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WATER MANAGEMENT BRANCH

FLOODPLAIN MAPPING PROGRAM

BEAR RIVER AT STEWART

DESIGN BRIEF

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1 INTRODUCTION

Hay and Company Consultants Inc. were engaged by the B.C. Ministry of Environment, Lands and Parks to undertake studies and prepare floodplain maps for the Bear River at Stewart. This work is covered under the 1987 joint Federal/Provincial Agreement on Floodplain Mapping.

The watershed of the Bear River is located within the Boundary Ranges of the Northern Coast Mountains, adjacent to the Alaska Border, Figure 1. The river has steep valley walls which rise 1200 to 1800 m above the U-shaped valley bottom. The Bear River has its headwaters in Strohn Lake (Photo 22) at the toe of the Bear Glacier which is part of the Cambria Icefield. Principal tributaries are American Creek and Bitter Creek. The catchment area is approximately 671 km^2 of which about 37% is glaciated. The river has a gravel bed with a wide valley bottom near the mouth which is characterized by a network of braided channels.

The river is actively aggrading due to a large sediment load with consequent advancement of the delta front. These processes have been accentuated by dyking works at Stewart which have constricted the delta front. An aggradation rate analysis was carried out as part of the current study.

The floodplain mapping studies described herein cover approximately the first 7 km of the Bear River above the mouth including 4.5 km below the Highway 37A Bridge and 2.3 km above the bridge. The studies also included the foreshore at Stewart.

Representative photographs of the study area are included with locations referenced to the survey cross sections or principal features.

2 SOURCES OF INFORMATION

This study made use of river and foreshore survey information supplied by Mr. R. W. Nichols of the Water Management Division, Ministry of Environment, Lands and Parks. The information package included cross section data, plots of cross sections, a VHS video tape showing river conditions at most of the cross sections, bridge sketches and bridge road profiles, 1:5000 base mapping and background reports. River surveys were undertaken in April-May 1991. Base mapping is dated February 1991 based on 1989 air photography. In addition, Water Survey of Canada streamflow records were utilized along with limited gauge information from the WMD gauge at Stewart. The study also utilized 1:50,000 topographic mapping. A complete listing of data sources and references is included in Appendix 5.

3 FIELD INSPECTIONS

A field inspection was conducted by Mr. R.J. Wallwork on September 23-24, 1992, prior to preparation of the flood frequency estimates and HEC-2 backwater model. The field inspection allowed Mr. Wallwork to become familiar with the study area and it was also used to ascertain if any changes had occurred subsequent to preparation of the river survey package. Mr. Wallwork took site photos to supplement the video tape supplied by WMD and he also met with Mr. Jim Ogilvie, District of Stewart - public works superintendent, regarding the proposed measurement of a fall flood profile.

Unfortunately the local museum was closed for the season so it was not possible to search for historical flood information. Historical information was unavailable at the District office and time constraints precluded a special opening of the museum.

4 HYDROLOGY

4.1 Flood Frequency Studies - Methodology

The Water Survey of Canada CFA-88 computer program was utilized for the frequency analysis of the Bear River flow data. This program utilizes several frequency distributions including the following:

1. Generalized Extreme Value Distribution (GEV Types 1,2, or 3)
2. Three Parameter Lognormal Distribution (3PLN)
3. Log Pearson Type III Distribution (LP III)

The selection of which results to incorporate into the studies was based on a number of considerations including the observed "fit", consistency of instantaneous and daily flood estimates and regional appropriateness.

4.2 Streamflow Records

The Water Survey of Canada (WSC) gauging station on the Bear River above Bitter Creek (08DC006) was used to obtain flood estimates for the Bear River. This gauge has 25 years of annual maximum daily discharges and 23 years of annual maximum instantaneous discharges (1967 - 1991).

4.3 Flood Estimates for Bear River Above Bitter Creek

The frequency estimates from the analysis of the maximum daily discharge records are summarized in Table 1.

Table 1
Bear River above Bitter Creek (Sta 08DC006)
Maximum Daily Flood Estimates (m^3/s)

Return Period years	Frequency Distribution		
	GEV	3-PLN	LP III
2	118	118	118
5	149	151	150
10	174	178	177
20	202	206	206
50	246	248	250
100	285	282	288
200	330	319	332
500	401	374	398

Details of the frequency analyses of daily floods are included in Appendix 1. No outliers were identified in the analyses. The maximum instantaneous flood records were similarly analyzed and results are listed in Table 2 with details included in Appendix 2. Once again there were no high or low outliers identified in the flow records.

Table 2
Bear River above Bitter Creek
Maximum Instantaneous Flood Estimates (m^3/s)

Return Period years	**Frequency Distribution**					
	GEV	***i/d***	**3-PLN**	***i/d***	**LP III**	***i/d***
2	149	1.263	145	1.229	153	1.297
5	197	1.322	200	1.325	200	1.333
10	234	1.345	246	1.382	232	1.311
20	274	1.356	297	1.442	263	1.277
50	334	1.358	375	1.512	305	1.220
100	385	1.351	442	1.567	336	1.167
200	443	1.342	516	1.618	369	1.111
500	529	1.319	628	1.679	414	1.040
	AVG	1.332	AVG	1.469	AVG	1.220

Selection of the most appropriate frequency distribution has taken into account the ratio between maximum instantaneous and maximum daily floods (*i/d*). The average observed *i/d* ratio was determined to be 1.29 based on 17 years with coincident instantaneous and daily flood peaks. The average *i/d* ratio based on the highest three daily floods was 1.27 and the corresponding ratio for the highest three instantaneous floods was 1.34. The results on Table 2 also include a tabulation of *i/d* ratios for the flood estimates derived for each of the three frequency distributions (Table 2 estimates compared to those on Table 1.) The GEV estimates are the most consistent in terms of *i/d* ratio versus return period and the average ratio of 1.33 is in good agreement with the observed ratios. The observed "fit" for the GEV estimates was also satisfactory and consequently these estimates were adopted.

It is worth noting that all three frequency distributions gave similar daily flood estimates, Table 1. The maximum variation in the estimates was only four percent at the 200 year return period. In terms of *i/d* ratios, however, the 3 PLN estimates had progressively higher ratios with increasing return periods whereas the opposite was true with the LP III estimates. In consideration of these factors, the GEV estimates appear to be the best choice.

4.4 Flood Estimates For Bear River at Stewart

The flood estimates for the Bear River at Stewart were derived based on an areal adjustment of the estimates derived for the upstream gauge above Bitter Creek. The drainage area for the Bear River gauge above Bitter Creek is listed by WSC as 350 km^2. In an earlier analysis by the Water Management Division (Appendix 5A.13), the area at this gauge was reported to be 427 km^2 (165 mi^2) or 22% higher than the WSC estimate, and the drainage area at Stewart was reported as 733 km^2 (283 mi^2). WMD also reported the portion of the catchment covered by permanent ice cover to be 171 km^2 (66 mi^2) at the gauge and 275 km^2 (106 mi^2) at Stewart. The percentage of the catchment which is glaciated is therefore 40% at the gauge and 37% at Stewart according to previous WMD measurements.

Hay and Company (Hayco) have since used the best available mapping and measured the drainage areas for the upstream gauge above Bitter Creek and at Stewart. Hayco areas were digitized from 1:50,000 NTS maps. The measurements are summarized in Table 3.

Table 3
Watershed Areas - Square Kilometres

	WSC	WMD (1976)	HAYCO (1992)
at gauge 08DC006	350	427	313
at Stewart	-	733	671

The drainage area ratio was subsequently revised from 1.72 to 2.14.

