B.C. ENVIRONMENT
WATER MANAGEMENT DIVISION

B239101/2

ELK RIVER, MICHEL CREEK AND CUMMINGS CREEK FLOODPLAIN MAPPING

DESIGN BRIEF

SRK - ROBINSON INC.
Consulting Engineers

B239101/2

ELK RIVER, MICHEL CREEK AND CUMMINGS CREEK FLOODPLAIN MAPPING

DESIGN BRIEF

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B239101/2

ELK RIVER, MICHEL CREEK AND CUMMINGS CREEK FLOODPLAIN MAPPING

DESIGN BRIEF

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ELK RIVER, MICHEL CREEK AND CUMMINGS CREEK FLOODPLAIN MAPPING

DESIGN BRIEF

1.0 INTRODUCTION

1.1 Canada/British Columbia Floodplain Mapping Agreement

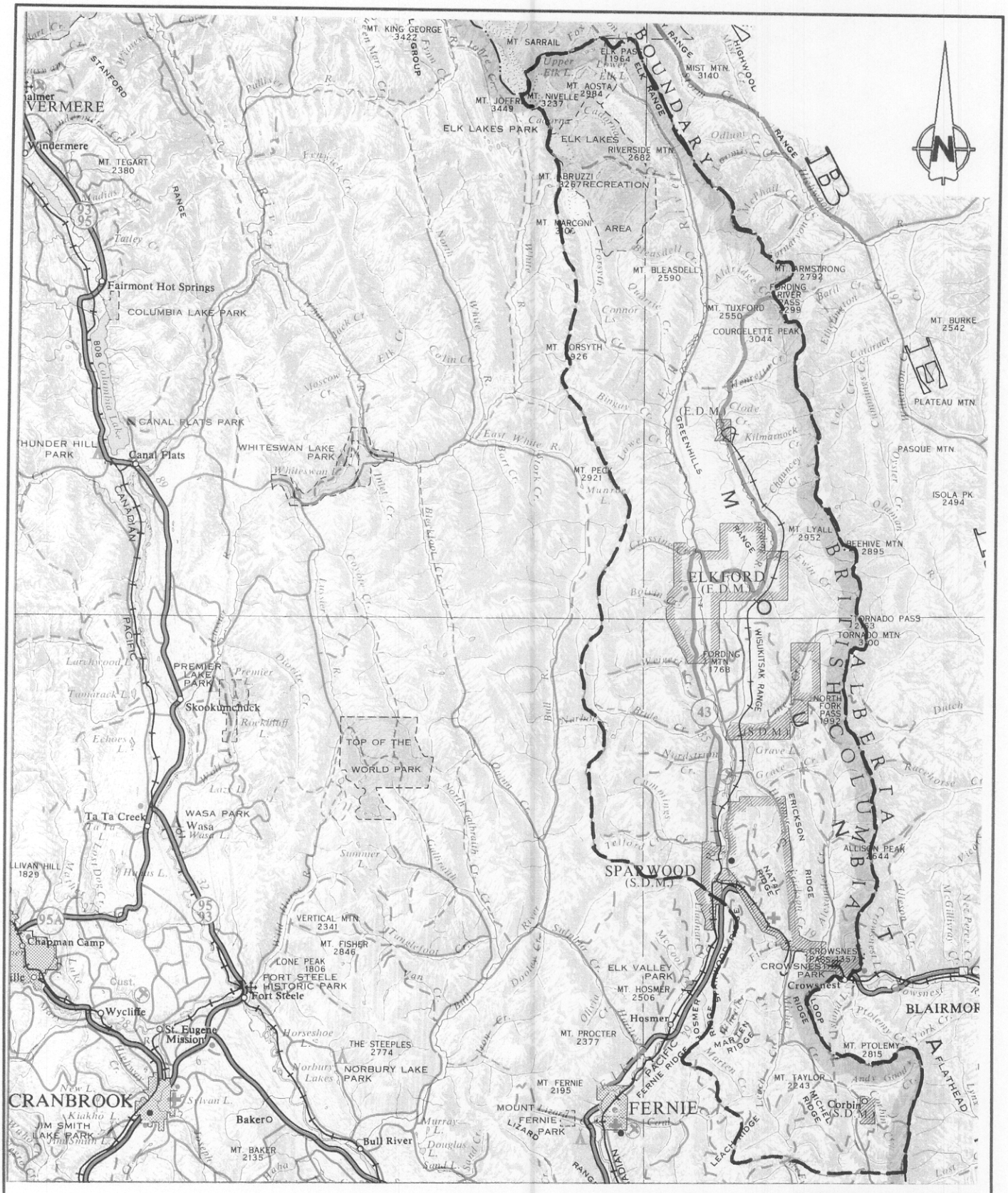
The 10-year Canada/British Columbia Floodplain Mapping Agreement was signed in December, 1987. An amending agreement providing funding for the last five years was approved in August, 1994.

Floodplain maps are used for administrative purposes and show the geographical extent of the floodplain and the flood levels used to determine minimum floodproofing elevation requirements. These requirements are used in development and administration of local bylaws and Official Community Plans, in administration of the Land Title Act and in other aspects of floodplain management to mitigate potential future damage and human suffering caused by flooding.

1.2 Description of Area and Watershed

The subject of this floodplain mapping study is the Elk River near Sparwood and two of its tributaries, Michel Creek and Cummings Creek.

The Elk River at Sparwood drains 2840 km^2 in the southeastern corner of British Columbia as shown in Figure 1.1. The long narrow north-south oriented basin lies in the extremely rugged terrain of the Rocky Mountains with peaks up to 3,300 m in the north and 2,200 m in the south (Obedkoff, 1985). The Elk River bisects the basin forming a valley one to six km wide, falling from an elevation of 1,700 m at its source to 750 m at its mouth at Lake Koocanusa 15 km south of Elko, B.C. This corresponds to a slope of 0.6 percent. Much of the basin is forested, with some farming activity in the valley bottom and coal mining, primarily on the east side of valley. The Elk



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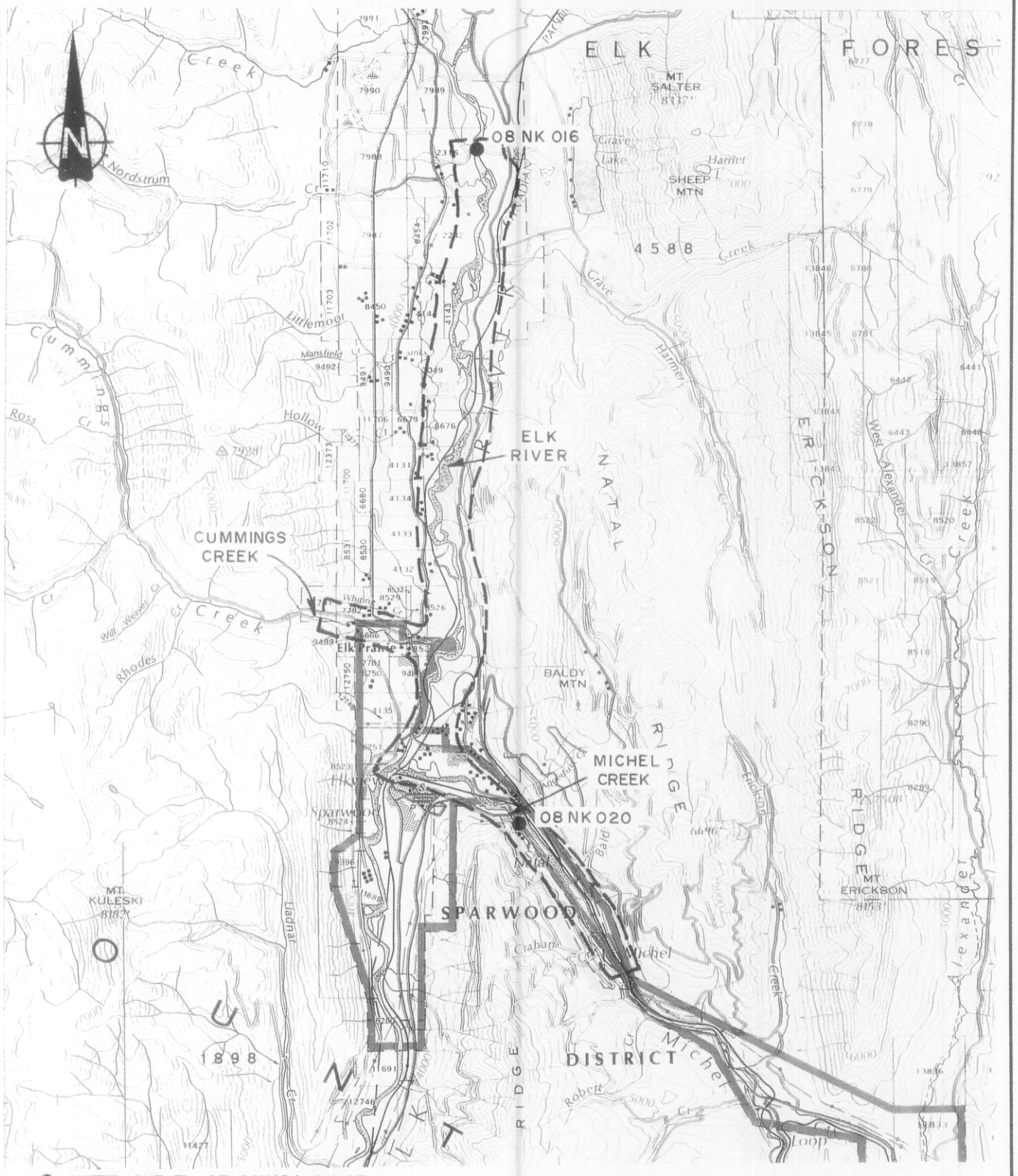
FLOODPLAIN MAPPING

ELK RIVER, MICHEL CK. AND CUMMINGS CK.

BASIN LOCATION PLAN

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC.,1994		1.1

FILE REF:



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BC ENVIRONMENT - WATER MANAGEMENT DIVISION

FLOODPLAIN MAPPING

ELK RIVER, MICHEL CK. AND CUMMINGS CK.
STUDY REACHES

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	FEB., 1995		1.2

FILE REF: FIG-1-2

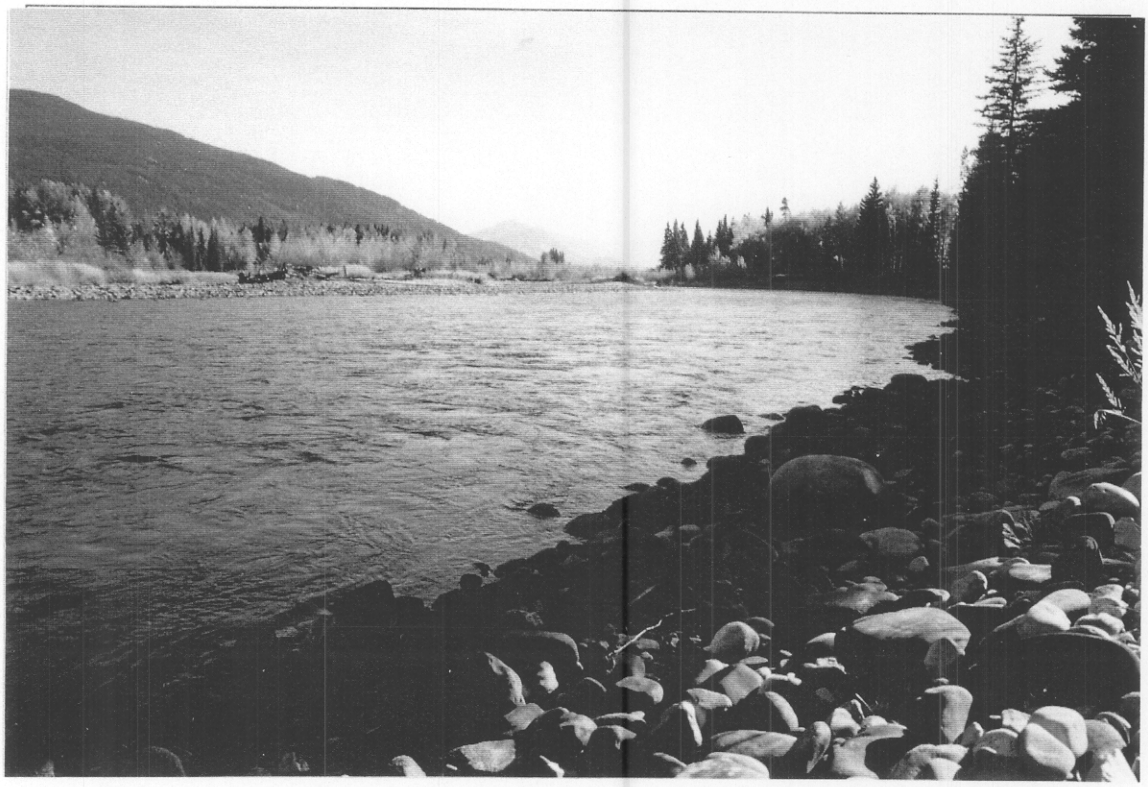


PHOTO 1.1 Elk River at XS-7, Looking Downstream

PHOTO 1.2 Elk River near XS-22, Looking Downstream from Radio Tower Hill

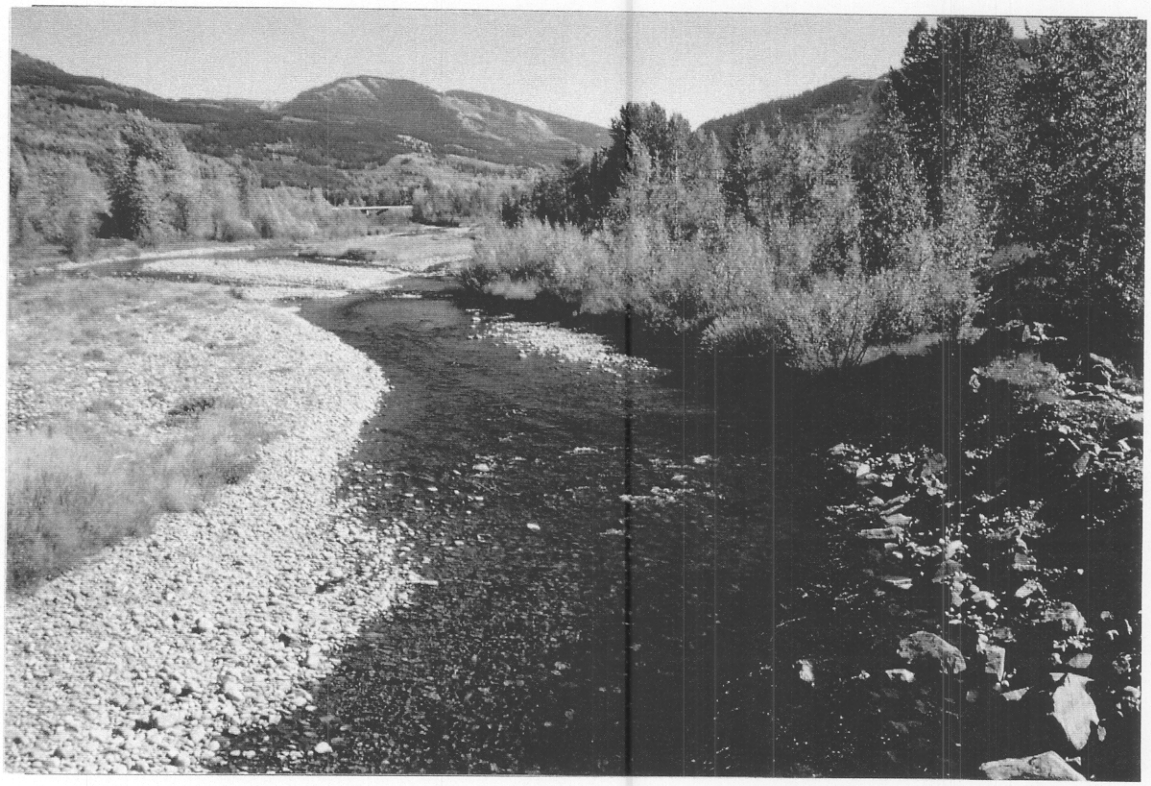


PHOTO 1.3 Michel Creek Looking Upstream from CPR Bridge at XS-3

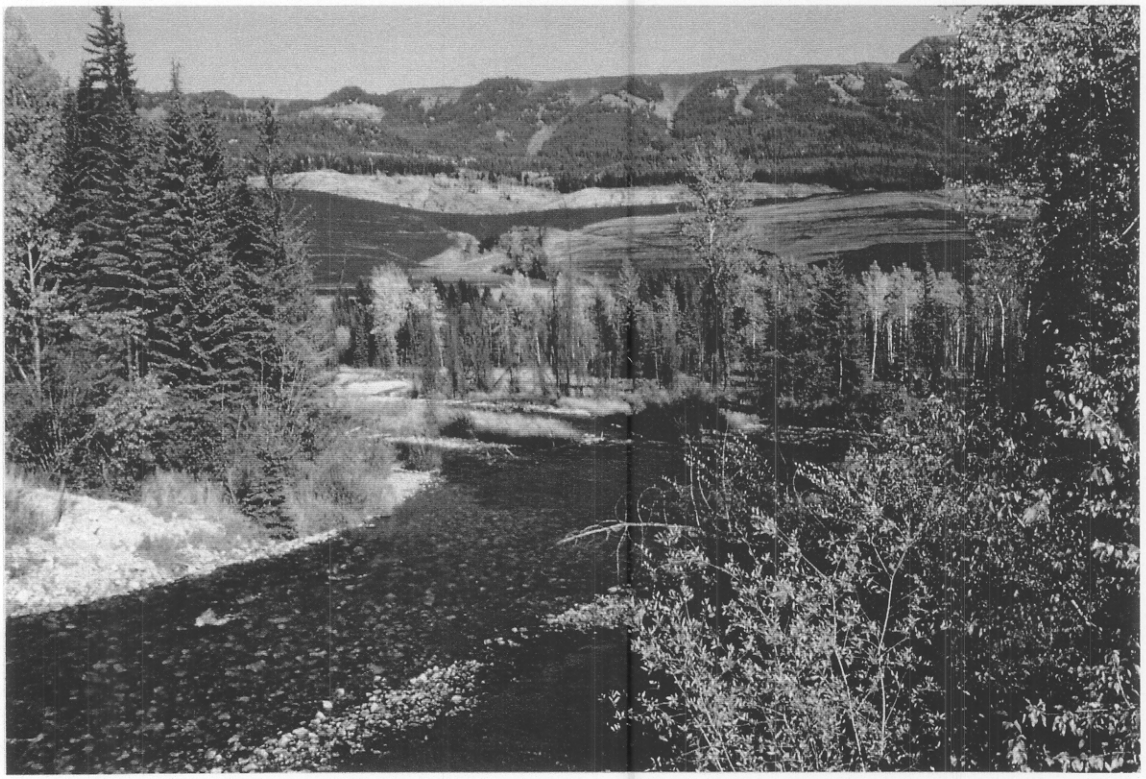


PHOTO 1.4 Cummings Creek Looking Downstream from CPR Bridge at XS-3

2.0 DATA SOURCES

2.1 Archival Material

The Sparwood District Library is a good source of archival material relating to the history of the settlements on Michel Creek and in the Elk Valley. It also has a collection of old photographs of life in the area, including some of flood events.

In the early part of this century it was the Michel Valley that was the focus of industrial and social activity. In 1898, the year that the CP Railway arrived, the community of Michel was established to house the miners who came to work in the newly opened mines. By 1903 the population had grown to over 500 and in 1907 a new subdivision, New Michel, later to become Natal, was developed. The population peaked at 2000 in 1920, followed by a reduction during the depression years of the '20s and '30s. The event which substantially transformed the area was the decision in 1964 by the Ministry of Municipal Affairs to relocate residents to the newly developed town of Sparwood, eight kilometres to the west. The provincial government was primarily interested in beautifying the southeastern entrance into British Columbia, as the coal black towns were an unsightly welcome to visitors to the province. Another reason given was that the thick smoke and dust were an unhealthy environment for the residents. The controversial relocation went ahead and the final phase was completed by 1977, with most of the homes, businesses and public buildings in Michel and Natal having been bulldozed and burned (Coutts, 1986).

According to a report by Bell-Irving Appraisals the early development of Natal was 'greatly restricted in area because of the Michel Creek, which flowed through the village and frequently flooded in the springtime'. The course of the creek was later moved to follow the base of the mountain and the bank was dyked to prevent flooding.

The most important event from the standpoint of this study is the May 1948 flood on Michel Creek. Unfortunately there were no streamflow records being kept in the area at the time, but a number of photographs can be found in the Provincial Archives, some of which are reproduced in Appendix A. There was extensive flooding and damage on Michel Creek at Michel and Natal. The creek was dredged after this flood. The creek had been channelized prior to this time and aligned along the left side of the valley, but during the 1948 flood it reverted temporarily to a meandering course.

2.2 Water Survey of Canada

Streamflow records for the Elk River are available at two gauging stations in the vicinity; Elk River near Natal and Elk River at Fernie, with data going back to 1951 and 1971, respectively. Michel Creek has been gauged at a station known as Michel Creek below Natal since 1970 (see Figure 1.2). The flood flow data from these and other gauges in the region are discussed and analyzed in Section 4.2.

2.3 Water Management Division

In preparation for this study the Water Management Division has undertaken a considerable amount of field work. The data provided included the following:

- river survey (September 1991) including photographs, written profiles and plots of 91 cross sections and several bridges on the Elk River, Michel Creek and Cummings Creek, a video tape of the sections and bridges, high water mark elevations, a listing of the HEC-2 GR data for these sections as surveyed;

- 1:5000 scale topographic maps showing cross section locations; and

- design file for Elk River at Fernie and Sparwood, containing data used to prepare existing floodplain mapping at Sparwood.

This information is detailed further in Appendix B.

2.4 District of Sparwood and Local Residents

A meeting was held on September 22, 1994 between A.G. Chantler, P.Eng., M.C. Mannerström, P.Eng. and two District of Sparwood Officials:

Danny Dwyer	Technical Planning Coordinator
Loretta Montemurro	Clerk

The District is pleased that this study is proceeding, having applied for it some time ago. Ms. Montemurro lived in Natal in 1948 and her house was one of those flooded. Ms. Montemurro also had recollections of a lesser flood in 1951 or 1952.

Areas of particular concern identified by the District are the lower reaches of Michel Creek on the right bank and Michel Creek at the lower Highway 3 crossing.

A. Chantler talked by phone with Frank Mitchell, a long term resident who had some recollections of the 1948 flood. He said there had been no problems since then. He has the impression that the spring freshet has got later and later over the years (not borne out by the streamflow records). Another resident, Mike Paskovich, thought there had been problems on the Elk River as well as Michel Creek in 1948. He also mentioned 1951 and 1956 as problem years in the lower areas of Sparwood and between Sparwood and Fernie. There were no problems in 1974 (the year of maximum recorded flow on the Elk). Valli Quarin, president of the Heritage Society, remembered the 1948 flood and thought there had been one in 1951 also.

Subsequent to the above discussions an article and interview were given to the Elk Valley Miner newspaper, describing the project and inviting contributions of information from long term residents, who may recall flooding incidents. The article appeared in October 1994. No further contributions were received.

Province of B.C. colour air photos, flown in 1988, were provided on loan by the District of Sparwood (30BCC 817 No. 3-6, 57, 58, 64-66, 111-113, 117-119, 30BCC 861 No. 57-59, 62-66, 106-109, 110, 111). An old blueprint (undated) entitled "Michel Creek Showing Old Channels" at 1 inch to 100 feet was also loaned by the District.

3.0 FIELD INSPECTIONS

In view of the considerable amount of information already available to the study team, only a brief visit was required for familiarization with the study reaches and to assist with estimation of some of the subjective parameters, such as roughness coefficients and expansion and contraction coefficients.

On September 21, 1994 A.G. Chantler, P.Eng. and M.C. Mannerström, P.Eng. made an inspection of the Elk River from the WSC gauge at the upstream end of the study reach to the old bridge alignment at the downstream end. Photographs were taken to supplement those taken by BC Environment's survey crew and 1:5000 plans were marked up according to type of vegetation on the floodplain and islands. Notes were also taken regarding the bed material. The Elk River was approached from the east upstream of Grave Creek and from the west below this point.

