Province of British Columbia
Ministry of Environment
Water Management Branch

FLOODPLAIN MAPPING PROGRAM

BEAVER CREEK NEAR FRUITVALE

DESIGN BRIEF

File: 2563

February, 1989

Ker, Priestman & Associates Ltd.
Consulting Engineers
300 - 2659 Douglas Street
Victoria, B. C.
V8T 4M3

Province of British Columbia
Ministry of Environment
Water Management Branch

FLOODPLAIN MAPPING PROGRAM
BEAVER CREEK NEAR FRUITVALE

DESIGN BRIEF

Table of Contents

List of Tables

List of Figures

Appendix

FLOODPLAIN MAPPING PROGRAM
BEAVER CREEK NEAR FRUITVALE

DESIGN BRIEF

1.0 INTRODUCTION

This Design Brief and the Floodplain Maps for Beaver Creek near Fruitvale were prepared under contract for the British Columbia Ministry of Environment by the engineering firm of Ker, Priestman & Associates Ltd. The floodplain delineation study, which was conducted from October 1988 to February 1989, covered approximately 21 km of the Beaver Creek Valley in southeastern British Columbia.

The Ministry of Environment, Water Management Branch contact persons in Victoria for this study were P. J. Woods, Head, Special Projects Section and R. W. Nichols, Senior Hydraulic Engineer. Ministry of Environment contact personnel in the Regional Office in Nelson were J. Dyck, Regional Manager, D. Boyer, Head, Engineering Section, and R. Baker, Hydraulic Engineer.

The floodplain delineation study completed by Ker, Priestman & Associates Ltd. contained the following components:

- a hydrology study to determine flood frequency characteristics of Beaver Creek
- development and calibration of a computer model to estimate flood profiles
- determination of flood levels
- transfer of flood levels to mapping.

River surveys were conducted by the Ministry of Environment, and the resulting survey data was provided to Ker, Priestman & Associates Ltd. The Ministry also provided topographic mapping for use as a base for the Floodplain Maps. The contour interval of this base mapping is 2 m, therefore the Floodplain Maps are submitted for adoption as "interim designation" mapping.

The Floodplain Maps for Beaver Creek near Fruitvale, prepared at a scale of 1:5000, appear on five sheets entitled "Floodplain Mapping, Beaver Creek, Beaver Falls to Meadows" (Drawing Numbers 88-35-1 to 88-35-5). These maps are not bound to this Design Brief.

Printed output from computer runs, plotted profiles (KPA Drawing Number 2563-1) and cross sections (KPA Drawing Numbers 2563-2 and 2563-3) and other supporting documentation has been submitted to the Ministry of Environment 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 DESCRIPTION OF THE WATERSHED

Beaver Creek is located in the West Kootenay Region of southeastern British Columbia to the east of the city of Trail (Figures 1 and 2). The stream drains 267 km^2 of mostly forested terrain in the Selkirk Mountains, and empties into the Columbia River 7.5 km north of the International Boundary. Elevations in the catchment range from 412 m at the mouth of Beaver Creek to the peak of Mount Kelly at 1954 m.

The urban and rural land amenable to development, which represents about 2 to 3% of the catchment area (3), is almost entirely located on the valley bottom. The mountain slopes are undisturbed, with the exception of some forestry activities. Approximately 1% of the catchment is logged each year (4, 5).

The Beaver Creek Valley is 24 km long and contains three communities. The largest of these is the Village of Fruitvale, which straddles the Creek approximately 7 km upstream of its mouth. Farther downstream, the settlements of Montrose and Beaver Falls are situated side by side on a terrace high above and to the north of Beaver Creek. The remainder of the valley bottom supports a mix of rural residential and agricultural uses. The only large industrial operations located in the Valley are two sawmills owned by Atco Lumber Ltd. One sawmill lies immediately northeast of Fruitvale and the other is located 7 km up the valley at Park Siding.

Two segments of the Beaver Creek Valley remain undeveloped. One of these is a 4 km segment at the downstream end of the valley through which the Creek flows in a narrow canyon. The creek exhibits a steep slope here and a waterfall, after which the settlement of Beaver Falls was named, occurs at the upstream end of this reach. The second segment, about 2.5 km in length, is located between Ross Spur and Park Siding (Figure 2).

The reach of Beaver Creek for which floodplain maps were prepared extends from a location immediately upstream of Beaver Falls (the waterfall) to a point just below its confluence with Archibald Creek in an area known as Meadows (Figure 2).

Beaver Creek flows through a hanging valley perched above the floor of the Columbia River Valley. In profile, the creek exhibits a unique shape, with two long low-slope reaches located between three steep sections (Figure 3). In these low-slope reaches, the valley bottom is generally wider and flatter with many occurrences of marsh and willow scrub vegetation in uncultivated areas.

Major tributaries of Beaver Creek are, from the upstream end, Archibald Creek, Beavervale Creek, Hudu Creek, Marsh Creek and Kelly Creek. One small water supply dam for the Village of Fruitvale exists on Kelly Creek, and a second system draws water from Fruitvale Creek (6).

A number of large alluvial fans exist in the valley. The largest fans occur at the mouths of some of the smallest tributaries and appear to be very old features formed under much more severe climatic and hydrologic conditions than those which exist now.

Conversely, many of the larger tributaries do not have fans at all. Kelly Creek and Beavervale Creek flow in narrow confined tributary valleys near their mouths, and do not have alluvial fans. Hudu Creek enters the Beaver Valley at a low slope, and also exhibits no fan deposition. Marsh Creek does have a moderately large fan, and Archibald Creek, which falls just outside the upstream study limit, has a very large fan.

At a point approximately 650 m south of the mouth of Marsh Creek, Beaver Creek splits into two main channels which flow separately for more than a kilometre before rejoining. The channels pass under the Burlington Northern Railway at different locations, although the geometry of the two bridge openings are similar.

3.0 DATA SOURCES

The type of hydrologic data most essential for this study was peak discharge information. Flood flows for Beaver Creek and other regional streams in British Columbia were obtained from the Water Survey of Canada (7, 8, 9). Similar data for regional streams in Washington State was provided by the United States Geological Survey (10, 11). A list of the stream gauges which contributed data for the regional study appears in Section 5.0 of this Brief.

A guide written by the B. C. Ministry of Environment (12) which summarized peak flow data for the region was also used to assist in the hydrologic investigations.

Very little high water mark data was found. One source of such information was a record of manual staff gauge readings kept by Bill Casler, the Village of Fruitvale Works Foreman. The staff gauge, located in the Village on the downstream side of the Columbia Gardens Road crossing, was read only when water levels were near a peak. During some years with low peaks, no readings were taken at all. Observations appeared to be more random than continuous, and the data was judged to be useful in an approximate manner only.

River cross section survey data, including bridge measurements, bridge photographs and channel photographs, were provided by the B. C. Ministry of Environment. The cross section data was provided in numerical form, both in print and on electronic media, and as cross section plots.

