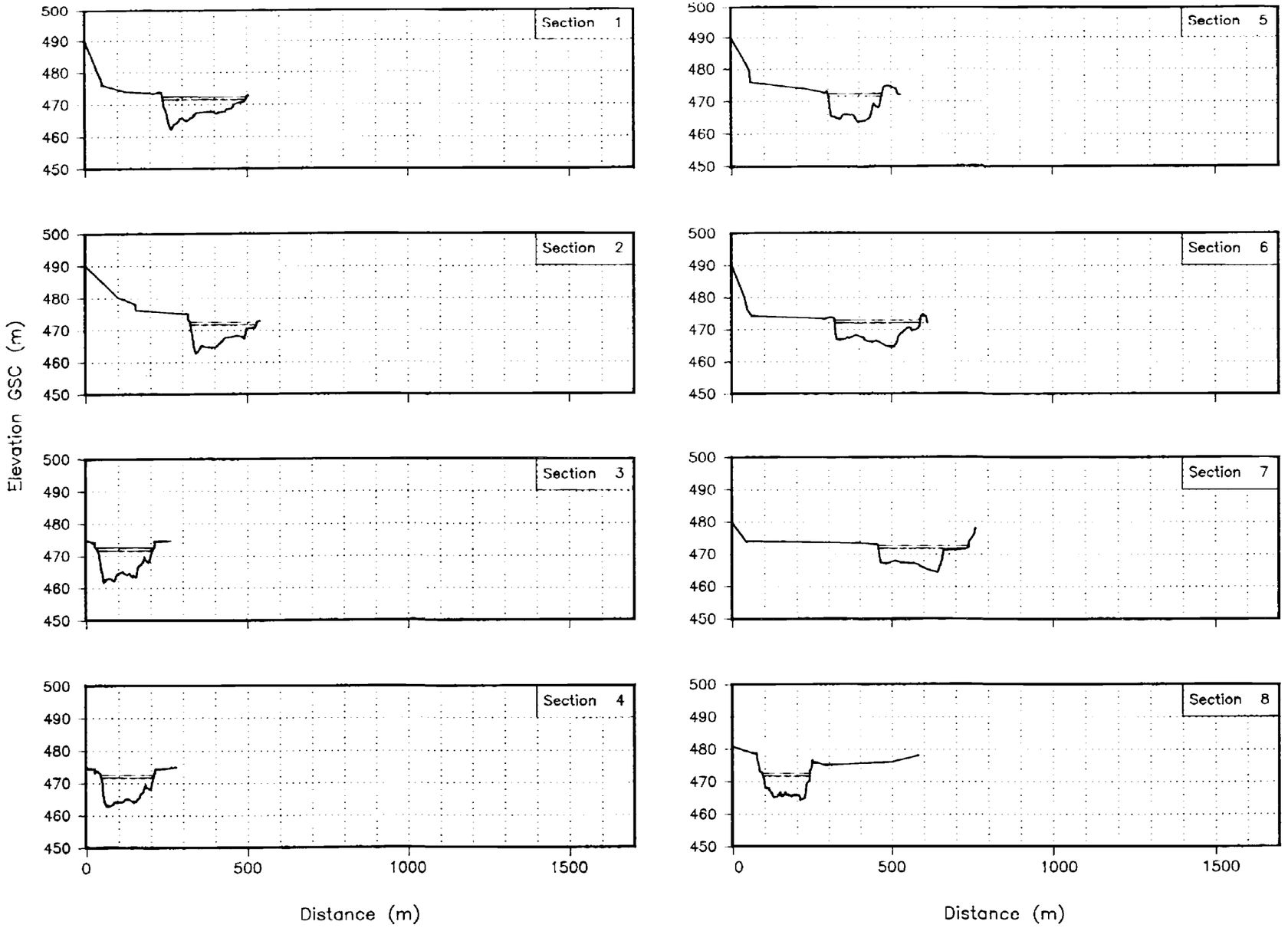
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Fraser River
Cross-sections (25-28)

northwest hydraulic consultants

NHCV1735-049



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawing 89-43-2
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20-Year Instantaneous Flood.
- 20-Year Daily Flood.

