B. C. MINISTRY OF ENVIRONMENT, LANDS AND PARKS

FLOODPLAIN MAPPING
BONAPARTE RIVER AT CACHE CREEK

DESIGN BRIEF

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Table of Contents

Table of Contents - Continued

List of Tables

List of Figures

Appendices

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1.0 INTRODUCTION

This Design Brief and related Floodplain Maps for the Bonaparte River at Cache Creek were prepared under contract for the British Columbia Ministry of Environment, Lands and Parks (MELP) by KPA Engineering, A Division of UMA Engineering Ltd. The floodplain delineation study, which was conducted from September 1995 to December 1995, covered approximately 14 km of the Bonaparte River Valley in southwestern British Columbia. This Brief presents a summary of the data and methodologies used in the study and the subsequent findings.

The MELP, Water Management Branch contact person in Victoria for this study was R. W. Nichols, P. Eng., Senior Hydraulic Engineer.

The floodplain delineation study described herein included the following components:

- a hydrology study to determine flood frequency characteristics of the Bonaparte River
- development and calibration of a computer model to estimate flood profiles
- determination of flood levels
- transfer of flood levels to mapping and delineation of floodplain area.

River surveys were conducted by MELP and the resulting survey data was provided to KPA along with high water mark (HWM) information and bridge dimensions. Also provided by the Ministry was topographic mapping for use as a base for the Floodplain Maps. The Floodplain Maps for Bonaparte River at Cache Creek, prepared at a scale of 1:5000, appear on three sheets entitled, "Floodplain Mapping, Bonaparte River" (Drawing Numbers 93-12-1 to 93-12-3). These maps have been submitted to MELP separately.

Printed output from computer runs, plotted profiles and cross sections, and other supporting documentation have been submitted to the Ministry of Environment, Lands and Parks under separate cover.

The methods and procedures used for the flood estimates, hydraulic analyses and preparation of the Floodplain Maps conformed to the standards and specifications set forth by the B.C. Ministry of Environment (1) and by Environment Canada (2).

2.0 BONAPARTE RIVER DRAINAGE BASIN

2.1 Geography

The Bonaparte River drainage basin is located in the Southern Interior region of British Columbia, lying mainly north of the Village of Cache Creek (Figure 1). It covers 5020 km^2 of terrain, most of which is located in the Fraser and Thompson portions of the Interior Plateau. A small percentage of the drainage area is occupied by mountainous terrain which forms part of the Coastal Range. Elevations in the catchment range from approximately 420 m above mean sea level on the lower Bonaparte River to 2332 m at Cairn Peak in the Clear Range (in the Hat Creek subcatchment).

Significant urban and rural land development is limited to the valley bottom where the river provides irrigation and supports natural vegetation. Along much of the study reach the valley walls are bare with forested land only at higher elevations.

The Bonaparte River is a tributary of the Thompson River with the confluence located just northeast of Ashcroft. Its origin is located directly north of Kamloops at the outlet of Bonaparte Lake. Approximately 25 km downstream of its origin the River is routed through Young Lake beyond which it flows uninterrupted. Outflows from Bonaparte Lake are regulated but regulation is not expected to affect the magnitude of extreme flood peaks significantly. Flood peak inflows to Young Lake may be attenuated slightly but the effect on downstream flood peaks is expected to be small.

Several large tributaries, draining moderately sloped terrain of the Fraser and Thompson Plateaus, join the Bonaparte River in its upper reaches. Over the last 20 km of its length the Bonaparte River flows through a broad gently sloped valley which progressively narrows and steepens near the downstream end.

The reach of the Bonaparte River for which floodplain maps were prepared (Figure 1) extends from the north end of the Bonaparte Indian Reserve downstream to the settlement of Boston Flats. The only sizable community along this stretch of the river is the Village of Cache Creek, located approximately 5 km upstream of Boston Flats. The remainder of the valley bottom supports a mix of rural residential and agricultural uses.

Two physically distinct sections of the study reach, characterized by different bed slopes, occupy the valley. In profile the two sections are distinguishable with a low-slope section upstream, and an abrupt steepening at approximately XS-30 followed by a high-slope section which continues to the downstream end of the study reach. (Surveyed cross section locations, denoted by the prefix XS-, are shown on the Floodplain Maps in plan, and selected locations are shown in Figure 4, in profile.)

Along the upstream section the floodplain is relatively wide and aerial photography shows evidence of lateral river activity. Many occurrences of marsh and willow scrub vegetation exist in uncultivated areas. The river is tortuous through this section with several large meanders and oxbows. Alluvial fans protrude into the floodplain from locations where once-active streams flowed into the Bonaparte River.

Through the steeper section, which occurs downstream of XS-30, the floodplain is generally narrower and the river flows more directly down the maximum land gradient. Less lateral motion of the river is evident along this section, partly because the river is confined by bedrock valley walls, and partly because of the increased slope.

2.2 Flood-Producing Events

Peak flows on the Bonaparte River typically occur from April to July with the vast majority occurring in May and June. Due to the substantial snowpacks which accumulate at higher elevations, the large drainage area, and the low rain intensity, the annual maximum flows are largely due to snowmelt. The drainage basin lies within the rain shadow of the Coast Range during the passage of Pacific frontal systems and rainfall does not appear to dominate flooding. Very large floods would most likely be produced by the combination of a large snow pack sustained over a cool spring, followed by the onset of warm weather and possibly widespread rainfall.

The snowmelt process usually differs between the high mountain regions and the lower plateau regions within the basin. Warmer temperatures at low elevations tend to melt the snow accumulated there early in the season. Since most of the basin is in the plateau region, flooding tends to coincide with melting there. It is conceivable that high mountain drainage, partially represented by Hat Creek flows, would peak several days later than plateau drainage since warming occurs later at high altitude and because the snowpack must first become saturated before releasing large amounts of water. In some years this appeared to be true but no consistent trend was observed in the data. In fact, for some years the Hat Creek flow peaks coincided with those for the rest of the basin. This may have been due to melting in the low areas within the Hat Creek catchment which governed the peak flows for that year. The high elevation Hat Creek inflows can influence flood peaks on the Bonaparte if significant high altitude snowmelt occurs concurrently with snowmelt in the lower areas.

2.3 Historic Floods

The two largest floods on the Bonaparte River in the past 70 years occurred in 1948 and in 1990. References to an earlier large flood in 1894 could not be confirmed by data or newspaper articles, although 1894 was the year in which a very large flood occurred on the Fraser River, to which the Bonaparte is a tributary, via the Thompson River.

Although no streamflow data or photographs could be obtained for the 1948 event on the lower Bonaparte River, a personal account from a local resident suggested that the flood was of a very similar magnitude as the 1990 flood.

The 1990 flood peaked at the Bonaparte River Below Cache Creek gauge on June 16 with a mean daily flow of 84.3 m^3/s. The flood frequency study, described below in Section 4.0, indicated that the 1990 flood event had an estimated return period of 72 years.

This event was well documented by local municipal employees and the Ash Creek T. V. Society who recorded and aired video footage of the flood. This video is on file at the MELP, Water Management Branch in Victoria, and is available through the Ash Creek T. V. Society.

During the flood, damage to a log stringer bridge on the Bonaparte Indian Reserve was sustained as a result of high water and debris. Provisions were made to protect other bridges and pipelines crossing the river at various locations. The footbridge near XS-20 was removed by a large crane during the flood as it was at risk of being dislodged and carried downstream by the high-velocity flow.

Inundation of low-lying areas was widespread. At some sites, as the video shows clearly, flow velocities were often great enough to carry large debris and significant volumes of sediment. Photos 1 through 4 (Appendix 1) show locations throughout the study area that encountered typical inundation during the 1990 flood. The rapid, energetic flow pictured in Photo 5, taken near the trailer park opposite the rear of the Wander Inn in Cache Creek (near XS-26), was typical of other sites along the river, such as the Sage and Sands Trailer Park (Photo 6), and eroded large amounts of sediment from the bed and banks. Significant erosion of the banks occurred in many areas such as that near XS-25, just upstream of the highway bridge, which is shown in Photo 7. At this location the paved surface was undermined and progressively failed as the bank was eroded.

3.0 DATA USED FOR STUDY

3.1 Data Sources

Many different types of information were acquired for this study from a variety of sources. The main sources of data are listed below, and reports from which information was obtained are listed in the References Section.

Mapping

Maps used for this study are listed below:

- NTS 1:250,000 scale map sheets 92I, 92P
- NTS 1:50,000 scale map sheet 92I/14
- B. C. Ministry of Environment, Lands and Parks, Water Management Division, 1:5,000 scale topographic maps (3 sheets) 95-1-1 to 95-1-3, showing location of cross sections, gauges and reference monuments on Bonaparte River
- B. C. Ministry of Environment/Environment Canada 1:5,000 scale topographic base floodplain maps (3 sheets) 93-12-1 to 93-12-3

Floodplain limits were delineated on the 1:5000 scale base maps. This mapping was found to agree closely with most of the cross section survey data. In a few heavily forested areas minor discrepancies were discovered. In these areas the survey information governed over the topographic base maps for floodplain delineation purposes.