Cummings Creek above the railway crossing was also inspected.

On September 22 the above-mentioned engineers inspected Michel Creek from the second Highway 3 crossing to the mouth, again taking notes of channel and floodplain conditions and taking photographs. The inspection of Cummings Creek from the railway crossing down to the confluence with the Elk was completed. Particular attention was paid to the second CP Rail crossing of Michel Creek, just upstream of the trailer park. At this point the main channel turns almost through a right angle to pass below the bridge. At times of high flow there is direct impingement on the riprapped dyke protecting the trailer park. This dyke was upgraded to BCE standards after construction and is inspected by BCE every few years (Boyer, 1995). A timber retaining wall at the left abutment of the CP Rail bridge requires some maintenance. The central pier is aligned perpendicular to the railway, not in line with the flow, and this has caused considerable build up of material downstream, restricting the channel capacity.

A second field inspection was conducted by A. G. Chantler, P.Eng. on April 20 and 21, 1995, at which time the valley bottom was snow-free. This inspection was used to make minor adjustments to the draft floodplain boundaries.

4.0 FLOOD HYDROLOGY

4.1 Introduction

This section describes the work undertaken to determine the peak flows at various points on the Elk River, Michel Creek and Cummings Creek. These flows were required as input to the HEC-2 model for determination of the flood water surface profiles in these river channels for 20 and 200-year floods. A more detailed report on this component of the study is contained in Progress Report No. 1 (SRK-Robinson, 1994), however the Cummings Creek flood discharges have been recalculated since that report was issued and the updated estimates are presented in this Design Brief.

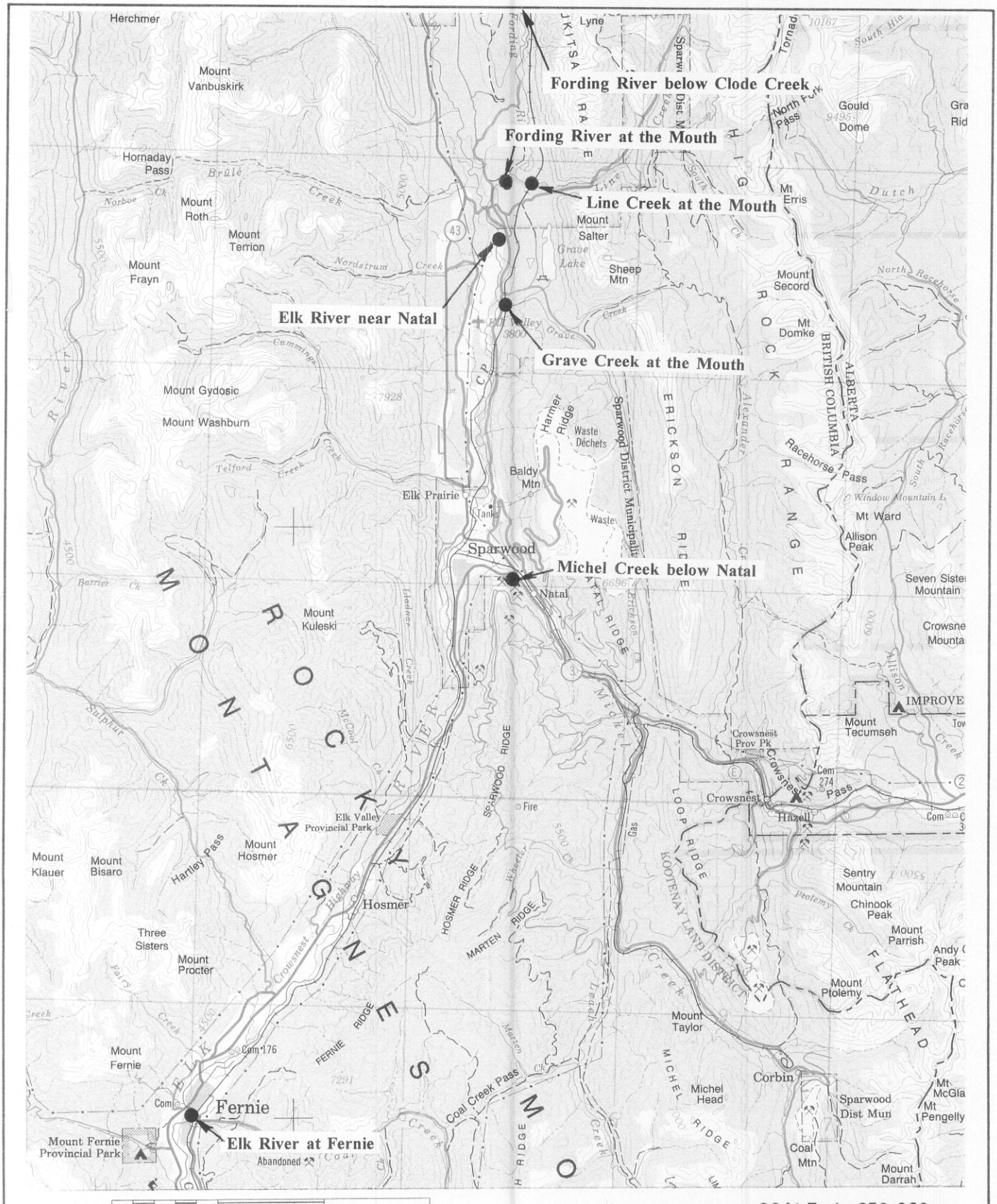
4.2 Peak Flow Data

There are several Water Survey of Canada (WSC) streamflow gauges in or near the study reaches. These are listed in Table 4.1 and indicated on Figure 4.1. These stations were selected on the basis of proximity to the study reaches and length of record period. All the stations are listed by WSC as having natural flows, so no adjustment was required prior to carrying out the frequency analysis.

In all cases the record period refers to the period for which maximum daily data are available. This is generally somewhat longer than the period for which maximum instantaneous flow data are available.

TABLE 4.1
Water Survey of Canada Hydrometric Stations

STATION NO.	STATION NAME	DRAINAGE AREA (km^2)	RECORD PERIOD USED	RECORD LENGTH (years)
08NK002	Elk River at Fernie	3110	1970-1992	23
08NK016	Elk River near Natal	1870	1951-1992	42
08NK020	Michel Creek below Natal	637	1970-1992	23
08NK022	Line Creek at the Mouth	138	1971-1992	22
08NK019	Grave Creek at the Mouth	83.9	1970-1992	23
08NK018	Fording River at the Mouth	619	1970-1992	23
08NK021	Fording River below Clode Creek	104	1971-1992	21



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BC ENVIRONMENT – WATER MANAGEMENT DIVISION

FLOOD PLAIN MAPPING

ELK RIVER, MICHEL CK. AND CUMMINGS CK.
FLOODPLAIN MAPPING

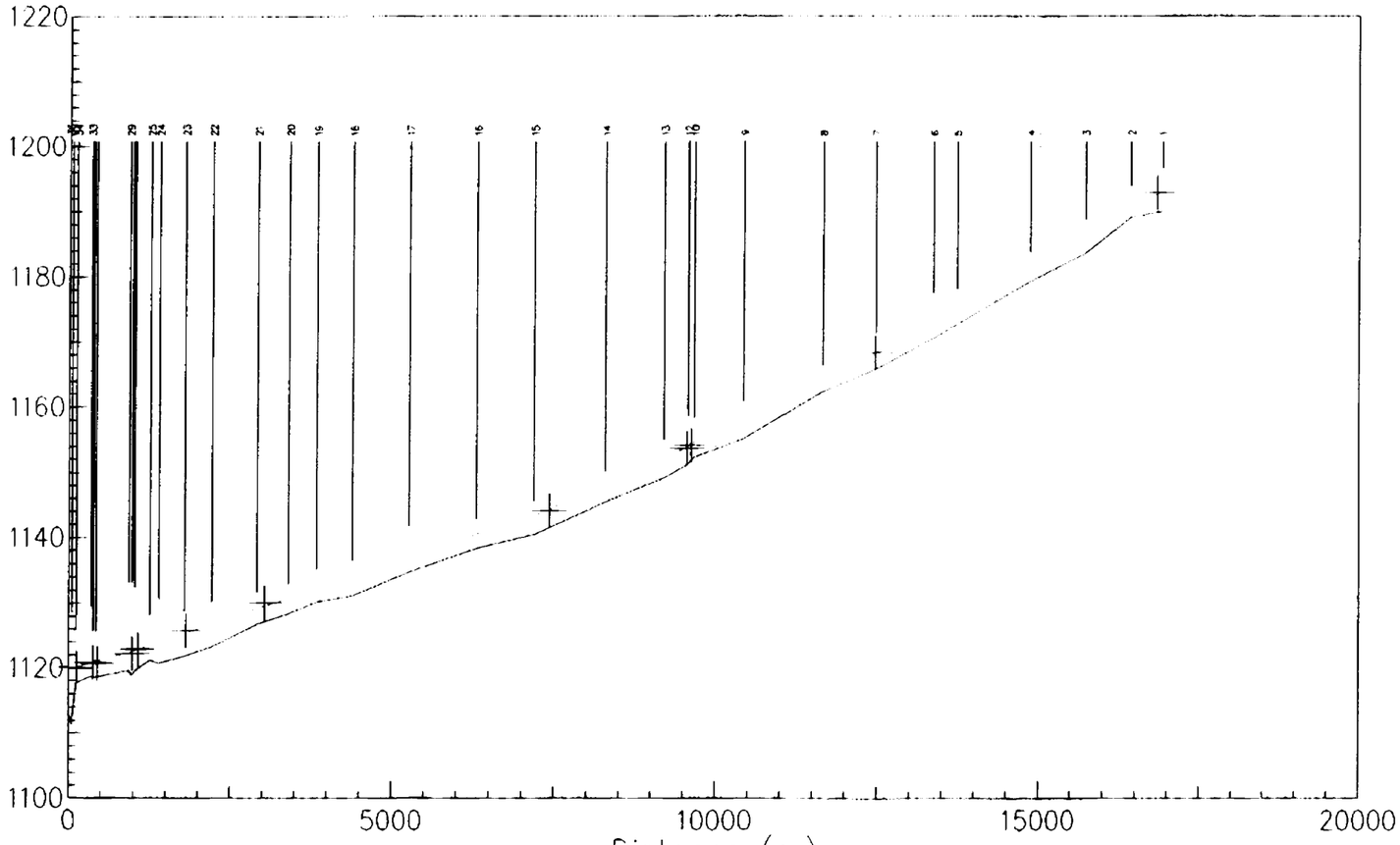
LOCATION OF WSC GAUGES

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	FEB., 1995		4.1

FILE REF: B2391001

ELK RIVER CALIBRATION PROFILE

Q = 166 cu m/s at 08NK016, HWM elevations for 1991



NAME: C:\PROJECTS\DELKRIV\B239101\ELKCAL01.DWG DATE: DEC 19, 1994 TIME: 11:09 AM

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B.C. ENVIRONMENT
WATER MANAGEMENT DIVISION

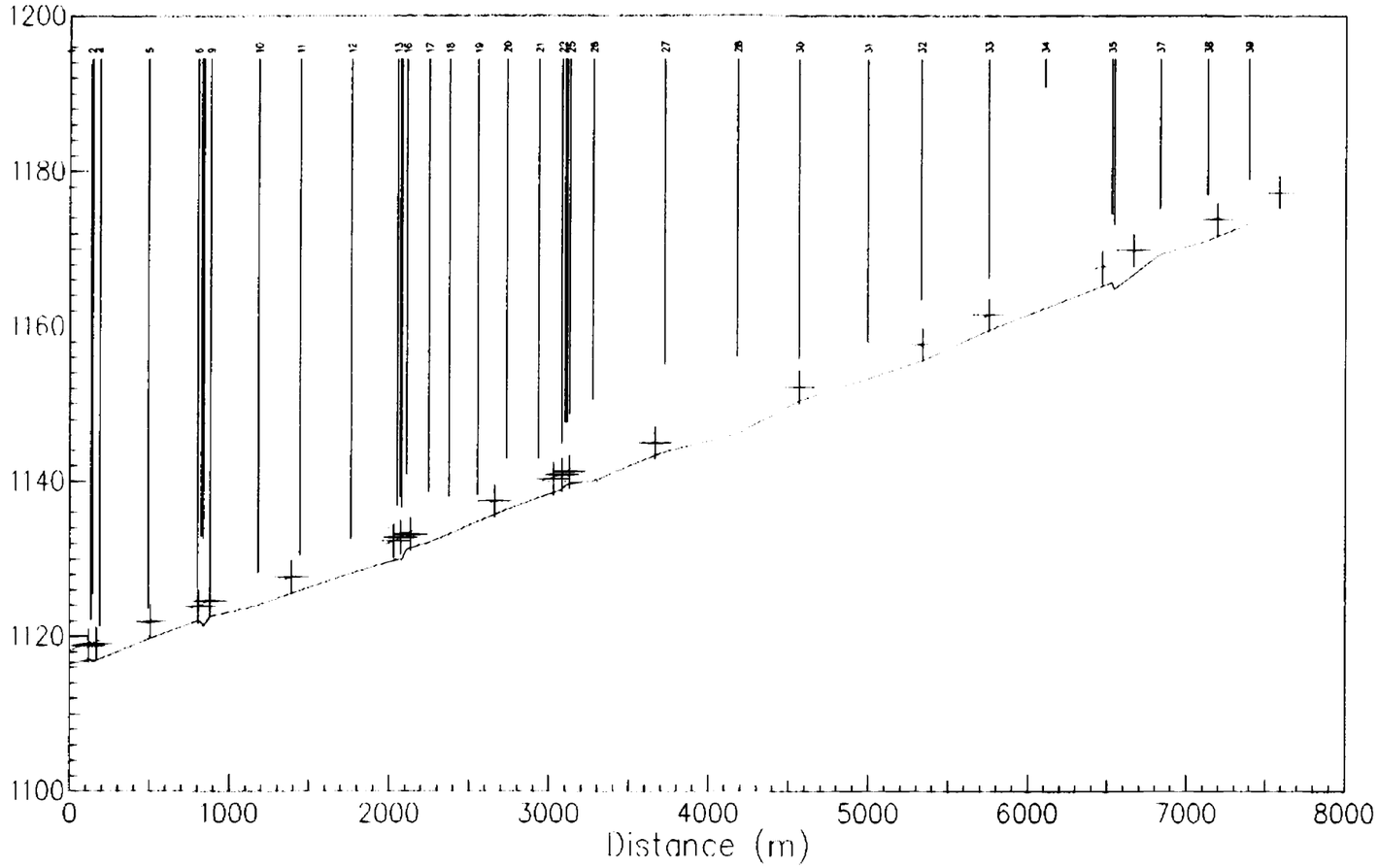
FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEK

ELK RIVER
CALIBRATION PROFILE

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC., 1994		5.2

MICHEL CREEK CALIBRATION PROFILE

Q = 153 cu m/s at 08NK020, HWM elevations for 1991



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WATER MANAGEMENT DIVISION

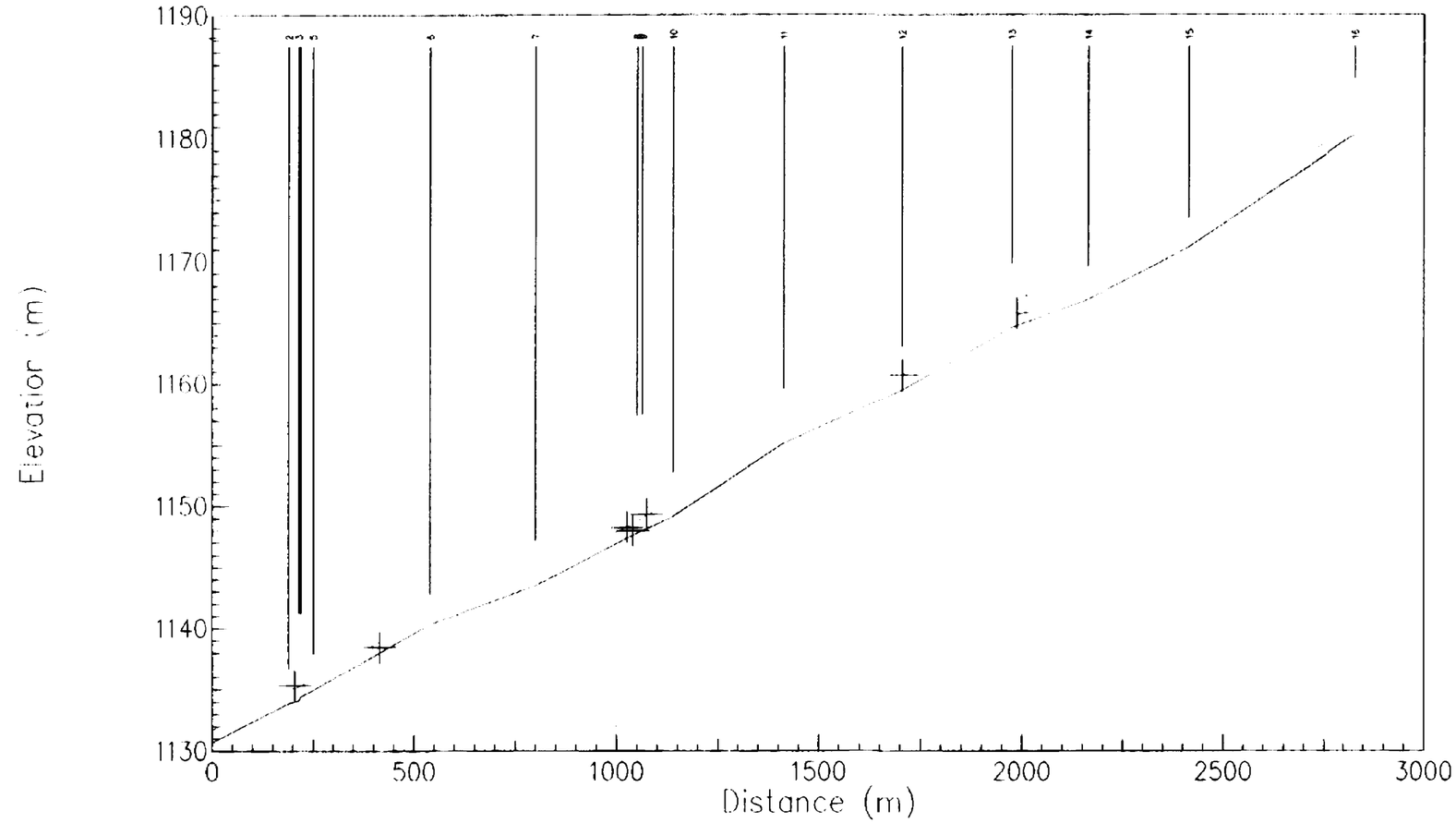
FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

MICHEL CREEK
CALIBRATION PROFILE

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.3

CUMMINGS CREEK CALIBRATION PROFILE

Q = 23.6 cu m/s, HWM elevations for 1991



SRK-ROBINSON INC. Consulting Engineers		FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS	
B.C. ENVIRONMENT WATER MANAGEMENT DIVISION		CUMMINGS CREEK CALIBRATION PROFILE	
PROJECT NO. B239101	DATE DEC.,1994	APPROVED	FIGURE 5.4

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4.3 Flood Frequency Analysis

Flood frequency analysis was carried out using Environment Canada's program entitled Consolidated Frequency Analysis Version 3.1 (CFA3.1), (Environment Canada, 1993). This program allows the user to enter data for analysis from the standard WSC flood data files; modify the data sets so as to add, delete, or modify all stored information; save modified data sets for future use; perform non-parametric tests for homogeneity, trend, independence and randomness; perform tests for high and low outliers; and determine T-year events. The probability distributions incorporated include:

- generalized extreme value (Gumbel);
- three parameter lognormal;
- Log Pearson Type III; and
- Wakeby.

In accordance with the Floodplain Mapping Program Specifications for Engineering Studies the analyses were carried out using the first three of the above distributions. Attention was focused on the 20-year and 200-year values, as the flood levels corresponding to these events are required for administrative purposes.

A complete set of the output from CFA3.1 on the seven selected WSC stations, including graphical output, is given in Progress Report No. 1 (SRK-Robinson, 1994). A summary of the results is presented in Table 4.2.

For each station judgement was applied in selecting the 20-year and 200-year flows. Where the three frequency distributions agreed closely the average value was selected. Where there was a significant discrepancy the maximum value was selected. A summary of the selected values and the basis for selection is given in Table 4.3.

TABLE 4.2
Flood Frequency Analysis

STA. NO.	STATION NAME	DR. AREA (km^2)	20-YEAR FLOW (m^3/s)			200-YEAR FLOW (m^3/s)			MEAN ANNUAL FLOOD (m^3/s)
			GEV	3P LOG NORMAL	LOG P III	GEV	3P LOG NORMAL	LOG P III	
08NK002	Elk River at Fernie	3110	511	499	494	773	703	696	290
08NK016	Elk River near Natal	1870	284	285	280	400	406	395	163
08NK020	Michel Creek below Natal	637	162	158	156	232	216	211	96
08NK022	Line Creek at the Mouth	138	33.5	33.8	33.1	74.7	62.4	65.1	17.0
08NK019	Grave Creek at the Mouth	83.9	11.7	11.4	11.0	15.3	15.1	13.4	6.9
08NK018	Fording River at the Mouth	619	123	133	133	216	254	281	62.8
08NK021	Fording River below Clode Creek	104	31.6	34.1	33.9	48.6	59.9	63.9	17.0

TABLE 4.3
Summary of Selected Flood Flows

STATION NO.	STATION NAME	DR. AREA (km^2)	ESTIMATED 20-YEAR FLOW (m^3/s)	BASIS FOR ESTIMATION	ESTIMATED 200-YEAR FLOW (m^3/s)	BASIS FOR ESTIMATION
08NK002	Elk River at Fernie	3110	511	Max. (GEV)	773	Max. (GEV)
08NK016	Elk River near Natal	1870	283	Average of 3 distrs.	400	Average of 3 distrs.
08NK020	Michel Creek below Natal	637	162	Max. (GEV)	232	Max. (GEV)
08NK022	Line Creek at the Mouth	138	33.5	Average of 3 distrs.	74.7	Max. (GEV)
08NK019	Grave Creek at the Mouth	83.9	11.7	Max. (GEV)	15.3	Max. (GEV)
08NK018	Fording River at the Mouth	619	133	Max. (Log Pearson III and 3P Log normal)	281	Max. (Log Pearson III)
08NK021	Fording River below Clode Creek	104	33.9	Max. (3P Lognormal)	63.9	Max. (Log Pearson III)

4.4 Development of Flows for Flood Profile Calculations

4.4.1 Elk River and Michel Creek

The correlation between peak flow and drainage area is not particulary good (SRK-Robinson, 1994). Similar scatter was evident in the peak flow regionalization study carried out as part of the Elk River Study Hydrology Overview (BC Environment, 1985). For the Elk River analysis it was decided to make use of only the two stations on the Elk River, as these are clearly the most applicable to the study reach. The Michel Creek records can be applied directly to the study reach of Michel Creek.

The linear relationships between maximum daily flow, Q (m^3/s), and drainage area, A (km^2), for the two Elk River stations are as follows:

$$Q_{20} = 0.1839A - 60.8$$

$$Q_{200} = 0.3008A - 162.5$$

The concurrent records of maximum daily flow and maximum instantaneous flow for the two Elk stations and the one on Michel Creek were used to derive a ratio between these two parameters. The Elk River and Michel Creek peak flow data are reproduced in Appendix C. By simply comparing the mean values of the two measures of peak flow the following relationships were derived:

$$Q_{max\ inst} = Q_{max\ daily} \times 1.03 \text{ (Elk River)}$$

$$Q_{max\ inst} = Q_{max\ daily} \times 1.06 \text{ (Michel Creek)}$$

4.4.2 Cummings Creek

To estimate the Cummings Creek discharge two drainage areas with similar catchment areas were selected, and the mean value of the unit area discharge was calculated for the 20 and 200-year events, as tabulated below.