Some additional bridge measurements were made as a part of this study in October, 1988, as six bridges had been replaced since the cross section surveys by the Ministry were completed in 1982. Elevations of the new bridges were determined by a level survey tied to bench marks established or used in the survey by the Ministry.

Mapping used for this study included the following:

- NTS 1:250,000 scale map sheet 82F
- NTS 1:50,000 scale map sheets 82 F/3, F/4, F/5, and F/6
- B. C. Ministry of Environment, Surveys and Resource Mapping Branch 1:5000 scale topographic map sheets 88-35-1, 2, 3, 4 and 5.

The 1:5000 scale mapping was used as the base for the Floodplain Maps. This mapping, which has a 2-m contour interval, was found to generally coincide with the cross section survey data, with discrepancies between the map contours and cross section survey points seldom exceeding 0.8 m.

The following B. C. Government aerial photography was used for the study:

Year	Flight Number	Photo Numbers
1981	BC 81102	120 to 131 137 to 147 158 to 161 170 to 185
1983	BC 83027 BC 83029	59, 60 21, 22
1987	BC 87063	80, 81

The 1981 photography provided stereo coverage of the entire Valley within the study limits, and was the same photography used to create the base maps. The selected stereo pairs of 1983 and 1987 photography were primarily used to delineate a channel diversion which occurred after the mapping was completed.

4.0 FIELD INVESTIGATIONS

Two field investigations were conducted during the course of the hydrologic and hydraulic studies. The first field visit commenced on 18 October 1988 and spanned four days. It included a thorough site reconnaissance, six bridge surveys, and interviews with local residents. The second visit, on 13 February 1989, was made in order to allow a detailed field check to eliminate any uncertainties identified on the preliminary floodplain mapping.

During the initial visit, the reconnaissance revealed that six bridges along the study reach had been replaced since the 1982 survey. These bridges were at the following locations:

Location	Cross Section No.
Kennedy Road	XS-7
Bluebird Road	XS-9, 10
Footbridge at Beaver Road	XS-15
Columbia Gardens Road	XS-19, 20
Hudu Creek Road	XS-61, 62
Ross Spur Road	XS-71, 72

In addition to the above, an aging bridge formerly located at Cross Section XS-29, was removed since 1982.

The dimensions of all the new bridges were measured, and level surveys were conducted to relate the new bridges to the same datum as the earlier surveys. Channel bed elevations at each new bridge were also surveyed. As a check on the bridge measurements, copies of design drawings for five of the new bridges were obtained from the B. C. Ministry of Transportation and Highways and reviewed.

Five of the new bridges were found to have waterway openings with greater hydraulic capacity than the bridges they replaced. However, the Columbia Gardens Road bridge in Fruitvale was replaced by an arch culvert with a smaller waterway opening and a reduced hydraulic capacity.

During the field investigations it was also discovered that a 200 m long diversion of Beaver Creek had been constructed since the river survey was completed. The diversion was located beside the Atco Lumber sawmill northeast of Fruitvale. The diverted section of the Creek happened to be located between surveyed cross sections, so that none of the cross section survey information became invalid.

Inspection of the new channel showed that its length was essentially the same as the prediversion channel, that the slope was evenly graded from one end of the diversion to the other, and that the new cross section was significantly larger than the original, but that the left overbank area was reduced by new fill. It appeared that the increase in channel capacity would at least offset the reduction in capacity on the left overbank to convey flow. Therefore it was concluded that the diversion would not cause any significant increase in flood levels in comparison with prediversion conditions, and that no additional cross section surveys along the diverted channel were required.

Other channel changes along Beaver Creek were reported by the Ministry of Environment's Regional Water Management staff in Nelson (13). All the changes were judged to be either minor or improvements which may be undone by natural sedimentation or revegetation processes if they are not continually maintained. Therefore the Creek was modelled as though the improvements had not been made.

A number of interviews were conducted by the Project Engineer during the field visit. The people interviewed, the dates of the interviews and the subjects discussed are listed below:

1. Bruce Bourdon, Planning Director for the Regional District of Kootenay Boundary (21 October 1988).

   Subjects discussed:
   - absence of recent high flood flows
   - related studies in RDKB library
   - new bridges along Beaver Creek
   - proposed application of Floodplain Maps

2. Bill Casler, Works Foreman for the Village of Fruitvale (18 October 1988).

   Subjects discussed:
   - high water marks
   - new bridges along Beaver Creek
   - staff gauge data and operation
   - beaver dams

3. Don Secco, 3-year resident between XS-5 and XS-6 (13 February 1989).

   Subjects discussed:
   - MoE survey monument 82HAW001
   - high water marks
   - beaver activity and bank erosion

4. Alec Morrison, 25-year resident on Kennedy Road near XS-6 (19 October 1988).

   Subjects discussed:
   - high water marks
   - beaver activity

5. John MacWilliams, farmer on Marsh Road near XS-38 (19 October 1988).

   Subjects discussed:
   - high water marks
   - beaver activity
   - channel improvements by other farmers

6. Val Shannon, 10-year resident on Champion Lakes Road near XS-56 (21 October 1988).

   Subjects discussed:
   - high water marks

7. Woman, 5-year resident on Hudu Road near XS-60 (21 October 1988).

   Subjects discussed:
   - high water marks

8. Jack Bell, farmer and long time resident near XS-59 (13 February 1989).

   Subjects discussed:
   - high water marks
   - soil types
   - channel improvements

5.0 HYDROLOGIC ANALYSES

5.1 Background

Water Survey of Canada (WSC) published records (7) for a manual streamflow gauge near the mouth of Beaver Creek. The gauge was operated from 1970 to 1978, and a total of nine daily peak flows were recorded during this period. Because this record is relatively short for the estimation of 200 year return period peak flows on the basis of a single station frequency analysis, a regional flood frequency analysis was conducted.

All the recorded Beaver Creek flood flows appear to have been primarily caused by snowmelt. This characteristic was typical for all streams of similar drainage area in the region. The peak flows on Beaver Creek typically occurred in May, but occasionally fell in April or June.

The B. C. Ministry of Environment prepared a Guide for peak flow estimation of ungauged catchments in the Kootenay Region (12) in 1987. It presents the available peak flow data for the region in tables, maps and graphs and provides a methodology for estimating peak flows for ungauged basins using this information.

The Guide locates the Beaver Creek catchment just inside B. C. Hydrologic Zone 8, on the border of Zone 7, and indicates a trend of increasing unit floods from west to east across the areas of interest within these zones.

The streamflow gauges selected for analysis in the Guide did not include the Beaver Creek at the Mouth gauge because its flow data was labelled as "regulated". Although there are water supply structures on Fruitvale and Kelly Creeks, the storage and withdrawal of water is small compared to flood flows and, therefore, would not affect peak flow estimates.

The regional flood study conducted for this floodplain mapping project included the Beaver Creek data. A list of all the streamflow gauging stations analyzed in this study appears as Table 1, and the locations of their catchment areas are shown in Figure 2. All the gauges are within a 50 km radius of the Study Area.