A review of the literature revealed that an areal transfer exponent of 0.65 may be appropriate for this region based on the Envelope Curve of Extreme Floods in Yukon Territory and Northern British Columbia (Environment Canada, 1982). Applying this exponent to the total drainage area ratio results in a flood transfer factor of 1.6.

It was originally intended to base the flood transfer factor on actual gauge data for the Bear River at Stewart versus the Bear River at Bitter Creek, however, this was not possible due to delays in processing the gauge records by WMD and WSC. The gauge on the Bear River at Stewart was established by the WMD of B.C. Environment in April of 1992 (see Photo 15).

The revised flood estimates, Table 4, are based on the 1.6 transfer factor applied to the GEV estimates for the Bear River above Bitter Creek as listed in Tables 1 and 2. These estimates are also plotted on Figure 2.

Table 4
Bear River at Stewart
Flood Estimates

Return Period years	Maximum Daily Discharge m^3/s	Maximum Instantaneous Discharge m^3/s
2	189	238
5	238	315
10	278	374
20	323	438
50	394	534
100	456	616
200	528	709
500	642	846

The design flood estimates for the water surface profile studies are therefore as follows:

200 year maximum daily flood = 528 m^3/s
20 year maximum daily flood = 323 m^3/s

200 year maximum instantaneous flood = 709 m^3/s
20 year maximum instantaneous flood = 438 m^3/s

It should be noted that the 200 year maximum instantaneous estimate is now 709 m^3/s or 42% higher than the 498 m^3/s previously derived by WMD for Hayco in 1986. An earlier estimate by WMD in August 1976 gave 753 m^3/s for this flood event which is 6% higher than the current estimate by Hayco. The earliest estimate was preliminary and used rainfall data to prorate the October 8, 1974 flood hydrograph at gauge 08DC006 to Stewart using an areal transfer factor of 1.4. The 1986 estimates were based on frequency analysis of the 17 years of records, again using a transfer factor of 1.4. The Hayco estimates are based on 25 years of record and a revised transfer factor of 1.6.

4.5 Historical Data

As previously mentioned, no historical information was obtained during the Hayco site visit. Past flooding threats were reported in a 1976 WMD report entitled "Bear River Dyking, Stewart B.C." by P.J. Woods. This report mentioned severe floods in 1947 and 1961 as well as other flood threats in 1959 and 1974 (Appendix 5A.9).

The 1947 flood was linked to a flood wave resulting from the sudden release of water impounded in Strohn Lake due to a blockage caused by the toe of the Bear Glacier. Rising lake levels floated the toe of the glacier resulting in a self-draining process know as a "jokulhlaup". This flood inundated the cemetery, located several kilometres upstream of the Bear River bridge at Stewart, and also damaged the highway and the bridge. No flooding was reported in Stewart.

The 1961 flood resulted from an October rainfall of 178 mm (7 inches) in 24 hours. Once again the cemetery flooded while the town did not.

The 1959 flood nearly overtopped the short dyke upstream of the Bear River bridge and the 1974 flood also nearly overtopped the dykes.

Flood waves were also reported due to partial damming of the Bear River by avalanches and landslides.

It should be mentioned that the Bear Glacier has since receded and consequently no lake outburst floods have occurred during the period of gauged records which commenced in 1967.

Recent studies by Hay & Company Consultants (Appendix 5A.5) have investigated bed aggradation with respect to harbour development and dyke freeboard. Bed aggradation was shown to be of considerable concern with estimated aggradation depths of 1.2 m to 1.7 m over a 48 year period, depending on harbour development plans.

In 1990 the lower Bear River was excavated to provide fill for a development area near the mouth. This area is shown on Drawing 1 (from Hayco "as built" drawings).

5 OCEAN WATER LEVELS

5.1 Tide Levels

Tide levels at Stewart were determined using standard correction factors applied to the tides at Prince Rupert, which is the closest Canadian Hydrographic Service (CHS) reference port. The tide estimation procedure is detailed in the Canadian Tide and Current Tables, published annually by CHS. Table 5 lists HHW large tide estimates for Stewart and Prince Rupert, as well as the large tide range for both stations.

Table 5
Tide Levels at Stewart and Prince Rupert

Station	HHW, Large Tide m above chart datum	Large Tide Range (m)
Prince Rupert	7.5 m	7.7
Stewart	8.0 m	8.1

Geodetic datum at Stewart is 4.05 m above chart datum based on mean sea level as reported in the above tide tables.

5.2 Storm Surge

An analysis of storm surge at a particular site requires an investigation of the effects of barometric pressure and wind stress. To determine the pressure effect on storm surge at Stewart, an extreme value estimate using the difference between measured and predicted tides at Prince Rupert was undertaken. It is assumed that passing storms and their decreased pressure levels will be of long enough duration to be recorded during a high tide and consequently the storm surge component will be reflected in the above difference. Monthly observed maxima and concurrent predicted tides at Prince Rupert were obtained from the Canadian Hydrographic Service in Sidney, for the period 1930 - 1992. From this data set, annual maximum residuals were extracted and then analyzed using four theoretical probability distributions: Generalized Extreme Value, 3- Parameter Log Normal, Log Pearson Type III and Wakeby. The estimates obtained for the 1:50 and 1:200 year residuals are listed in Table 6.

Table 6
Storm Surge Residuals - Frequency Estimates

	Surge Estimates (m above SWL)			
Return Period	**Generalized Extreme Value**	**3 Parameter Log Normal**	**Log Pearson Type III**	**Wakeby**
1 in 50 years	0.83	0.83	0.82	0.84
1 in 200 years	0.96	0.97	0.95	1.12

The standard bathostrophic theory found in the Shore Protection Manual (1977, 1984) was used to calculate the storm surge at Stewart due to wind stress. Winds recorded at the AES station in Stewart were adjusted to compensate for the effect of being recorded over land, as concurrent overwater wind speeds can be substantially higher. The adjusted winds were then plotted on a graph of windspeed versus frequency, and extreme windspeeds corresponding to return periods of 50 and 200 years were estimated from the graph.

For both the 50 and 200 year return period events, it was found that the setup at Stewart due to wind stress was on the order of 3 cm, which is primarily due to the sensitivity of the calculation to the extreme depths in Portland Canal. Thus, the wind stress effects are very small compared to the barometric pressure effects, and can be ignored.

5.3 Wave Runup

To estimate wave runup, a hindcast was undertaken to determine the deepwater wave climate in Portland Canal using the modified SMB procedure (Shore Protection Manual, 1984). A very shallow (1:100) nearshore slope was assumed for the runup calculations, as it was observed during the site visit that the water's edge was approximately one kilometre offshore from the local high water marks (Photo 1). Wave runup was estimated using the transformation procedures detailed in Shore Protection Manual (1984) and programmed in our own in-house transformation software. The estimated runups for the hindcast deepwater wave conditions are given in Table 7.