Air Photos

The following selected stereo pairs from B.C. Government aerial photography were used for this study:

- May, 1992, Roll No. 30BCC92006, Photo Numbers 6, 7, 88, 89, 120, 121
- June, 1992, Roll No. 30BCC92015, Photo Numbers 55, 56, 109, 110
- August 1987, Roll No. BC87084, Photo Numbers 269, 270, 271

The 1992 photos provided 1:15,000 scale coverage of the study reach and the 1987 photos provided 1:50,000 coverage.

Surveys

Survey data for a total of 74 cross sections, measurements for the 15 bridges in the study reach as they were in 1994, bridge photographs and channel photographs were provided by B.C. Ministry of Environment, Lands and Parks (Project 94 15 FO81). The survey was found to be reliable and accurate for the purposes of this study. Also obtained from MELP was a list of 29 surveyed high water marks for the 1990 flood.

Hydrologic Data

The flood data, comprising both daily and instantaneous peaks, was obtained from Water Survey of Canada for the Bonaparte River Below Cache Creek Gauge and several regional stations. Some supplemental data for regional stations was obtained from MELP.

3.2 Field Investigations

Two site investigations were conducted during the course of this study. The first field visit commenced on 18 September, 1995, and spanned 3 days. It included a thorough site reconnaissance with visits to every one of the 15 bridge sites in the study reach. Meetings were conducted with Spencer Robillard, Public Works Foreman for the Village of Cache Creek, Paul Doyle from the MELP Regional Office and Rick Bennett, Band Manager at the Bonaparte Indian Reserve. Contact was also made with Mr. Verdi of the Thompson-Nicola Regional District. In addition, most of the farmers in the study area were interviewed.

The second site investigation took place on 17 November, 1995. A detailed field check of the preliminary mapping was conducted for the entire study area. At some locations, where the elevation change was difficult to resolve from the topographic maps, the field check provided information which allowed a reliable flood limit to be prescribed.

4.0 FLOOD FREQUENCY STUDIES

4.1 Regional Streamflow Gauges

Inside the Bonaparte River drainage basin, the streamflow gauging stations selected for analysis extended from the gauge above Young Lake in the north down to the gauge below Cache Creek in the south. Several stations on tributaries were selected to provide information about the different hydrologic regimes present.

Outside the Bonaparte catchment area three gauges were included. These were selected on the basis of their length of record, proximity to the Bonaparte region and the hydrologic similarity of their catchments. The gauge on Big Creek shows the combined effect of high mountain drainage and plateau type drainage, similar to Hat Creek. Deadman River is very near the Bonaparte River study area and is thus within the same climatic zone with similar hydrologic properties as some parts of the Bonaparte drainage basin. Criss Creek is a tributary of Deadman River and reflects upland runoff characteristics for the basin.

The selected gauging stations and their drainage areas are listed in Table 1.

Table 1 - Streamflow Stations					
Station Number	Station Name	Drainage Area (km²)	Period of Record	Mean Annual Flood (m³/s)	MAF Unit Runoff (m³/s/km²)
	Within Bonaparte River Catchment				
08LF002	Bonaparte River Below Cache Creek	5020	1912-21,1972-95	25.68	0.005
08LF002	Extended Bonaparte R Below Cache Cr	5020	1912-21,1962-71(ext.),1972-95	26.50	0.005
08LF060	Bonaparte River Near Cache Creek	4090	1961-74	18.19	0.004
08LF015	Hat Creek Near Cache Creek	658	1911-13,1961-94	5.65	0.009
08LF062	Bonaparte River Near Bridge Lake	666	1960-94	13.77	0.021
08LF066	Bonaparte River Above Loon Creek	3520	1968-70,1983-95	19.31	0.005
08LF071	Loon Creek Near the Mouth	479	1968-71,1983-1990,1992-95	1.51	0.003
08LF013	Hat Creek Near Ashcroft	74.1	1911-22	1.91	0.026
08LF021	Scottie Creek Near Cache Creek	174	1912-13,1916-21,1963-74	1.90	0.011
08LF081	Ambusten Creek Near the Mouth	32.9	1911-15,1960-95 used for peaking factor investigation only		
	Outside Bonaparte River Catchment				
08LF007	Criss Creek Near Savona	490	1913-21,1962-90	21.40	0.044
08LF027	Deadman River Above Criss Creek	862	1913-21,1962-90	13.20	0.015
08MB006	Big Creek Above Groundhog Creek	1020	1975-90	38.80	0.038

4.2 Methodology

The flood frequency estimates for the Bonaparte River were primarily based on a single station analysis for a key gauging station, and were augmented by a regional analysis. In this case the regional method involved estimating flood frequencies for several gauged streams within the Bonaparte catchment area and in hydrologically similar regions nearby.

There is one WSC streamflow gauge on the Bonaparte River within the floodplain mapping study area. This gauge location, referred to as "Bonaparte River below Cache Creek (08LF002)," has 33 years of data which could have been used in isolation to estimate design flood discharges, at upstream and downstream locations, by prorating on a drainage area basis. However, the regional analysis provided a valid way of extending flood estimates to other locations on the river.

There are several active and inactive streamflow gauges within the Bonaparte River catchment. Many of these, however, do not have a long enough period of record to allow the estimation of a 200-year flood. A total of eight gauges within the basin were selected for flood frequency analysis. These are listed in Table 1 where their periods of record are indicated.

In an attempt to increase the reliability of predictions based on data from the key Bonaparte River gauge (08LF002), a method of extending the period of record was investigated. By correlating with peak discharges from the nearby Deadman River, the data at the key Bonaparte River gauge was extended. Because the two catchments are hydrologically similar, it was possible to use the trend of additional Deadman River data, from 1962-1971, to estimate discharges for the Bonaparte River. An unbiased regression analysis was performed to determine an approximate linear relationship between the two gauges for all years of coincident recorded data. The correlation technique used to determine this relationship is described in the Interim Report (3) submitted to MELP, by KPA, in September 1995. The equation resulting from the regression analysis was used to estimate discharges at the key Bonaparte River gauge for the years 1962-1971.

4.3 Flood Frequency Analysis

A flood frequency analysis, producing 20 year and 200 year flood estimates, was performed on the data from each gauging station listed in Table 1 and located within the Bonaparte River drainage basin. Three gauges, with lengthy periods of record, from nearby catchments which appeared to be hydrologically similar, were used to supplement the data. Frequency analyses were performed on this data and mean annual floods were calculated (Flood Regionalization Study by MELP, 1988) (4).

Flood frequencies for each individual station were analyzed with the aid of a computer program known as the Consolidated Frequency Analysis Package (CFA), prepared by Environment Canada as a supplement to their Guide for procedures for floodplain delineation (2). The program provides routines which screen for data independence, trend, homogeneity and randomness. The data may also be examined graphically. The program will perform tests for low and high outliers, and permit incorporation of historic data. Four probability distributions are provided in CFA, and these are:

- Generalized Extreme Value
- Three Parameter Log Normal
- Log Pearson Type III
- Wakeby.

Peak daily flows were analyzed because there generally was much more daily than instantaneous peak flow data. Initially, all four probability distributions were applied to each set of flood peak data. A plot of each flood frequency curve showing the individual data points was reviewed before a "best fit" probability distribution was selected.

In general, each of the four probability distributions exhibited good fit and the predictions of peak flow were similar. In most cases the Three Parameter Log Normal distribution provided a median flood estimate and a good fit. The range from the high to low estimate for the four distributions was small compared to the range in unit peak flows over the region.

4.4 Variation of Unit Flood Flows with Drainage Area

The unit runoff values corresponding to mean annual daily floods and floods with 20 and 200-year return periods, were plotted against drainage area for the gauges listed in Table 1. The plotted points were used as guides for determining trend lines for the purpose of estimating floods for the study area of Bonaparte River.

The points for the extended and unextended data for the Bonaparte River Below Cache Creek, which plotted close to one another, were relied upon for the positioning of a trend line. In each figure the line was anchored on the higher (more conservative) of the two points, while the regional points provided guidance in setting the slope.

Figure 2 shows the resulting trend lines for the 20 year and 200-year maximum daily flood unit runoffs.

4.5 Ratios of Instantaneous to Daily Peaks

Some of the streamflow gauges listed in Table 1 reported maximum instantaneous flows in addition to daily flows. To estimate the instantaneous peaks throughout the study area, it was necessary to develop a relationship between the instantaneous to daily peak ratio, or peaking factor, and drainage area.

Peaking factors were investigated for all regional gauging stations which reported instantaneous maximum flows. It was found that, in general, peaking factors corresponding to high floods were not higher than the mean peaking factor for the entire period of record. Therefore, mean peaking factors for the entire period of record were assumed to be applicable to large floods.

A curve following the trend of the peaking factors was plotted against drainage area and is shown in Figure 3. This curve and the daily peak flow estimates were used to estimate 20 and 200-year instantaneous peak flows for the Bonaparte River Study area.