TABLE 4.4
WSC Stations Used to Determine Cummings Creek Flows

STATION NO.	WSC STATION NAME	DRAINAGE AREA (km^2)	Q_{20}		Q_{200}	
			(m^3/s)	($L/s/km^2$)	(m^3/s)	($L/s/km^2$)
08NK021	Fording R below Clode Creek	104	33.9	326	63.9	614
08NK022	Line Creek at the Mouth	138	33.5	243	74.7	541

Interpolating between the specific discharges for the Fording River and Line Creek for the Cummings Creek drainage area of 125 km^2 gives the following:

$$Q_{20} \text{ (max. daily)} = 275 \text{ L/s/km}^2 = 34.3 \text{ m}^3/\text{s}$$

$$Q_{200} \text{ (max. daily)} = 569 \text{ L/s/km}^2 = 71.1 \text{ m}^3/\text{s}$$

The ratios of the maximum instantaneous to maximum daily flow are 1.28 and 1.18 for the Line Creek and Fording River stations respectively. These are based on 15 years of concurrent daily and instantaneous data for Line Creek and 14 years for the Fording River. Applying the mean ratio of 1.23 gives the following for Cummings Creek:

$$Q_{20} \text{ (max. instantaneous)} = 42.2 \text{ m}^3/\text{s}$$

$$Q_{200} \text{ (max instantaneous)} = 87.5 \text{ m}^3/\text{s}$$

4.4.3 Peak Flows for Use in HEC-2

The resulting estimates for peak flows at various points along the study reach of the Elk River and in Michel Creek and Cummings Creek are given in Table 4.5.

TABLE 4.5
Discharges along the Elk River, Michel and Cummings Creeks

LOCATION	DRAINAGE AREA (km^2)	MAXIMUM DAILY FLOW (m^3/s)		MAXIMUM INSTANTANEOUS FLOW (m^3/s)	
		20-YEAR	200-YEAR	20-YEAR	200-YEAR
Elk River near Natal (WSC 08NK016)	1870	283	400	292	412
Elk River below Nordstrum Creek	1962	300	428	309	440
Elk River below Grave Creek	1989	305	436	314	449
Elk River below Dalzell Creek	2031	313	448	322	462
Elk River below Cummings Creek	2192	342	497	352	511
Elk River above Michel Creek	2198	343	499	354	514
Michel Creek below Natal (WSC 08NK020)	637	162	232	172	246
Cummings Creek at the Mouth	125	34.3	71.1	42.2	87.5

5.0 WATER SURFACE PROFILE ANALYSIS

5.1 Model Development

The HEC-2 standard-step backwater program (U.S. Army Corps of Engineers, 1990) was used to compute the 20-year and 200-year daily and instantaneous flood profiles for the Elk River, Michel Creek and Cummings Creek. Separate models were assembled for each watercourse. Channel and floodplain geometry, bridge descriptions and surface roughness coefficients formed the input data for the models. In 1991, BCE surveyed 36 cross-sections on the Elk River, 39 cross-sections on Michel Creek and 16 cross-sections on Cummings Creek. The cross-section locations were marked by BCE on 1:5000 scale, 2 m contour interval topographic maps produced in 1985. These base maps were produced under the Provincial Large Scale Mapping Program and utilized in the study pursuant to Section 7.(3)(h) of the Canada/British Columbia Mapping Agreement. Thalweg and overbank distances between sections were scaled from the maps. The maps were also used for extending the surveyed sections over the floodplain.

Initial channel roughness values, represented by Manning's roughness coefficient, n (U.S. Dept. of the Interior, 1967), were estimated based on photo and video documentation provided by BCE and on site visit observations. Overbank roughness coefficients were evaluated from air photography flown in 1988.

Several bridges are located within the study area; three on the Elk River, five on Michel Creek and two on Cummings Creek. The bridges were modelled according to the HEC-2 Normal or Special Bridge Methods (Table 5.1).

5.2 Calibration

The HEC-2 backwater models were calibrated to high water marks produced by the 1991 freshet and surveyed by BCE on June 21 and 22, 1991. A maximum instantaneous flow of 166 m^3/s was recorded at Station 08NK016, Elk River near Natal, on May 22, 1991. The daily maximum flow was 164 m^3/s, which roughly corresponds to a 3-year flood. The instantaneous maximum discharge was used in the calibration and the flow was increased downstream of the gauge, proportionately to the 20-year maximum instantaneous discharge distribution (Table 4.5).

TABLE 5.1
Bridge Summary

Location	Type	No. of Piers	Method	Angle of Skewness (degrees)	Max. Elev. Low Chord (m)	Min. Elev. Top Road (m)	Comments
ELK RIVER:							
XS-31/32 HWY 43	Concrete	3	Special	30	1133.54	1132.13	
XS-27/28 CPR	Steel	4	Special	50 (2)	1128.91	1131.42	
XS-11/12 CPR	Steel	1	Normal (1)	20	1160.52	1160.54	
MICHEL CREEK:							
XS-2/3 CPR	Steel	1	Normal (1)	22	1122.48	1123.30	No flow assumed through culverts
XS-7/8 HWY 43	Concrete	3	Normal (1)	0	1131.44	1129.66	No flow assumed through culverts
XS-14/15 CPR	Steel	1	Normal (1)	43 (2)	1135.12	1135.51	Critical flow - Choke potential (3)
XS-23/24 HWY 3	Steel	0	Normal	20	1143.77	1145.25	
XS-35/36 Abandoned	Steel	0	Normal	0	1171.27	1172.81	
CUMMINGS CREEK:							
XS-3/4 CPR	Steel	0	Normal	23	1136.43	1139.72	Critical flow - Choke potential (3)
XS-8/9 HWY 43	Concrete	2	Normal (1)	16	1155.23	1155.25	

Notes: 1. Trapezoidal approximation of opening not appropriate, Normal Method used with piers.
2. Results are approximate only for skewness angles greater than 30 degrees.
3. Even minor blockages at the bridge section may "choke" the flow and cause sudden large increases in upstream water levels. Computed flood levels should be considered approximate only.

The Michel Creek maximum instantaneous flow for 1991 was 153 m^3/s, recorded at Station 08NK020, Michel Creek below Natal, on May 19. The maximum daily flow was 144 m^3/s and corresponds to a return period of over 10 years.

There are no flow records for Cummings Creek. Based on Fording River below Clode Creek (08NK021) and Line Creek at the Mouth (08NK022) the maximum daily flow was estimated at 19.2 m^3/s. This flow has a return period of less than 5 years. Applying an average instantaneous to daily flow ratio of 1.23 (Section 4.4.2), the maximum instantaneous Cummings Creek discharge was estimated at 23.6 m^3/s for May 22, 1991.

The high water marks observed by BCE are summarized in Tables 5.2, 5.3 and 5.4. A total of 12 marks were surveyed for the Elk River, 22 marks for Michel Creek and 7 marks for Cummings Creek.

Water surface profiles were also recorded by BCE in September, 1991, at the time of the cross-section survey. However, discharge during the survey was very low (Elk River: 14.9 m^3/s - 16.9 m^3/s and Michel Creek: 3.35 m^3/s - 3.55 m^3/s) and the profile information was not appropriate for model calibration.

Historic flood levels for the 1948 flood on Michel Creek are available from photographs but do not reflect present river conditions. Historic data for the Elk River or Cummings Creek have not been located.

The streamflow gauges Elk River near Natal (08NK016) and Michel Creek below Natal (08NK020) were tied to GSC datum as part of BCE's cross-section survey. The WSC and corresponding rating tables computed using HEC-2 are given in Table 5.2 and plotted in Figure 5.1. The Elk River gauging section was not included in the survey and so the computed HEC-2 rating curve is based on interpolated levels between Cross-Section 1, 80 m upstream, and Cross-Section 2, 410 m downstream. At the calibration flow, the agreement between the WSC and HEC-2 data is good (error = 0.08 m). For Michel Creek the WSC rating curve does not extend up to the calibration flow, but at lower discharges the water levels computed for Cross-Section 25 compare well with the WSC rating curve.

TABLE 5.2
Rating Curve Comparisons - Elk River and Michel Creek

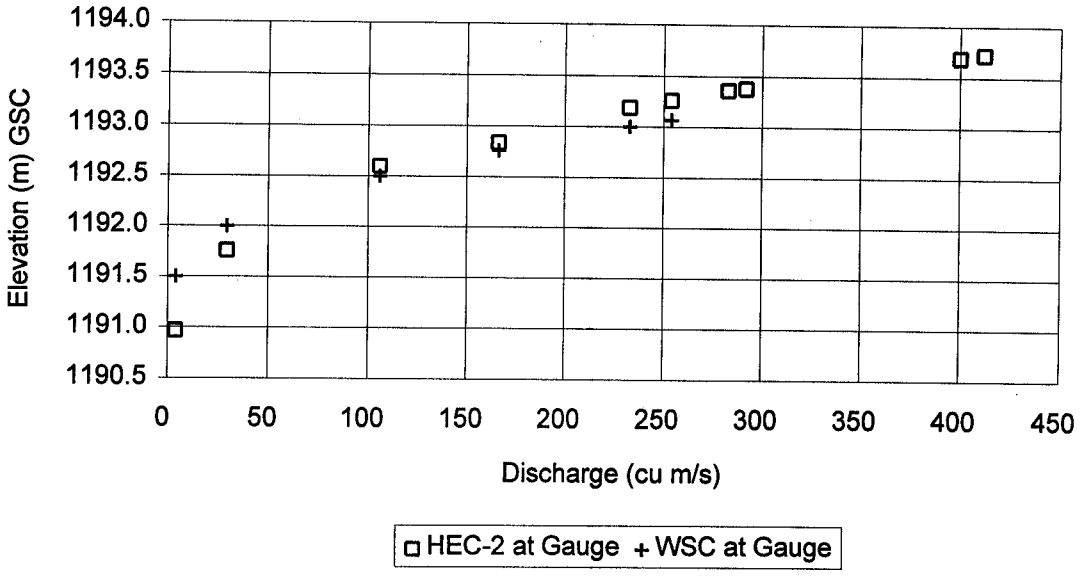
ELK RIVER NEAR NATAL (08NK016)

Discharge (cu m/s)	Definition	WSC gauge Elevation (m)	HEC-2 XS-1 Elevation (m)	HEC-2 XS-2 Elevation (m)	HEC-2 Gauge Elevation (m)	Error HEC-2 - WSC (m)
4.03		1191.50	1191.20	1189.79	1190.97	-0.53
29.6		1192.00	1192.07	1190.18	1191.76	-0.24
106		1192.50	1193.08	1190.78	1192.60	0.10
166	Calibration	1192.76	1193.20	1190.99	1192.84	0.08
233		1193.00	1193.60	1191.07	1193.19	0.19
254		1193.07	1193.68	1191.13	1193.26	0.19
283	20-yr daily	-	1193.78	1191.20	1193.36	-
292	20-yr inst.	-	1193.80	1191.22	1193.38	-
400	200-yr daily	-	1194.13	1191.46	1193.69	-
412	200-yr inst	-	1194.16	1191.48	1193.72	-

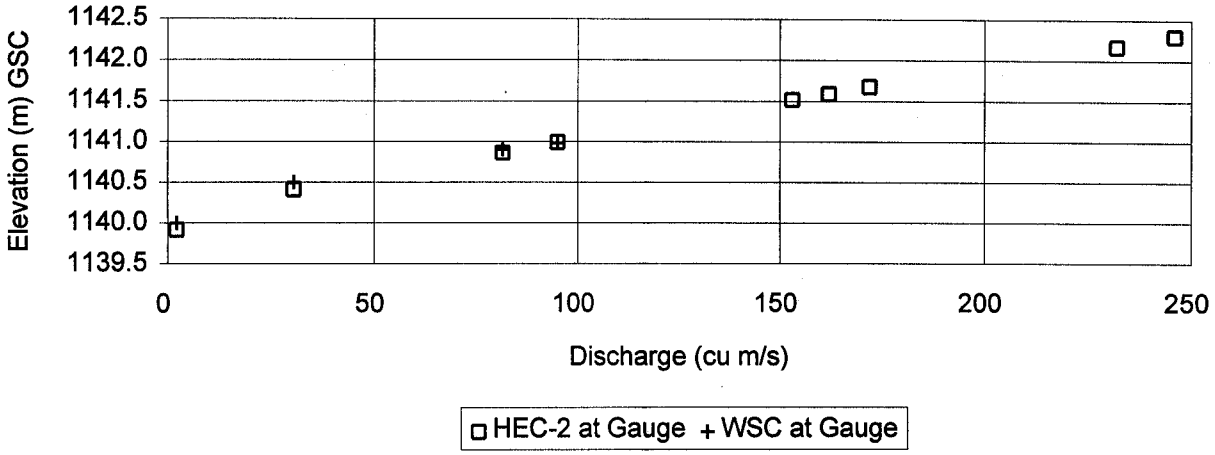
MICHEL CREEK BELOW NATAL (08NK020)

Discharge (cu m/s)	Definition	WSC gauge Elevation (m)	HEC-2 XS-25 Elevation (m)	Error HEC-2 - WSC (m)
2.21		1140.00	1139.92	-0.08
30.5		1140.50	1140.41	-0.09
81.6		1140.90	1140.86	-0.04
95		1140.98	1140.99	0.01
153	Calibration	-	1141.52	-
162	20-yr daily	-	1141.59	-
172	20-yr inst.	-	1141.68	-
232	200-yr daily	-	1142.17	-
246	200-yr inst	-	1142.30	-

Rating Curve Comparison - Elk River



Rating Curve Comparison - Michel Creek



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BC ENVIRONMENT – WATER MANAGEMENT DIVISION

FLOODPLAIN MAPPING

ELK RIVER, MICHEL CK. AND CUMMINGS CK.

COMPARISON OF RATING CURVES

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	FEB., 1995		5.1

FILE REF:FIG-5-1

The Elk River, Michel Creek and Cummings Creek models were calibrated solely to the 1991 high water marks. Since other calibration data were unavailable, verification of suspect recorded water levels (HWM 30 and HWM 35A) was not feasible. Computed calibration profiles are given in Tables 5.3, 5.4 and 5.5. Water surface elevations were interpolated between sections to give the computed levels at high watermark locations. The calibration profiles and high water marks are plotted in Figures 5.2, 5.3 and 5.4.

Initial estimates of the starting conditions and the Manning's roughness coefficients were slightly adjusted. Cross-sectional data for some sections was modified to represent the active channel and overbank portions only, eliminating dead-end channels and areas of ponding (Table 5.6). The agreement between recorded and computed profiles as tabulated was considered acceptable. The errors appear to be within the accuracy of the high water mark information.

Roughness coefficients for the Elk River ranged from 0.037 to 0.052. The starting level was adjusted to match the level at HWM 27. HWM 30 on the Elk River appears to be in error (the recorded elevation is less than the downstream elevation at HWM 29). Excluding HWM 30, the mean absolute error was 0.12 m.

Roughness coefficients for the Michel Creek study reach varied from 0.035 to 0.045. Starting conditions could not be made to match HWM 24/25 more accurately. The mean absolute error for the entire reach was 0.14 m.

Cummings Creek roughness coefficients ranged from 0.045 to 0.070. HWM 35A is 0.27 m less than downstream HWM 35 and was disregarded. The mean absolute error was 0.17 m.

5.3 Starting Elevation Sensitivity Studies

The Elk River, Michel Creek and Cummings Creek peak flows are typically snowmelt generated. Flood flows tend to occur roughly at the same time of the year and it is conceivable to have simultaneous 20-year or 200-year floods on all three watercourses. However, backwater effects caused by the Elk River in Michel Creek, or vice versa, are limited to only short reaches due to the steep channel slopes. Similarly, backwater from Elk River has no influence on the Cummings Creek profile. Selected starting

TABLE 5.3

Elk River Calibration Profile, Flow = 166 m^3/s at Station 08NK016

Model Summary: XS	Station (m)	Channel Min. Elev. (m)	Computed WS Elev. (m)	Manning n
36	0	1113.29	1119.95	0.040
35	45	1111.50	1120.01	0.040
34	115	1117.63	1119.99	0.040
33	340	1118.70	1120.82	0.037
32	370	1118.46	1120.98	0.037
31	385	1118.68	1121.04	0.037
30	420	1118.60	1121.12	0.037
29	930	1119.62	1122.35	0.037
28	980	1118.89	1122.48	0.037
27	985	1119.03	1122.58	0.037
26	1020	1119.48	1122.66	0.040
25	1255	1121.15	1123.60	0.045
24	1395	1120.74	1124.01	0.047
23	1795	1121.77	1125.40	0.047
22	2215	1123.25	1126.96	0.047
21	2915	1126.80	1129.63	0.047
20	3405	1128.34	1131.00	0.047
19	3835	1130.08	1132.09	0.045
18	4395	1131.10	1133.97	0.040
17	5265	1134.77	1136.76	0.037
16	6305	1138.39	1140.60	0.037
15	7185	1140.50	1143.21	0.037
14	8285	1145.48	1148.17	0.037
13	9205	1149.23	1152.33	0.037
12	9575	1151.30	1153.80	0.037
11	9582	1151.42	1153.86	0.037
10	9672	1152.39	1154.67	0.037
9	10432	1155.20	1157.39	0.042
8	11652	1162.42	1164.24	0.045
7	12467	1165.90	1168.35	0.045
6	13357	1170.64	1172.88	0.050
5	13727	1172.75	1175.18	0.050
4	14857	1179.33	1181.71	0.050
3	15727	1183.62	1186.31	0.050
2	16427	1189.46	1190.99	0.052
1	16917	1190.10	1193.20	0.052

High Water Mark Summary: HWM No.	Station (m)	HWM WS Elev. (m)	Computed WS Elev. (m)	Error (m)
27	122	1119.99	1120.02	0.03
29	370	1120.89	1120.98	0.09
30	445	1120.73	1121.18	0.45
45	980	1122.19	1122.48	0.29
46	1075	1122.85	1122.88	0.03
43	1815	1125.72	1125.47	-0.25
44	3030	1130.07	1129.95	-0.12
32	7425	1144.17	1144.29	0.12
42	9555	1153.76	1153.72	-0.04
41	9622	1154.24	1154.22	-0.02
31	12457	1168.38	1168.30	-0.08
39/40	16827	1192.96	1192.79	-0.17

TABLE 5.4

Michel Creek Calibration Profile Flow = 153 m^3/s at Station 08NK020

Model Summary:

XS	Station (m)	Channel Min. Elev. (m)	Computed WS Elev. (m)	Manning n
1	0	1116.54	1118.60	0.037
2	135	1116.99	1119.16	0.037
3	143	1116.80	1119.28	0.037
4	188	1117.13	1119.48	0.040
5	493	1119.68	1121.86	0.040
6	803	1122.08	1123.95	0.040
7	828	1121.82	1123.98	0.040
8	842	1121.32	1124.37	0.040
9	882	1122.57	1124.63	0.040
10	1182	1124.02	1126.17	0.040
11	1442	1125.92	1128.09	0.040
12	1762	1128.17	1130.41	0.040
13	2052	1129.90	1132.50	0.040
14	2072	1129.98	1132.74	0.040
15	2079	1129.83	1133.24	0.040
16	2109	1131.27	1133.45	0.042
17	2249	1132.10	1134.12	0.042
18	2374	1133.20	1135.08	0.042
19	2554	1134.80	1136.50	0.042
20	2734	1136.33	1138.24	0.042
21	2934	1137.85	1139.86	0.040
22	3079	1138.95	1140.83	0.035
23	3099	1139.41	1141.49	0.035
24	3113	1139.58	1141.51	0.035
25	3128	1139.68	1141.52	0.035
26	3273	1140.00	1142.26	0.035
27	3723	1143.79	1145.73	0.035
28	4178	1146.07	1148.95	0.035
30	4563	1150.40	1152.21	0.035
31	4993	1153.27	1155.27	0.035
32	5328	1155.50	1157.74	0.035
33	5748	1159.50	1161.46	0.040
34	6103	1162.33	1164.76	0.042
35	6523	1165.65	1168.26	0.045
36	6538	1164.79	1168.43	0.045
37	6828	1169.29	1171.49	0.045
38	7128	1171.10	1173.69	0.045
39	7393	1173.30	1175.41	0.045

High Water Mark Summary:

HWM No.	Station (m)	HWM WS Elev. (m)	Computed WS Elev. (m)	Error (m)
26	-75	1117.78	-	-
24/25	120	1118.81	1119.10	0.29
23	168	1119.05	1119.39	0.34
22	508	1121.96	1121.96	0.00
20	808	1123.90	1123.96	0.06
21	882	1124.54	1124.63	0.09
19	1392	1127.65	1127.72	0.07
18	2030	1132.33	1132.34	0.01
17	2072	1132.80	1132.74	-0.06
16	2134	1133.22	1133.57	0.35
15	2659	1137.48	1137.52	0.04
14	3029	1140.34	1140.50	0.16
13	3079	1140.82	1140.83	0.01
12	3128	1141.24	1141.52	0.28
11	3663	1144.98	1145.27	0.29
10	4563	1152.16	1152.21	0.05
9	5336	1157.64	1157.81	0.17
8	5748	1161.47	1161.46	-0.01
7	6463	1167.67	1167.76	0.09
6	6658	1169.87	1169.70	-0.17
5	7183	1173.82	1174.05	0.23
3	7583	1177.28	-	-

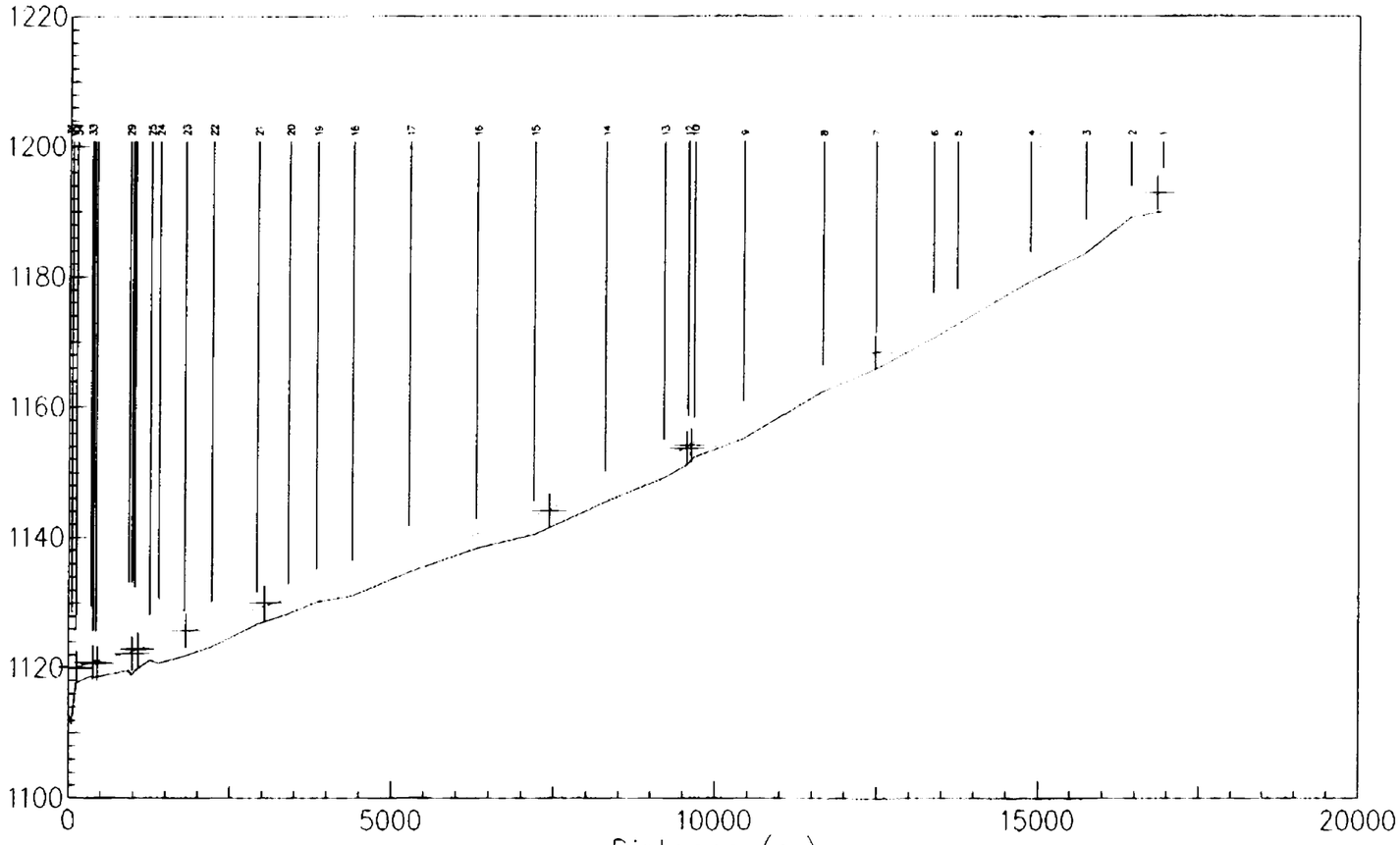
TABLE 5.5
Cummings Creek Calibration Profile Estimated Flow = 23.6 m^3/s