Table 7
Design Wave Height and Runup Estimates at Stewart

Return Period	Wave Height (m)	Wave Runup (m)
1 in 1 year	1.6	0.27
1 in 10 year	2.2	0.35
1 in 25 year	2.5	0.39
1 in 50 year	2.6	0.40
1 in 200 year	3.0	0.45

5.4 Ocean Flood Levels

The 200 year and 50 year levels for the ocean at Stewart were determined for a combination of higher high water, large tide, storm surge and wave runup as per the values tabulated above. Accordingly, the following flood level combinations were derived for the foreshore at Stewart:

a) HHW Large Tide + 200 yr storm surge + 200 yr wave runup
= 8.0 + 0.96 + 0.45
= 9.41 m chart datum
= 5.36 m GSC
≈ 5.4 m GSC

b) HHW Large Tide + 50 yr storm surge + 50 yr wave runup
= 8.0 + 0.83 + 0.40
= 9.23 m chart datum
= 5.18 m GSC
≈ 5.2 m GSC

The above flood levels are based on either a 200 year or 50 year storm coincident with a large high tide. In the water surface profile studies discussed in the following section, it was concluded that a surge component should be incorporated into the starting water levels for the 200 year event as the flood producing mechanism cannot be disassociated from storm events. It was decided to apply the 50 year storm surge to the 200 year event and not apply any surge component with the 20 year event. The corresponding starting water levels for the HEC-2 studies are therefore as follows:

c) 200 Year Event:

HHW Large Tide + 50 yr Storm surge

= 8.0 + 0.83

= 8.83 m chart datum

= 4.78 m GSC

d) 20 Year Event:

HHW Large Tide

= 8.0 m chart datum

= 3.95 m GSC

It should be noted that when 0.6 m freeboard is added to the HEC-2 starting levels for the 200 year event, the resulting Flood Level of 5.4 m GSC will be identical to the design flood levels for the ocean as applied to the foreshore.

5.5 Tsunami Hazard

The coastline of British Columbia is subject to potential tsunami hazards due to offshore earthquakes in the Pacific Ocean. In a 1988 study, Seaconsult Marine Research Ltd. estimated sea level rise in numerous inlets along the B.C. coast from tsunamis generated by potential undersea earthquakes in the Pacific, including a recurrence of the 1964 Alaska earthquake. The maximum estimates of water level rise at Stewart ranged between 2.3 and 4.1 m above mean water level, depending upon the location and the magnitude of the source earthquake. With a large tide range of 8 m at Stewart, tsunami effects may not be critical unless the tsunami wave arrived in conjunction with water levels above mean sea level. For example, tsunami levels would not exceed the 200 year ocean flood level of 5.4 m GSC unless the coincident ocean level were 5.4 - 4.1 = 1.3 m GSC (5.35 m chart datum) or above. The maximum amount by which tsunami levels could exceed the ocean flood level would be as follows:

HHW Large Tide + Tsunami Rise - Ocean Flood Level

= 3.95 + 4.1 - 5.4

= 2.65 m

Tsunami is not a criteria for Designation under the Federal/Provincial Agreement although a note is made regarding this potential on the Floodplain Map.

6 HYDRAULIC ANALYSIS - BEAR RIVER

6.1 Model Calibration

The U.S. Army Corps of Engineers HEC-2 computer program, Version 4.6.0 - February 1991, was utilized in the water surface profile analysis, as implemented by Haestad Methods (HM version 6.20).

The HEC-2 water surface profile model of the Bear River was developed from 32 cross sections supplied by the Ministry. An additional four cross sections were supplied for Winachee Creek near the garbage dump bridge (Photo 21), however, these were not included in the model. It was concluded that Winachee Creek, with a drainage area of only 6.5 km^2 (less than one percent of the total drainage area at Stewart), would not have a significant impact on the results.

A skew adjustment was applied to cross sections 1, 2, 3, 5 and 6 as these sections were not oriented perpendicular to the flow. Also cross section 6 was entered in the model downstream of cross section 5, after skew adjustments were made.

The sections were extended to the limit of the floodplain, except for the town of Stewart, using the 1:5000 base mapping. Non-effective portions of the cross sections, beyond the dykes, were excluded from the flow analysis by means of X3 cards. Areas to the left of Highway 37A, upstream of the bridge, were likewise excluded from the analysis unless overtopping of the road occurred.

The Highway 37A bridge was modelled using the special bridge method. The lower chord of the bridge at the centre pier is at E1. 16.29 m which is approximately equal to the lowest point in the road profile, E1.16.31 m, near the junction with the cutoff dyke on the right bank.

Calibration of the HEC-2 model was difficult as the use of a fixed bed model, such as HEC-2, is a compromise in a steep, braided channel with high bedload. This compromise was reflected in the calibration. The only high water mark data available for calibration corresponded to the October 14, 1991 flood which was recorded as a peak flow of 249 m^3/s at the upstream gauge above Bitter Creek. Using a transfer factor of 1.6, this flood corresponded to 398 m^3/s at the site. Attempts to match the known water level corresponding to HWM 3, 10 m downstream of the bridge, were unsuccessful using realistic Manning's n values.

A calibration was then attempted using the June 24, 1992 measured flow of 134 m^3/s, which had the advantage that the flow did not require adjustment. The model overestimated water levels at the WMD gauge location, on the downstream face of the bridge (cross section 25) by 0.29 m even after lowering

Manning's n to 0.025 throughout the lower channel. With a Manning's n of 0.030, the model overestimated the known water level by 0.37 m.

An analysis of the cross sections revealed that cross section 24, approximately 45 m downstream of the bridge, was constricting the flow resulting in overestimation of the upstream water levels. A satisfactory calibration was subsequently achieved by using the channel improvement option to artificially remove the left bank gravel bar at cross section 24. The channel was excavated to El 13.0 m over a 60 m width which enlarged the cross-sectional area by 64 m^2. It was assumed that the October 1991 flood, which was the second largest on record, must have scoured out a gravel bar which showed up in the April 1991 survey section. Photographs of the river during the April 1992 gauge installation revealed significant channel shifting with a gravel bar on the right side of the channel contrary to the April 1991 survey.

The adopted Manning's n values for the channel were as follows:

N	=	0.030	from	XS-1	to	XS-6
N	=	0.032	from	XS-7	to	XS-26
N	=	0.048	from	XS-27	to	XS-32

A single Manning's n value of 0.100 was used for all overbank areas. The contraction and expansion coefficients at the bridge were 0.4 and 0.5 respectively. The Manning's n values in the channel upstream of the bridge were increased by 50% over the downstream channel values to account for increased roughness associated with a wider, more highly braided channel with shallow flow depths and more extensive channel debris.

The aforementioned model exceeded the known water level at cross section 25 by only 0.02 m with the June 24, 1991 flow. Likewise, the model predicted the water level at HWM 2 within 0.03 m during the October 14, 1991 flood. The model also predicted a value for the energy grade line at HWM 3 of 15.39 m which was only 0.09 m higher than the measured high water mark (15.26 m) adjusted for velocity head. The predicted energy grade line at HWM 3 was taken as the average of the energy levels at cross sections 26 and 27. Likewise the adjustment to the high water mark elevation was assumed to be equal to the velocity head at cross section 27.

6.2 Sensitivity Studies

6.2.1 Discharge

The sensitivity of the calibrated model to variations in discharge was investigated by means of a multiple flow run in which the 200 year instantaneous discharge was increased by 10, 20 and 30% (see HEC-2

Study File: Bear River at Stewart). Starting water levels were 4.78 m GSC based on higher high water, large tide plus 50 year storm surge.

The profile was virtually flat from cross section 1 to 8 and critical depth was indicated at cross section 10. A subsequent analysis revealed that subcritical flow would occur at section 10 if lower starting water levels were used in the model although the resulting depth increase was small, approximately 0.12 m. Critical depths were also indicated at cross section 17 and a hydraulic jump was predicted downstream of cross section 26.