Flow Condition	Discharge (m^3/s)
20yr daily	1080
20yr inst.	1140
200yr daily	1330
200yr inst.	1400

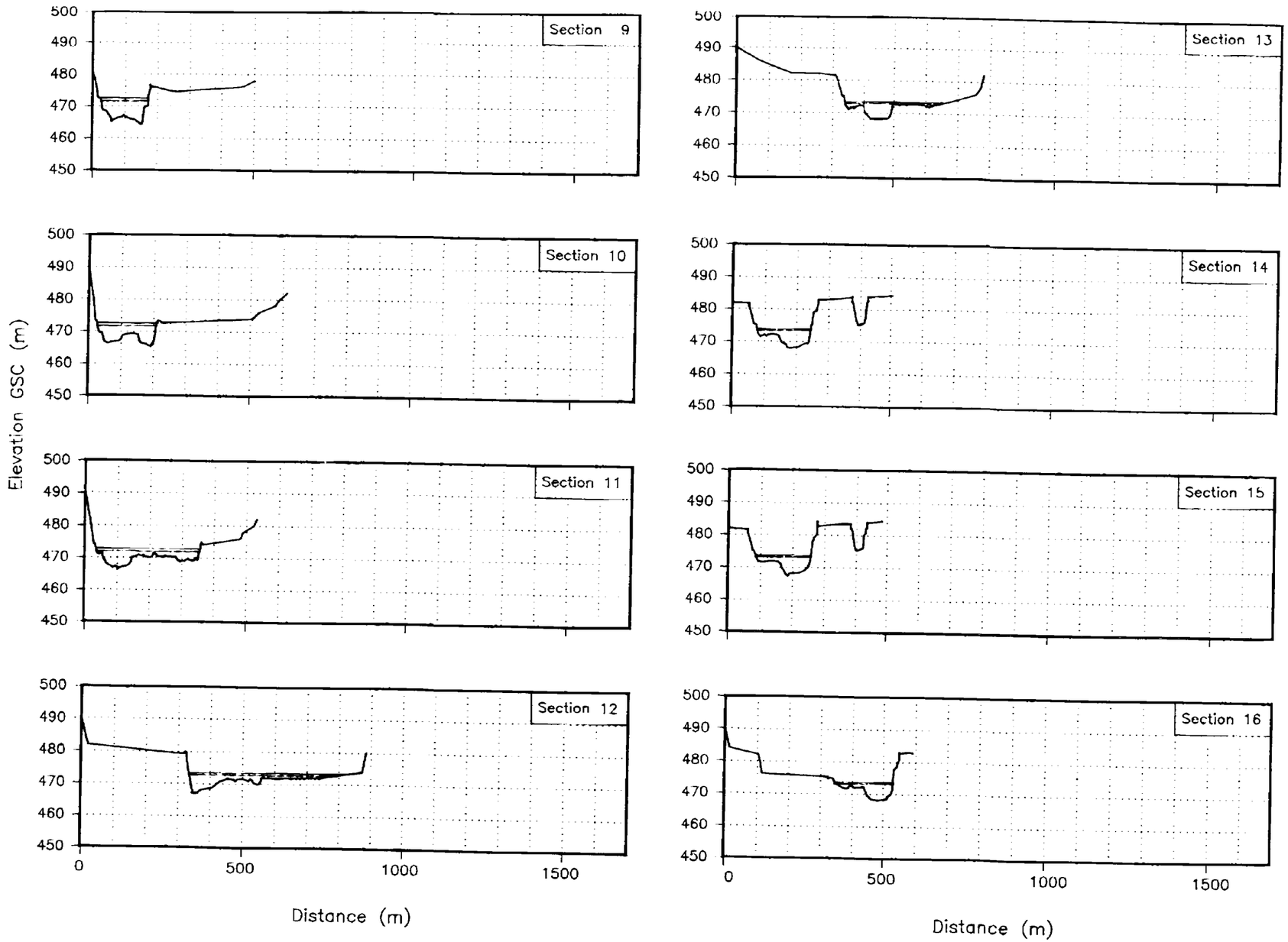
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Quesnel River
Cross-sections (1-8)