Model Summary:				
XS	Station (m)	Channel Min. Elev. (m)	Computed WS Elev. (m)	Manning n
1	0	1130.68	1132.73	0.045
2	190	1133.85	1134.95	0.045
3	215	1134.10	1135.13	0.045
4	220	1134.40	1135.33	0.045
5	250	1134.93	1135.85	0.045
6	540	1140.33	1141.16	0.050
7	800	1143.48	1144.68	0.050
8	1050	1147.80	1148.67	0.050
9	1064	1148.00	1149.06	0.050
10	1139	1149.13	1150.49	0.060
11	1414	1155.14	1155.88	0.060
12	1704	1159.50	1160.74	0.060
13	1974	1164.59	1165.38	0.060
14	2164	1166.91	1168.33	0.060
15	2414	1171.12	1172.24	0.070
16	2829	1180.31	1181.31	0.070

High Water Mark Summary:				
HWM No.	Station (m)	HWM WS Elev. (m)	Computed WS Elev. (m)	Error (m)
33	205	1135.30	1135.06	-0.24
34	415	1138.45	1138.87	0.42
35	1025	1148.26	1148.27	0.01
35A	1040	1147.99	1148.51	0.52
36	1074	1149.35	1149.25	-0.10
37	1704	1160.73	1160.74	0.01
38	1986	1165.79	1165.57	-0.22

ELK RIVER CALIBRATION PROFILE

Q = 166 cu m/s at 08NK016, HWM elevations for 1991



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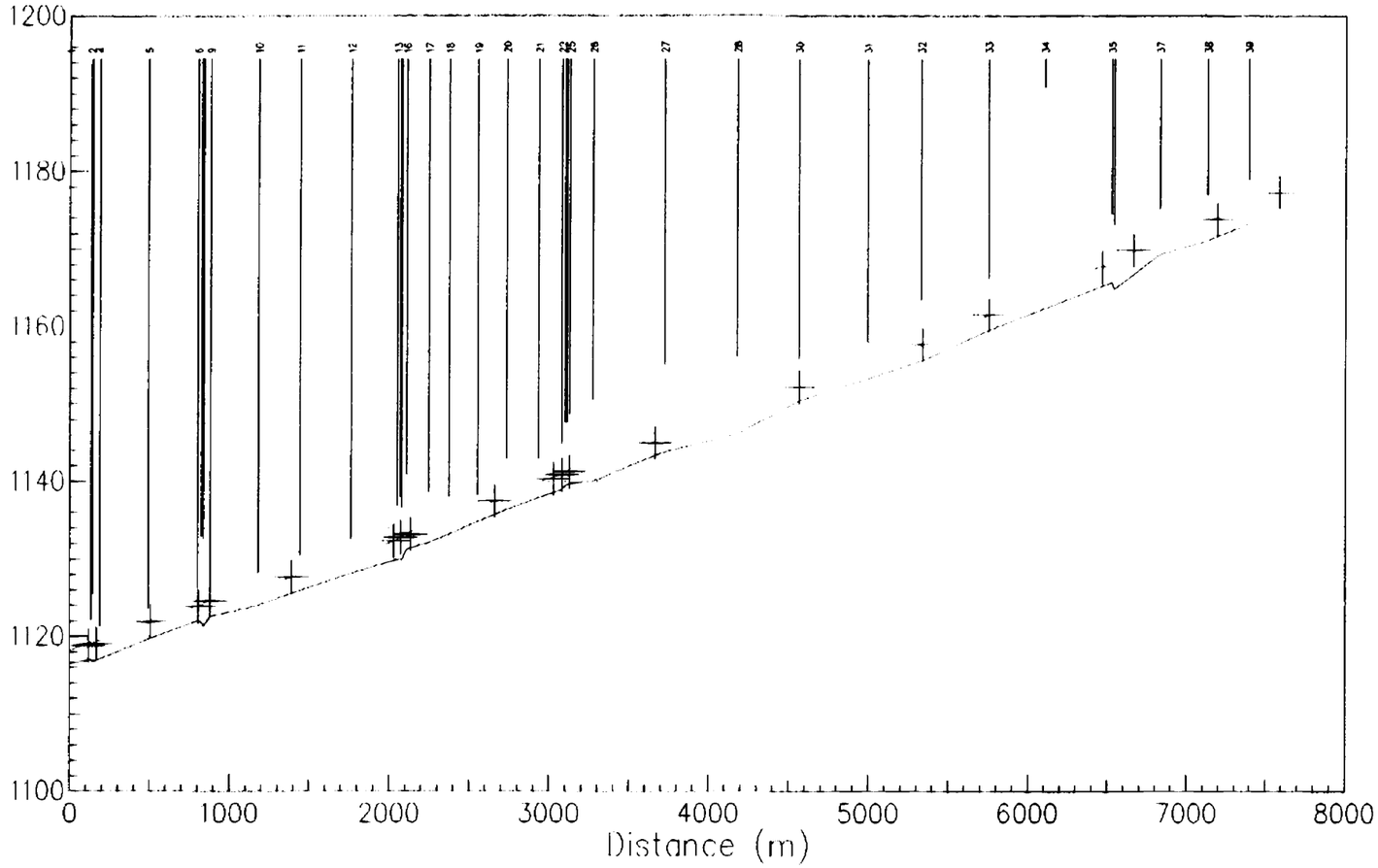
FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEK

ELK RIVER
CALIBRATION PROFILE

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC., 1994		5.2

MICHEL CREEK CALIBRATION PROFILE

Q = 153 cu m/s at 08NK020, HWM elevations for 1991



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WATER MANAGEMENT DIVISION

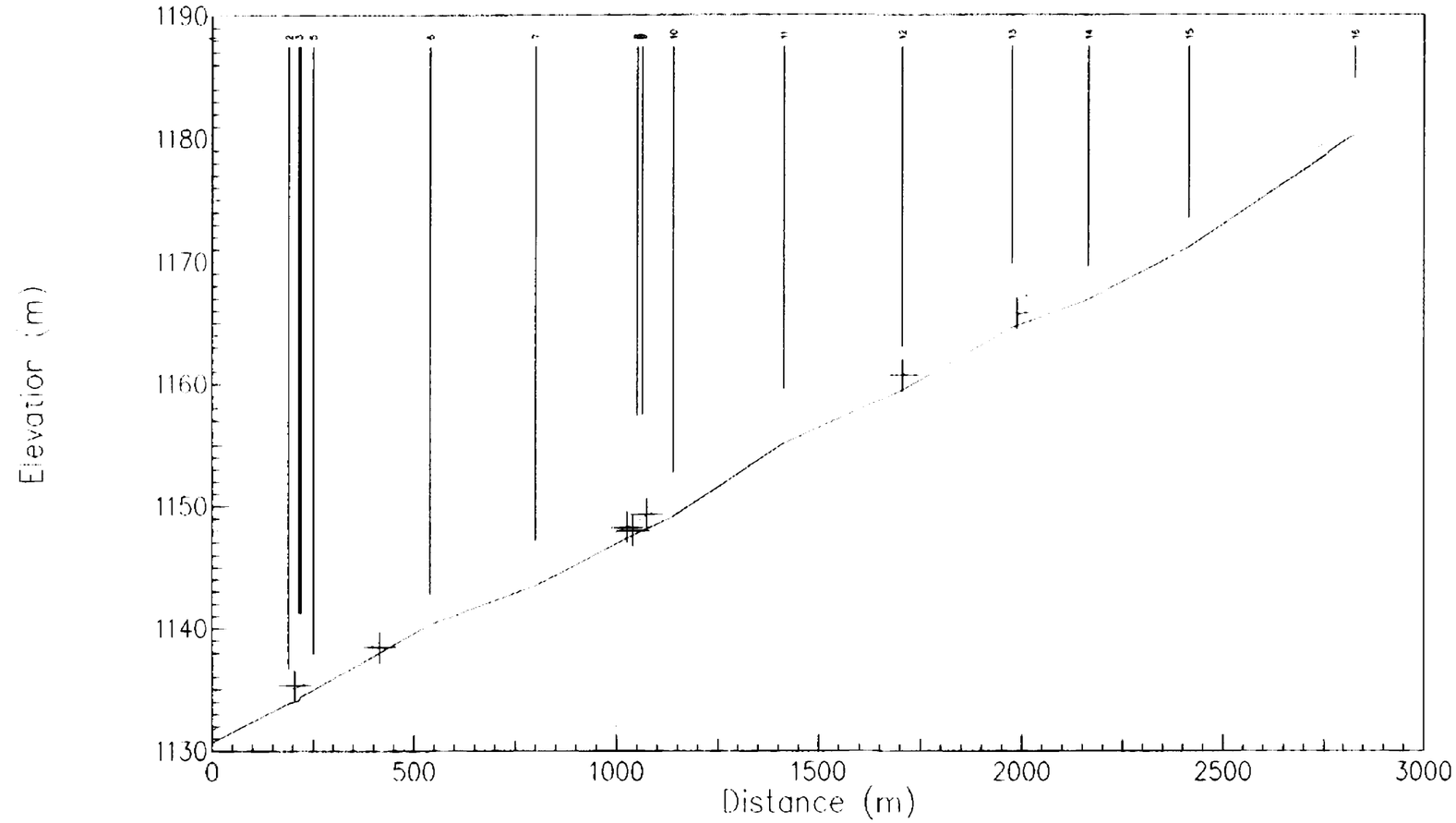
FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

MICHEL CREEK
CALIBRATION PROFILE

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.3

CUMMINGS CREEK CALIBRATION PROFILE

Q = 23.6 cu m/s, HWM elevations for 1991



SRK-ROBINSON INC. Consulting Engineers		FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS	
B.C. ENVIRONMENT WATER MANAGEMENT DIVISION		CUMMINGS CREEK CALIBRATION PROFILE	
PROJECT NO. B239101	DATE DEC.,1994	APPROVED	FIGURE 5.4

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TABLE 5.6
Cross-Section Modifications

ELK RIVER:		MICHEL CREEK:		CUMMINGS CREEK:	
Cross-Section	**Modification to HEC-2 GR-Data**	**Cross-Section**	**Modification to HEC-2 GR-Data**	**Cross-Section**	**Modification to HEC-2 GR-Data**
22	Section simplified, max. 100 data points allowed.	2/3	Piers included.	5	Left bank pond filled in.
18	Right bank pond filled in.	7/8	Piers included.	7	Left bank dead-end channel filled in.
16	Section simplified, max. 100 data points allowed.	11	Right bank dead end channels filled in.	8/9	Piers included.
15	Left bank dead-end channels, right bank pond filled in. Section simplified, max. 100 data points allowed.	12	Left and right bank dead-end channels filled in.	13	Input elevations low by approx. 30 m and not matching hard copy. Hard copy data used.
14	Right Bank dead-end channel filled in.	18	Back channel corrected for skewness, left bank dead-end channel filled in.		
11/12	Piers included.	29	Section not included.		
8	Left bank dead-end channels filled in.	28	Piers from Cross-Section 29 added.		
6	Back channel corrected for skewness.				
3	Left and right bank dead-end channels filled in.				
2	Back channel corrected for skewness, left bank dead-end channel filled in.				
Cross-Section	**Artificial Levees Limiting Flow to Active Portion of Floodplain**	**Cross-Section**	**Artificial Levees Limiting Flow to Active Portion of Floodplain**	**Cross-Section**	**Artificial Levees Limiting Flow to Active Portion of Floodplain**
20	Section extended vertically at right bank.	1	Right bank encroachment (Elk confluence).	1	Right bank encroachment.
17	Right bank encroachment at railway embankment.	4	Right bank encroachment (influence of bridge abutment).	15	Left bank encroachment.
16	Right bank encroachment at railway embankment.	5	Right bank encroachment (influence of bridge abutment).		
15	Right bank encroachment at railway embankment.	6	Left / Right bank encr. (influence of bridge abutments).		
14	Right bank encroachment at railway embankment.	9	Left / Right bank encr. (influence of bridge abutments).		
13	Right bank encroachment at railway embankment.	16	Left bank encroachment at dyke, right bank encroachment at railway.		
10	Right bank encroachment at end of surveyed section.				
9	Right bank encroachment at end of surveyed section.	17	Left bank encroachment.		
8	Right bank encroachment at end of surveyed section.				
6	Right bank encroachment at end of surveyed section.				
4	Right bank encroachment at end of surveyed section.				
2	Left bank encroachment.				
1	Left bank encroachment.				
Cross-Sections added to prevent model from assuming critical flow:		**Cross-Sections added to prevent model from assuming critical flow:**		**Cross-Sections added to prevent model from assuming critical flow:**	
13.5	(calibration flow)	21.5	(20-year and 200-year floods)	10.5	(20-year and 200-year floods)
		25.5	(20-year and 200-year floods)		
		30.5	(20-year and 200-year floods)		
		38.5	(20-year and 200-year floods)		

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May, 1995

conditions for each model and their sensitivity to variations in the starting level are described below.

Floodplain maps were issued for the Elk River in 1980, covering a downstream reach but overlapping the present study by about 1.2 km. The maps gave a flood construction level (including an allowance for hydraulic and hydrological uncertainty) of approximately 1120.0 m at the starting point of the present study. At this location, the river passes through a constriction and the bed drops off sharply, making an accurate assessment of the starting level difficult. The 1980 map shows a 2 m rise in the 200-year profile over the next upstream 70 m. The 200-year instantaneous flood profile was computed for three sets of Elk River starting levels and then compared:

- a minimum water level of 1118.87 m, corresponding to critical flow;
- a water level of 1120.63 m, corresponding to an average upstream slope of 0.0033; and
- a water level of 1121.0 m, corresponding to a discharge adjusted, high estimate flood level based on the 1980 profile.

For the three different starting levels, the computed profiles merged within a short distance, and were essentially the same at the upstream Highway 43 bridge crossing. The highest water surface elevation (1121.0 m) was selected, and starting conditions for intermediate flows were interpolated between the flood levels for the calibration flow and the 200-year instantaneous flow.

The 1980 floodplain map, based on backwater calculations for the Elk River, gave a 200-year flood construction level of 1118.5 m at approximately the starting point of the present Michel Creek study reach. Using the Michel Creek model, the minimum starting level, corresponding to critical flow, was computed to be 1118.5 m for the 200-year instantaneous flood. The sensitivity of the starting level was assessed by comparing two profiles, one starting at 1118.5 m and the other at 1119.5 m. The 1 m differential did not influence the water level at Cross-Section 2, 135 m upstream, indicating that the model was quite insensitive to the starting elevation. An approximate starting level equal to critical flow depth plus 1 m was assumed for the various design flows.

The Cummings Creek starting level for the maximum instantaneous 200-year flood was estimated based on the 200-year instantaneous Elk River flood stage at Cross-Section 20, plus 1.5 m, assuming an average slope of 0.02 over a distance of 75 m between Elk River and Cummings Creek Cross-Section 1. The Cummings Creek channel is very steep and a starting level differential of 2 m caused only very local changes to the profile, not affecting levels at Cross-Section 2, 190 m upstream. Starting elevations for the other design profiles were interpolated based on the calibration and the 200-year instantaneous profile.

5.4 Roughness and Discharge 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 selected as 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.

The sensitivity to changes in the Manning's roughness coefficients was evaluated by varying the calibrated n-values by a factor of 0.9, 1.1, and 1.2. All three watercourses were found to be relatively insensitive to changes in the roughness. Compared to the base profile the average drop in the computed water surface elevation for the Elk River was 0.11 m for a 10% reduction in roughness. The average increases for respectively 10% and 20% higher roughness values were 0.11 m and 0.21 m. The equivalent variations for Michel Creek were -0.08 m, 0.08 m and 0.16 m; and for Cummings Creek -0.05 m, 0.03 m and 0.08 m. Results are summarized in Table 5.7.

The sensitivity of the computed water surface profiles to variations in the design flow was evaluated by reducing the discharge by 10% and increasing it by 10% and 20%. In terms of the flood frequency results for the Elk River near Natal, the corresponding flows have return periods of roughly 100, 400 and exceeding 500 years, respectively. Compared to the 200-year base profile, the mean absolute differences were -0.13 m, 0.12 m and 0.24 m for the Elk River; -0.12 m, 0.11 m and 0.23 m for Michel Creek and -0.07 m, 0.04 m and 0.11 m for Cummings Creek. Table 5.8 summarizes the results of the discharge sensitivity analysis.

It is concluded from the above that an increase of 20% in either the roughness factor or the discharge would lead to average increases in water surface elevation of less than 0.25 m.

5.5 Flood Profiles

Flood profiles were prepared to show the computed water surface elevations for the 20-year and 200-year daily and instantaneous floods (Figures 5.5 to 5.10). The river thalweg, bridge crossings and bank profiles are also shown. Figures 5.11 to 5.13 are 3-dimensional representations of the three profiles. The flood profiles do not include a freeboard allowance. The standard ministry freeboard allowance for hydraulic and hydrological uncertainties of either 0.3 m for the instantaneous flood level, or 0.6 m for the daily flood level, whichever gives the greater surface elevation, was applied to the computed water surface elevations. The computed elevations are tabulated in Table 5.9 (without freeboard) and Table 5.10 (with freeboard). As indicated in Table 5.10, the daily flood level plus freeboard was found to dominate.

The flood levels and floodplain limits shown on the floodplain mapping sheets are based on the selected 200-year flood levels listed in Table 5.10. The 20-year flood levels, including the freeboard allowance, are also shown on the mapping sheets for assistance in the administration of the Health Act (septic tank) requirements.

Some changes were necessary to the calibrated models to accommodate the higher discharges of the design profiles. Additional cross-sections (Table 5.6) were inserted manually into the models to prevent the backwater computations from assuming critical flow conditions, where actual river flows would unlikely become critical. Artificial levees were inserted at some sections to limit the flow to the portions of the floodplain actively conveying flow (Table 5.6).

The computed profiles assume unobstructed flow conditions and are only valid for the rivers in their present state.

TABLE 5.7

Elk River, Michel Creek and Cummings Creek - Roughness Sensitivity Analysis (page 1 of 2)

ELK RIVER:					MICHEL CREEK:					CUMMINGS CREEK:				
Cross-Section	Computed WS Elev. (m)	Difference compared to base case (m)			Cross-Section	Computed WS Elev. (m)	Difference compared to base case (m)			Cross-Section	Computed WS Elev. (m)	Difference compared to base case (m)		
	200-year max. daily	90% roughness	110% roughness	120% roughness		200-year max. daily	90% roughness	110% roughness	120% roughness		200-year max. daily	90% roughness	110% roughness	120% roughness
36	1120.95	0.00	0.00	0.00	1	1119.45	0.00	0.00	0.00	1	1132.95	0.00	0.00	0.00
35	1121.20	-0.02	0.02	0.05	2	1119.70	-0.06	0.06	0.12	2	1135.39	-0.08	0.03	0.09
34	1121.33	-0.06	0.06	0.13	3	1119.78	-0.05	0.06	0.12	3	1135.63	0.00	0.01	0.00
33	1122.11	-0.15	0.14	0.27	4	1119.98	-0.10	0.08	0.15	4	1135.83	-0.08	0.09	0.13
32	1122.26	-0.13	0.13	0.26	5	1121.94	-0.02	0.08	0.16	5	1136.34	-0.04	0.05	0.11
31	1122.41	-0.10	0.10	0.21	6	1124.43	-0.11	0.07	0.09	6	1141.56	-0.05	0.05	0.08
30	1122.47	-0.11	0.11	0.23	7	1124.42	-0.15	0.10	0.13	7	1145.11	-0.03	0.05	0.11
29	1123.81	-0.20	0.20	0.38	8	1124.61	0.02	0.10	0.18	8	1149.28	-0.08	0.08	0.14
28	1124.07	-0.19	0.18	0.35	9	1125.31	-0.04	0.05	0.10	9	1149.60	-0.07	0.08	0.15
27	1124.24	-0.14	0.15	0.29	10	1126.40	-0.11	0.08	0.17	10	1151.12	-0.05	0.05	0.10
26	1124.21	-0.16	0.17	0.33	11	1128.31	0.00	0.04	0.01	11	1156.49	-0.03	0.03	0.07
25	1125.29	-0.16	0.15	0.30	12	1130.76	-0.14	0.08	0.20	12	1161.10	-0.08	0.06	0.11
24	1125.56	-0.17	0.17	0.32	13	1132.82	-0.06	0.07	0.12	13	1165.92	-0.05	0.03	0.08
23	1126.59	-0.14	0.14	0.28	14	1133.13	0.00	0.03	0.12	14	1168.81	-0.09	0.05	0.11
22	1127.84	-0.13	0.12	0.23	15	1133.68	-0.02	0.01	-0.01	15	1172.86	-0.04	0.06	0.11
21	1130.16	-0.10	0.09	0.18	16	1133.96	-0.04	0.03	0.05	16	1181.65	-0.05	-0.21	-0.21
20	1131.49	-0.11	0.11	0.21	17	1134.59	-0.08	0.08	0.14					
19	1133.04	-0.12	0.11	0.22	18	1135.29	-0.09	0.09	0.17		Average:	-0.05	0.03	0.08
18	1134.95	-0.12	0.11	0.21	19	1136.85	-0.08	0.08	0.16					

TABLE 5.7

Elk River, Michel Creek and Cummings Creek - Roughness Sensitivity Analysis (page 2 of 2)

ELK RIVER:					MICHEL CREEK:				
Cross-Section	Computed WS Elev. (m)	Difference compared to base case (m)			Cross-Section	Computed WS Elev. (m)	Difference compared to base case (m)		
	200-year max. daily	90% roughness	110% roughness	120% roughness		200-year max. daily	90% roughness	110% roughness	120% roughness
17	1137.58	-0.13	0.12	0.25	20	1138.46	-0.08	0.06	0.13
16	1141.10	-0.08	0.07	0.14	21	1140.29	-0.07	0.05	0.11
15	1143.94	-0.10	0.09	0.17	22	1141.26	-0.03	0.11	0.22
14	1148.58	-0.07	0.06	0.12	23	1142.16	-0.01	-0.01	0.00
13	1152.62	-0.11	0.10	0.21	24	1142.19	-0.02	0.00	0.03
12	1154.91	-0.10	0.10	0.20	25	1142.17	-0.03	0.01	0.06
11	1154.96	-0.10	0.11	0.21	26	1143.01	-0.09	0.09	0.19
10	1155.79	-0.06	0.08	0.15	27	1146.04	-0.14	0.14	0.27
9	1158.27	-0.18	0.15	0.27	28	1149.50	-0.06	0.09	0.19
8	1164.75	-0.03	0.04	0.07	30	1152.76	-0.17	0.12	0.24
7	1168.91	-0.11	0.09	0.17	31	1155.73	-0.14	0.12	0.24
6	1173.63	-0.05	0.06	0.12	32	1158.30	-0.13	0.13	0.25
5	1175.75	-0.13	0.11	0.20	33	1161.93	-0.10	0.14	0.26
4	1182.52	-0.08	0.08	0.16	34	1165.29	-0.15	0.12	0.23
3	1186.62	-0.13	0.10	0.20	35	1168.87	-0.18	0.20	0.38
2	1191.46	-0.04	0.06	0.12	36	1169.02	-0.18	0.19	0.38
1	1194.13	-0.15	0.13	0.25	37	1172.23	-0.16	0.16	0.28
					38	1174.19	-0.13	0.12	0.21
	Average:	-0.11	0.11	0.21	39	1176.39	-0.12	0.09	0.18
						Average:	-0.08	0.08	0.16