The model was not very sensitive to discharge, a 30% increase in flow resulted in stage increases ranging from 0.14 m at cross sections 29 and 31 to 0.51 m at cross section 27. The typical stage change below the bridge was about 0.26 m while the corresponding stage change above the bridge was only 0.17 m, excluding cross sections 27 and 28 which were backwatered by the bridge.

6.2.2 Roughness

The sensitivity of the calibrated model to changes in bed roughness was also investigated (multiple "n" run). The calibrated model roughness values were increased by 20 and 40% with the 200 year mean daily discharge. The model was not very sensitive to channel roughness as a 40% increase in Manning's n resulted in stage increases which ranged from 0.13 m at cross section 29 to 0.37 m at cross section 10. The average stage change below the bridge was 0.27 m whereas the corresponding stage change above the bridge was 0.22 m.

6.3 Designated Flood Level and Freeboard Requirements

The designated flood level generally consists of the computed 200 year instantaneous peak profile plus 0.3 m of freeboard or the computed 200 year mean daily peak profile plus 0.6 m of freeboard, whichever level is higher; or as deemed advisable if special conditions are apparent. Stated another way, unless the instantaneous profile is 0.3 m or more above the maximum daily profile, the maximum daily profile plus 0.6 m freeboard allowance will govern. Freeboard is provided as a contingency allowance to account for uncertainty and changing conditions such as bed aggradation.

The 200 year mean daily flood profile plus 0.6 m freeboard was found to govern the designated flood profile determination throughout most of the study reach. The only exceptions were at cross sections 11, 12, 26, and 27. Tabulated values for the Bear River flood profile, including freeboard, are listed in Appendix 3.

The freeboard allowance used for the designated flood level therefore appears adequate to accommodate a 200 year instantaneous flow increase of approximately 18 to 94% depending on location. Likewise the freeboard allowance would also be adequate to accommodate an increase in roughness of between 35 and 105% depending on location. The latter range was based on an additional roughness sensitivity run which used the 200 year instantaneous flow (see Study File). The range would have been greater still had the freeboard been evaluated in terms of the 200 year mean daily discharge.

The freeboard was also evaluated in terms of its potential to accommodate bed aggradation. Assuming a net bed aggradation rate of approximately 0.033 m/year (see Section 8.1), the total available freeboard should be sufficient to last approximately 20 to 60 years depending on dyke location. With gravel borrows taken into consideration, the freeboard should last even longer.

Interpolated flood levels at one metre spacing were derived from the designated flood profile, Figure 3, and used to draw flood level isograms on the enclosed floodplain maps with the exception of the right overbank areas below the bridge (town of Stewart). A separate breach analysis was used to determine flood level isograms in this area behind the river dyke.

Twenty year flood levels, including freeboard, were derived in a similar manner and noted on the floodplain maps. The breach analysis did not include the 20 year event as it was considered extremely unlikely for such an event to precipitate a breach.

6.4 Standard Dyke Profile Evaluation

An additional sensitivity run (Bear-40.HC2 in Study File) was performed in which Manning's n was varied in conjunction with the 200 year instantaneous flow of 709 m^3/s, similar to the approach taken with the discharge sensitivity analysis. Standard dyke freeboard was examined as part of the analysis by entering the dyke crest elevation as the known water surface elevation (WSELK) on the X2 data cards. In the causeway area (cross sections 1 to 8) and upstream of the bridge, the road crest elevations were used. In the model output, the variable DIFKWS then represents the total available freeboard (disregard negative sign). A plot of the standard dyke, causeway, and road crest levels are included on the water surface profile plots (Figure 3).

The above sensitivity analysis revealed an adequate freeboard allowance throughout most of the river reach below the bridge with the exception of the reach near cross section 23 where freeboard is marginal. Overtopping of the road (Highway 37A) is likely to occur at cross section 32, during the 200 year instantaneous flood.

The standard dyke crest profile as well as the causeway and road profiles are also included with the tabulation of the designated flood profile in Appendix 3. As the designated flood profile includes the standard freeboard allowance, any additional freeboard up to the dyke crest elevation can be considered a contingency allowance for bed aggradation and this has also been tabulated. The minimum contingency freeboard downstream of the bridge occurs at cross section 23, ignoring conditions along the causeway (cross sections 1 to 8). The freeboard on the west bridge approach, near the intersection with the cutoff dyke, may be inadequate by 0.17 m based on interpolated energy levels (sections 26 and 27), minus the velocity head at cross section 27.

Consideration should be given to raising the standard dyke profile near cross section 23 to achieve a more consistent freeboard compared to most other dyke locations downstream of the bridge.

7 EXTENSION OF FLOOD LEVEL ISOGRAMS

7.1 Breach Model Development

A separate HEC-2 model was developed to evaluate flow conditions and permit flood level isograms to be extrapolated over the right overbank area in a realistic manner. The model was initially developed from seven cross sections which were derived from the 1:5000 base mapping. An eighth cross section was added later to improve model accuracy near the foreshore. The first and last sections were simple, trapezoidal sections used to simulate end conditions. The breach itself was assumed to be 200 m wide with an invert elevation of 14.0 m. The 200 m width represents the maximum extent of the breach from the right bridge abutment to the valley wall.

A possible scenario for development of a river dyke breach would involve a debris blockage at the perched highway bridge resulting in overtopping of the right bank (west) road approach (Highway 37A). It should be noted that the lowest point in the right bank road approach to the bridge is at El.16.31 m near the junction with the cutoff dyke. Similarly the low point in the left bank road approach is at El.16.86 m or 0.55 m higher than on the right bank. This arrangement would favour breach development in the right bank bridge approach as postulated. It should be recognized that this arrangement is unsatisfactory as it would be preferable for overtopping to occur along the left bank (east) bridge approach in the event of a blockage at the bridge. Consideration should therefore be given to raising the west bridge approach, along with the cutoff dyke crest, to approximately El.17.5 m in order to promote overtopping on the east bridge approach, rather than a standard dyke breach.

7.2 Breach Analysis

The 200 year instantaneous discharge of 709 m^3/s was used in the breach analysis as a blockage would likely be associated with an extreme event, capable of mobilizing much of the upstream log debris from the braided channel system. A Manning's n of 0.070 was initially used to represent the composite roughness of the overbank which consists of wooded areas, brush, lawns, roads, ditches and obstructions due to buildings. A freeboard allowance of 0.3 m was added to the calculated water levels and the results were compared to the corresponding design flood profile in the Bear River on the opposite side of the dyke. It was found that the breach levels exceeded the Bear River profile except for the two sections nearest the ocean. Breach levels near the bridge exceeded the dyke crest so an "n" sensitivity test was conducted to determine how breach levels would vary with Manning's n. Results of this analysis are given in Table 8. The starting water level was 4.78 m for all runs.

Table 8
Breach Analysis: Sensitivity to Manning's N

Cross Section	Main Channel Flood Level m	Dyke Crest m	Q_b = 100% (709 m^3/s) Breach Flood Level Including 0.3 m Freeboard - m			
			n = 0.070	n = 0.050	n = 0.040	n = 0.032
101	5.45	5.9	5.08	5.08	5.08	5.08
102	6.0	6.6	6.01	5.77	5.62	5.62
103	7.3	8.6	7.78	7.71	7.67	7.56
104	9.3	10.4	9.85	9.65	9.50	9.46
105	11.5	12.6	12.36	12.24	12.20	12.10
106	13.7	14.1	14.64	14.35	14.14	14.02
107	16.0*	15.7	16.62	16.30	16.14	15.96

* Applies to upstream face of bridge

An n value of 0.050 was considered to be the best estimate for the composite overbank roughness and this value was used in subsequent tests.