northwest hydraulic consultants

NHCV1735-050



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawing 89-43-2 and 89-43-3
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20-Year Instantaneous Flood.
- 20-Year Daily Flood.

Flow Condition	Discharge (m^3/s)
20yr daily	1080
20yr inst.	1140
200yr daily	1330
200yr inst.	1400

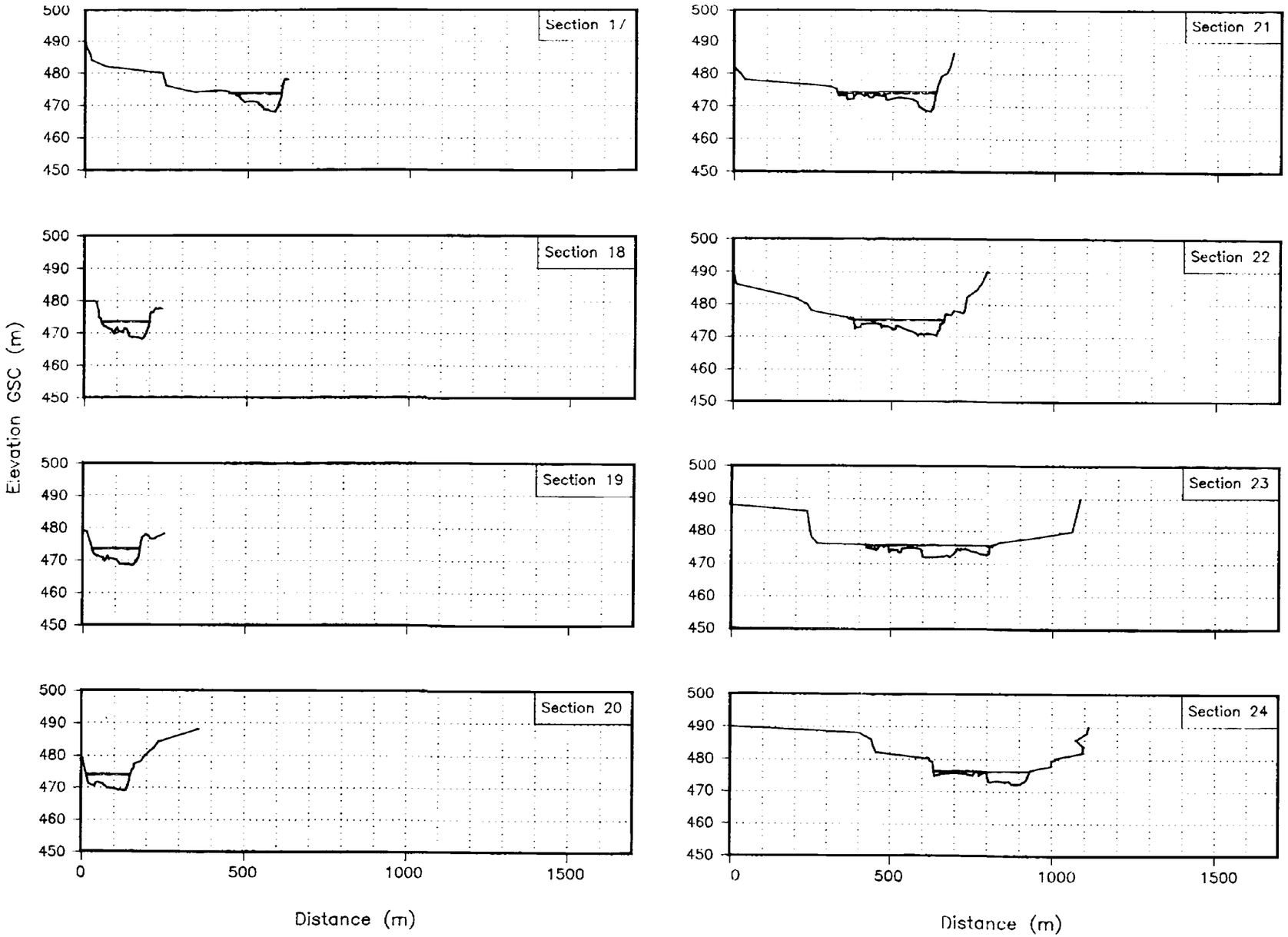
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Quesnel River
Cross-sections (9-16)