Although the periods of record for Beaver and Kelly Creeks are shorter than those for other stations, the short-term data for Beaver and Kelly Creeks appeared to be quite representative of a longer term. This conclusion is based on split sample homogeneity tests using Salmo River and Big Sheep Creek peak flow data.

The local Water Survey of Canada Technician (14) expressed the opinion that the data for Beaver Creek was as accurate as any station in the region and that the stage-discharge relationship was well controlled. He also expressed confidence in the Kelly Creek data for the station at the 850 m contour.

5.2 Flood Frequency Analysis

Single station flood frequencies were analyzed with the aid of a computer program known as the Consolidated Frequency Analysis Package (CFA) (15), 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.

The CFA program was used to analyze peak daily flow data for all the gauges listed in Table 1. The peak daily flows were analyzed first 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 Wakeby distribution, however, tended to be more extreme and frequently produced the highest predicted flood value. 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.

5.3 Comparison of Regional Results

The unit runoff values corresponding to the selected daily floods of 2, 20 and 200-year return period were plotted against drainage area for all the regional streams. Using these points as guides, curves were drawn for the purpose of estimating floods for several locations along Beaver Creek.

Salmo River, Boundary Creek and Hidden Creek showed the highest unit peak flows while Beaver, Blueberry, Deer and Anderson Creeks had the lowest unit peak flows. The relative magnitudes of the mean annual floods for the various stations are generally as expected despite the fact that unit flows at Beaver Creek are considerably lower than at the nearby Big Sheep Creek and Salmo River stations. Therefore, the curves on the regional plot were drawn to pass below the data points for both Big Sheep Creek and Salmo River but above the calculated values for Beaver Creek and Kelly Creek due to uncertainty associated with their shorter periods of record.

Table 1

Regional Streamflow Stations

Station Number	Name	Period of Record For Peak Flows	Type of Gauge	Years of Record For Peak Flow Daily (Inst.)	Type of Flow	Drainage Area km^2
08NE106	Beaver Creek at Mouth	1970 - 78	Manual	9 (0)	Regulated	267.
08NE113	Kelly Creek at 850 m Contour	1971 - 82	Manual	12 (0)	Natural	23.1
08NE071	Kelly Creek near Fruitvale	1947 - 51	Manual	5 (0)	Regulated	31.3
08NE073	Blueberry Creek near Blueberry Creek	1948 - 69	Manual	14 (0)	Natural	145.
08NE074	Salmo River near Salmo	1949 - 87	Recording	39 (38)	Natural	1230.
08NE114	Hidden Creek near the Mouth	1973 - 88	Recording	16 (15)	Natural	75.4
08NE039	Big Sheep Creek near Rossland	1949 - 88	Recording	39 (37)	Natural	347
08NJ130	Anderson Creek near Nelson	1945 - 87	Recording	27 (8)	Natural	9.07
08NJ112	Goose Creek near Crescent Valley	1971 - 81	Manual	11 (0)	Natural	83.7
08NE087	Deer Creek at Deer Park	1959 - 87	Manual	29 (0)	Natural	80.5
08NH032	Boundary Creek near Porthill	1928 - 88	Recording	61 (27)	Natural	251
12396900	Sullivan Creek above Outlet Creek near Metaline Falls, WA	1960 - 72	Recording	13 (17)	Natural	182

The slope of the curves was drawn parallel to the flood envelope curves for the Interior Plateau and Interior Mountains published by Water Survey of Canada. The curves for daily peak unit runoff appear in Figure 4, together with curves for instantaneous unit flood peaks, which are discussed below.

5.4 Design Floods

Daily floods were derived from Figure 4 for use in the hydraulic modelling portion of this study to satisfy one set of criteria. Instantaneous peak flows were also required to meet a second set of criteria for delineating the floodplain.

Using only concurrent data for the six regional stations which were equipped with recording gauges, the CFA program was used to determine the flood frequency relationships of the instantaneous peak data and, where necessary, of the daily peaks for any gauge where the period of record was modified to ensure concurrency. From the results of these analyses, the ratios of peak instantaneous to peak daily flows were calculated for 2, 20 and 200-year return periods. These peaking ratios were plotted against drainage area, and a curve for each return period was fit to the points.

Using the daily peak unit flood curves as shown in Figure 4, and the peaking factors from the analysis described above, the instantaneous peak unit runoff curves for the Beaver Creek drainage area were developed. These curves also appear in Figure 4.

Beaver Creek has a drainage area of 267 km^2 at the mouth. However, the drainage area for the portion of the creek within the limits of the floodplain mapping project ranges from 34.6 to 249 km^2. Cumulative catchment areas along the study reach were measured for locations immediately upstream of all tributaries larger than 6 km^2.

Using the curves shown in Figure 4, flood discharges at these locations were determined for use in the hydraulic modelling. These design floods are listed in Table 2.

Table 2 - Design Flows

Location Upstream of:	Cumulative Drainage Area km^2	Estimated Peak Flows - m^3/s Instantaneous 2-Yr.	Instantaneous 20-Yr.	Instantaneous 200-Yr.	Daily 20-Yr.	Daily 200-Yr.
Archibald Creek	34.6	8.8	17	28	11	15
Benton Creek	40.4	9.9	19	31	13	17
Query Creek	50.3	12	22	35	15	20
Beavervale Creek	63.7	14	26	41	18	24
Bell Creek	104	19	36	55	26	34
Hudu Creek	111	20	38	58	27	36
Marsh Creek	144	24	45	68	33	44
Unnamed Creek	175	27	51	75	39	50
Fruitvale Creek	194	29	54	81	42	55
Kelly Creek	202	30	57	83	44	56
Beaver Falls	249	35	65	95	51	66

6.0 HYDRAULIC ANALYSES

6.1 Model Development

The computer program known as HEC-2 was used to simulate 20-year and 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 curves for steady state flow conditions based on the Standard Step Method (16, 17).

The most recent (1986) version of the HEC-2 program for microcomputers using MS-DOS was obtained from the Corps of Engineers and used for this study. The computers which executed the program were all IBM-compatible machines, each equipped with either an Intel 80286 or 80386 microprocessor.

The HEC-2 model was prepared for the Beaver Creek study reach in the following manner:

1. The cross section data from the Beaver Creek survey was provided in HEC-2 input format (GR data) by the B. C. Ministry of Environment.

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

3. Bridges were coded for analysis by the HEC-2 program. In a few cases additional cross sections were inserted to achieve the recommended cross section spacing upstream and downstream from the bridge.

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

5. Manning's "n" values for the Creek channel were estimated using photographic and tabular guides by Chow (18), taking into consideration roughness height (approximated by using bed material sizes), vegetation, debris, sinuosity and cross section uniformity.

   Roughness coefficients used for the simulation ranged from .035 to .045. Most of the length of the Creek was assigned a value of .040 or greater. The steeper reaches contained larger bed material and, therefore, were rougher than the low-slope reaches were. However in the steep sections, the channel was generally free of vegetation, but the channel along each low-slope reach was typically more sinuous and vegetated with overhanging willows along much of its length. As a result of all these factors, the Manning's "n" values selected for both types of channel fell in the same range.