Following the "n" sensitivity tests, an additional cross section 101.5 was added to improve model accuracy near the foreshore. The previous model generated a critical depth assumption at cross section 102 for n values of 0.040 and lower. This assumption was not considered valid.

As complete diversion at the bridge is highly unlikely, a sensitivity test was conducted on breach flows. Results of this analysis are summarized in Table 9.

Table 9
Breach Analysis: Sensitivity to Discharge

Cross Section	Main Channel Flood Level m	Dyke Crest m	Breach Flood Level Including 0.3 m Freeboard (1)		
			Q_b = 100% (709 M^3/s)	Q_b = 75% (2) (532 m^3/s)	Q_b = 60% (425 m^3/s)
101	5.45	5.9	5.08	5.08(3)	5.08
101.5	5.45	6.0	5.34	5.24(3)	5.19
102	6.0	6.6	5.93	5.80	5.71
103	7.3	8.6	7.60	7.52	7.46
104	9.3	10.4	9.75	9.62	9.53
105	11.5	12.6	12.16	12.06	11.98
106	13.7	14.1	14.42	14.24	14.10
107	16.0(4)	15.7	16.25	16.00	15.83

(1) Manning's n = 0.050
(2) $Q_b = 0.75 \times Q_{200i} = 532\ m^3/s$
$\approx 528\ m^3/s = Q_{200d}$
(3) Ocean Flood Level Dominates at XS 101 and 101.5 (5.4 m).
(4) Applies to upstream face of bridge

The diversion flow water level at cross section 107 cannot physically be higher than the dyke crest elevation of 15.7 m as flow would re-enter the main channel overtop the dyke. The maximum diversion flow was therefore determined to be 532 m^3/s or 75% of the total flow in the Bear River. The corresponding water level at cross section 107 was 15.70 m. It should be noted that 75% of the 200 year instantaneous discharge is also approximately equal to the 200 year daily flood flow.

The breach water levels were rather insensitive to discharge, a 40% flow reduction only resulted in stage changes of about 0.2 m throughout most of the reach.

7.3 Selected Breach Flood Profile

The second profile in Table 9, corresponding to a breach flow of 532 m^3/s (75% of Q_{200I}) was selected for use in extending the flood level isograms behind the dyke. Breach flood levels are higher than the corresponding flood levels in the main channel except near the foreshore where the ocean flood level of 5.4 m would govern flood levels to a line just inland of cross section 101.5. The adopted profile (75% of Q_{200I}), with 0.3 m of freeboard, exceeds the profile for 100% of Q_{200I} without freeboard.

It should be mentioned that the adopted breach flood profile only applies to a breach located at the bridge. A dyke breach further downstream would result in flood levels behind the dyke which are lower than in the main channel.

8 AGGRADATION RATE ANALYSIS

8.1 Methodology

The Bear River is actively aggrading due to advancement of the delta front. Previous studies (Hayco 1986) have estimated the rate of delta advancement at 12.5 m per year corresponding to a bed aggradation rate of approximately 1.6 m every 48 years with the present causeway development (0.033 m/year). An analysis of survey cross sections was carried out in order to quantify the bed changes which have taken place in recent years.

The survey cross sections obtained by McElhanney in 1980 (drawings dated May 7, 1980) were digitized and matched up with the corresponding sections from the April 1991 WMD survey. A good match was difficult to achieve in some cases due to a lack of identifiable features in the earlier survey sections. A common base width was identified and the net bed change was determined for each section.

8.2 Study Results

The cross sections used in the aggradation rate analysis are included in Appendix 4, Figures A4.1 to A4.12 with two cross sections per figure. The HEC-2 calculated water surface corresponding to the October 14, 1991 flood is also shown on the figures as a reference water level (horizontal dashed line). The bed changes are summarized in Table A4.1.

The aggradation analysis was compromised by the extensive channel dredging which has taken place between surveys. Most noteworthy were the dredge fills placed on the right bank near cross sections 7 and 8 in 1990 (Photo 5). Gravel is also dredged regularly from the river bed in the vicinity of cross section 14 (Photos 9 and 10). The results appear erratic between cross sections 1 and 18, however, consistent aggradation is evident between cross sections 19 and 24. The average bed elevation increased by 0.38 m in this upper reach below the bridge which translates into an annual increase of 0.035 m/year. Therefore if we restrict our analysis to the river reach which was least impacted by dredging, the results agree quite well with those predicted by earlier studies.

9 SPECIAL FLOOD CONDITIONS

There are a number of special flood conditions for the Bear River which include: aggradation impacts on dyke freeboard; tsunami hazards (Section 5.5); the potential for a dyke breach due to either a blockage at the bridge (Section 7.1), or resulting from a piping failure; avalanches; landslides; and the potential for lake outburst floods (jokulhlaup) from Strohn Lake. There is also a danger of local flooding from Rainy Creek. Perhaps the most serious of the above is the gradual loss of dyke freeboard due to riverbed aggradation. At present there is adequate freeboard except for a few locations which were identified in section 6.4. The potential for a dyke breach is also of great concern due to the large amount of log debris found on the braided channels upstream of the bridge. This material could easily hang up due to the limited clearance at the bridge which is on the order of 0.8 m at the abutments during the 200 year instantaneous flood.

There is also a potential for channel shifting and lateral erosion due to bedload movement in the braided reach, especially upstream of the bridge. Special flood conditions have been noted on the mapping. Also the extension of the flood level isograms behind the standard dyke has been based on the breach analysis discussed in Section 7. These flood level isograms, in the dyke protected area (Stewart), average approximately one metre above ground level except near the dyke breach itself where isograms average about two metres above ground level.

10 FLOODPLAIN MAPS

The floodplain maps for the Bear River at Stewart are enclosed, Drawing nos. 91-30-1 and 91-30-2, (2 sheets). The limits of the respective floodplains are shown together with flood level isograms showing approximate lines of equal 200 year flood level to the edge of the floodplain.

As noted on the drawings, the floodplain limits have not been established on the ground by legal survey and the maps depict open water conditions only. The flood levels behind the dyke were based on analysis of an assumed dyke breach at the bridge. As noted on the drawings, the flood level isograms have been dashed across the area behind the standard dykes.

11 CONCLUSIONS AND RECOMMENDATIONS

The following recommendations/conclusions are based on our investigations for this study:

1. The floodplain maps prepared for the Bear River at Stewart, as presented herein, should be interim designated under the terms of the joint Federal/Provincial Floodplain Mapping Agreement.

2. The floodplain maps should be reviewed and updated as required on the basis of future flood data, assessments of channel aggradation, or other information related to major physical changes in the floodplain.

3. A dyke safety review is recommended with particular attention to the inconsistent freeboard near cross section 23 and the west bridge approach including the cutoff dyke crest.

4. Portions of Highway 37A upstream of the bridge would be threatened during extreme flood events particularly near cross section 29, 31 and 32.

Prepared by: R.J. Wallwork

R.J. Wallwork, P.Eng.

Approved by: SRM Gardiner

Dr. S.R.M. Gardiner, P.Eng.