northwest hydraulic consultants

NHCV1735-051



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawing 89-43 2 and 89-43-3
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200 Year Instantaneous Flood.
- 200 Year Daily Flood.
- 20 Year Instantaneous Flood.
- 20 Year Daily Flood.

Flow Condition	Discharge (m^3/s)
20yr daily	1080
20yr inst.	1140
200yr daily	1330
200yr inst.	1400

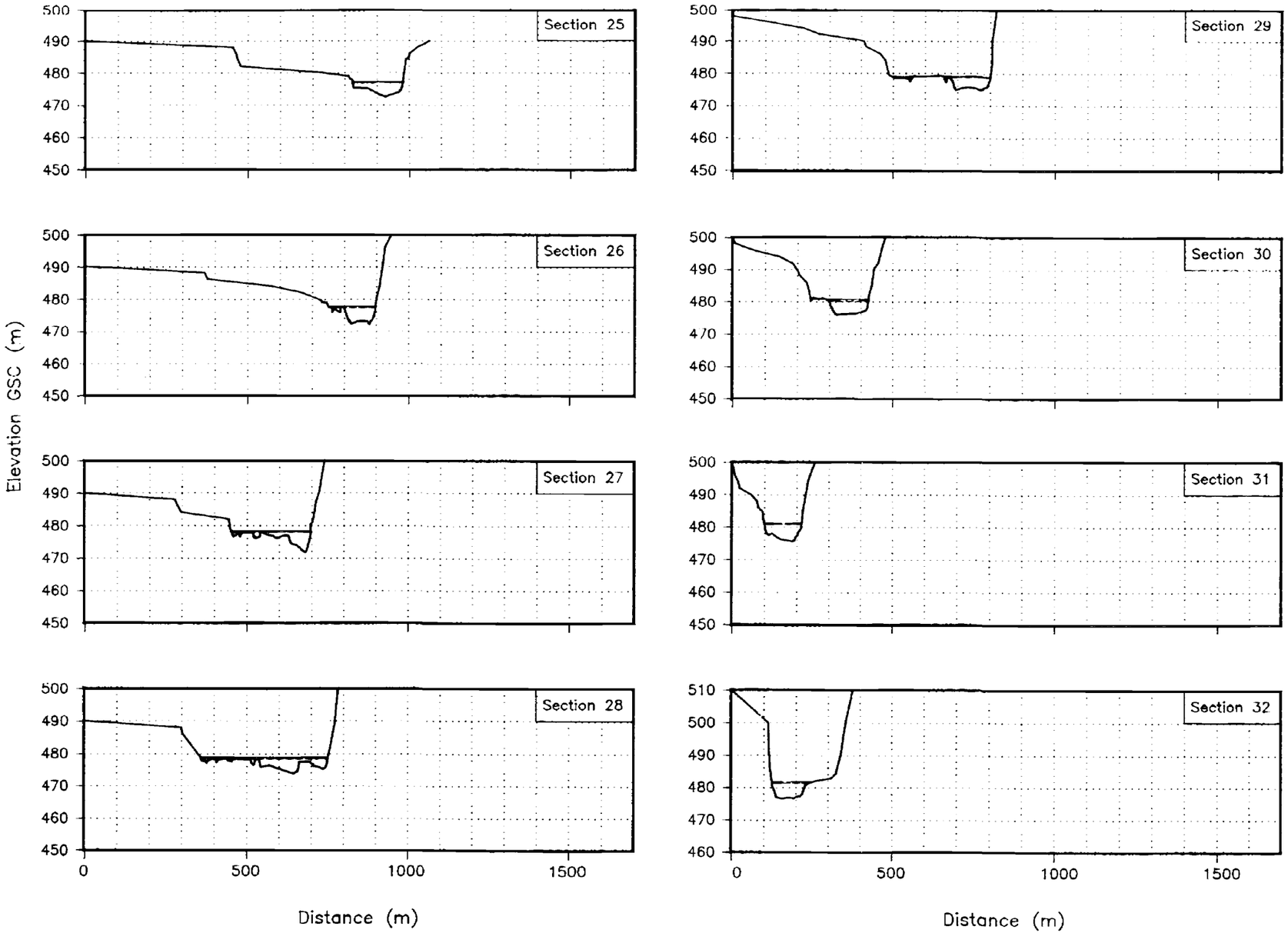
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Quesnel River
Cross-sections (17-24)