   Manning's "n" values for the overbank areas were estimated primarily on the basis of vegetation type. The values used ranged from .080 to .150.

6. Hydraulic loss coefficients for expansion, contraction, pier shape, orifice flow and weir flow at bridges were selected in accordance with the recommendations outlined in the HEC-2 User's Manual (16) with modifications as deemed necessary to reflect special or unusual conditions.

7. The input data set was completed by the addition of flood peak data and necessary job control parameters. The starting water level was determined by the program for each run, using an estimated water surface slope of .017 for the downstream end of the study reach. This value was the water surface slope measured during the channel surveys between the two lowest cross sections (XS-1 and XS-2).

The approach used to model the major channel bifurcation which occurs downstream of Marsh Creek required developing two HEC-2 cross section data sets, one containing the West Channel data, and the other with the East Channel data. In this manner, the model would simulate the events that each channel becomes completely plugged, and diverts all the flow to the other channel. The higher of the two water levels for each section on each side of the railway grade would be used for determining the designated flood levels, since the railway could act as a flow barrier.

This approach was used instead of the split flow option contained within the HEC-2 program, for the following reasons:

- the area is well vegetated, and blockage of either channel is not unlikely in a large flood because both channels pass under the railway grade by way of bridges with several closely-spaced river piers.
- it is unlikely that channel geometry or hydraulic conditions at the bifurcation point would remain unchanged in the future
- no survey data was available for the bifurcation point

The possibility of both bridges becoming plugged with debris was also considered. If this would happen, then water levels would rise to the elevation of the railway grade on the upstream side before overtopping the grade.

6.2 Model Calibration

After development of the HEC-2 model of Beaver Creek to the stage where simulations could be performed without causing any error messages or obviously unreasonable results, the modelling entered the calibration phase. However, because of the scarcity of concurrent stage and discharge data, only limited calibration was possible.

The first attempt at calibration involved simulation of a 2-year return period profile and comparison of computed water levels to the top-of-bank elevations. In a mobile boundary channel, the recurrence interval of bankfull discharge is usually between 1 and 2 years (19). Along most of the length of the study reach, Beaver Creek has a mobile boundary channel. Using the initial estimates for roughness and loss coefficient values, a simulation of a 2-year instantaneous peak flood resulted in a flood profile that exceeded top-of-bank elevations throughout the low slope reaches of Beaver Creek by an average 0.3 m, but fell below the top-of-bank elevations in the steep reaches by an average of 0.2 m.

During the interviews, Bill Casler and two other residents reported frequent apparent flooding in some of the areas where Beaver Creek has a low slope, but less frequent overbank flows along the reaches where it is steep. Given the approximate nature of this calibration, the results obtained by the initial run were considered a general confirmation that the Manning's "n" estimates were approximately correct.

An attempt was made to pinpoint the calibration at one location by using the only available stage records in the study reach measured during the period when the WSC streamflow gauge at the mouth of Beaver Creek was operating. Maximum observed water levels were recorded from 1973 through 1986 at the staff gauge near the Columbia Gardens Road crossing (XS-19). The streamflow data spanned the period 1970 to 1978. The concurrent period of both these sets of data was 1973 to 1977 inclusive. (WSC flow data was missing on 16 May 1978, the date that the high flow was read at the Fruitvale gauge.)

WSC daily flow data for Beaver Creek at the mouth was plotted against the Fruitvale gauge readings. The resulting plot showed considerable scatter, indicating that the relationship between the two was not reliable. The maximum stage variation in the plot for a given flow was approximately 0.3 m. It became apparent, therefore, that an exact calibration was not possible with this data, and that an approximate calibration was all that could be achieved.

The highest peak in the 1973-77 period occurred in 1975. The Fruitvale gauge recorded the peak on 16 May 1975, but the WSC records show the peak occurring on 15 May 1975. The flow for the calibration was estimated by prorating the 16 May flow at the mouth of Beaver Creek on a drainage area basis. The simulation was performed and the results showed a simulated water level .05 m lower than the measured water level.

The procedure was repeated for the 1976 and 1977 peaks, using the same roughness and loss coefficients. The simulated 1976 water level was .03 m higher than the measured level, and the simulated 1977 level was .16 m lower than the measured level. The Manning's "n" values were increased by 10% and all three simulations were repeated. This resulted in a good match for the 1975 peak, but differences of +.09 and -.13 m for the 1976 and 1977 runs respectively.

Another approximate calibration was attempted at cross section XS-16, where Bill Casler reported that only once in 20 years had he seen water as high as the edge of the pavement at the end of Laurier Avenue. The survey had picked up the elevation of this point as 598.31 m. The simulated 20-year flood profile calculated a 20 year peak instantaneous water level of 598.38, or .07 m higher.

The calibrations indicated that the model was achieving at least approximate agreement with reality. Therefore the hydraulic roughness and loss coefficients used in the calibration runs were adopted for the sensitivity analyses which followed.

6.3 Sensitivity Analyses

One method of estimating the impact of modelling inaccuracies on the final results is a sensitivity analysis. In floodplain delineation these analyses can be used as a guide in parameter selection, and to estimate the appropriate magnitude for freeboard requirements. In this study, the sensitivity tests were used to check whether the standard freeboard requirements suggested by the B. C. Ministry of Environment matched modelling uncertainties in the Beaver Creek study.

The sensitivity analyses concentrated on two major parameters, flow and channel roughness. Starting with a datafile for the 200-year peak instantaneous flow containing the calibrated parameters (referred to here as the base simulation) each parameter was varied over a range of values. The flow was increased in three simulations from the initial values listed in Table 2 by factors of 10%, 20% and 30%. In three additional model runs, the Manning's "n" values were increased by factors of 5%, 10% and 20% from the values used in the base simulation.

The result of these sensitivity analyses are summarized in Table 3 below:

Table 3

Summary of Sensitivity Test Results

Range of flow Values (m^3/s)	% Increase	Typical Water Level Increases from Base Simulation (m) XS-3	XS-30	XS-68	XS-76
31 - 95(base)	0%	0	0	0	0
34 - 105	10%	.03	.11	.09	.07
37 - 114	20	.08	.23	.17	.13
40 - 124	30%	.12	.33	.25	.20
Range of Manning's "n" Values (channel only)					
.035 - .045(base)	0%	0	0	0	0
.037 - .047	5%	.03	.04	.02	.03
.039 - .050	10%	.06	.08	.04	.06
.042 - .054	20%	.11	.17	.08	.12

In general the results indicate that the water levels are not highly sensitive to changes in flow or roughness, and that if the estimated flow or roughness is within 20% of the "correct" value, the water level change would be less than 0.2 m for most locations along Beaver Creek.

A review of the detailed printed output from the sensitivity runs showed that water levels of the low-slope reaches were more sensitive to changes in both roughness and flow than in the steep reaches. A greater sensitivity to changes in flow was noted at locations upstream of most bridges, especially those with the more constrictive waterway openings.