TABLE 5.8

Elk River, Michel Creek and Cummings Creek - Discharge Sensitivity Analysis (page 1 of 2)

ELK RIVER:					MICHEL CREEK:					CUMMINGS CREEK:				
Cross-Section	Computed WS Elev. (m)	Difference compared to base case			Cross-Section	Computed WS Elev. (m)	Difference compared to base case			Cross-Section	Computed WS Elev. (m)	Difference compared to base case		
	200-year max. daily	90 % discharge	110 % discharge	120 % discharge		200-year max. daily	90 % discharge	110 % discharge	120 % discharge		200-year max. daily	90 % discharge	110 % discharge	120 % discharge
36	1120.95	0.00	0.00	0.00	1	1119.45	0.00	0.00	0.00	1	1132.95	0.00	0.00	0.00
35	1121.20	-0.05	0.06	0.13	2	1119.70	-0.04	0.05	0.11	2	1135.39	-0.08	0.03	0.09
34	1121.33	-0.08	0.09	0.19	3	1119.78	-0.06	0.06	0.13	3	1135.63	-0.05	0.07	0.13
33	1122.11	-0.15	0.14	0.29	4	1119.98	-0.10	0.10	0.20	4	1135.83	-0.13	-0.02	0.04
32	1122.26	-0.15	0.16	0.30	5	1121.94	-0.05	0.06	0.11	5	1136.34	-0.01	0.10	0.16
31	1122.41	-0.17	0.17	0.34	6	1124.43	-0.10	0.06	0.15	6	1141.56	-0.06	0.02	0.06
30	1122.47	-0.17	0.17	0.33	7	1124.42	-0.08	0.00	0.06	7	1145.11	-0.04	0.09	0.13
29	1123.81	-0.20	0.20	0.39	8	1124.61	-0.09	0.17	0.31	8	1149.28	-0.08	0.03	0.11
28	1124.07	-0.23	0.21	0.42	9	1125.31	-0.15	0.15	0.29	9	1149.60	-0.07	0.07	0.13
27	1124.24	-0.24	0.23	0.44	10	1126.40	-0.08	0.07	0.16	10	1151.12	-0.09	0.07	0.15
26	1124.21	-0.22	0.21	0.42	11	1128.31	-0.02	0.03	0.11	11	1156.49	-0.07	0.05	0.09
25	1125.29	-0.25	0.24	0.47	12	1130.76	-0.08	0.10	0.16	12	1161.10	-0.05	0.05	0.10
24	1125.56	-0.23	0.23	0.45	13	1132.82	-0.10	0.04	0.13	13	1165.92	-0.07	0.05	0.10
23	1126.59	-0.17	0.17	0.34	14	1133.13	-0.10	0.10	0.20	14	1168.81	-0.07	0.05	0.09
22	1127.84	-0.13	0.11	0.22	15	1133.68	-0.11	0.11	0.22	15	1172.86	-0.06	0.06	0.13
21	1130.16	-0.11	0.09	0.18	16	1133.96	-0.14	0.13	0.26	16	1181.65	-0.05	-0.18	0.08
20	1131.49	-0.10	0.11	0.20	17	1134.59	-0.13	0.13	0.25					
19	1133.04	-0.11	0.11	0.19	18	1135.29	-0.06	0.06	0.12		Average:	-0.07	0.04	0.11
18	1134.95	-0.14	0.12	0.23	19	1136.85	-0.09	0.09	0.17					

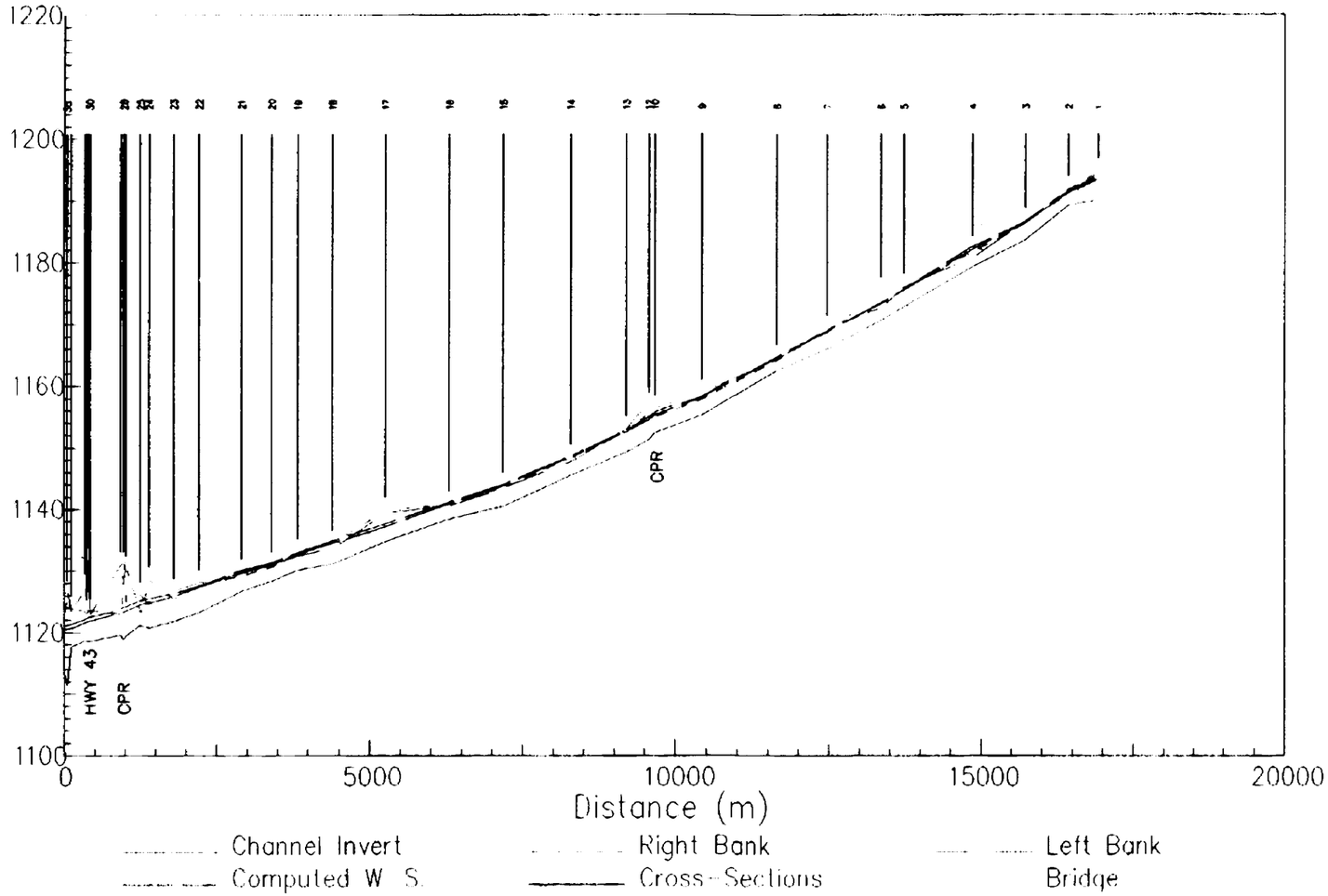
TABLE 5.8

Elk River, Michel Creek and Cummings Creek - Discharge Sensitivity Analysis (page 2 of 2)

ELK RIVER:					MICHEL CREEK:				
Cross-Section	Computed WS Elev. (m)	Difference compared to base case			Cross-Section	Computed WS Elev. (m)	Difference compared to base case		
	200-year max. daily	90% discharge	110% discharge	120% discharge		200-year max. daily	90% discharge	110% discharge	120% discharge
17	1137.58	-0.11	0.11	0.22	20	1138.46	-0.06	0.06	0.12
16	1141.10	-0.09	0.08	0.16	21	1140.29	-0.09	0.06	0.13
15	1143.94	-0.08	0.07	0.14	22	1141.26	-0.11	0.10	0.21
14	1148.58	-0.08	0.07	0.15	23	1142.16	-0.19	0.19	0.36
13	1152.62	-0.07	0.07	0.15	24	1142.19	-0.20	0.22	0.39
12	1154.91	-0.13	0.11	0.21	25	1142.17	-0.19	0.21	0.38
11	1154.96	-0.13	0.13	0.26	26	1143.01	-0.13	0.12	0.25
10	1155.79	-0.16	0.16	0.31	27	1146.04	-0.14	0.13	0.25
9	1158.27	-0.06	0.06	0.12	28	1149.50	-0.08	0.10	0.27
8	1164.75	-0.10	0.08	0.15	30	1152.76	-0.20	0.16	0.29
7	1168.91	-0.04	0.04	0.07	31	1155.73	-0.16	0.14	0.26
6	1173.63	-0.12	0.11	0.21	32	1158.30	-0.13	0.12	0.24
5	1175.75	-0.07	0.06	0.12	33	1161.93	-0.14	0.13	0.26
4	1182.52	-0.12	0.12	0.22	34	1165.29	-0.12	0.13	0.25
3	1186.62	-0.08	0.07	0.15	35	1168.87	-0.19	0.17	0.34
2	1191.46	-0.08	0.08	0.15	36	1169.02	-0.18	0.16	0.32
1	1194.13	-0.12	0.11	0.21	37	1172.23	-0.20	0.20	0.37
					38	1174.19	-0.15	0.14	0.22
	Average:	-0.13	0.12	0.24	39	1176.39	-0.17	0.17	0.31
						Average:	-0.12	0.11	0.23

ELK RIVER PROFILE

20 & 200-Year Maximum Daily Flows



NOTES:
1. FREEBOARD NOT INCLUDED.
2. LOWER AND UPPER W.S. LINES ARE 20 & 200-YEAR FLOOD PROFILES, RESPECTIVELY.

SRK-ROBINSON INC.
Consulting Engineers

B.C. ENVIRONMENT
WATER MANAGEMENT DIVISION

FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

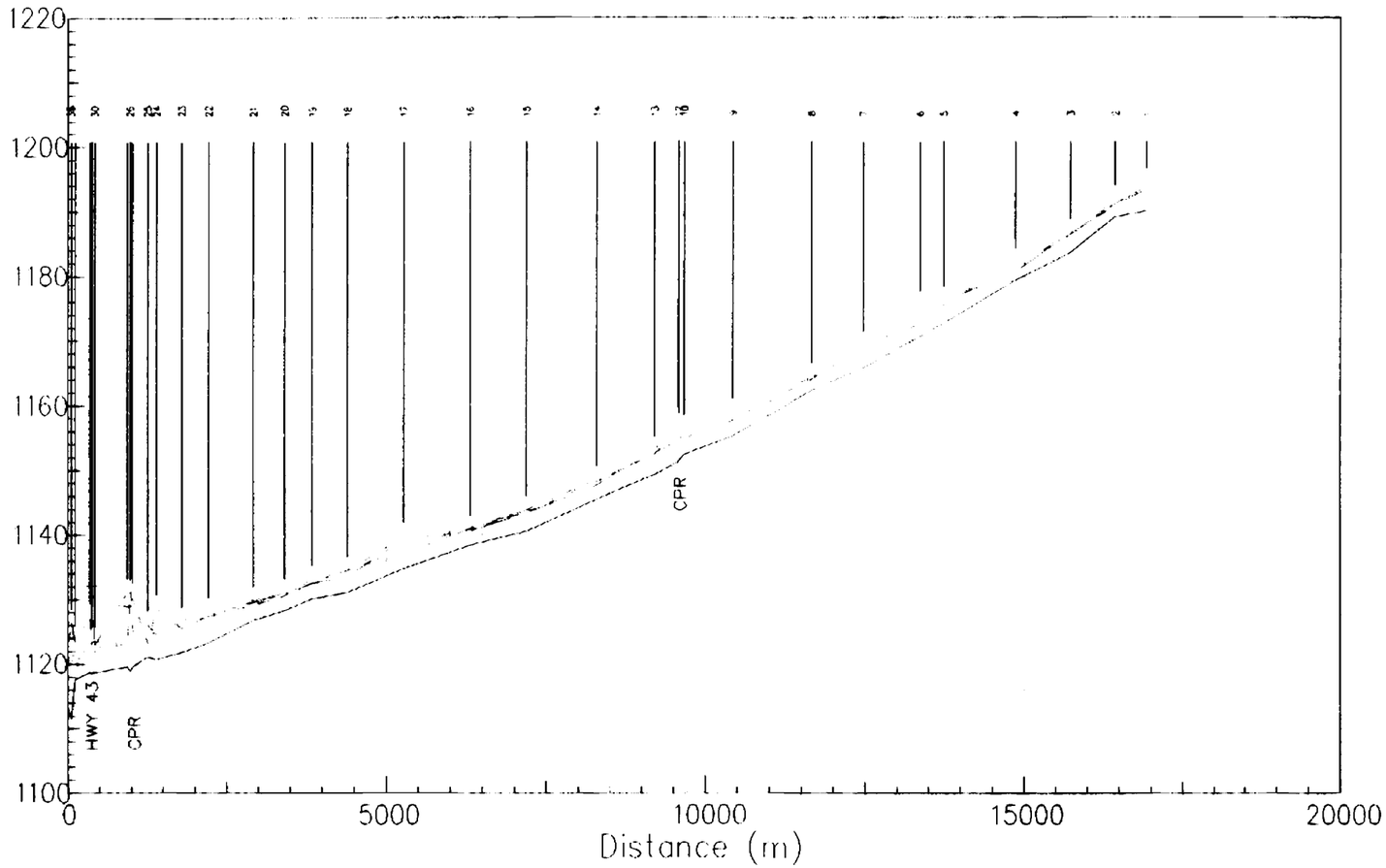
ELK RIVER PROFILE
20 & 200-YEAR MAXIMUM DAILY FLOWS

PROJECT NO	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.5

NAME: C:\PROJECTS\ELKRIV\B239101\FL200AY.DWG DATE: DEC 08, 1994 TIME: 12:09 AM

ELK RIVER PROFILE

20 & 200-Year Maximum Instantaneous Flows



NOTES.
1. FREEBOARD NOT INCLUDED.
2. LOWER AND UPPER W.S. LINES ARE 20 & 200-YEAR FLOOD PROFILES, RESPECTIVELY.

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WATER MANAGEMENT DIVISION

FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

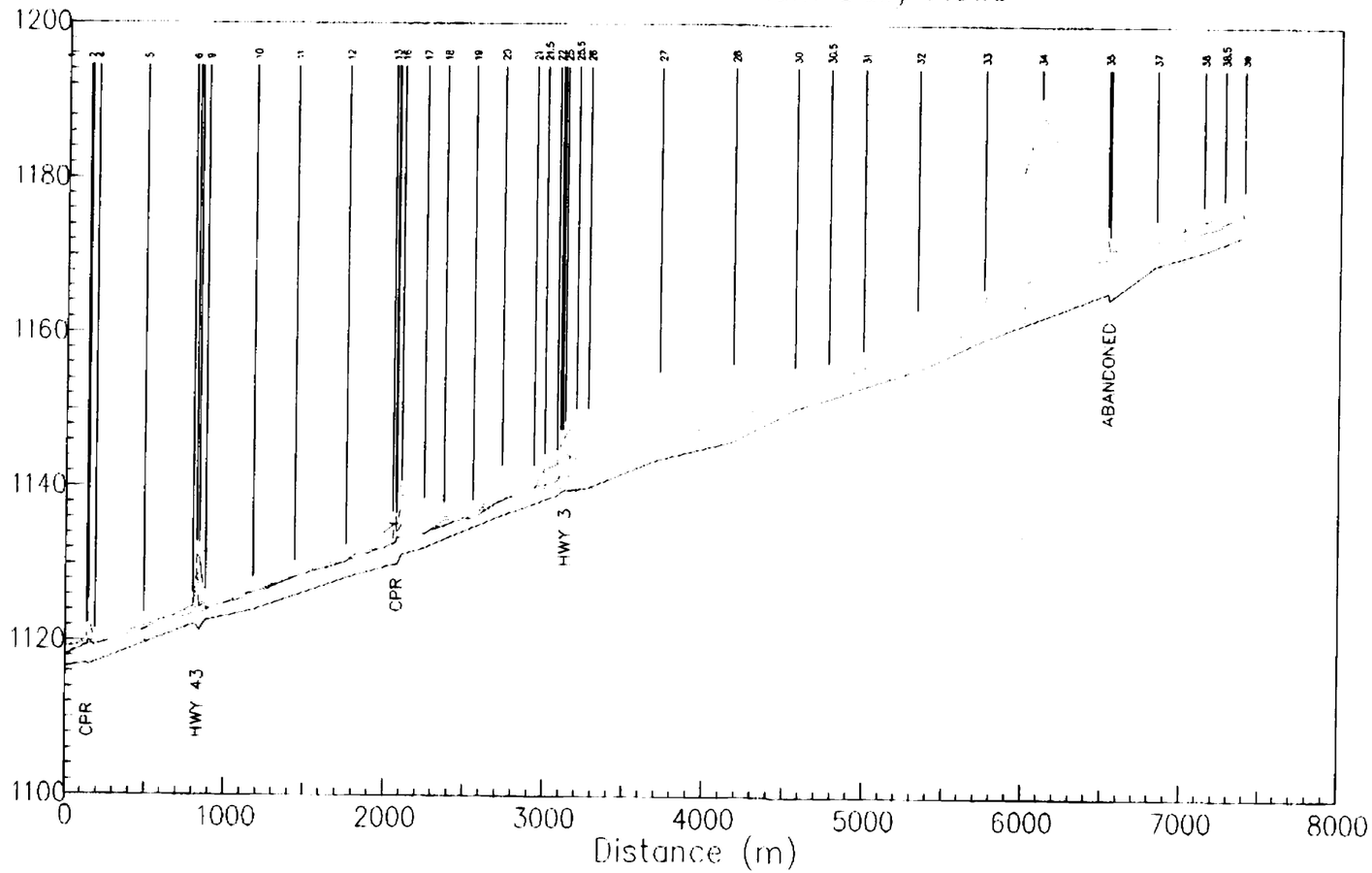
ELK RIVER PROFILE 20 & 200 YEAR MAXIMUM INSTANTANEOUS FLOWS

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.6

NAME: C:\PROJECTS\ELK8\VA\B239101\FL20YRS.DWG DATE: DEC 08, 1994 TIME: 10:25 AM

MICHEL CREEK PROFILE

20 & 200 - Year Maximum Daily Flows



NOTES:
1. FREEBOARD NOT INCLUDED.
2. LOWER AND UPPER W.S. LINES ARE 20 & 200-YEAR FLOOD PROFILES, RESPECTIVELY.

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FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

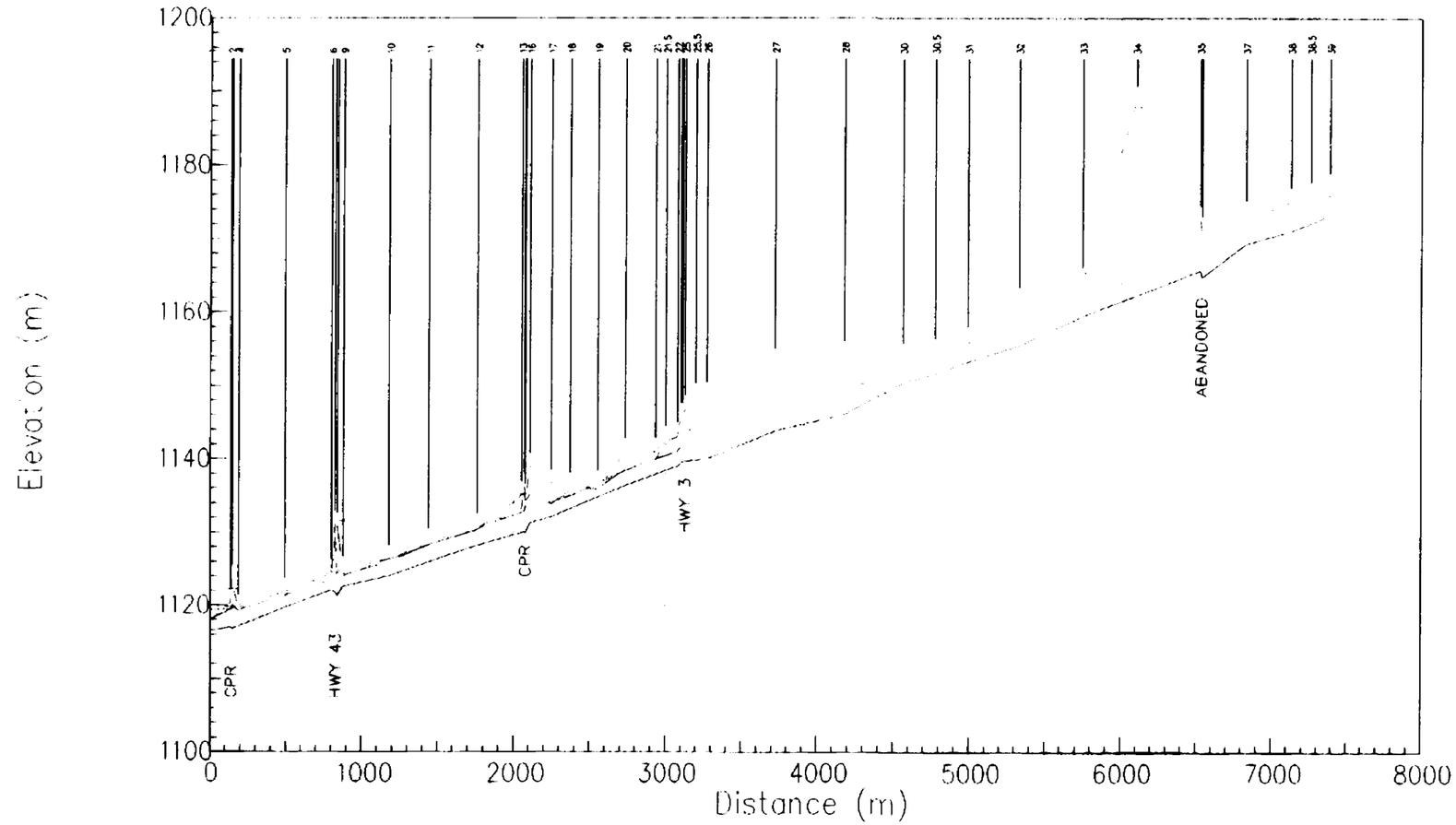
MICHEL CREEK PROFILE, 20 & 200-YEAR MAXIMUM DAILY FLOWS

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC., 1994		5.7

NAME: C:\PROJECTS\ELKRIVER\B239101\M20DAY.DWG DATE: DEC 08 1994 TIME: 10:40 AM

MICHEL CREEK PROFILE

20 & 200-Year Maximum Instantaneous Flows



NOTES:
1. FREEBOARD NOT INCLUDED.
2. LOWER AND UPPER W.S. LINES ARE 20 & 200-YEAR FLOOD PROFILES, RESPECTIVELY.