northwest hydraulic consultants

NHCV1735-052



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawing 89-43-3
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200 Year Instantaneous Flood.
- 200 Year Daily Flood.
- 20 Year Instantaneous Flood.
- 20 Year Daily Flood.

Flow Condition	Discharge (m^3/s)
20yr daily	1080
20yr inst.	1140
200yr daily	1330
200yr inst.	1400

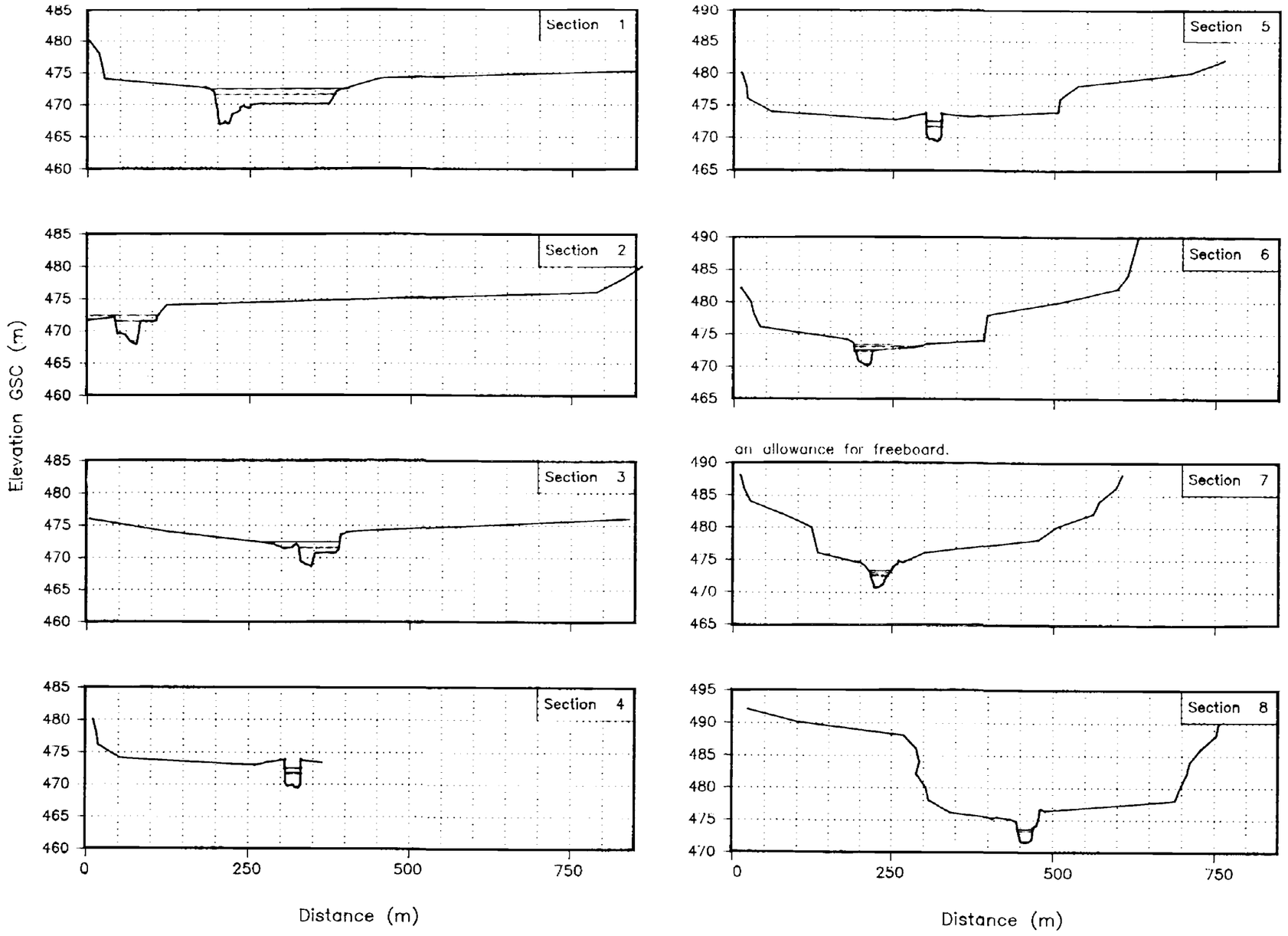
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Quesnel River
Cross-sections (25-32)

northwest hydraulic consultants

NHCV1735-053



an allowance for freeboard.

Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include
3. Cross section locations shown on Drawing 89-43-2
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20-Year Instantaneous Flood.
- 20-Year Daily Flood.

Flow Condition	Discharge (m^3/s)
20yr daily	77
20yr inst.	100
200yr daily	112
200yr inst.	146