A 20% increase in Manning's "n" values would represent very high estimates for Beaver Creek channel and overbank roughnesses. Similarly, a 30% increase in the 200-year flood peak values would represent a major departure from the flood frequency relationships developed for the Beaver Creek, especially considering the conservative assumptions used in deriving the 200-year flows.

The criteria suggested by the Ministry for freeboard were as follows:

- for 200-year peak instantaneous flows: 0.3 m
- for 200-year daily peak flows: 0.6 m

The magnitude of the water level changes indicated by the sensitivity analyses was generally less than the instantaneous peak freeboard criterion, if the flow and roughness increases were considered separately. This was judged to provide reasonable comfort that the designated flood levels based on the profiles would provide a "safe" delineation of the floodplain, without unreasonably limiting future development in the Beaver Creek Valley.

6.4 Flood Levels

Using the HEC-2 program, flood profiles were generated for 20 and 200-year peak instantaneous flows, and for 20 and 200-year mean daily peak flows. The water levels calculated for the 200-year peak instantaneous flows were adopted as the Designated Flood Levels.

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. At each cross section, the highest 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 1.

The same procedure was then repeated for the 20-year flood data, so that the 20-year flood values, including freeboard, could be shown numerically on the Floodplain Mapping.

The Flood Levels (including freeboard) were used to delineate the floodplain by transferring these levels to the 1:5000 scale topographic mapping. This was done by first identifying the location in plan where the Flood Level would meet the ground elevation at each cross section. In the event of a discrepancy between the surveyed cross section and the contours, the survey information was taken to be more accurate. The contours were used to identify the floodplain limits between the cross sections.

Isograms for the 200-year Flood Levels (including freeboard) 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 OTHER HAZARDS RELATED TO FLOODING

Throughout most of the length of its study reach, Beaver Creek flows in a relatively stable channel, with very few signs of recent erosion or deposition which would indicate lateral instability of the channel. Judging by the streamside vegetation, meanders appear to be very slow moving in most locations.

One exception occurs at the upstream end of the study reach, where Archibald Creek enters the Beaver Valley. At their confluence, the catchment area of Archibald Creek is 8.4 times larger than the catchment of Beaver Creek. Therefore, almost all the upper Beaver Creek flow is contributed by Archibald Creek. The Archibald Creek fan has spread across and down the Beaver Creek Valley. At the upstream limit of the study, Beaver Creek flows on the lower portion of this fan. Signs of high velocity flow and lateral instability exist, and rudimentary channel training works consisting of berms formed from channel substrate material lined both banks of the Creek on the steeper part of the fan down to Cross Section XS-84.

Archibald Creek crosses under Highway 3 in two culverts, a 2 m diameter circular pipe and a 1.6 by 2.4 m pipe arch. Because of the obvious potential for the two culverts to become plugged with debris or bed material during a flood and cause an avulsion, most of the fan area below the road is prone to flooding in such an event. Also, in the long term, deposition on the fan is causing gradual aggradation and, therefore, lateral instability of the Archibald Creek channel. For these reasons, the portion of the Archibald Creek fan within the limits of the study have been designated as floodplain due to a special flood hazard.

Almost all the area residents mentioned a very prolific beaver population along the Creek, and identified beaver dams as a cause of flooding. One resident related local bank scour problems caused by large trees felled into the channel by beavers. Residents, farmers and

Village maintenance staff reported frequent removal of the beaver dams. Because the dams are nonpermanent features of the Creek, their presence could not be modelled in any meaningful way. During a large flood, there is a strong likelihood that the high velocities concentrated at a beaver dam site would either remove the dams or cause bank scour and eventual outflanking of the dams, rather than cause a large increase in flood levels over those which would occur with no dam present. No additional freeboard allowance was provided to account for the presence of beaver dams.

The two railway bridges over Beaver Creek downstream of the bifurcation below Marsh Creek (discussed in Section 6.1 of this Design Brief) may be prone to at least partial plugging with debris during a large flood. The likelihood of both bridges becoming totally plugged is remote, but partial plugging would result in elevated flood levels on the upstream side of the railway grade. To accommodate higher than modelled water levels in this area, an elevation of 610.3 m (top of the railway grade) was adopted as the Flood Level (including freeboard) for the area immediately upstream of the railway bridge over the west channel of Beaver Creek.

8.0 RECOMMENDATIONS

On the basis of the work performed and the findings of this study, we recommend the following:

1. That the floodplain mapping prepared for Beaver Creek from Beaver Falls to Meadows as a part of this study be adopted as interim designation Floodplain Maps under the joint Federal/ Provincial Floodplain Mapping Agreement.

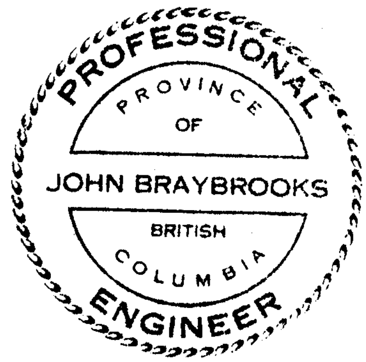
2. That a more formal method of monitoring flood peak water levels, such as the establishment of crest gauges, be instituted in order to provide accurate measurements of future peak water levels. The locations where such information would be of most value, considering the potential for future flood damages, would be at the following sites in the Village of Fruitvale:

   - near Cross Section XS-14
   - between Cross Sections XS-15 and XS-16
   - just upstream of the Columbia Gardens Road crossing of Beaver Creek (near XS-21).

3. That the feasibility of reactivating the Water Survey of Canada streamflow gauge, Beaver Creek at the Mouth (No. 08NE106), be investigated, to provide a larger database for flood frequency estimates and to augment the value of any peak water level information collected as a result of Recommendation 2. Without concurrent peak flow and water level data, future refinement of the model is not possible.

4. That the Floodplain Maps be reviewed and, if deemed necessary, updated at any time that new flood discharges, water levels or other flood hazard information becomes available which indicates a significant departure from the data used or the results produced by this study.

This Design Brief for the Floodplain Mapping Program for Beaver Creek near Fruitvale is respectfully submitted by:



KER, PRIESTMAN & ASSOCIATES LTD.

J. Braybrooks, P. Eng.
Review Principal

Y. Shumuk, P. Eng.
Project Engineer

REFERENCES

1. British Columbia Ministry of Environment, Water Management Branch, "Floodplain Mapping Program, Specifications for Engineering Studies", Attachment A, Invitation for Proposal for Engineering Services, Victoria, 20 July 1988.

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

3. Personal communication with Bruce Bourdon, Planning Director, Regional District of Kootenay Boundary, Trail, B. C. 25 November 1988.

4. Personal communication with N. Fipke, Ministry of Forests and Lands, Arrow District, Castlegar, B. C. November 21, 1988.

5. Personal communication with N. Weldon, Kelly Creek Timber Company, Salmo, B. C. November 23, 1988.

6. Piteau Associates, "Predrilling Hydrogeological Assessment for Fruitvale Waterworks Improvement Program", report to the Regional District of Kootenay Boundary, Vancouver, May 1986.