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FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

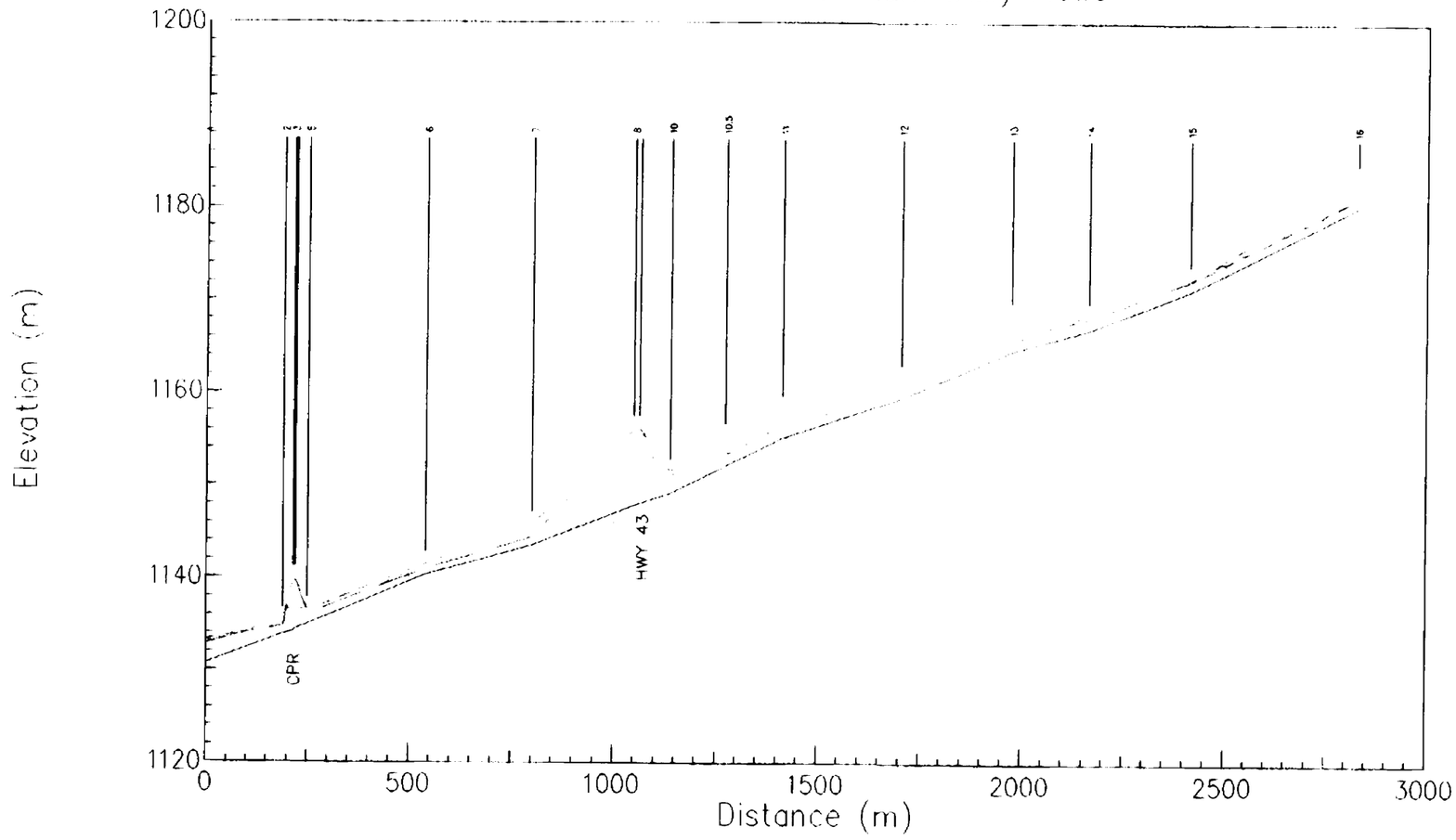
MICHEL CREEK PROFILE, 20 & 200-YEAR MAXIMUM INSTANTANEOUS FLOWS

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.8

NAME: S:\PROJECTS\ELKRIV\B239101\M20INS1.DWG DATE: DEC 08, 1994 TIME: 10:56 AM

CUMMINGS CREEK PROFILE

20 & 200- Year Maximum Daily Flows



NOTES:

1. FREEBOARD NOT INCLUDED.
2. LOWER AND UPPER W.S. LINES ARE 20 & 200-YEAR FLOOD PROFILES, RESPECTIVELY.

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FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

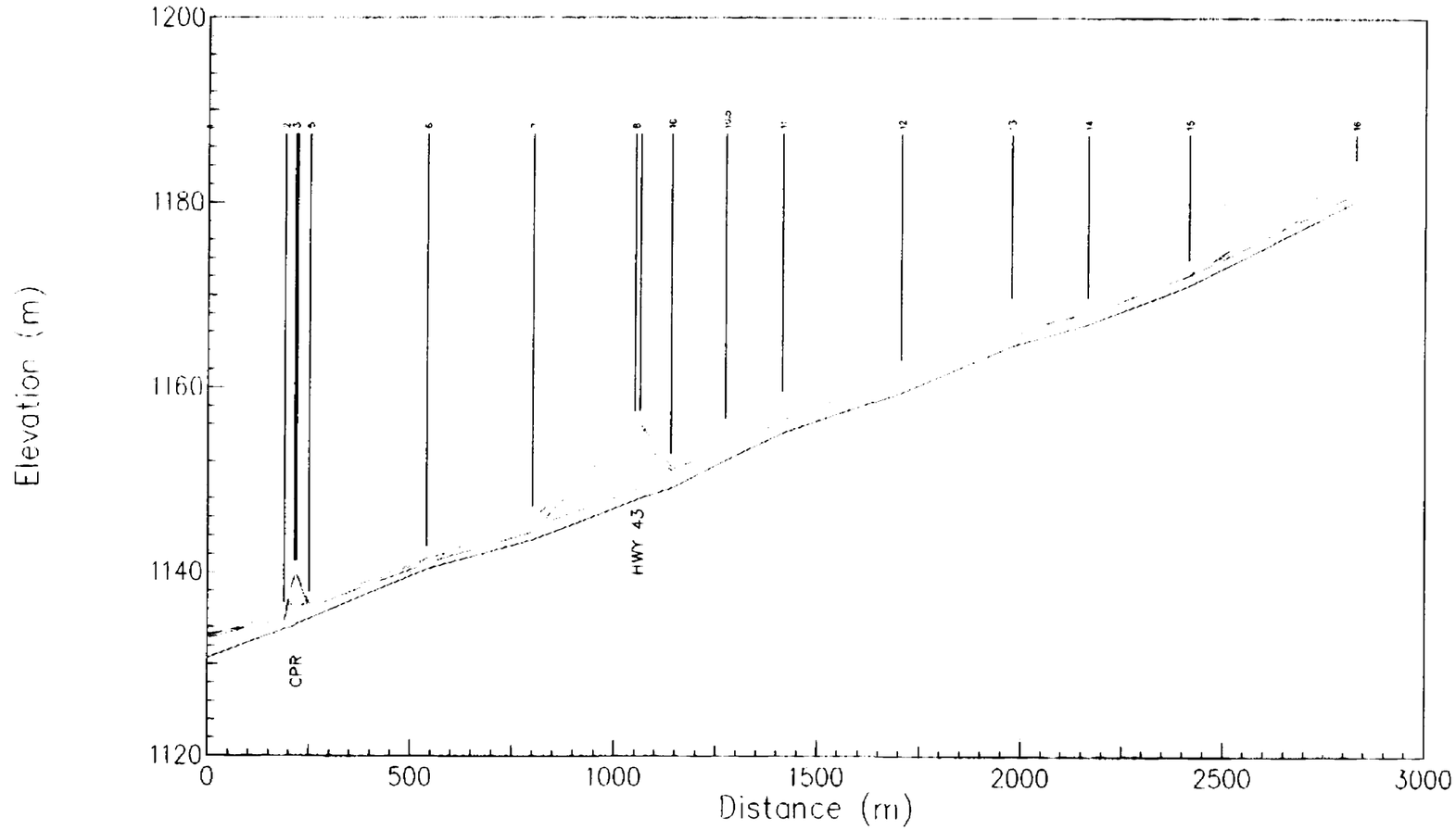
CUMMINGS CREEK PROFILE, 20 & 200-YEAR MAXIMUM DAILY FLOWS

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.9

NAME: C:\PROJECTS\ELKRIV\B239101\CU200DAY1.DWG DATE: DEC 08 1994 TIME: 11:08 AM

CUMMINGS CREEK PROFILE

20 & 200-Year Maximum Instantaneous Flows



NOTES:
1. FREEBOARD NOT INCLUDED.
2. LOWER AND UPPER W.S. LINES ARE 20 & 200-YEAR FLOOD PROFILES, RESPECTIVELY.

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FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

CUMMINGS CREEK PROFILE, 20 & 200 YEAR INSTANTANEOUS FLOWS

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.10

NAME: C:\PROJECTS\ELKRIV\B239101\GU\20INS1.DWG DATE: DEC 08, 1994 TIME: 11:14 AM

TABLE 5.9

Elk River, Michel Creek and Cummings Creek - Computed Flood Profiles (no freeboard) (Page 1 of 2)

ELK RIVER:					MICHEL CREEK:					CUMMINGS CREEK:				
Cross-Section	Computed Water Surface Elevation (m)				Cross-Section	Computed Water Surface Elevation (m)				Cross-Section	Computed Water Surface Elevation (m)			
	20-year max. daily	20-year max. inst.	200-year max. daily	200-year max. inst.		20-year max. daily	20-year max.inst.	200-year max. daily	200-year max.inst.		20-year max. daily	20-year max. inst.	200-year max. daily	200-year max. inst.
36	1120.43	1120.46	1120.95	1121.00	1	1119.20	1119.24	1119.45	1119.50	1	1132.78	1132.81	1132.95	1133.02
35	1120.57	1120.61	1121.20	1121.26	2	1119.40	1119.45	1119.70	1119.76	2	1135.02	1135.12	1135.39	1135.46
34	1120.61	1120.66	1121.33	1121.40	3	1119.46	1119.51	1119.78	1119.84	3	1135.28	1135.36	1135.63	1135.77
33	1121.53	1121.57	1122.11	1122.17	4	1119.62	1119.67	1119.98	1120.05	4	1135.47	1135.56	1135.83	1135.88
32	1121.68	1121.72	1122.26	1122.32	5	1121.79	1121.81	1121.94	1121.97	5	1135.99	1136.07	1136.34	1136.53
31	1121.78	1121.82	1122.41	1122.47	6	1124.07	1124.13	1124.43	1124.51	6	1141.29	1141.38	1141.56	1141.63
30	1121.85	1121.89	1122.47	1122.53	7	1124.13	1124.18	1124.42	1124.49	7	1144.81	1144.89	1145.11	1145.27
29	1123.13	1123.18	1123.81	1123.87	8	1124.30	1124.35	1124.61	1124.68	8	1148.84	1148.94	1149.28	1149.41
28	1123.32	1123.38	1124.07	1124.13	9	1124.84	1124.91	1125.31	1125.40	9	1149.19	1149.29	1149.60	1149.76
27	1123.46	1123.52	1124.24	1124.31	10	1126.16	1126.19	1126.40	1126.45	10	1150.66	1150.77	1151.12	1151.29
26	1123.48	1123.54	1124.21	1124.28	11	1128.17	1128.20	1128.31	1128.34	11	1156.10	1156.20	1156.49	1156.59
25	1124.47	1124.53	1125.29	1125.36	12	1130.43	1130.49	1130.76	1130.81	12	1160.80	1160.87	1161.10	1161.21
24	1124.80	1124.86	1125.56	1125.63	13	1132.56	1132.60	1132.82	1132.84	13	1165.56	1165.64	1165.92	1166.03
23	1126.03	1126.08	1126.59	1126.64	14	1132.78	1132.84	1133.13	1133.19	14	1168.43	1168.53	1168.81	1168.92
22	1127.43	1127.46	1127.84	1127.87	15	1133.32	1133.37	1133.68	1133.75	15	1172.47	1172.57	1172.86	1173.00
21	1129.80	1129.83	1130.16	1130.18	16	1133.53	1133.59	1133.96	1134.04	16	1181.38	1181.44	1181.65	1181.74
20	1131.15	1131.17	1131.49	1131.52	17	1134.18	1134.24	1134.59	1134.67					
19	1132.69	1132.71	1133.04	1133.07	18	1135.11	1135.14	1135.29	1135.33					
18	1134.50	1134.54	1134.95	1134.99	19	1136.54	1136.60	1136.85	1136.90					
17	1137.21	1137.23	1137.58	1137.62	20	1138.26	1138.29	1138.46	1138.50					
16	1140.84	1140.86	1141.10	1141.13	21	1140.02	1140.05	1140.29	1140.34					

TABLE 5.9

Elk River, Michel Creek and Cummings Creek - Computed Flood Profiles (no freeboard) (Page 2 of 2)

ELK RIVER:					MICHEL CREEK:				
Cross-Section	Computed Water Surface Elevation (m)				Cross-Section	Computed Water Surface Elevation (m)			
	20-year max. daily	20-year max. inst.	200-year max. daily	200-year max. inst.		20-year max. daily	20-year max. inst.	200-year max. daily	200-year max. inst.
15	1143.70	1143.72	1143.94	1143.97	22	1140.91	1140.96	1141.26	1141.32
14	1148.29	1148.31	1148.58	1148.60	23	1141.57	1141.66	1142.16	1142.28
13	1152.43	1152.45	1152.62	1152.64	24	1141.59	1141.68	1142.19	1142.32
12	1154.55	1154.59	1154.91	1154.94	25	1141.59	1141.68	1142.17	1142.30
11	1154.60	1154.63	1154.96	1155.00	26	1142.64	1142.71	1143.01	1143.18
10	1155.29	1155.32	1155.79	1155.84	27	1145.59	1145.64	1146.04	1146.07
9	1158.07	1158.08	1158.27	1158.28	28	1149.22	1149.28	1149.50	1149.61
8	1164.45	1164.47	1164.75	1164.78	30	1152.14	1152.23	1152.76	1152.83
7	1168.78	1168.79	1168.91	1168.93	31	1155.23	1155.31	1155.73	1155.81
6	1173.26	1173.29	1173.63	1173.66	32	1157.89	1157.95	1158.30	1158.38
5	1175.56	1175.59	1175.75	1175.77	33	1161.45	1161.53	1161.93	1162.00
4	1182.12	1182.15	1182.52	1182.55	34	1164.88	1164.95	1165.29	1165.39
3	1186.37	1186.39	1186.62	1186.64	35	1168.28	1168.38	1168.87	1168.96
2	1191.20	1191.22	1191.46	1191.48	36	1168.48	1168.56	1169.02	1169.11
1	1193.78	1193.80	1194.13	1194.16	37	1171.59	1171.68	1172.23	1172.36
					38	1173.75	1173.81	1174.19	1174.27
					39	1175.84	1175.93	1176.39	1176.49

TABLE 5.10

Elk River, Michel Creek and Cummings Creek - Computed Flood Profiles (with freeboard) (Page 1 of 2)

ELK RIVER:					MICHEL CREEK:					CUMMINGS CREEK:				
Cross-Section	Computed Water Surface Elevation +FB (m)				Cross-Section	Computed Water Surface Elevation +FB (m)				Cross-Section	Computed Water Surface Elevation +FB (m)			
	20-year max.daily +0.6 m	20-year max.inst. +0.3 m	200-year max.daily +0.6 m	200-year max.inst. +0.3 m		20-year max.daily +0.6 m	20-year max.inst. +0.3 m	200-year max.daily +0.6 m	200-year max.inst. +0.3 m		20-year max.daily +0.6 m	20-year max.inst. +0.3 m	200-year max.daily +0.6 m	200-year max.inst. +0.3 m
36	**1121.03**	1120.76	**1121.55**	1121.30	1	**1119.80**	1119.54	**1120.05**	1119.80	1	**1133.38**	1133.11	**1133.55**	1133.32
35	**1121.17**	1120.91	**1121.80**	1121.56	2	**1120.00**	1119.75	**1120.30**	1120.06	2	**1135.62**	1135.42	**1135.99**	1135.76
34	**1121.21**	1120.96	**1121.93**	1121.70	3	**1120.06**	1119.81	**1120.38**	1120.14	3	**1135.88**	1135.66	**1136.23**	1136.07
33	**1122.13**	1121.87	**1122.71**	1122.47	4	**1120.22**	1119.97	**1120.58**	1120.35	4	**1136.07**	1135.86	**1136.43**	1136.18
32	**1122.28**	1122.02	**1122.86**	1122.62	5	**1122.39**	1122.11	**1122.54**	1122.27	5	**1136.59**	1136.37	**1136.94**	1136.83
31	**1122.38**	1122.12	**1123.01**	1122.77	6	**1124.67**	1124.43	**1125.03**	1124.81	6	**1141.89**	1141.68	**1142.16**	1141.93
30	**1122.45**	1122.19	**1123.07**	1122.83	7	**1124.73**	1124.48	**1125.02**	1124.79	7	**1145.41**	1145.19	**1145.71**	1145.57
29	**1123.73**	1123.48	**1124.41**	1124.17	8	**1124.90**	1124.65	**1125.21**	1124.98	8	**1149.44**	1149.24	**1149.88**	1149.71
28	**1123.92**	1123.68	**1124.67**	1124.43	9	**1125.44**	1125.21	**1125.91**	1125.70	9	**1149.79**	1149.59	**1150.20**	1150.06
27	**1124.06**	1123.82	**1124.84**	1124.61	10	**1126.76**	1126.49	**1127.00**	1126.75	10	**1151.26**	1151.07	**1151.72**	1151.59
26	**1124.08**	1123.84	**1124.81**	1124.58	11	**1128.77**	1128.50	**1128.91**	1128.64	11	**1156.70**	1156.50	**1157.09**	1156.89
25	**1125.07**	1124.83	**1125.89**	1125.66	12	**1131.03**	1130.79	**1131.36**	1131.11	12	**1161.40**	1161.17	**1161.70**	1161.51
24	**1125.40**	1125.16	**1126.16**	1125.93	13	**1133.16**	1132.90	**1133.42**	1133.14	13	**1166.16**	1165.94	**1166.52**	1166.33
23	**1126.63**	1126.38	**1127.19**	1126.94	14	**1133.38**	1133.14	**1133.73**	1133.49	14	**1169.03**	1168.83	**1169.41**	1169.22
22	**1128.03**	1127.76	**1128.44**	1128.17	15	**1133.92**	1133.67	**1134.28**	1134.05	15	**1173.07**	1172.87	**1173.46**	1173.30
21	**1130.40**	1130.13	**1130.76**	1130.48	16	**1134.13**	1133.89	**1134.56**	1134.34	16	**1181.98**	1181.74	**1182.25**	1182.04
20	**1131.75**	1131.47	**1132.09**	1131.82	17	**1134.78**	1134.54	**1135.19**	1134.97					
19	**1133.29**	1133.01	**1133.64**	1133.37	18	**1135.71**	1135.44	**1135.89**	1135.63					
18	**1135.10**	1134.84	**1135.55**	1135.29	19	**1137.14**	1136.90	**1137.45**	1137.20					

Note: The floodplain mapping sheets are based on the selected flood levels shown in **bold** on this table.

TABLE 5.10

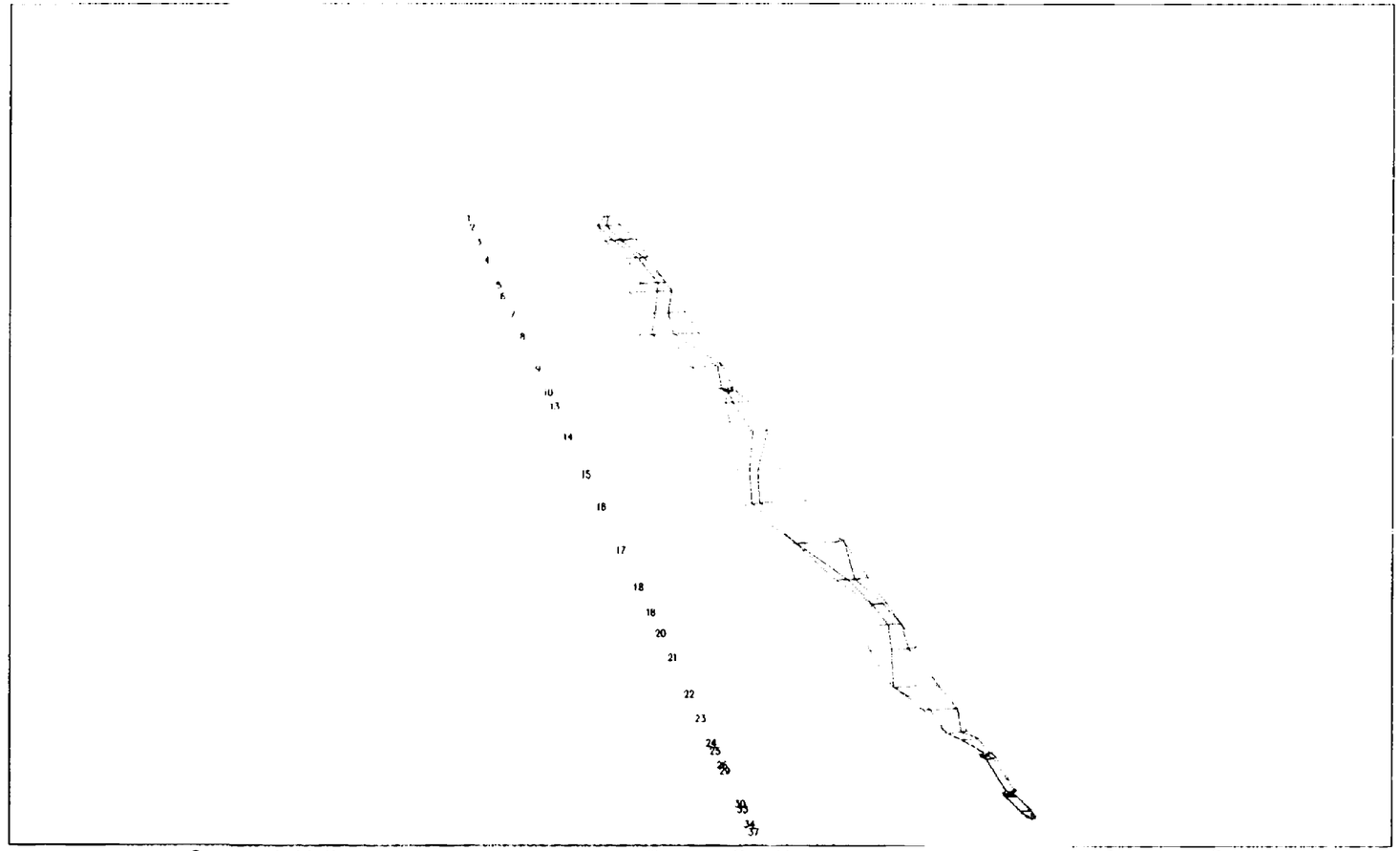
Elk River, Michel Creek and Cummings Creek - Computed Flood Profiles (with freeboard) (Page 2 of 2)

ELK RIVER:					MICHEL CREEK:				
Cross-Section	Computed Water Surface Elevation + FB (m)				Cross-Section	Computed Water Surface Elevation + FB (m)			
	20-year max. daily +0.6 m	20-year max. inst. +0.3 m	200-year max. daily +0.6 m	200-year max.inst. +0.3 m		20-year max. daily +0.6 m	20-year max.inst. +0.3 m	200-year max. daily +0.6 m	200-year max. inst. +0.3 m
17	**1137.81**	1137.53	**1138.18**	1137.92	20	**1138.86**	1138.59	**1139.06**	1138.80
16	**1141.44**	1141.16	**1141.70**	1141.43	21	**1140.62**	1140.35	**1140.89**	1140.64
15	**1144.30**	1144.02	**1144.54**	1144.27	22	**1141.51**	1141.26	**1141.86**	1141.62
14	**1148.89**	1148.61	**1149.18**	1148.90	23	**1142.17**	1141.96	**1142.76**	1142.58
13	**1153.03**	1152.75	**1153.22**	1152.94	24	**1142.19**	1141.98	**1142.79**	1142.62
12	**1155.15**	1154.89	**1155.51**	1155.24	25	**1142.19**	1141.98	**1142.77**	1142.60
11	**1155.20**	1154.93	**1155.56**	1155.30	26	**1143.24**	1143.01	**1143.61**	1143.48
10	**1155.89**	1155.62	**1156.39**	1156.14	27	**1146.19**	1145.94	**1146.64**	1146.37
9	**1158.67**	1158.38	**1158.87**	1158.58	28	**1149.82**	1149.58	**1150.10**	1149.91
8	**1165.05**	1164.77	**1165.35**	1165.08	30	**1152.74**	1152.53	**1153.36**	1153.13
7	**1169.38**	1169.09	**1169.51**	1169.23	31	**1155.83**	1155.61	**1156.33**	1156.11
6	**1173.86**	1173.59	**1174.23**	1173.96	32	**1158.49**	1158.25	**1158.90**	1158.68
5	**1176.16**	1175.89	**1176.35**	1176.07	33	**1162.05**	1161.83	**1162.53**	1162.30
4	**1182.72**	1182.45	**1183.12**	1182.85	34	**1165.48**	1165.25	**1165.89**	1165.69
3	**1186.97**	1186.69	**1187.22**	1186.94	35	**1168.88**	1168.68	**1169.47**	1169.26
2	**1191.80**	1191.52	**1192.06**	1191.78	36	**1169.08**	1168.86	**1169.62**	1169.41
1	**1194.38**	1194.10	**1194.73**	1194.46	37	**1172.19**	1171.98	**1172.83**	1172.66
					38	**1174.35**	1174.11	**1174.79**	1174.57
					39	**1176.44**	1176.23	**1176.99**	1176.79

Note: The floodplain mapping sheets are based on the selected flood levels shown in **bold** on this table.