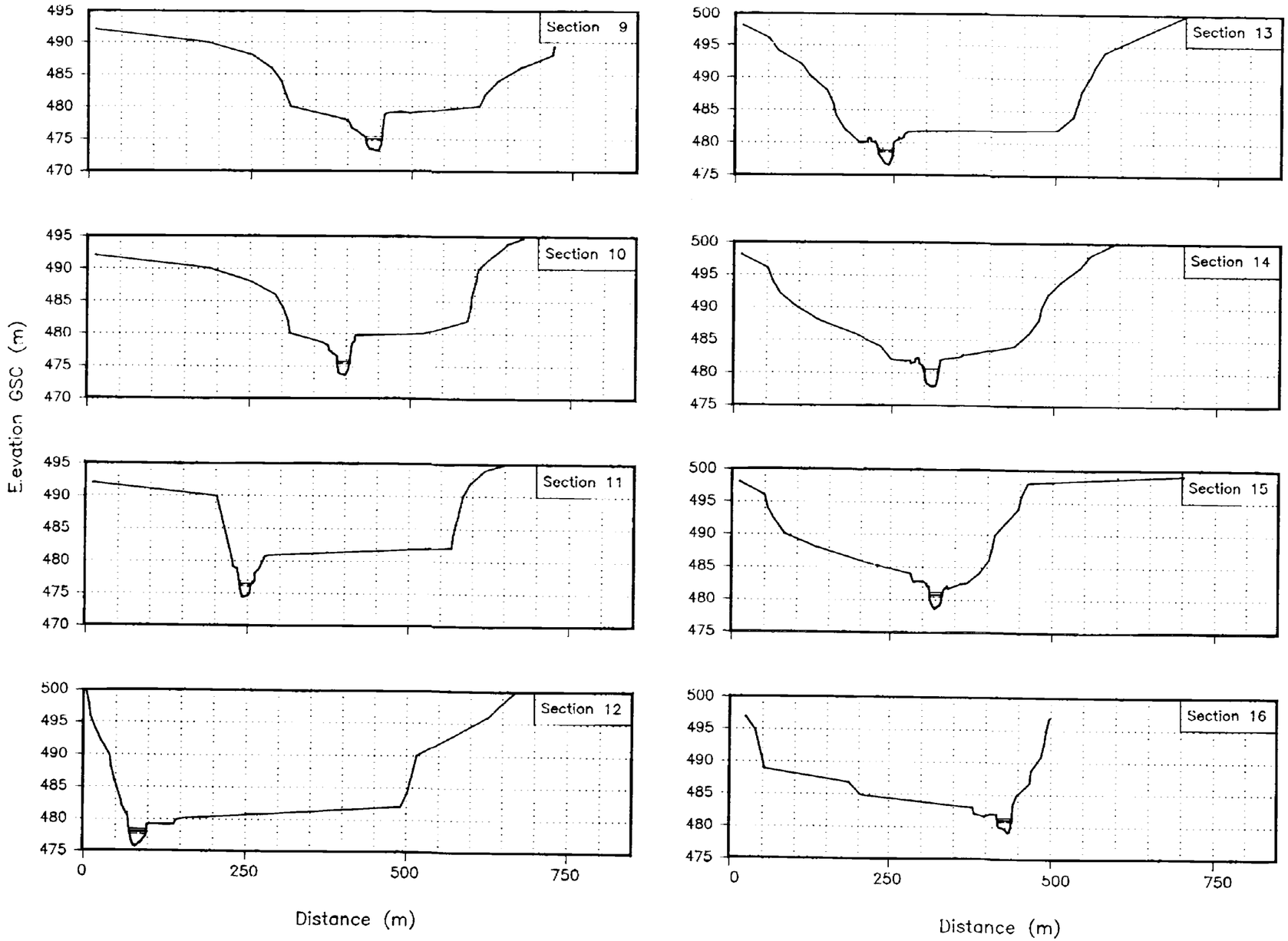
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Baker Creek
Cross-sections (1-8)

northwest hydraulic consultants

NHCV1735-054



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawing 89-43--2
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200 Year Instantaneous Flood.
- 200 Year Daily Flood.
- 20 Year Instantaneous Flood.
- 20-Year Daily Flood.

Flow Condition	Discharge (m^3/s)
20yr daily	77
20yr inst.	100
200yr daily	112
200yr inst.	146