APPENDIX 1

Frequency Analysis of Maximum Daily Floods - Bear River Above Bitter Creek

WSC STATION NO=08DC006
WSC STATION NAME=BEAR RIVER ABOVE BITTER CREEK

MONTH (1)	YEAR (2)	DATA (3) (CMS)	ORDERED (4) (CMS)	RANK (5)	PROB. (6) (%)	RET. PER[I] (7) (YEARS)
8	1967	141.000	225.000	1	2.38	42.000
9	1968	88.600	204.000	2	6.35	15.750
6	1969	114.000	189.000	3	10.32	9.692
8	1970	99.100	159.000	4	14.29	7.000
10	1971	155.000	155.000	5	18.25	5.478
9	1972	141.000	143.000	6	22.22	4.500
9	1973	115.000	141.000	7	26.19	3.818
10	1974	225.000	141.000	8	30.16	3.316
7	1975	119.000	139.000	9	34.13	2.930
11	1976	130.000	130.000	10	38.10	2.625
8	1977	88.100	125.000	11	42.06	2.377
10	1978	112.000	119.000	12	46.03	2.172
10	1979	103.000	115.000	13	50.00	2.000
10	1980	139.000	114.000	14	53.97	1.853
9	1981	125.000	114.000	15	57.94	1.726
10	1982	143.000	112.000	16	61.90	1.615
9	1983	84.900	111.000	17	65.87	1.518
8	1984	102.000	103.000	18	69.84	1.432
7	1985	98.500	102.000	19	73.81	1.355
10	1986	159.000	100.000	20	77.78	1.286
9	1987	189.000	99.100	21	81.75	1.223
7	1988	111.000	98.500	22	85.71	1.167
9	1989	100.000	88.600	23	89.68	1.115
8	1990	114.000	88.100	24	93.65	1.068
10	1991	204.000	84.900	25	97.62	1.024

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FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
08DC006 BEAR RIVER ABOVE BITTER CREEK

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	128.008	36.097	0.282	1.261	4.692
LN X SERIES	4.818	0.258	0.054	0.712	3.444

X(MIN)= 84.900
X(MAX)= 225.000
LOWER OUTLIER LIMIT OF X= 65.149

TOTAL SAMPLE SIZE= 25
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

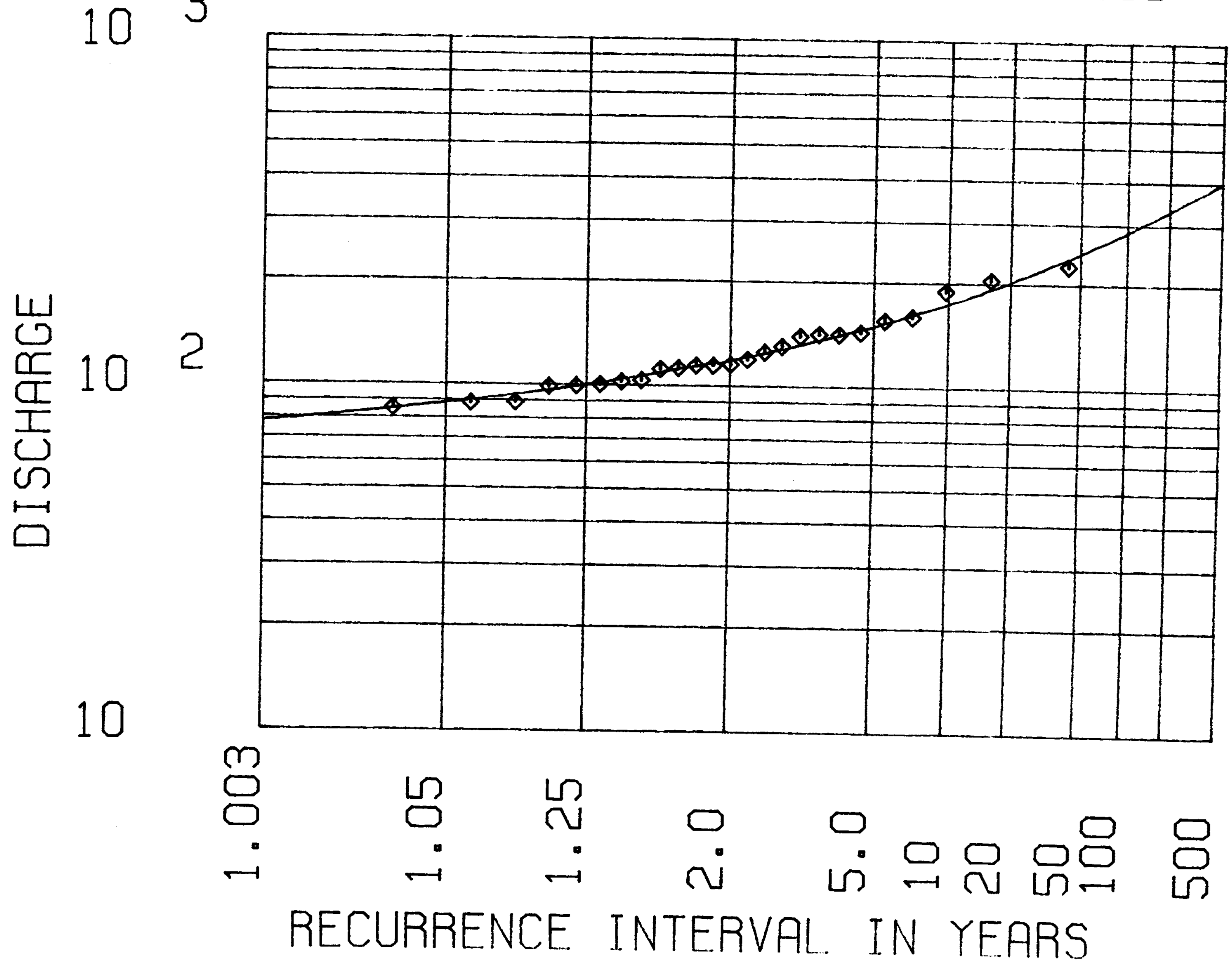
GEV PARAMETERS: U= 109.85 A= 22.198 K= -0.216

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	77.40
1.050	0.952	87.90
1.250	0.800	99.80
2.000	0.500	118.00
5.000	0.200	149.00
10.000	0.100	174.00
20.000	0.050	202.00
50.000	0.020	246.00
100.000	0.010	285.00
200.000	0.005	330.00
500.000	0.002	401.00

FREQUENCY ANALYSIS - 08DC006

GENERALIZED EXTREME VALUE-MAX LIKELIHOOD



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FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
08DC006 BEAR RIVER ABOVE BITTER CREEK

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	128.008	36.097	0.282	1.261	4.692
LN X SERIES	4.818	0.258	0.054	0.712	3.444
LN(X-A) SERIES	3.808	0.659	0.173	-0.132	3.066