4.6 Flood Flow Estimates

The outcome of the flood frequency study was the estimation of a set of flood discharges which were entered in the HEC-2 computer program to estimate flood levels. The total drainage area variation along the Bonaparte River, within the study area, is relatively small, and was found to have little effect on the total river discharge. The only significant inflow to the Bonaparte River, within the study reach, is that of Cache Creek. Discharge values were calculated for the Bonaparte River just upstream of Cache Creek and just downstream of Cache Creek. The difference between these values represents the amount of inflow from Cache Creek. It was found that this inflow is approximately 1% of the total river discharge downstream. This small inflow was not expected to significantly affect estimated water levels. Therefore, the computed discharge for the downstream end of the study reach was applied and held constant throughout the modelled region.

The daily discharges were estimated on the basis of drainage area and the unit runoff value, for each return period, taken from the trend line in Figure 2. These resulting values are listed in Table 2. The maximum instantaneous flows were calculated using the maximum daily flows and peaking factors taken from the curve in Figure 3.

Table 2

Estimated Flood Discharges

	20-Year Peak Flood	200-Year Peak Flood
Maximum Daily (m^3/s)	56.2	99.2
Peaking Factor	1.040	1.040
Maximum Instantaneous (m^3/s)	58.5	103.2

5.0 RIVER MORPHOLOGY

On the basis of information collected during the site investigations and interpretation of aerial photographs, some trends in river morphology are apparent. It appears that none of these trends are rapid enough to affect the flood levels in the next half century to a magnitude similar to the freeboard amounts applied to the calculated flood levels. However, extremely rare floods or climate changes could accelerate the morphological changes.

The study reach of the Bonaparte River for this floodplain mapping assignment straddles a major gradient change in the river profile, as shown clearly in Figure 4. The change occurs near the mouth of the stream named Cache Creek, but appears to be largely unrelated to the sediment input from this tributary. Instead, the bed slope of the channel appears to be governed by geologic structures in the valley, resulting in a narrow bedrock-controlled canyon just below the downstream end of the study reach and a wide recently-formed floodplain along the upper two-thirds of the study reach.

There are several alluvial fans which protrude into the floodplain along the study reach. All except one of these appear to be virtually inactive, as the Bonaparte River has significantly eroded the toes of all these fans, and there are no signs of recent regrowth of the toes. None of the inactive fans appear to be controlling the profile of the Bonaparte River, even in areas such as near XS-64 where the floodplain in constrained between two large fans on both sides of the valley.

Cache Creek is the only tributary that potentially has sufficient flow to be actively changing under the current climatic regime. The fan is old, irregular and appears mostly dormant, except for a narrow zone near the stream itself. The most developed part of the Village of Cache Creek is primarily located on the alluvial fan of Cache Creek.

The slope change in the Bonaparte River bed near the mouth of Cache Creek may be partly due to the tributary sediment gradation and load, but there is only one very short reach of the river where it is confined between the toe of the fan and the opposite valley wall. Even without a Cache Creek tributary present, a similar major slope change would exist within a couple kilometres downstream.

Upstream of the Village of Cache Creek there are many signs, such as meander scars, oxbow lakes and channel plugs, that the Bonaparte River is laterally active within the floodplain. There are no recent river terraces along this reach that would indicate a former floodplain elevation above the current one.

Downstream of Cache Creek, however, there are terraces visible in several locations, suggesting that, in this reach, the river valley is incising through former sediments. This would be consistent with the expectation that the channel below the study reach is slowly eroding the bedrock and deepening the canyon in which it is located. It does stand in contrast with the absence of terraces farther upstream.

Highway bridges and built-up areas in the Village appear to have blocked some of the natural floodway conveyance of the Bonaparte River. In flood situations, the reduced floodway conveyance results in a backwater effect causing higher flood levels upstream, and more discharge concentrated in the channel. The increased channel flow occurs with higher velocities, and this may promote bed and bank scour. It is possible that the erosion which occurred in 1990 at the rear of the Wander Inn and other locations in the Village was exacerbated by developments which blocked floodway flows.

6.0 HYDRAULIC ANALYSES

6.1 Model Development

The computer program known as HEC-2 was used to simulate 200-year flood profiles for the study reach. This program, written by the U.S. Army Corps of Engineers and widely used throughout North America for floodplain delineation studies, computes backwater profiles for steady state flow conditions using the Standard Step Method (10,11).

The HEC-2 model was prepared for the study reach of the Bonaparte River in the following manner:

1. The cross section data from the river survey was provided in HEC-2 input format (GR data) by the Ministry of Environment, Lands and Parks.

2. Cross sections which appeared to have insufficient height to contain a large flood flow were extended using the contours on the 1:5000 scale topographic mapping.

3. Twelve of the 15 bridges within the study area were coded for the HEC-2 program. The 3 bridges not coded were each small foot bridges. It was assumed that the flows encountered during a 200-year flood would dislodge these bridges and carry them away. Additional cross sections were inserted at 2 bridge locations to achieve the recommended cross section spacing upstream and downstream from the bridges.

   Where bridges or piers were skewed to the direction of high-stage flows, care was taken to ensure the apparent widths of the bridge openings and apparent pier widths were represented in the model.

4. Thalweg distances were obtained from MELP and overbank distances were measured from the 1:5000 scale mapping and entered in the model.

5. Manning's "n" values for the river channel were estimated using photographic and tabular guides by Chow (12), taking into consideration roughness height (approximated from bed material sizes), river slope, vegetation, debris, sinuosity and cross section uniformity.

   Channel roughness coefficients used for the Bonaparte River simulation ranged from 0.03 to 0.08. Generally, the steeper reaches contained larger bed material and were assigned higher roughness coefficient values. The low-slope reaches were typically more sinuous and vegetated with overhanging willows along much of their length.

   The highest coefficients were applied to the downstream reaches of Bonaparte River, where the bed was lined with large cobbles and boulders.

   Manning's "n" values for the overbank areas were estimated primarily on the basis of vegetation type. The values used ranged from 0.066 to 0.2.

6. Hydraulic loss coefficients for expansion, contraction, pier shape, orifice flow and weir flow at bridges were generally selected in accordance with the recommendations outlined in the HEC-2 User's Manual (10).

7. The input data was completed by the addition of peak discharge data and necessary job control parameters. For all sensitivity and final runs, the starting water level was determined by the program using a starting slope for the energy grade line of 0.005 at XS-1.

6.2 Model Calibration

After the initial HEC-2 model of the Bonaparte River was developed it was calibrated using observed flow and high-water mark data from the 1990 flood event. The HEC-2 program was executed, then the resulting profiles were plotted with the observed high-water marks and a comparison was made. Channel roughness coefficients were adjusted, the bridge coding was altered and the model was run again. This was repeated until a reasonable fit was achieved for the majority of the high-water marks. The resulting profile appears in Figure 4.

In most cases the predicted profile fell on or above the measured high-water marks. Two high water marks located between XS-4 and XS-5, which were obtained though a personal account of the 1990 flood level, were unreasonably high and were assumed to be erroneous.

At another location, near the bridge at XS-25, some high water marks fell below the simulated profile. Attempts were made to lower the profile but the measured high water marks could not be matched using realistic values of model parameters. It is possible that bed scour occurred during the flood, altering the channel dimensions, and lowering the actual river profile relative to that estimated by the model, which used the channel dimensions as they existed in 1994, after bed material deposition likely occurred. In this case the simulated levels exceeded the reported high water marks, therefore the final flood profiles produced by this model may be slightly conservative at this location.

6.3 Sensitivity Analyses

Sensitivity tests were conducted to estimate the impact of inaccurate data or modelling assumptions on the final results. The tests were used to indicate whether the standard freeboard quantities generally used by the B.C. Ministry of Environment, Lands and Parks were in a reasonable proportion to the effects of uncertainties in this study. The sensitivity analyses concentrated on two major parameters, flow and channel roughness.

The calibrated model using the 200-year peak daily flow was established as the base simulation. The discharge in the model was decreased by 10% and the program was executed. The discharge was then increased by 10% and 25% above the base simulation for two subsequent runs. Similarly, three more simulations were made with Manning's "n" factored by -10%, +10% and +25%. The results of these six runs are summarized in Table 3 in terms of mean and maximum water level differences, at cross sections, between each test run and the base simulation.

Table 3 - Summary of Sensitivity Test Results

Sensitivity Test	Variation in Water Level From Base Simulation (m)	
	Mean	Maximum
Roughness Coefficient, Manning's "n"		
-10%	-0.09	-0.23
+10%	0.08	0.43
+25%	0.19	0.58
200-Year Peak Daily Flow		
-10%	-0.10	-0.25
+10%	0.10	0.54
+25%	0.24	0.65

6.4 River Flood Levels

Using the HEC-2 program, flood profiles were generated for the 200-year instantaneous and daily peak flows. A freeboard of 0.3 m was added to the peak instantaneous flood profiles, and a freeboard of 0.6 m was added to the daily flood profiles. A plotted profile for 200-year peak daily water level (not including freeboard) appears in Figure 5. At each cross section the higher combination of 200-year flood level plus freeboard was selected. This combination became the Flood Level (including freeboard) for that cross section, and a listing of these levels for all cross sections used in the modelling appears in Appendix 2.