ELK RIVER VALLEY

3-D Representation (200-Year Maximum Daily Flow)



Channel Valley
Channel Overbanks

Cross-Sections
200-Year Max. Daily Q

1 Section ID

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SRK-ROBINSON INC.
Consulting Engineers

B.C. ENVIRONMENT
WATER MANAGEMENT DIVISION

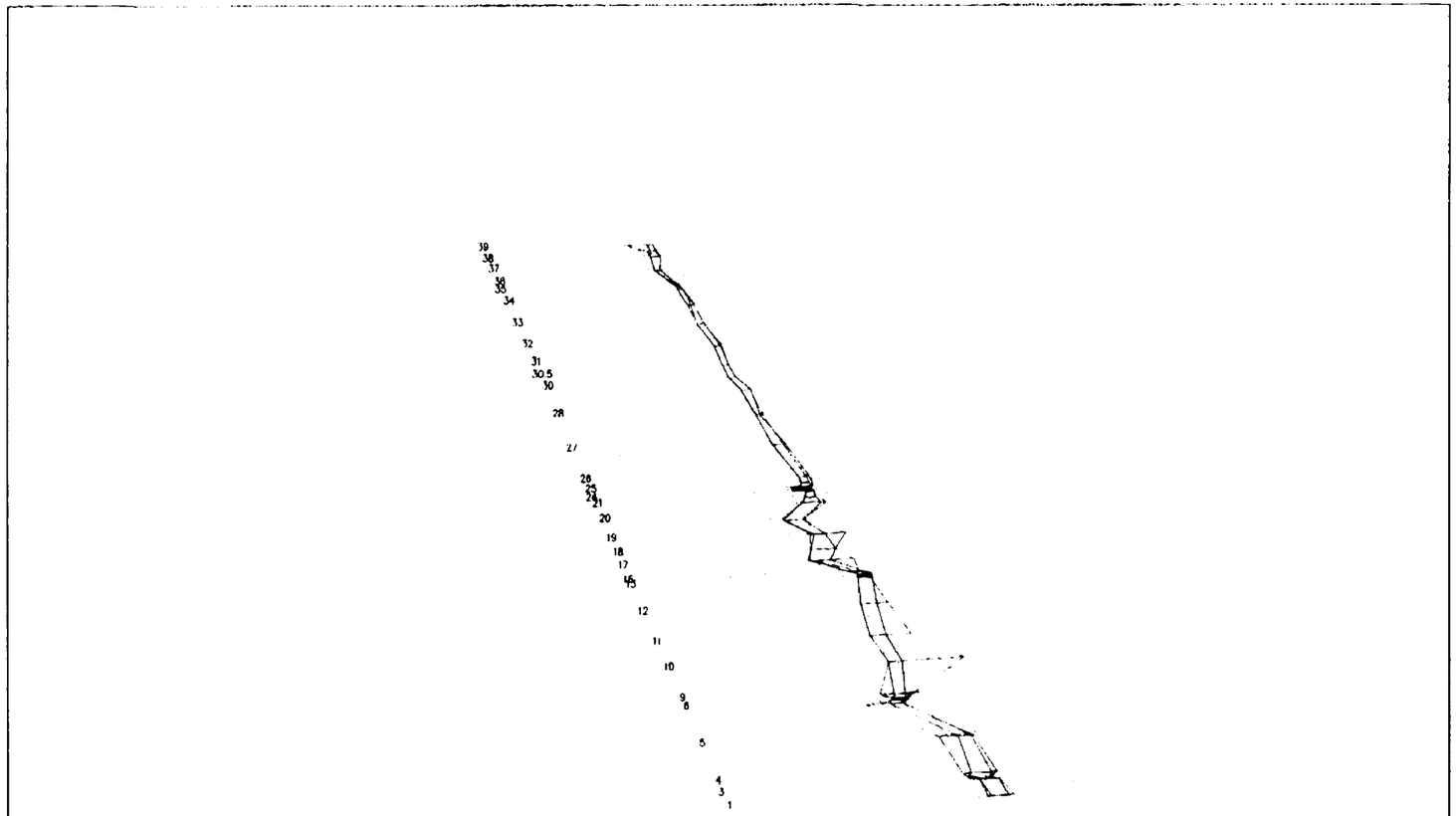
FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

ELK RIVER VALLEY
3D REPRESENTATION
200-YEAR MAXIMUM DAILY FLOW

PROJECT NO	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.11

MICHEL CRLLK VALLEY

3-D Representation (200--Year Maximum Daily Flow)



Channel Valley
Channel Overbanks

Cross-Sections
200--Year Max. Daily Q

1 Section ID

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SRK-ROBINSON INC.
Consulting Engineers

B.C. ENVIRONMENT
WATER MANAGEMENT DIVISION

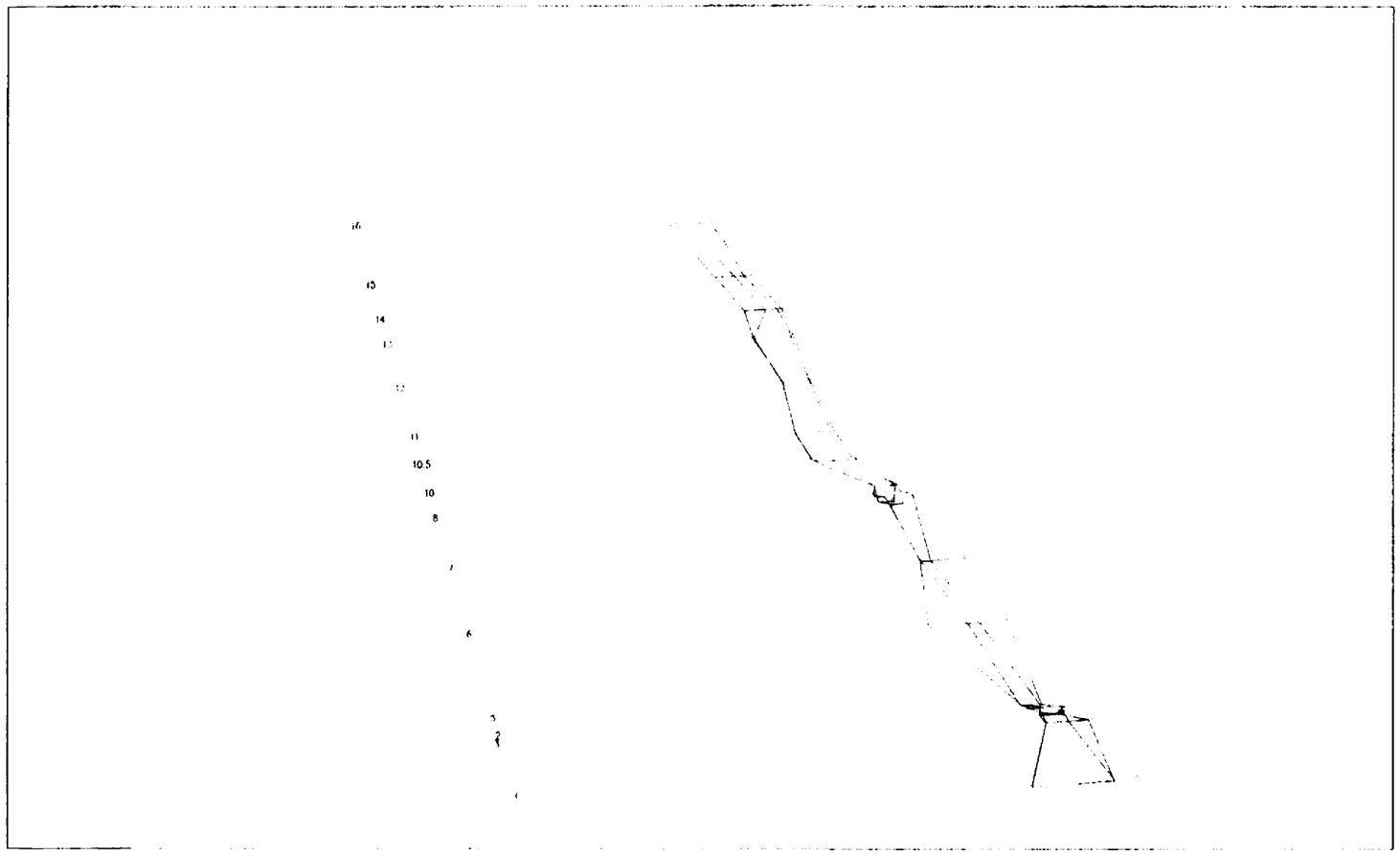
FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

MICHEL CREEK
3D REPRESENTATION
200-YEAR MAXIMUM DAILY FLOW

PROJECT NO.	DATE	APPROVED	FIGURE
B239101	DEC., 1994		5.12

CUMMINGS CREEK VALLEY

3 D Representation (200 Year Maximum Daily Flow)



Channel Valley
Channel Overbanks

Cross Sections
200-Year Max. Daily Q

Section ID

SRK-ROBINSON INC.
Consulting Engineers

B.C. ENVIRONMENT
WATER MANAGEMENT DIVISION

FLOODPLAIN MAPPING- ELK RIVER, MICHEL AND CUMMINGS CREEKS

CUMMINGS CREEK
3D REPRESENTATION
200-YEAR MAXIMUM DAILY FLOW

PROJECT NO	DATE	APPROVED	FIGURE
B239101	DEC.,1994		5.13

6.0 GEOMORPHOLOGY AND SPECIAL CONDITIONS

6.1 Introduction

The geomorphology of the study reaches was reviewed (Kellerhals *et al*, 1976) to try to assess what future channel changes may occur and how they will influence the computed flood profiles. Special conditions affecting flooding were also investigated.

6.2 Elk River

Over most of the study reach the Elk River has an irregular braided channel, except near the downstream end where it becomes a single sinuous channel. The braided reach, with bed material in the coarse gravel to cobble size range, is laterally quite active. In the time span between the topographic mapping and the river survey, the location of the main channel shifted near Cross-Section 17 and now runs along the railway. This shift will likely produce a series of changes further downstream. However, the changes result in only local variations in the flood profiles. Historically, the channel has shifted over most of the valley floor (Photo 6.1), but is now partly confined by either railway or road embankments. Areas within these limits are at risk from flooding and from erosion by the river changing its course. Bank erosion is taking place at several locations; along the right bank at Cross-Sections 7, 15, 18 and at the left bank near Cross-Section 3, as shown on the floodplain maps.

During a 200-year flood the right bank, just upstream of the Canadian Pacific railway bridge by Cross-Section 10, would overtop by about 1 m and a portion of the Elk River would be diverted along the west side of the railway and then merge with Dalzell Creek. For the Elk River design profiles, flow was assumed to remain in the channel. The floodplain boundaries are based on the absence of all dykes and road and railway embankments. However, if a substantial amount of flow is diverted to the west side of the railway, water may pond along the embankment, resulting in higher flood levels than those computed for the Elk River main channel. Dalzell Creek passes through two 1.5 m culverts under the railway embankment. During a combined Elk River/Dalzell Creek 200-year flood, these culverts would likely get partially plugged and cause the embankment to act as a dam. At Cross Section 14 the railway embankment is 1 m higher than the flood construction level (including freeboard). Therefore the flood levels along the west side of the railway could potentially be raised by about 1 m before the embankment starts to overflow. (Upstream and downstream

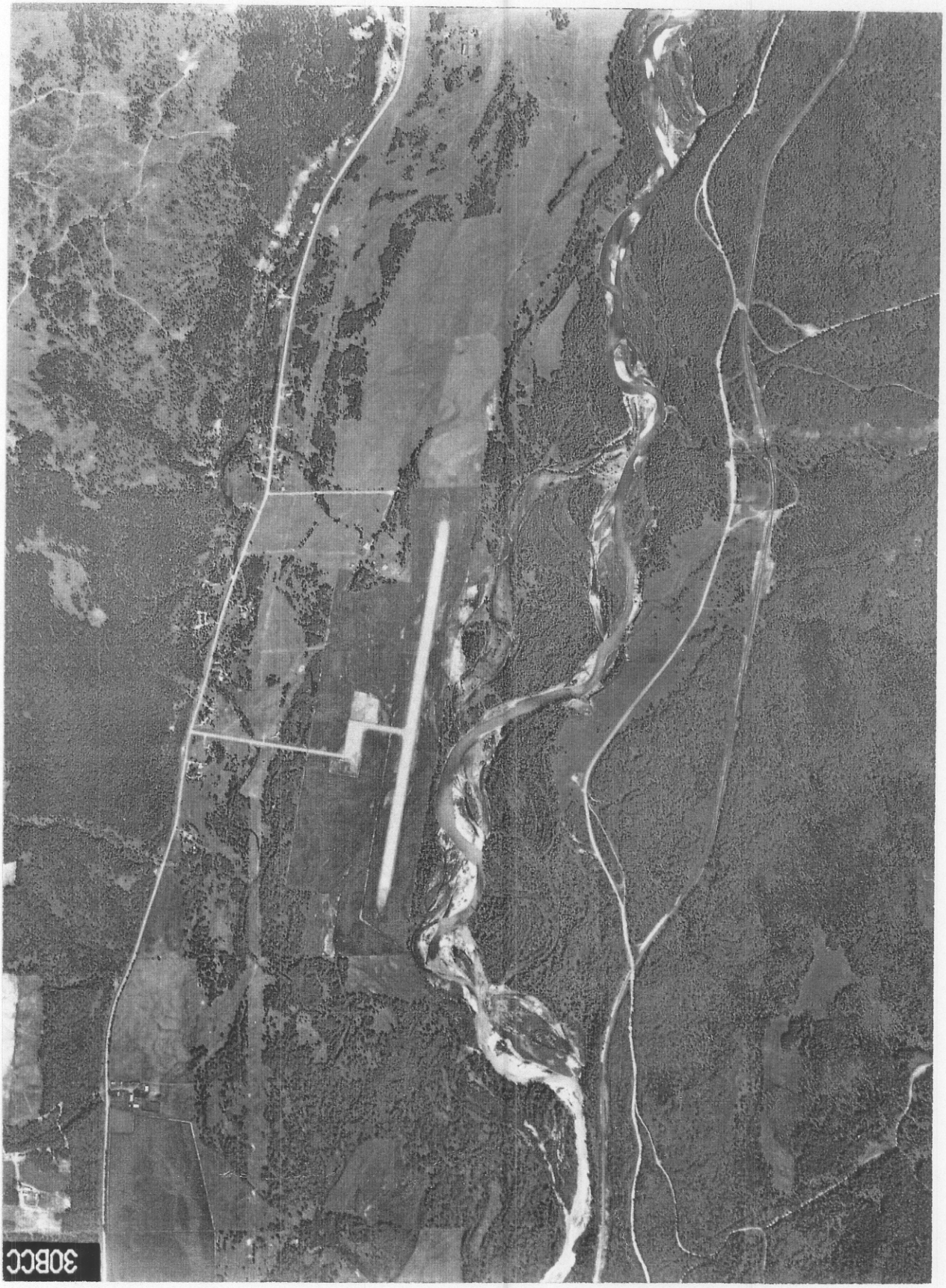


PHOTO 6.1 Air photo of Elk River from XS-4 at Top (N) to XS-8 at Bottom

SRK-Robinson Inc.
May, 1995

of Cross-Section 14 the elevation of the railway embankment exceeds the FCL by more than 1 m.) A note of caution has been included on the floodplain map for the area.

Historic rating curves for the WSC station at the upstream end of the study reach were reviewed. WSC has produced 26 different rating curves during the 43 year history of the gauge. A comparison of selected curves did not indicate that the section is consistently aggrading or degrading. The changes in the rating likely reflect bedload movement through the reach.

The Elk River typically freezes over in December and remains frozen until about March. Ice conditions have not historically caused flooding (personal communication, Dwyer, 1994).

6.3 Michel Creek

Over the upstream half of the study reach, Michel Creek has been channelized and confined to the west side of the valley. Along the downstream half, the creek has an irregular braided channel. An undated drawing from the early 1920s (District of Sparwood, 1994) shows Michel Creek as having a braided channel through the upper study reach as well. The drawing shows a lay-out for dredging and channelizing the creek to protect the communities of Michel and Natal from flooding and erosion. This channelized section was extended and the right bank was raised after the 1948 flood. The channelization resulted in aggradation of the downstream braided gravel-bed channel. A review of historic air photos did not show whether this trend is still continuing.

Substantial infilling of the Canadian Pacific bridge crossing (Cross-Sections 14 and 15) has severely restricted the capacity of the bridge opening. At present, in low discharge conditions, the approach flow is aligned almost perpendicularly to the central pier. Different methods were used to model the bridge. Computed water surface elevations at upstream Cross-Sections 16 and 17 were found to be quite sensitive to the assumptions made regarding the skewness of the pier. Minor variations in the modelling resulted in water level increases of up to 1.5 m. As the dyke crest elevations exceed the computed flood construction levels by only about 0.4 m, such water level increases would cause the left bank dyke, just upstream of the bridge, to

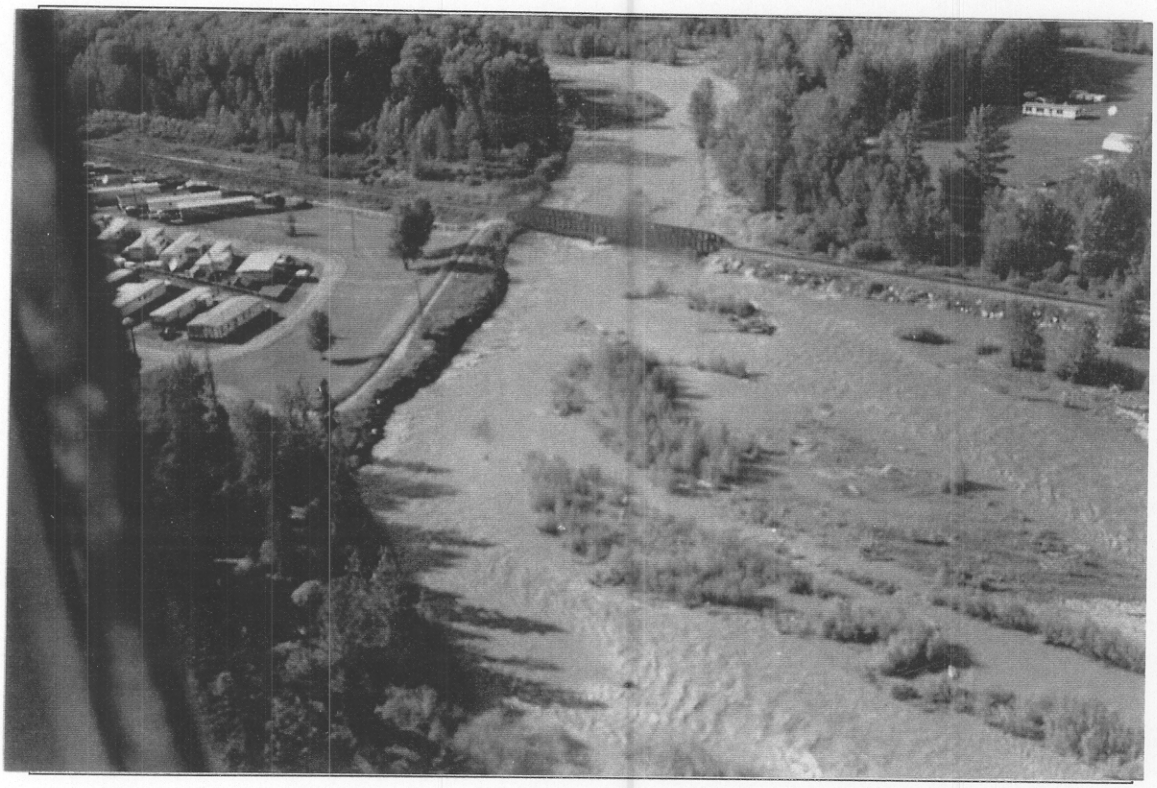


PHOTO 6.2 Michel Creek During 1986 Freshet (29 May 1986), Looking Downstream to CPR Bridge at XS-15

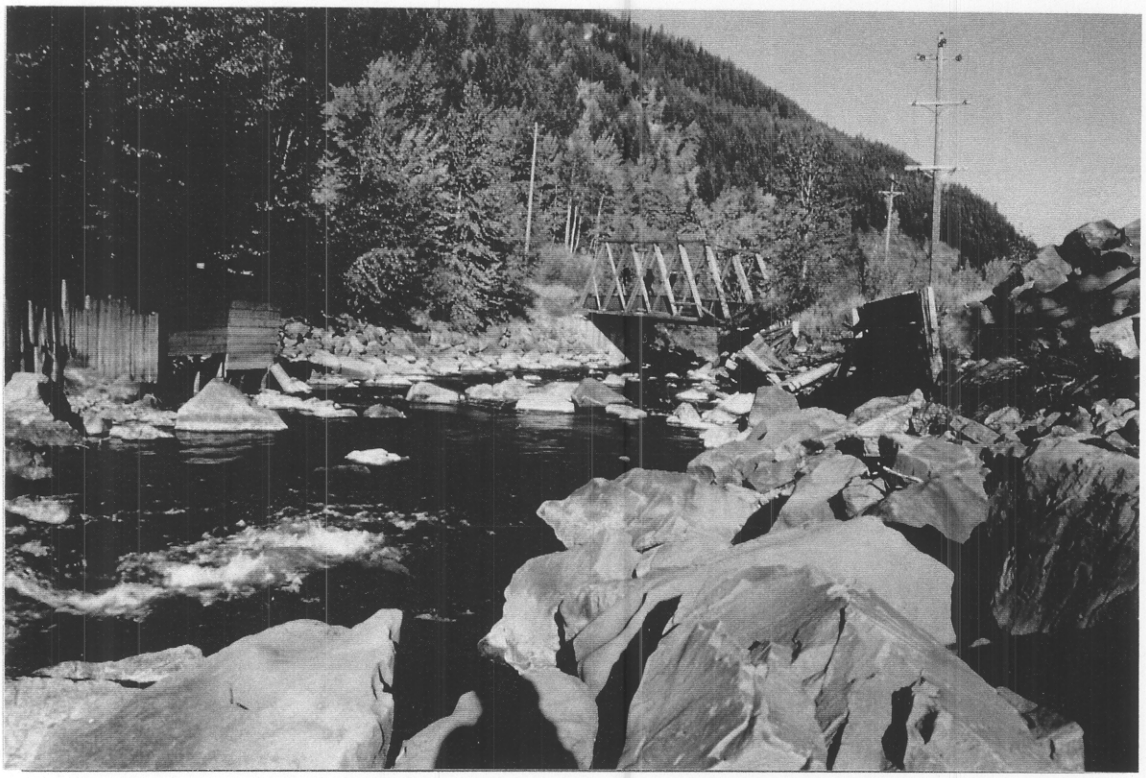


PHOTO 6.3 Abandoned Bridge over Michel Creek XS-35, Looking Downstream

overflow. Flow conditions during the 1986 freshet, with a maximum daily discharge of 144 m^3/s, are shown in Photo 6.2 (BC Environment, 1986).

The flow capacity of the abandoned bridge at Cross-Sections 35 and 36 was reviewed. The abutments are failing and the opening may become plugged by the semi-loose wooden board-walls located upstream along both banks (Photo 6.3). A partial blockage could cause dramatic water level increases of several metres and result in substantial overbank flow upstream of the bridge.

Since 1970, WSC has prepared 25 rating curves for their gauging station near Cross-Section 25. In the 1970s the section consistently degraded but since then random changes have occurred.

Bank erosion is taking place on the left bank at sections 5 and 12. Some local bridge pier scour was detected by the piers of the Highway 43 bridge. A landslide occurred in the late 1960s or early 1970s west of the creek near Cross-Section 18 but did not affect the channel. Michel Creek freezes over from about November to March. According to Mr. D. Dwyer (personal communication, 1994) ice-blockages are not a problem.