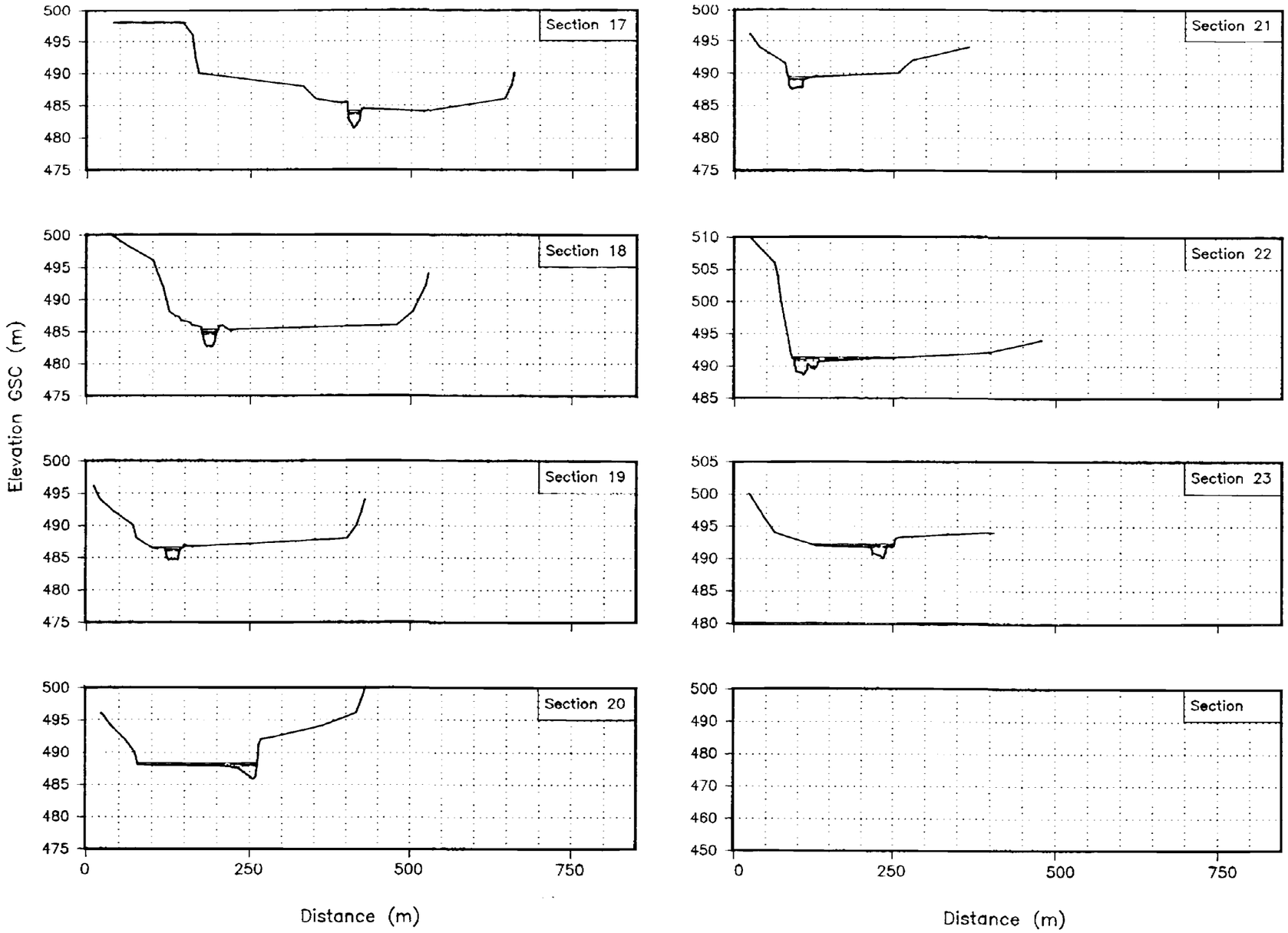
British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Baker Creek
Cross-sections (9-16)

northwest hydraulic consultants

NHCV1735-055



Notes

1. The water surface elevations were computed using a standard step backwater model assuming open water flow conditions.
2. The water surface elevations do not include an allowance for freeboard.
3. Cross section locations shown on Drawing 89-43-3
4. Cross Sections are viewed downstream.
5. Daily and instantaneous flood levels coincide closely and may appear as a single line.

Legend

- 200-Year Instantaneous Flood.
- 200-Year Daily Flood.
- 20 Year Instantaneous Flood.
- 20 Year Daily Flood.

Flow Condition	Discharge (m^3/s)
20yr daily	77
20yr inst.	100
200yr daily	112
200yr inst.	146

British Columbia Ministry of Environment

Floodplain Mapping Investigation
Fraser River at Quesnel

Baker Creek
Cross-sections (17-23)

northwest hydraulic consultants

NHCV1735-056