Water levels corresponding to instantaneous and daily peak flows differed by a mean value of 0.043 m, and the governing condition was the 200-year daily peak water level plus 0.6 m freeboard at all cross sections. The magnitude of the water level changes indicated by the sensitivity analyses was generally less than the 0.6 m freeboard criterion, therefore this freeboard value appears to provide a reasonable margin of safety to account for uncertainties in the data and the computer model.

The flood levels (including freeboard) were used to delineate the floodplain by plotting them on the 1:5000 scale topographic mapping at each cross section. The contours were used to identify the floodplain limits between cross sections.

Isograms for the 200-year flood levels were located on the mapping and the corresponding 20-year flood level (including freeboard) for each isogram was calculated. Both flood levels were labelled at each isogram on the mapping.

7.0 CONCLUSIONS

1. This Design Brief presents an overview of the studies undertaken to produce the floodplain mapping sheets for the Bonaparte River. The floodplain limits shown on the maps correspond to the area which would be inundated by the designated flood.

2. The floodplain in the study area has a documented history of flooding dating back to 1948, and anecdotal references were made to a large flood in or near 1894.

3. The floodplain maps are not comprehensive floodplain management plans, nor do they provide solutions to site-specific problems such as bank erosion.

4. Flooding may occur outside 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 and under notes of caution on individual sheets.

8.0 RECOMMENDATIONS

On the basis of the findings of this study we recommend the following:

1. That the Floodplain maps produced by this study, numbered 93-12-1 through 93-12-3, be designated under terms of the Canada - British Columbia Floodplain Mapping Agreement.

2. That these Floodplain Maps be reviewed and updated as required on the basis of significant future flood data or information relating to major physical changes to the floodplain.

3. That Village, Regional District and Regional MELP regulators, and the Bonaparte Band Council cooperate to preserve floodway capacity by preventing future developments which would block or diminish floodway flows, unless the loss of capacity is offset by a corresponding channel or floodway enlargement.

This "Design Brief for the Floodplain Mapping Program for the Bonaparte River at Cache Creek," is respectfully submitted by:

KPA ENGINEERING
A Division of UMA Engineering Ltd.

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REFERENCES

1. B.C. Ministry of Environment, Lands and Parks, Water Management Division, "Floodplain Mapping Program, Specifications for Engineering Studies," Attachment A, Invitation for Proposal for Engineering Services, Victoria, 10 July, 1995.

2. Environment Canada, Inland Waters Directorate, Water Planning and Management Branch, "Hydrologic and Hydraulic Procedures for Flood Plain Delineation," Ottawa, May 1976.

3. KPA Engineering Ltd., "Interim Report-Flood Frequency Studies," Floodplain Mapping, Bonaparte River at Cache Creek, September 1995.

4. B. C. Ministry of Environment, Lands and Parks, Water Management Division, "Flood Regionalization Study," 1988.

5. Environment Canada, Inland Waters Directorate, "Historical Streamflow Summary, British Columbia, to 1989," Ottawa, 1990.

6. Environment Canada, Inland Waters Directorate, "Surface Water Data, British Columbia, 1990," Ottawa, 1991.

7. Environment Canada, Inland Waters Directorate, "Surface Water Data, British Columbia, 1991," Ottawa, 1992

8. Environment Canada, Inland Waters Directorate, Surface Water Data for Selected Gauges for 1992 - 1994.

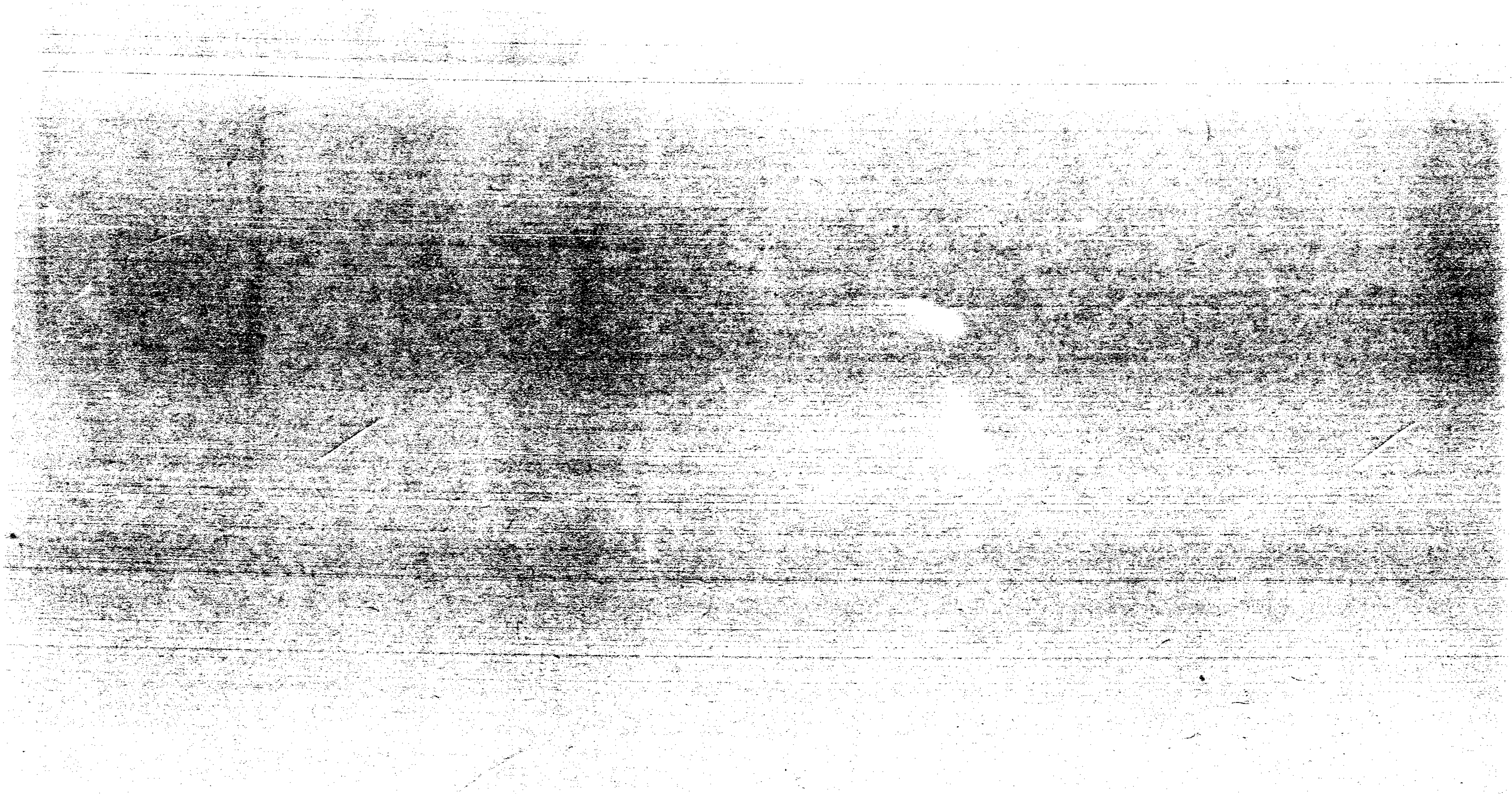
9. Environment Canada, Inland Waters Directorate, Preliminary Surface Water Data for Selected Gauges for 1991.