7. Environment Canada, Inland Waters Directorate, "Historical Streamflow Summary, British Columbia, to 1986", Ottawa, 1988.

8. Environment Canada, Inland Waters Directorate, "Surface Water Data, British Columbia, 1987", Ottawa, 1988.

9. Environment Canada, Inland Waters Directorate, Preliminary Discharges for 1988 for: Hidden Creek near the Mouth, Big Sheep Creek near Rossland, and Boundary Creek near Porthill, Vancouver, November 1988.

10. United States Geological Survey, "Water Resources Data, Washington, Water Year 1986", Water Data Report WA-86-1, 1987.

11. United States Geological Survey, "Streamflow Statistics and Drainage Basin Characteristics for the Southwestern and Eastern Regions, Washington, Volume II. Eastern Washington", Open-File Report 84-145-B, Tacoma, 1985.

12. Ministry of Environment and Parks, Water Management Branch, Hydrology Section, "Guide to Peak Flow Estimation for Ungauged Watersheds in the Kootenay Region", by D. E. Reksten, Victoria, January 1987.

13. Personal communications with John Dyck, Dwain Boyer, and Ric Baker, Ministry of Environment, Water Management Branch, Nelson, B. C., 24 October and 2 November, 1988.

14. Personal communication with Brent Tipple, Technician, Water Survey of Canada, Nelson, B. C., 18 November 1988.

15. Environment Canada, Inland Waters Directorate, Water Resources Branch, Consolidated Frequency Analysis Package, CFA, User Manual for Version 1-DEC PRO Series by P. J. Pilon, R. Condie, K. D. Harvey, Ottawa, July 1985.

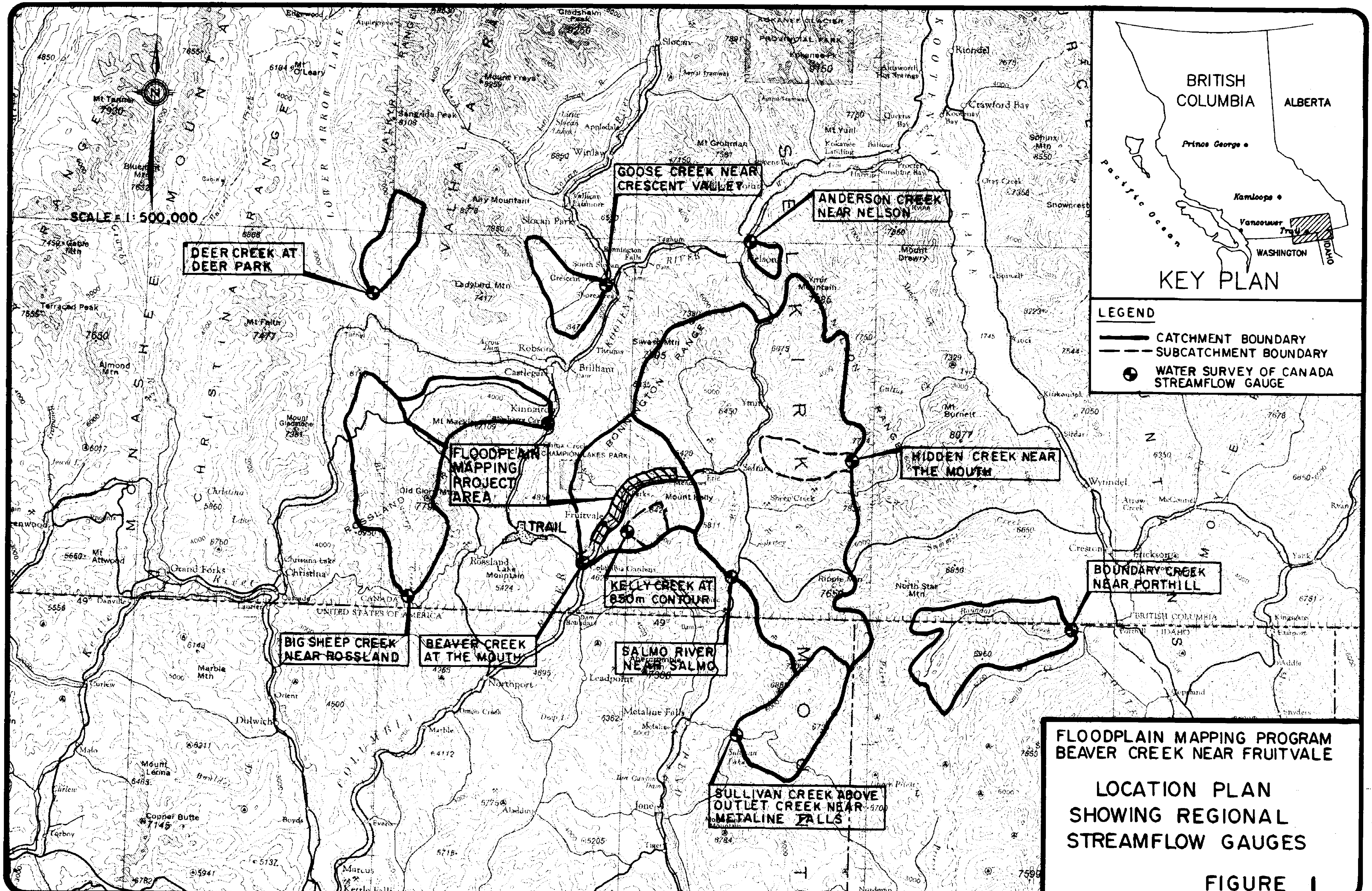
16. U. S. Army Corps of Engineers, The Hydrologic Engineering Center, "HEC-2 Water Surface Profiles Users Manual", Davis, CA, September 1982.

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

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

19. Leopold, L. B., Wolman, M. G., Miller, J. P., "Fluvial Processes in Geomorphology", W. H. Freeman and Co., San Francisco, 1964, pp. 319-322.