X(MIN)= 84.900
X(MAX)= 225.000
LOWER OUTLIER LIMIT OF X= 65.149

TOTAL SAMPLE SIZE= 25
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

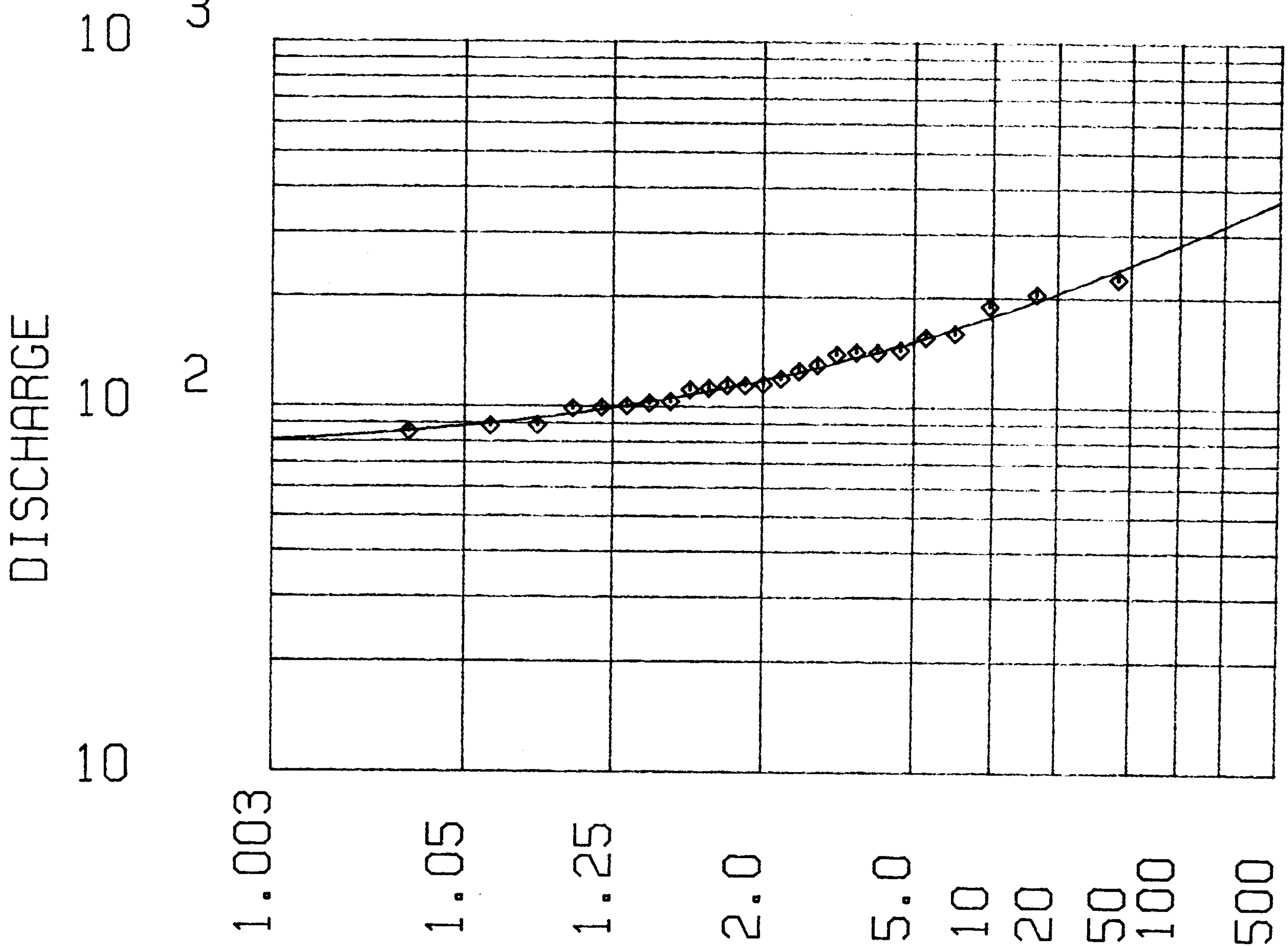
3LN PARAMETERS: A= 72.960 M= 3.808 S= 0.659

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	80.30
1.050	0.952	88.00
1.250	0.800	98.80
2.000	0.500	118.00
5.000	0.200	151.00
10.000	0.100	178.00
20.000	0.050	206.00
50.000	0.020	248.00
100.000	0.010	282.00
200.000	0.005	319.00
500.000	0.002	374.00

FREQUENCY ANALYSIS - 08DC006

THREE PARAMETER LØGNØRMAL-MAX LIKELIHØØD



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FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
08DC006 BEAR RIVER ABOVE BITTER CREEK

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	128.008	36.097	0.282	1.261	4.692
LN X SERIES	4.818	0.258	0.054	0.712	3.444

X(MIN)= 84.900
X(MAX)= 225.000
LOWER OUTLIER LIMIT OF X= 65.149

TOTAL SAMPLE SIZE= 25
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

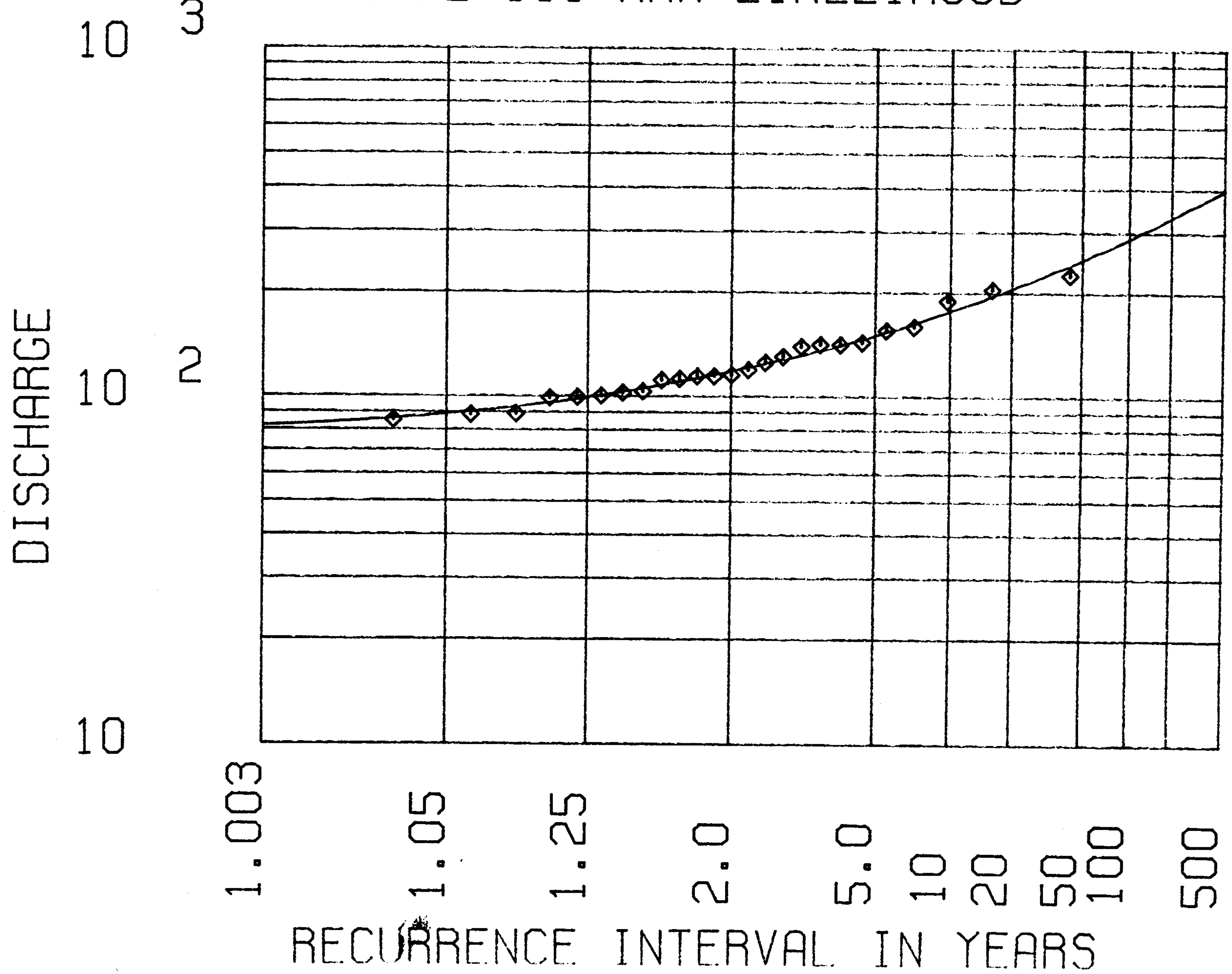
LP3 PARAMETERS: A= 0.1604 B= 2.786 LOG(M)= 4.372
M = 79.17