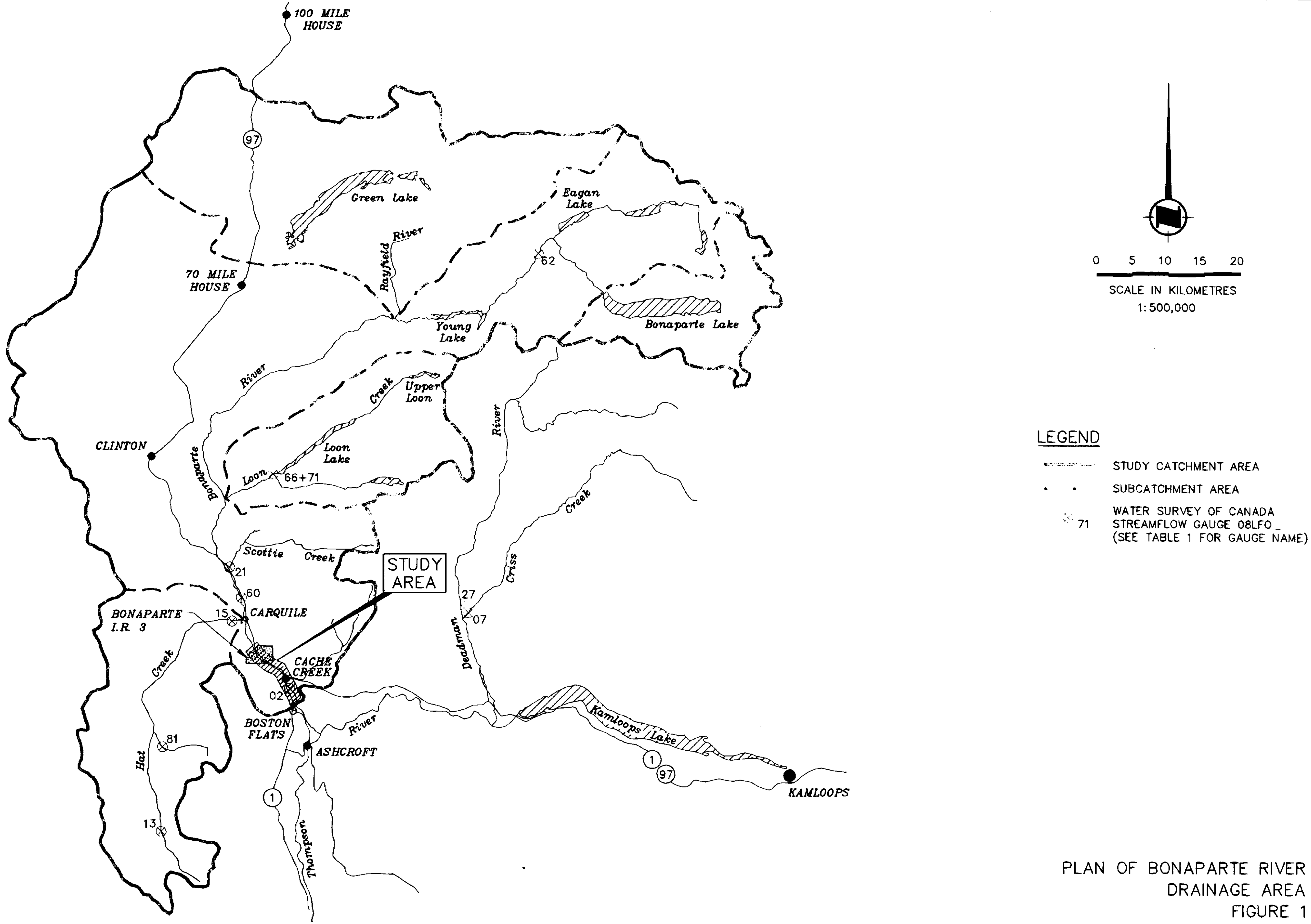
10. U.S. Army Corps of Engineers, The Hydrologic Engineering Center, "HEC-2 Water Surface Profiles Users Manual," Davis, CA, September 1982.

11. Course notes from "Advanced Water Surface Profile Computation Using HEC-2 on the IBM-PC," University of California, Davis, 16-18 November, 1987.

12. Chow, Ven Te, "Open Channel Hydraulics," McGraw-Hill, New York, 1959, pp 101-123.

FIGURES





PLAN OF BONAPARTE RIVER DRAINAGE AREA

FIGURE 1

uma KPA Engineering
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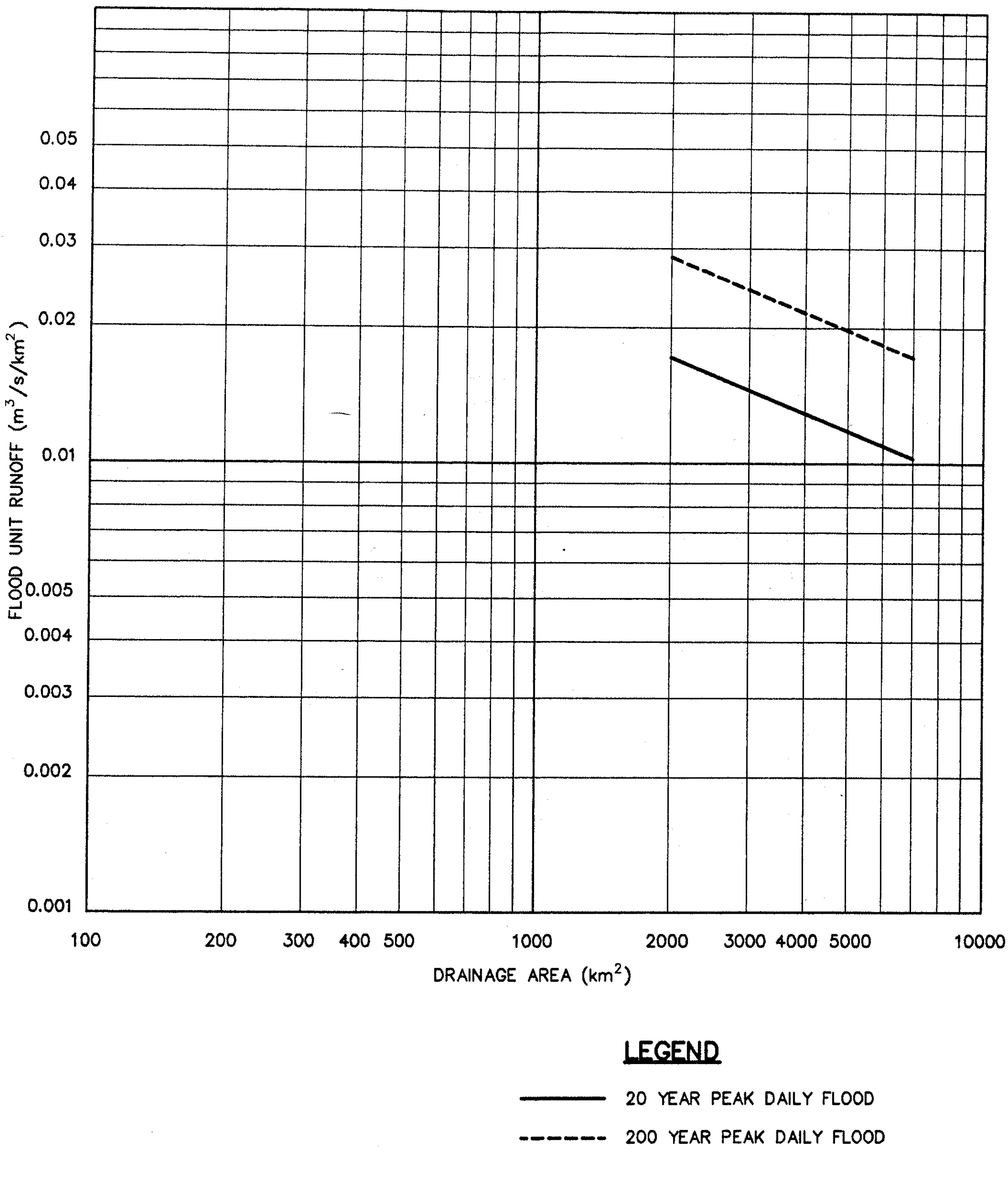
FILE NO.5739 008 00 02 (A3789-09) JANUARY 1986



RELATION OF PEAK UNIT RUNOFF TO DRAINAGE AREA
LOWER BONAPARTE RIVER

FIGURE 2

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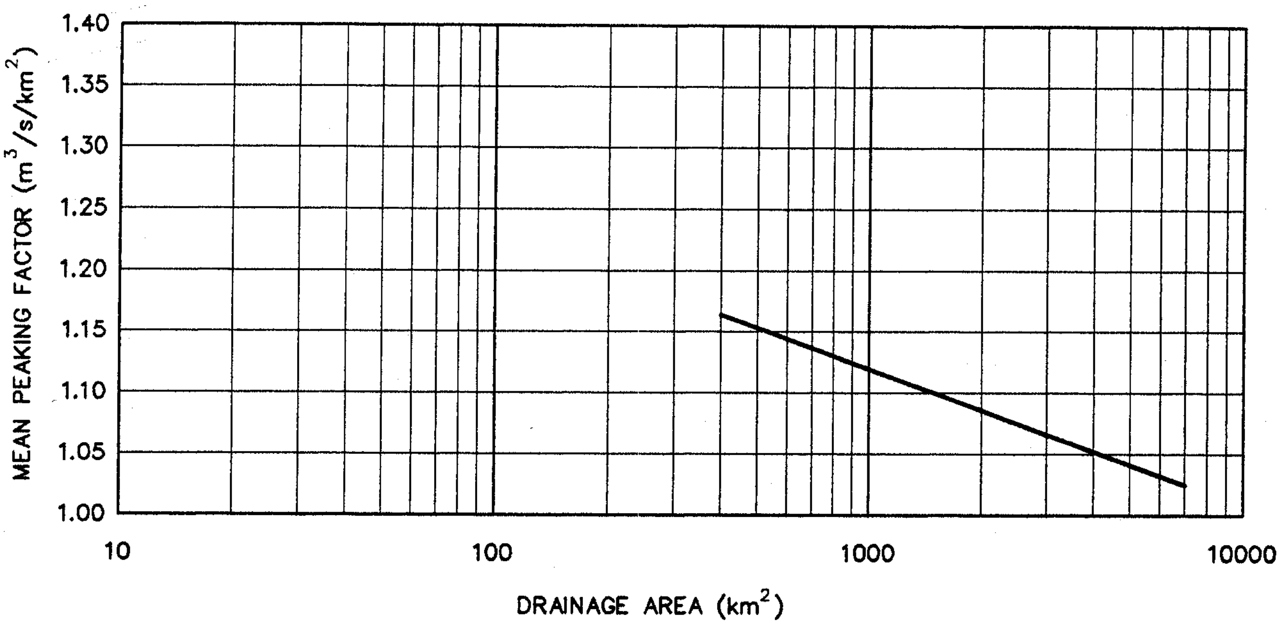
A3789-10 (5739 008 00 02) DECEMBER 1995