FIGURES



FLOODPLAIN MAPPING PROGRAM
BEAVER CREEK NEAR FRUITVALE

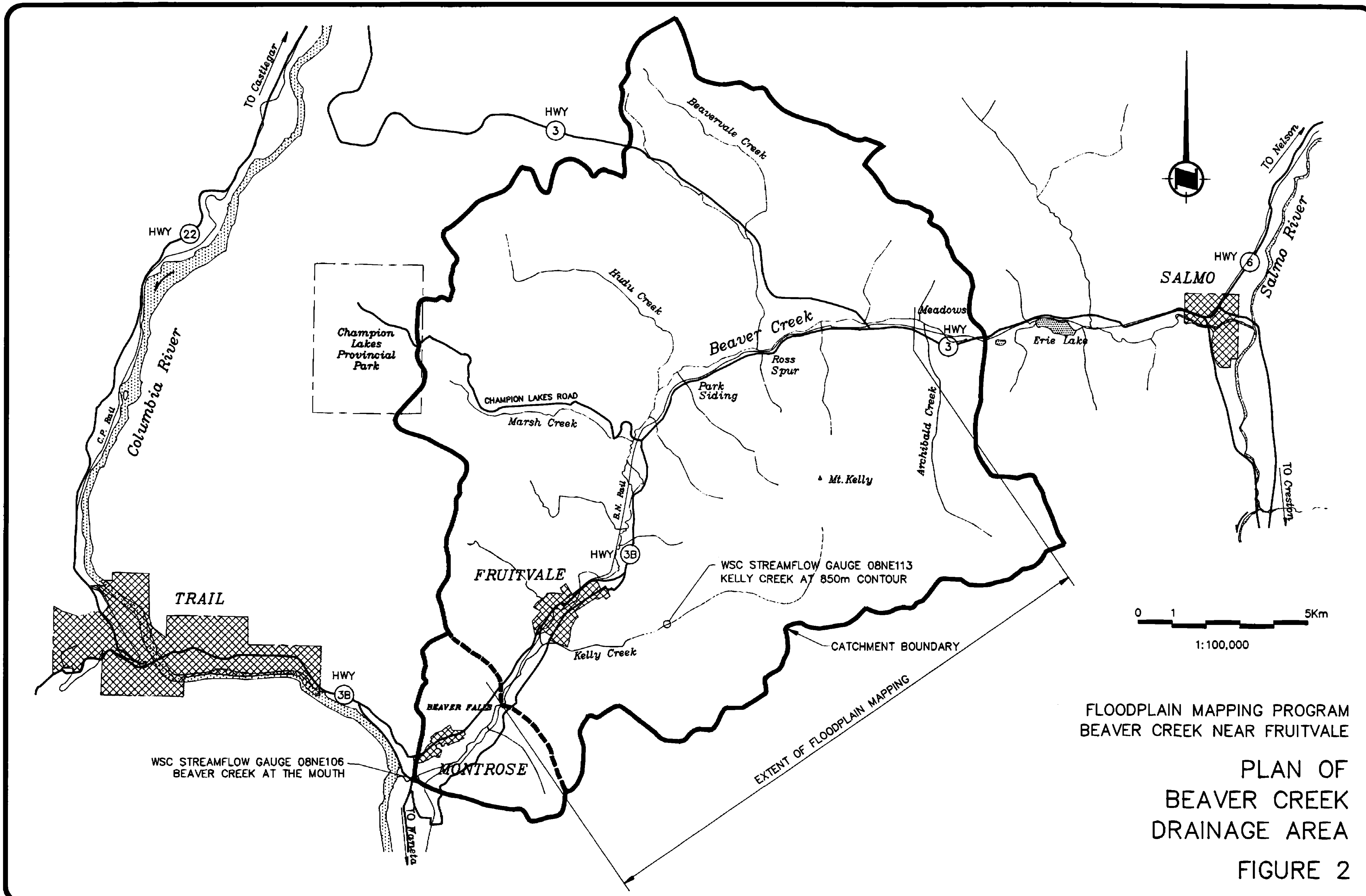
LOCATION PLAN SHOWING REGIONAL STREAMFLOW GAUGES

FIGURE 1

KER, PRIESTMAN & ASSOCIATES LTD

FILE NO. 2563 DATE FEB. 1983

NCI-411 KPA



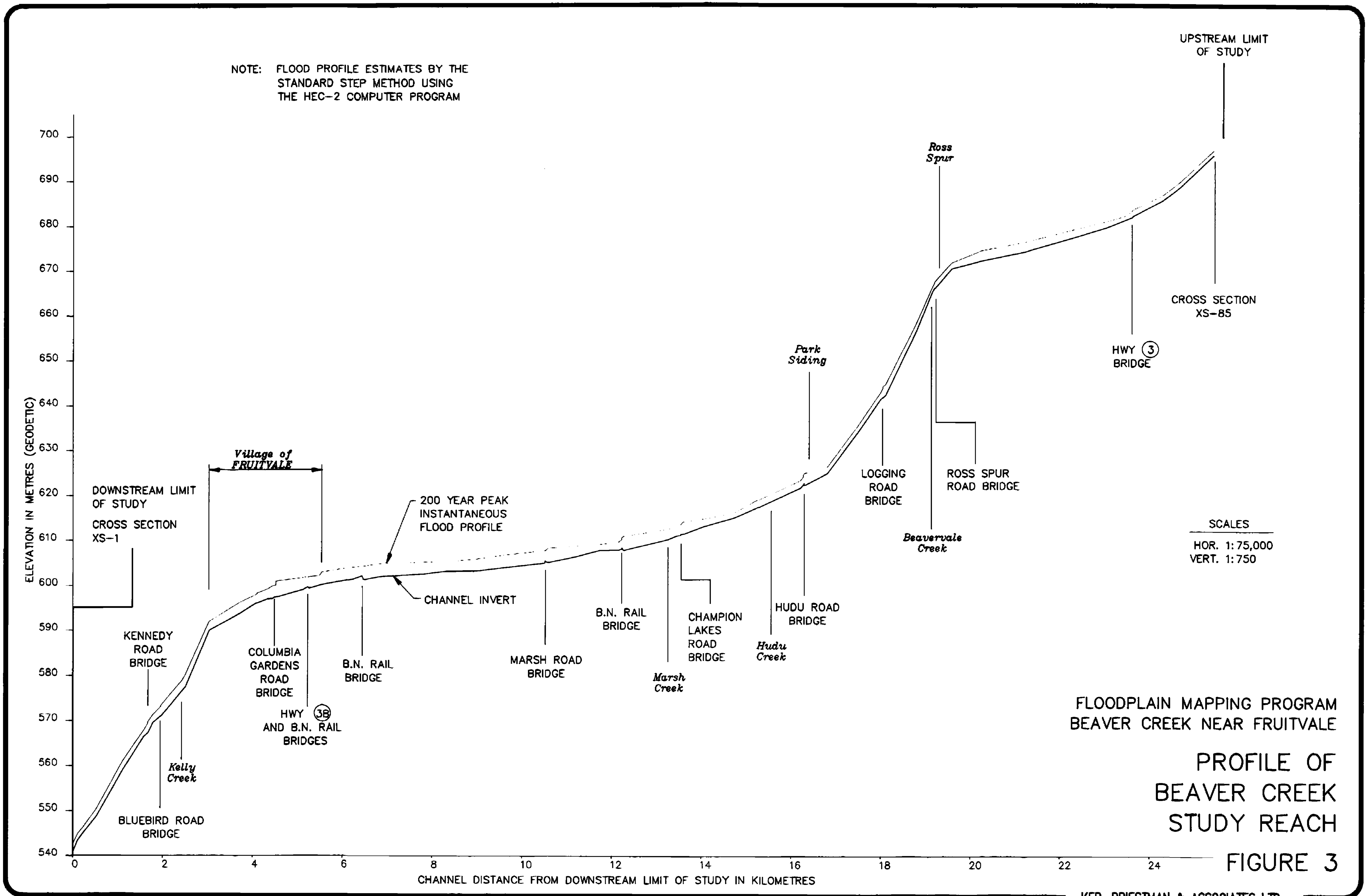
FLOODPLAIN MAPPING PROGRAM
BEAVER CREEK NEAR FRUITVALE

PLAN OF BEAVER CREEK DRAINAGE AREA

FIGURE 2

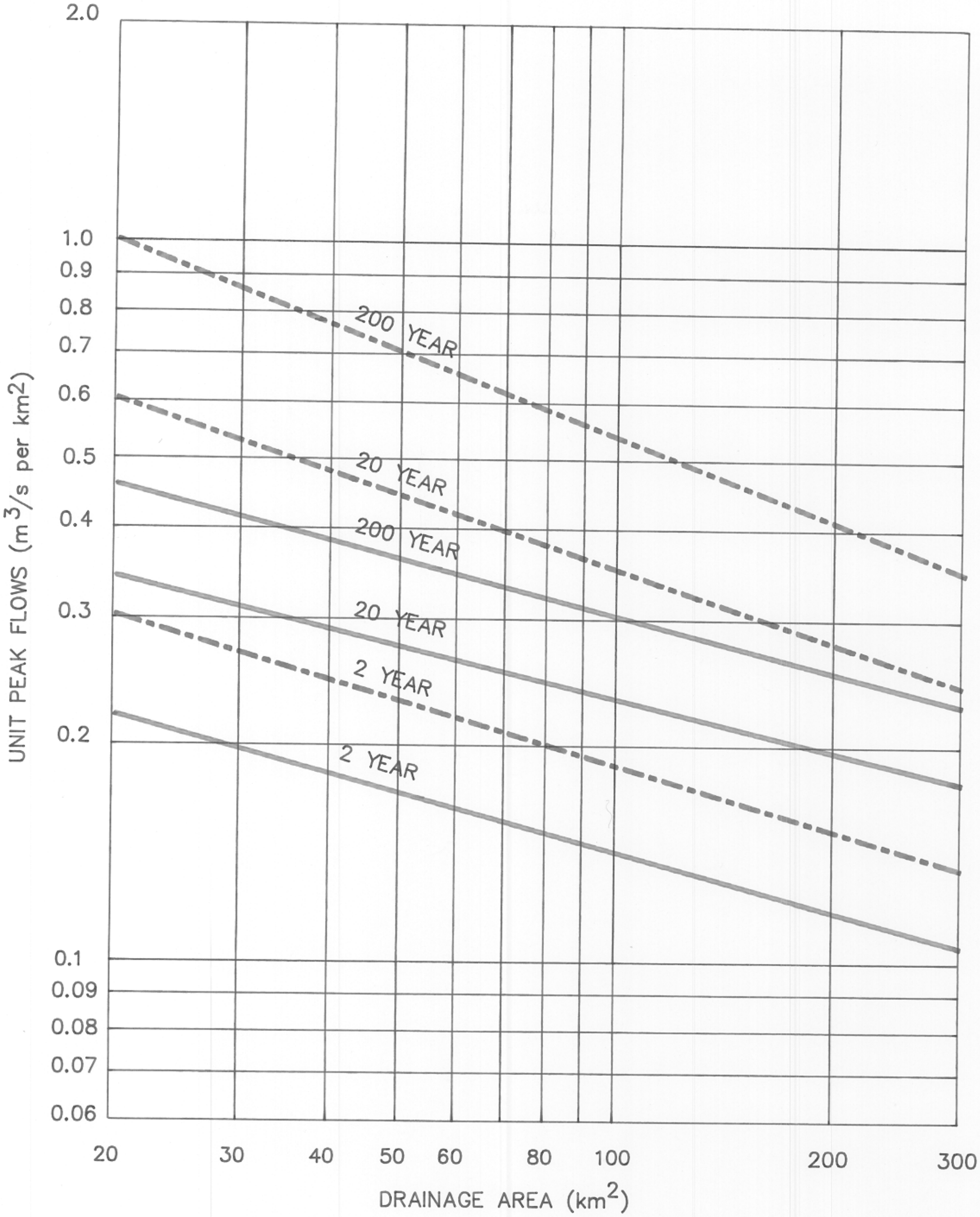
KER, PRIESTMAN & ASSOCIATES LTD

FILE NO.2563 DATE FEB 1989



FILE NO.2563 DATE FEB 1989

FILE NO. 2563 DATE FEB 1989



FLOODPLAIN MAPPING PROGRAM
BEAVER CREEK NEAR FRUITVALE

LEGEND

— · — · —	PEAK INSTANTANEOUS FLOWS
———	PEAK DAILY FLOWS
x YEAR	RETURN PERIOD

RELATION OF PEAK UNIT RUNOFF TO DRAINAGE AREA

FIGURE 4

KER, PRIESTMAN & ASSOCIATES LTD.

APPENDICES

APPENDIX 1

FLOOD LEVELS INCLUDING FREEBOARD

Appendix 1

Flood Levels Including Freeboard

Cross Section Number XS-	FCL (m)	Cross Section Number XS-	FCL (m)	Cross Section Number XS-	FCL (m)
1.0	543.18	28.0	602.60	59.0	619.21
2.0	545.36	29.0	603.37	60.0	624.19