6.4 Cummings Creek

Cummings Creek has a steep irregular channel. The banks are heavily vegetated and large log jams may form in the creek. The location of the confluence with the Elk River shifts, depending on the Elk flood stage. The model indicated critical flow at the CPR bridge crossing at Sections 3 and 4. Even a minor blockage of the opening would cause the flow to choke and possible weir flow over the bridge.

The upper end of the study reach is laterally active. However, channel changes will result in only local changes to the flood profiles, because of the steep slopes. Signs of aggradation or degradation were not detected. Ice problems have not been reported.

6.5 Accuracy of Computed Profiles

The models were calibrated to only one set of high water marks. Suspect water levels could not be verified and the potential variation in roughness with flow was not assessed. In some reaches, the surveyed high water marks were sparse, having

elevation differences of up to 24 m. The WSC rating curves for the Elk River station showed a stage range of about 0.5 m at the upper end of the curves, roughly corresponding to the 20-year flood. This variation translates to about a plus or minus 20% variation in the discharge. The Elk River rating curve suggests that HEC-2 overestimates water levels at the gauge by about 0.2 m for the highest flows on the rating curve. The equivalent stage range for the Michel Creek rating curves was slightly less. The agreement between the current Michel Creek rating curve and computed water levels was good.

Braided channels often have an almost two dimensional flow pattern. Large midchannel bars can produce considerable fluctuations in the water levels between the left and the right banks. For example, high water elevation differences of over 1 m were surveyed by BCE on the Coquihalla River. Super-elevation of the flow in some of the steeper bends was computed to be 0.5 m, 0.2 m and 0.3 m for respectively Elk River, Michel Creek and Cummings Creek.

Climatic changes, logging activities and other man-made changes in the basins may alter the hydrology and consequently the flood profiles.

The BCE standard 0.6 m freeboard allowance over the maximum daily flood level was assumed to envelope potential discrepancies in the computed water surface profiles for the three watercourses.

7.0 FLOODPLAIN MAPS

Floodplain maps (Map Sheets 91-2-1 through 91-2-5) at a scale of 1:5000 and with 2 m contour intervals 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 were determined assuming 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) along the river thalweg;
- flood level isograms showing approximate lines of equal 200-year flood level to the edge of the floodplain.

8.0 RECOMMENDATIONS AND CONCLUSIONS

1. It is recommended that the flood levels and floodplain limits shown on Map Sheets 91-2-1 to 91-2-5 be interim designated, pursuant to the terms of the Canada/British Columbia Floodplain Mapping Agreement.

2. The maps are issued for administrative purposes to show the geographic extant of the floodplain and flood levels used to determine the minimum floodproofing elevation requirements.

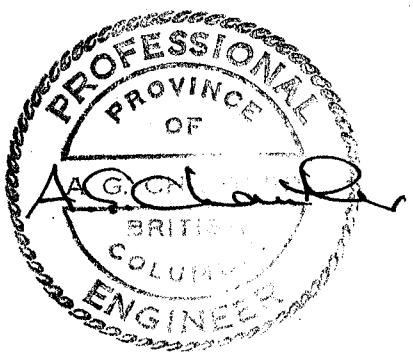
3. The maps are not comprehensive floodplain management plans, nor do they provide solutions to site specific flood hazard problems.

4. Flooding may occur outside the designated floodplain. Tributaries, ice jamming, channel obstructions, groundwater and larger flood events may cause flooding which exceeds the designated flood construction level. These limitations are noted on the floodplain mapping sheets under floodplain data and under notes of caution on individual sheets.

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

This report, **B239101/2, Elk River, Michel Creek and Cummings Creek Floodplain Mapping - Design Brief**, is respectfully submitted by:

SRK-ROBINSON INC.



M. C. Mannerström, P.Eng.

Dr. A. G. Chantler, P.Eng.

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Photograph (Photo. 6.2) provided by Dwain Boyer, Head, Engineering Section, Water Management Division, Nelson, B.C.

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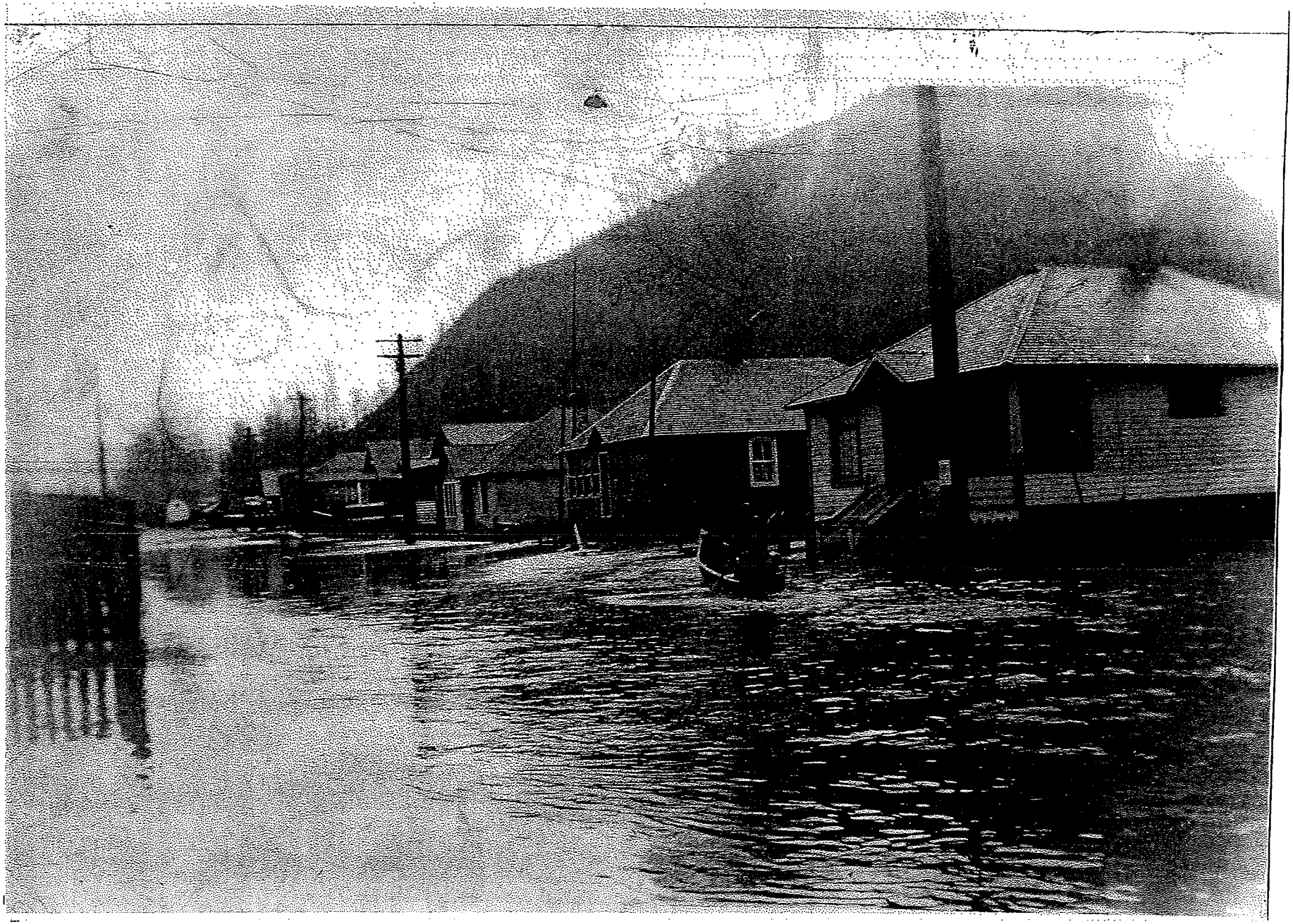
APPENDIX A

PHOTOGRAPHS OF THE 1948 FLOOD ON MICHEL CREEK

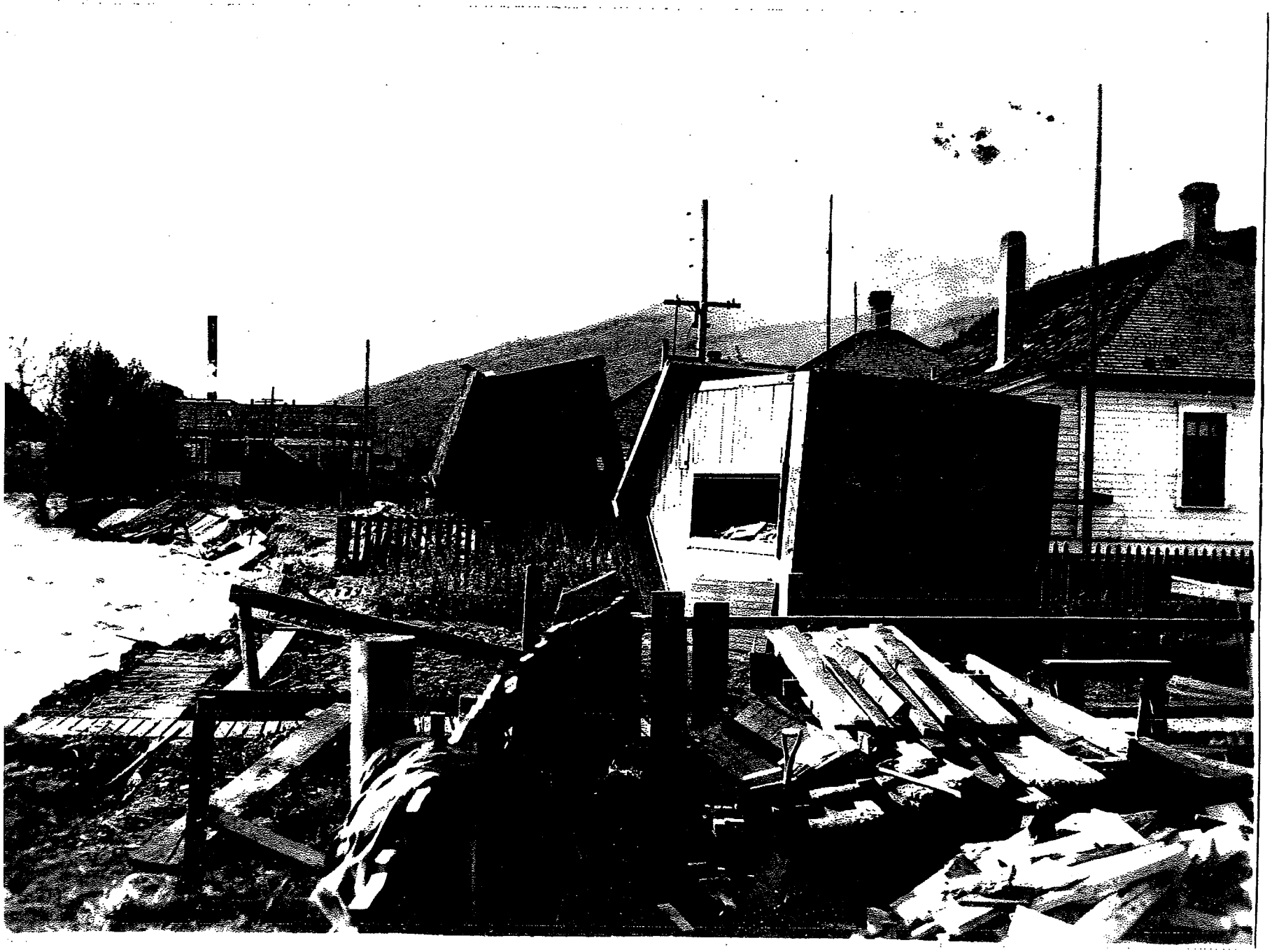
The 1948 Flood in Natal *(Provincial Archives, Victoria)*



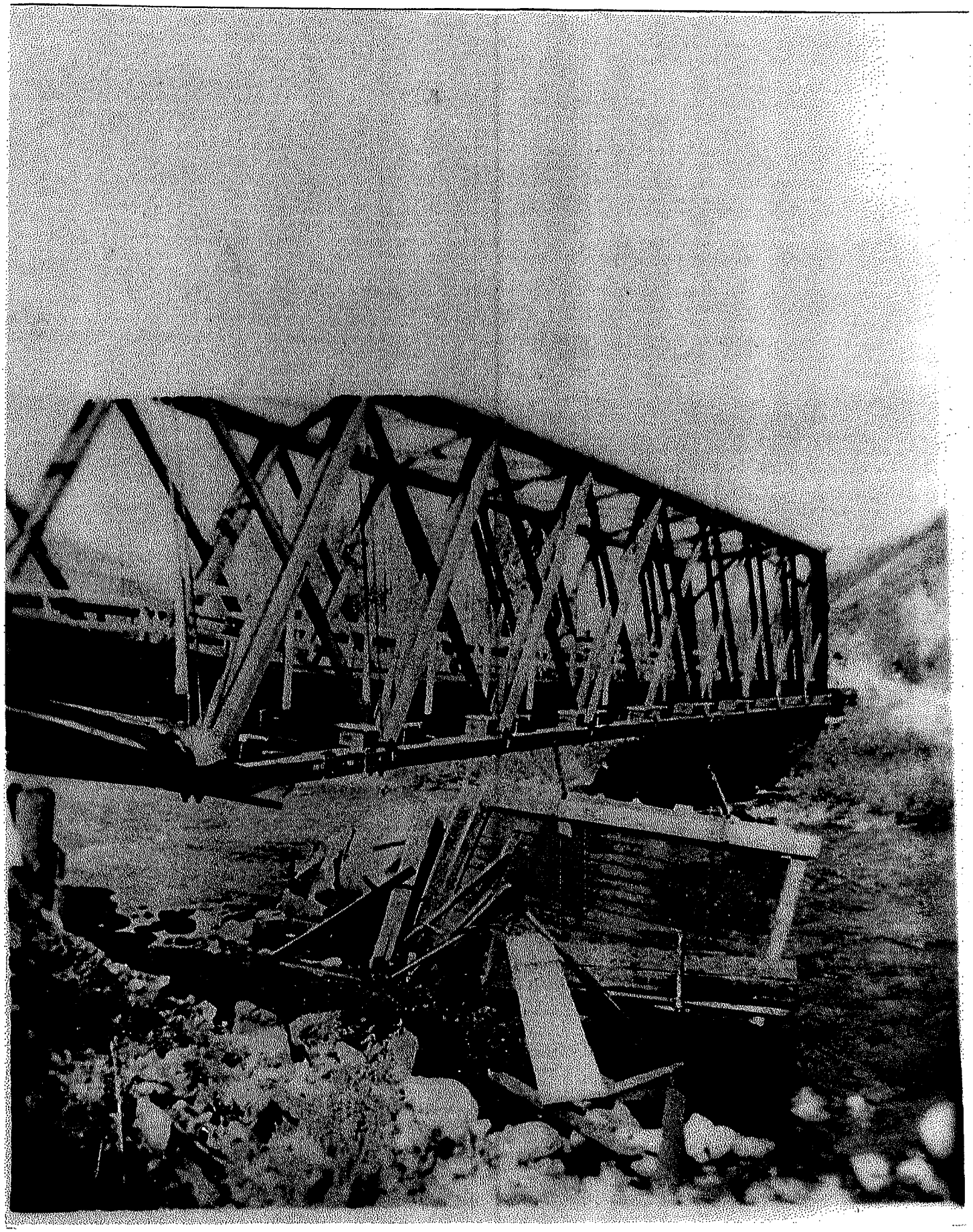
The 1948 Flood in Natal *(Provincial Archives, Victoria)*

Damage to CPR During 1948 Flood *(Provinical Archives, Victoria)*

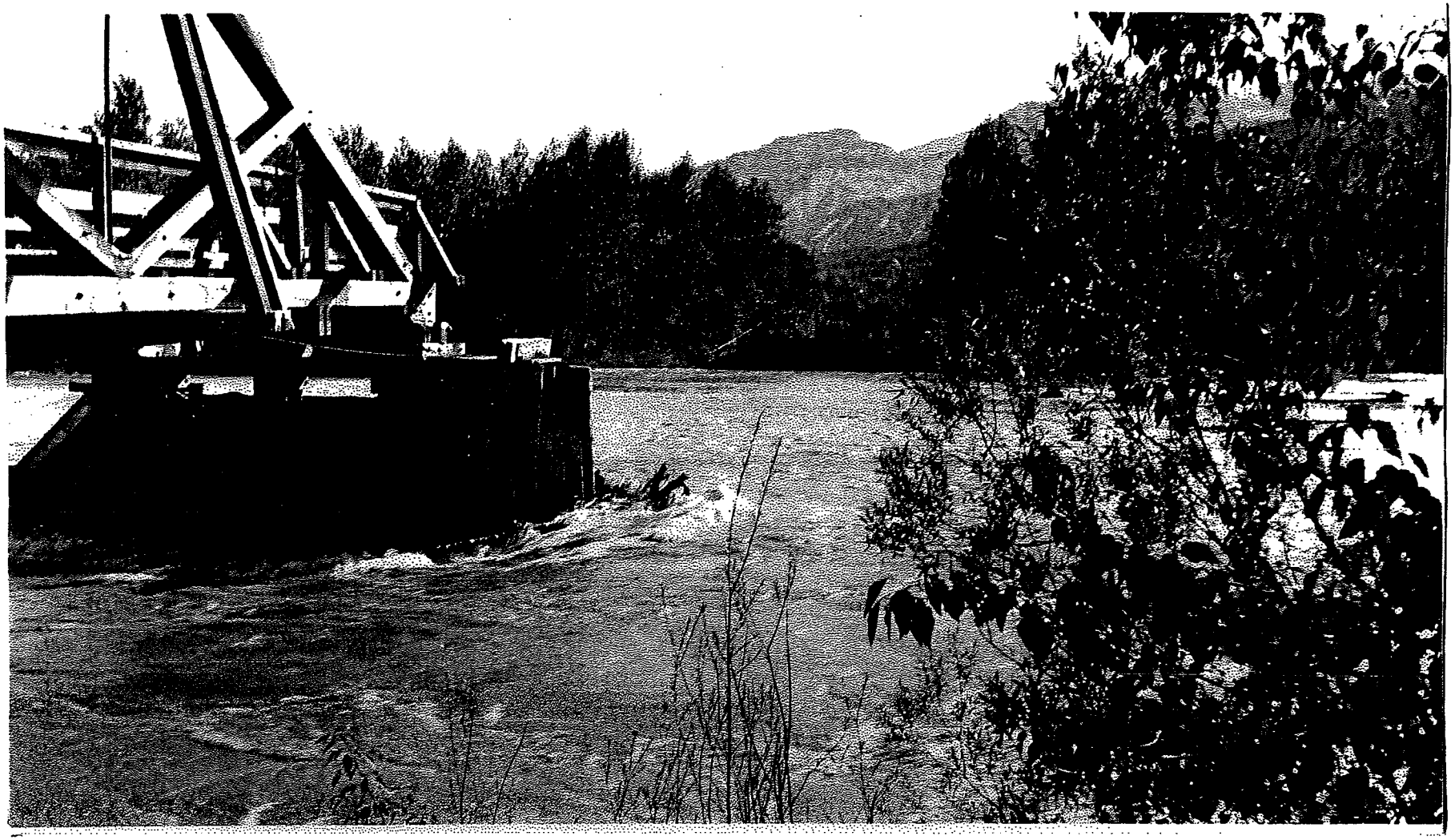
Damage to CPR During 1948 Flood *(Provincial Archives, Victoria)*



Flood Damage in Michel, 1948 *(Provincial Archives, Victoria)*



The CPR Bridge During the 1948 Flood *(Provincial Archives, Victoria)*



The CPR Bridge During the 1948 Flood *(Provincial Archives, Victoria)*

APPENDIX B

LIST OF INFORMATION SUPPLIED BY WATER MANAGEMENT DIVISION

List of Available Information

Elk River, Michel Creek and Cummings Creek at Sparwood

1. River Survey - Project 91 30 F040 (September 1991) - Volume 1 of 2

   A. One VHS video tape showing cross section locations for Elk River, Michel Creek and Cummings Creek. All coverage starts downstream. (Note: There is no video of a very few sections on Michel Creek where there is little change between sections.)
   B. List of contents.
   C. Project request.
   D. High water mark elevations.
   E. Listing of GR data for all three watercourses with and without decimals.
   F. Elk River
      i. Photographs, left-to-right written profiles and plots (H 1:2000 V 1:200) for 36 Elk River cross sections.
      ii. Written profiles, plots (H 1:5000 V 1:500) and sketches (various scales) of 3 bridges over the Elk River.
   G Michel Creek
      i. Photographs, left-to-right written profiles and plots (H 1:1000 V 1:100) for 39 Michel Creek cross sections.
      ii. Written profiles, plots (H 1:5000 V 1:500) and sketches (various scales) of rail and road profiles, culverts and bridges at Michel Creek.

2. River Survey - Project 91 30 F040 (September 1991) - Volume 2 of 2

   A. List of contents
   B. Cummings Creek
      i. Photographs, left-to-right written profiles and plots (H 1:1000 V 1:100) for 16 Cummings Creek cross sections.
      ii. Written profiles, plots (H 1:5000 V 1:500) of rail and road profiles and sketches (H 1:500 V 1:100) of bridges over Cummings Creek.
   C. Pouch containing Drawing 92-8-1 to 92-8-5, 1:5000 scale topographic maps dated May 5, 1992, showing cross section locations.
   D. One 3.5 inch high density 2MB double sided disk containing HEC-2 GR data with and without decimals.

3. Drawings

A. Prints of Drawing 91-2-1 to 91-2-5, base map sheets for proposed interim designated floodplain mapping titled "Elk River and Michel Creek near Sparwood", 1:5000 scale, 2m contour interval.
B. Prints of Drawing 92-8-1 to 92-8-5 titled "Elk River, Michel Creek and Cummings Creek at Sparwood, Topographic Plan Showing Cross Section Locations" (see 2C above).
C. Drawing A5196-1A and A5196-2A titled "Elk River at Sparwood", 1:5000 scale, 1m contour interval, dated March 1980.

4. Miscellaneous

A. Binder with listing of 21 surveyed spot heights with elevations and differences to base mapping. Also contains prints of Drawings 92-8-1 to 92-8-5 showing location of spot heights. (Project 91 30 F040).
B. Binder with photographs and descriptions of 46 high water marks observed on June 21 & 22, 1991. See Volume 1 of 2 (item 1.D above) for elevations.
C. Design file for Elk River at Fernie and Sparwood (1976) containing data used in the production of existing floodplain mapping at Sparwood (item 3.C above).

APPENDIX C

ELK RIVER AND MICHEL CREEK HYDROMETRIC DATA

WATER SURVEY OF CANADA HYDROMETRIC DATA

	08NK016 ELK RIVER NEAR NATAL		08NK002 ELK RIVER AT FERNIE		08NK020 MICHEL CREEK BELOW NATAL	
YEAR	MAX INST cu m/s	MAX DAILY cu m/s	MAX INST cu m/s	MAX DAILY cu m/s	MAX INST cu m/s	MAX DAILY cu m/s
1950		#N/A				
1951		213				
1952		97.7				
1953		174				
1954		192				
1955		168				
1956		283				
1957		115				
1958		113				
1959		#N/A				
1960		199				
1961		270				
1962		99.1				
1963		231				
1964		219				
1965		185				
1966		195				
1967		214				
1968		130				
1969		173				
1970		137		247		84.4
1971		173		357		109
1972		292		507		148
1973		124		281		92.0
1974	340	326		620		180
1975	131	128		297		107
1976	124	120		306		113
1977	74.8	72.2		121		43.0
1978	176	172	297	289		84.1
1979	141	136	285	277		84.1
1980	139	136	234	229		71.4
1981	220	215	376	360		104
1982	188	172	264	257		85.8
1983	126	124	255	247		98.5
1984	112	111	197	193		60.9
1985	113	110	217	214		77.2
1986	229	226	446	428		144
1987	132	129	245	234		78.5
1988	124	119	204	199		69.6
1989	111	108	218	214		73.3
1990	195	193	344	330	114	109
1991	166	164	324	318	153	144
1992	91.8	89.3	141	138	62.1	57.6
MEAN **	**154.4**	**150.0**	**269.8**	**261.8**	**109.7**	**103.5**

** For concurrent period of record for max. inst. and max. daily flows