A3789-11 (5739 008 00 02) DECEMBER 1995

RELATION OF PEAKING FACTOR TO DRAINAGE AREA
LOWER BONAPARTE RIVER

FIGURE 3

uma KPA Engineering
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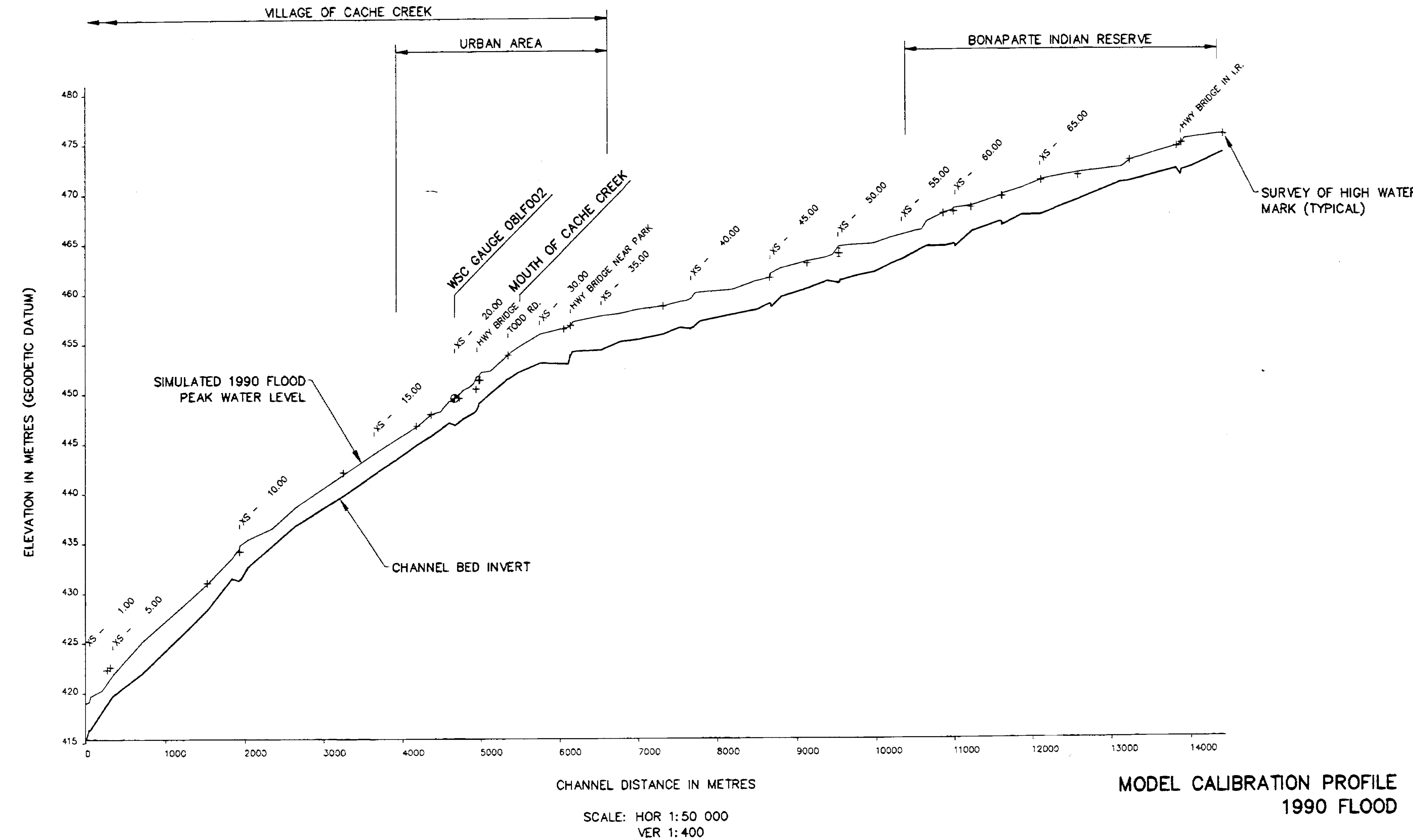

MODEL CALIBRATION PROFILE
1990 FLOOD

FIGURE 4

KPA Engineering
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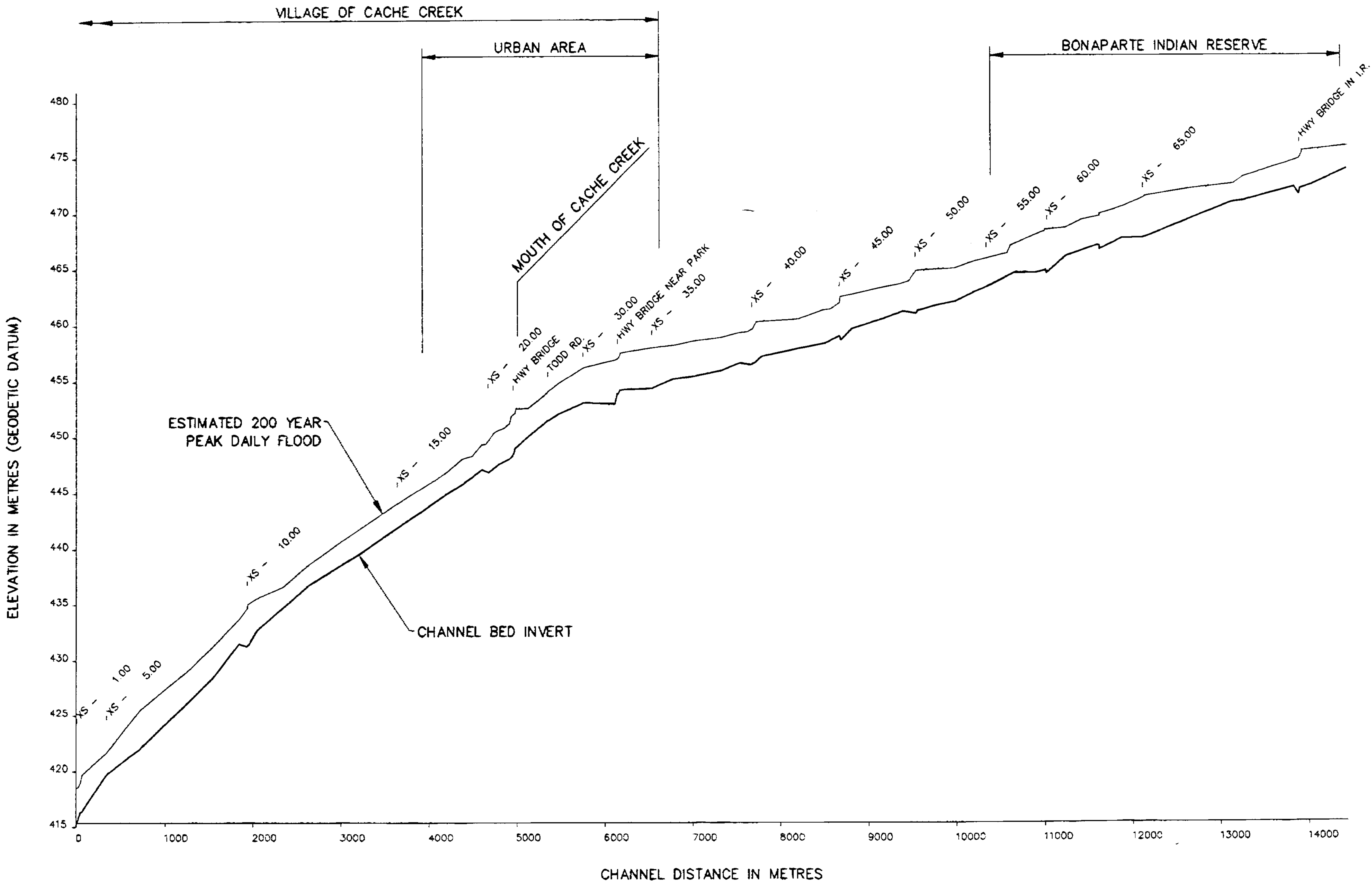
A3789-12 (5739 008 00 02) DECEMBER 1995