3.0	546.82	30.0	604.48	61.0	624.64
4.0	550.83	31.0	604.69	61.1	625.21
5.0	561.43	32.0	604.71	61.9	625.28
6.0	568.43	33.0	604.71	62.0	625.29
6.9	569.81	34.0	605.27	63.0	625.45
7.0	570.37	35.0	605.63	64.0	626.94
8.0	571.67	36.0	605.78	65.0	636.15
9.0	573.63	37.0	606.49	66.0	643.56
10.0	573.88	38.0	607.24	67.0	644.35
11.0	579.36	38.2	607.26	67.2	644.87
12.0	580.55	39.0	608.23	68.0	645.21
12.1	580.56	40.0	608.21	69.0	658.85
13.0	592.42	41.0	608.32	70.0	666.94
14.0	596.66	42.0	608.81	71.0	667.85
14.9	598.42	43.0	609.22	72.0	668.24
15.0	598.48	44.0	609.49	73.0	668.37
15.2	598.78	45.0	609.55	74.0	672.38
16.0	599.03	46.0	610.30	75.0	675.04
17.0	599.72	47.0	610.34	76.0	676.89
18.0	600.22	48.0	611.38	77.0	679.76
19.0	600.46	49.0	611.42	78.0	681.59
20.0	600.46	50.0	611.43	79.0	682.77
20.1	601.34	51.0	611.44	80.0	683.93
21.0	601.42	52.0	613.28	81.0	684.15
22.0	602.13	53.0	613.71	82.0	684.45
23.0	602.22	54.0	613.90	83.0	687.33
24.0	602.24	55.0	614.06	84.0	690.39
25.0	602.27	56.0	614.62	85.0	697.42
26.0	602.28	57.0	615.26		
27.0	602.35	58.0	616.89		