SCALE: HOR 1:50 000
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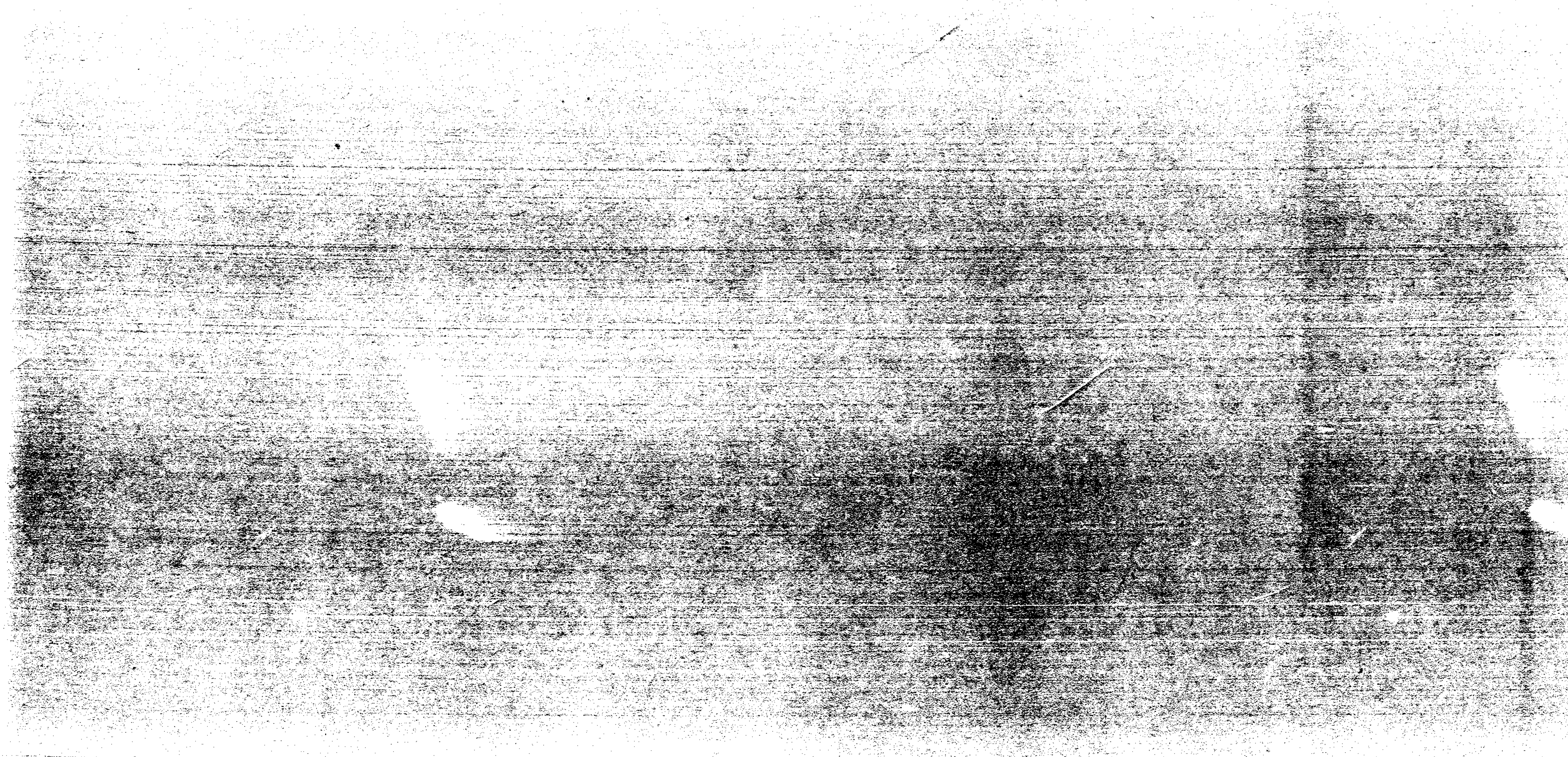
200 YEAR FLOOD PROFILE

FIGURE 5

KPA Engineering
A Division of UMA Engineering Ltd.

A3789-12 (5739 008 00 02) DECEMBER 1995

APPENDICES



Appendix 1

<u>1990 Flood Photos</u>

Photo 1 Park in Cache Creek, near XS-35

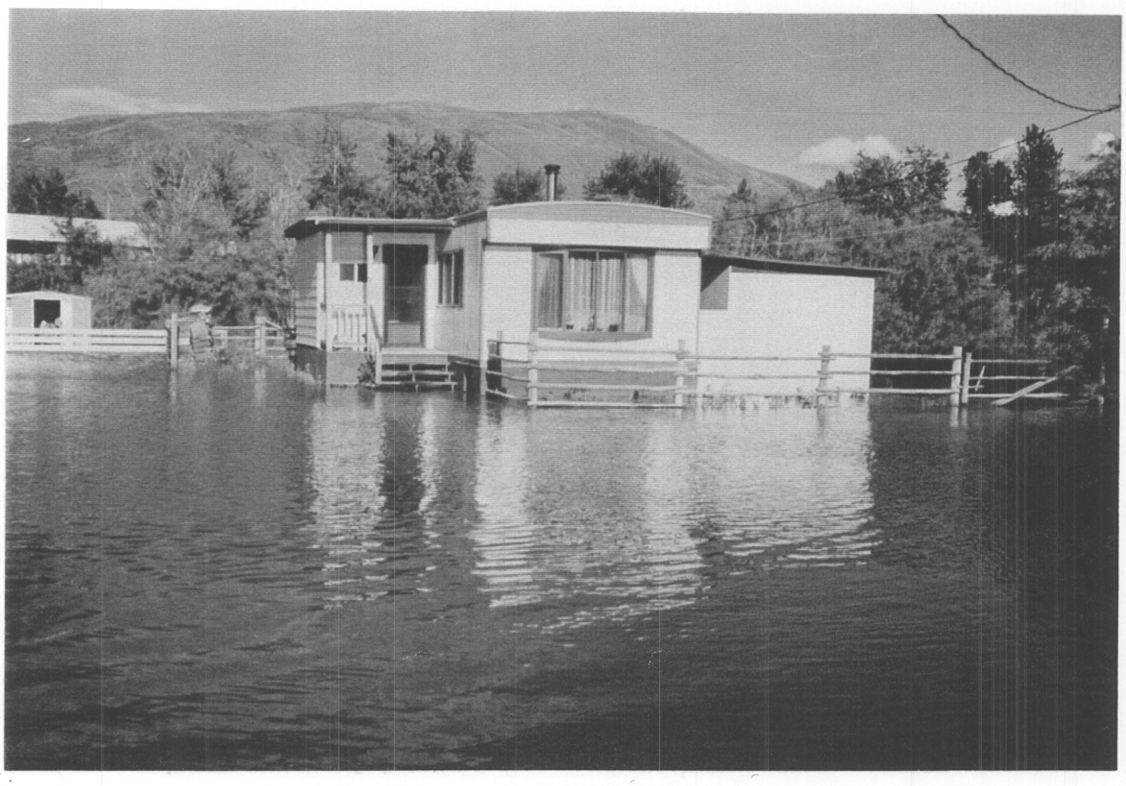


Photo 2 Trailer Park Across the river from the School in Cache Creek

Photo 3 Farm near XS-39 north of Cache Creek

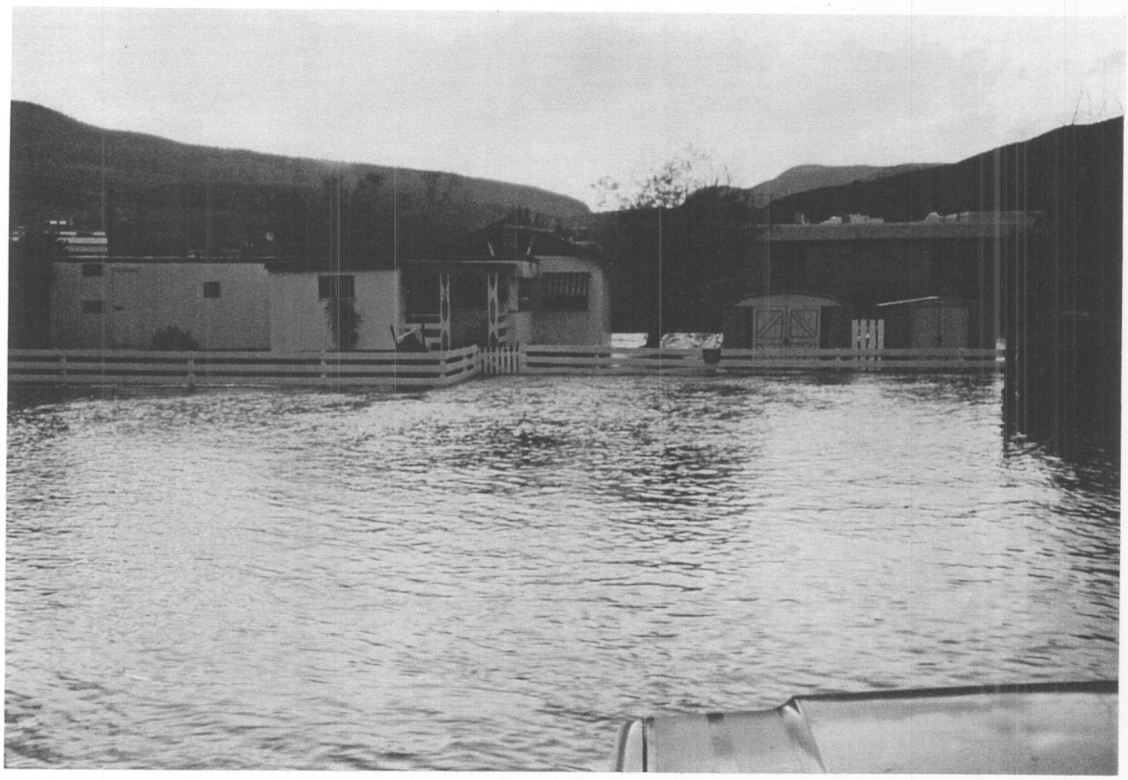


Photo 4 Trailer Park across from school in Cache Creek

Photo 5 Trailer Park behind Wander Inn in Cache Creek

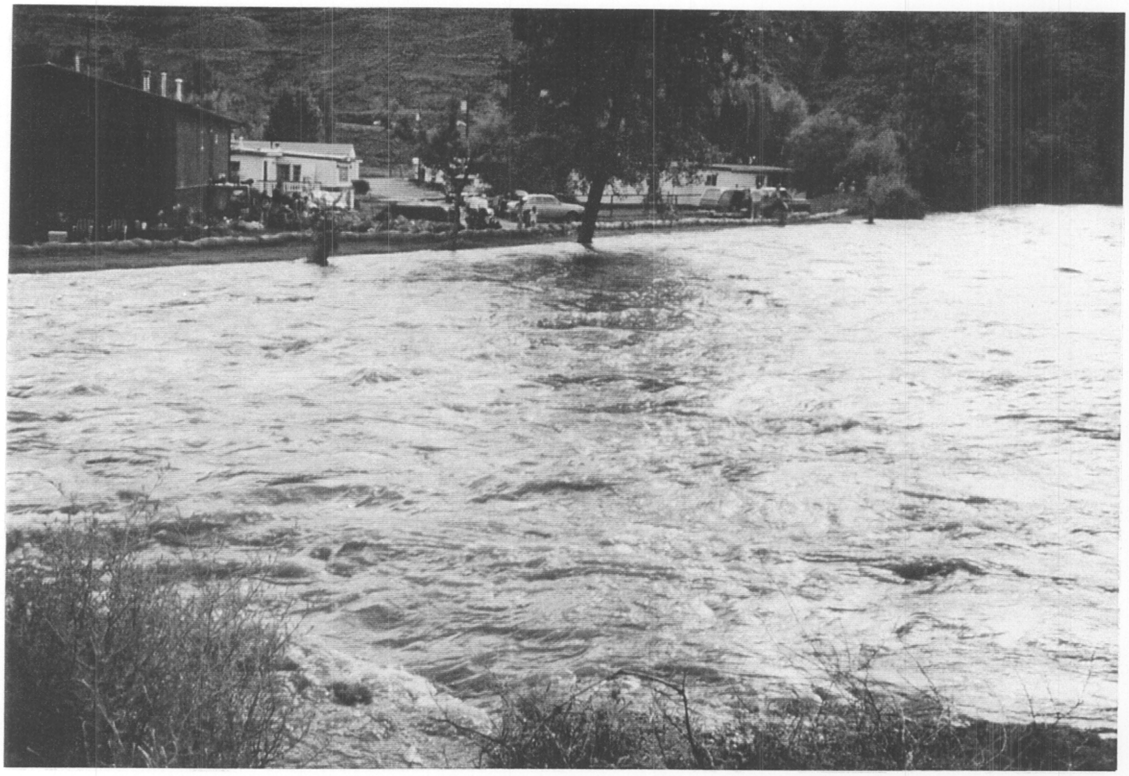


Photo 6 Looking across the Bonaparte River towards the Sage and Sands Trailer Park

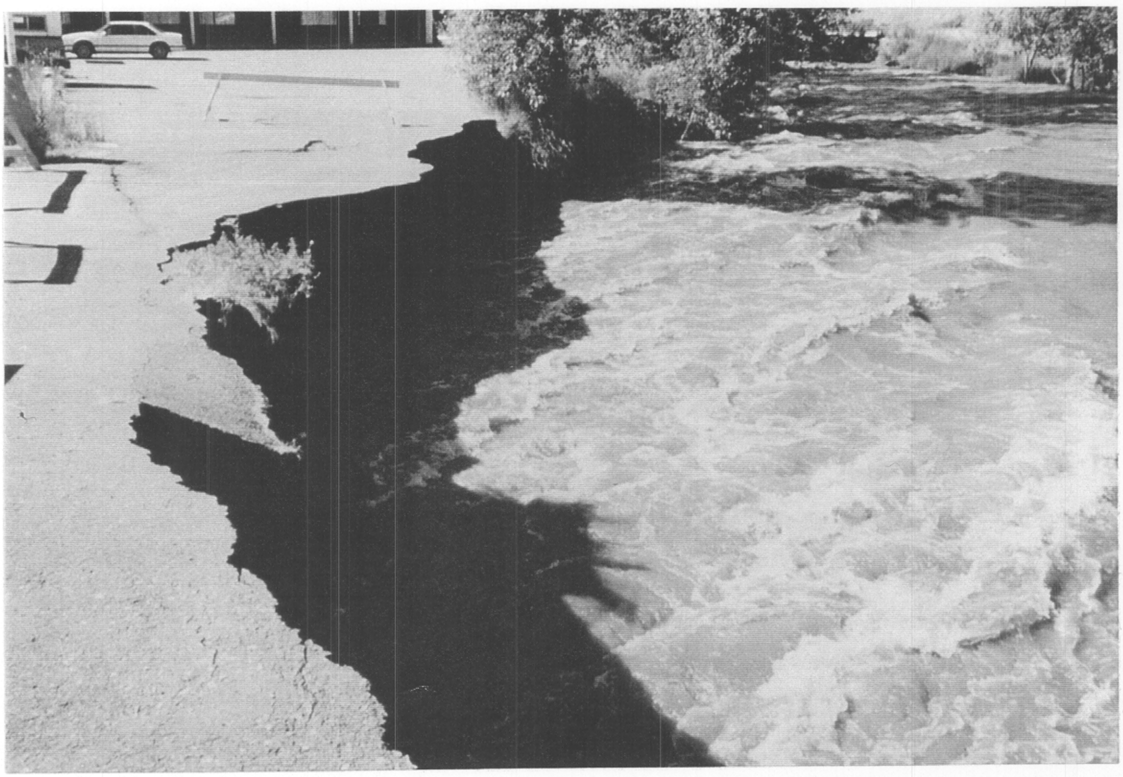


Photo 7 Erosion of the right bank just north of the Highway bridge at the south end of Cache Creek

Appendix 2

Flood Levels Including Freeboard

Cross Section Number	Flood Level (m)	Cross Section Number	Flood Level (m)	Cross Section Number	Flood Level (m)
XS- 1.0	419.10	XS- 27.0	454.55	XS- 50.0	465.37
XS- 2.0	419.51	XS- 28.0	454.67	XS- 51.0	465.37
XS- 3.0	419.60	XS- 29.0	455.39	XS- 51.1	465.49
XS- 4.0	420.28	XS- 30.0	456.78	XS- 52.0	465.52
XS- 5.0	422.34	XS- 31.0	457.46	XS- 53.0	465.59
XS- 6.0	426.13	XS- 32.0	457.52	XS- 54.0	466.15
XS- 7.0	429.84	XS- 33.0	457.67	XS- 55.0	466.41
XS- 8.0	431.78	XS- 34.0	458.05	XS- 56.0	466.87
XS- 9.0	434.27	XS- 35.0	458.54	XS- 57.0	467.76
XS- 10.0	435.35	XS- 36.0	458.73	XS- 58.0	468.54
XS- 11.0	435.65	XS- 37.0	459.10	XS- 59.0	468.94
XS- 12.0	436.14	XS- 38.0	459.43	XS- 60.0	469.05
XS- 13.0	439.21	XS- 39.0	459.85	XS- 61.0	469.16
XS- 14.0	442.57	XS- 40.1	459.92	XS- 62.0	470.21
XS- 15.0	444.64	XS- 40.0	460.16	XS- 63.0	470.43
XS- 16.0	445.95	XS- 41.0	460.17	XS- 64.0	471.05
XS- 17.0	447.32	XS- 42.0	460.84	XS- 65.0	471.92
XS- 18.0	448.60	XS- 43.0	461.05	XS- 66.0	472.00
XS- 19.0	449.93	XS- 44.0	461.90	XS- 67.0	472.63
XS- 20.0	450.27	XS- 45.1	462.41	XS- 68.0	473.10
XS- 21.0	451.14	XS- 45.0	462.47	XS- 69.0	473.74
XS- 22.0	451.81	XS- 46.0	462.47	XS- 70.0	475.29
XS- 23.0	452.50	XS- 46.1	463.04	XS- 71.0	475.47
XS- 24.0	452.69	XS- 47.0	463.25	XS- 72.0	475.68
XS- 25.0	453.13	XS- 48.0	463.85	XS- 73.0	476.09
XS- 26.0	453.11	XS- 49.0	464.22	XS- 74.0	476.48