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	81.70
1.050	0.952	88.40
1.250	0.800	98.80
2.000	0.500	118.00
5.000	0.200	150.00
10.000	0.100	177.00
20.000	0.050	206.00
50.000	0.020	250.00
100.000	0.010	288.00
200.000	0.005	332.00
500.000	0.002	398.00

FREQUENCY ANALYSIS - 08DC006

LOG PEARSON TYPE III-MAX LIKELIHOOD



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APPENDIX 2

Frequency Analysis of Maximum Instantaneous Floods
Bear River Above Bitter Creek

WSC STATION NO=08DC006I
WSC STATION NAME=BEAR RIVER ABOVE BITTER CREEK (MAX. INSTANTANEOUS)

MONTH (1)	YEAR (2)	DATA (3) (CMS)	ORDERED (4) (CMS)	RANK (5)	PROB. (6) (%)	RET. PERI (7) (YEARS)
8	1967	169.000	271.000	1	2.59	38.667
8	1968	99.000	249.000	2	6.90	14.500
11	1969	130.000	248.000	3	11.21	8.923
8	1970	102.000	220.000	4	15.52	6.444
10	1971	248.000	206.000	5	19.83	5.043
10	1972	192.000	198.000	6	24.14	4.143
9	1973	138.000	192.000	7	28.45	3.515
10	1974	271.000	182.000	8	32.76	3.053
11	1976	206.000	180.000	9	37.07	2.698
10	1977	114.000	169.000	10	41.38	2.417
10	1978	180.000	168.000	11	45.69	2.189
10	1979	126.000	148.000	12	50.00	2.000
10	1980	198.000	138.000	13	54.31	1.841
9	1981	182.000	136.000	14	58.62	1.706
10	1982	168.000	130.000	15	62.93	1.589
9	1983	110.000	126.000	16	67.24	1.487
8	1984	112.000	125.000	17	71.55	1.398
7	1985	101.000	114.000	18	75.86	1.318
10	1986	220.000	112.000	19	80.17	1.247
7	1988	125.000	110.000	20	84.48	1.184
9	1989	136.000	102.000	21	88.79	1.126
8	1990	148.000	101.000	22	93.10	1.074
10	1991	249.000	99.000	23	97.41	1.027

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
08DC006I BEAR RIVER ABOVE BITTER CREEK (MAX. INSTANTANEOUS)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	161.913	51.824	0.320	0.622	2.803
LN X SERIES	5.040	0.313	0.062	0.218	2.303

X(MIN)= 99.000
X(MAX)= 271.000
LOWER OUTLIER LIMIT OF X= 71.719

TOTAL SAMPLE SIZE= 23
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

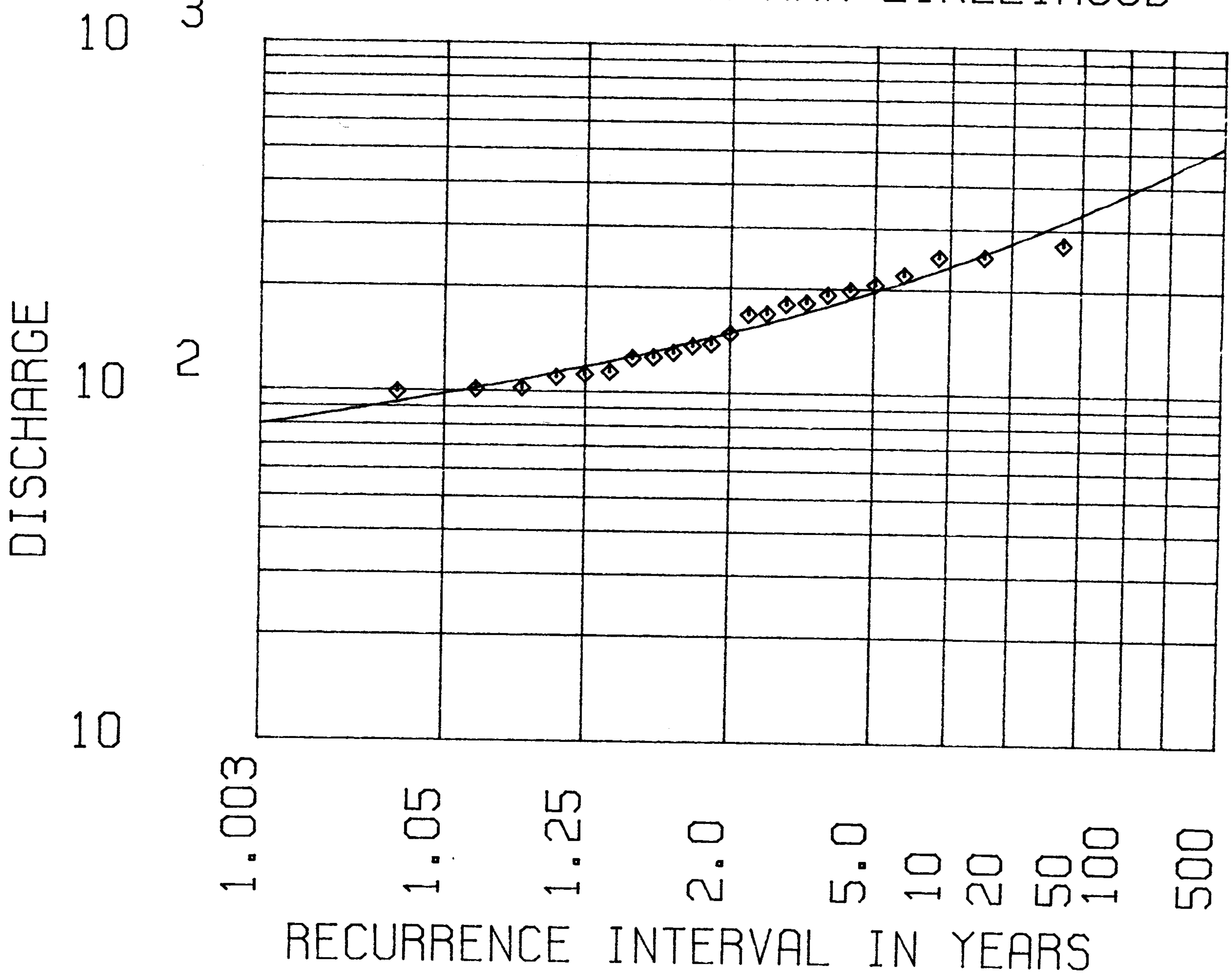
GEV PARAMETERS: U= 134.84 A= 36.321 K= -0.166

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	79.40
1.050	0.952	97.90
1.250	0.800	118.00
2.000	0.500	149.00
5.000	0.200	197.00
10.000	0.100	234.00
20.000	0.050	274.00
50.000	0.020	334.00
100.000	0.010	385.00
200.000	0.005	443.00
500.000	0.002	529.00

FREQUENCY ANALYSIS - 08DC006I

GENERALIZED EXTREME VALUE-MAX LIKELIHOOD



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FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
08DC006I BEAR RIVER ABOVE BITTER CREEK (MAX. INSTANTANEOUS)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	161.913	51.824	0.320	0.622	2.803
LN X SERIES	5.040	0.313	0.062	0.218	2.303
LN(X-A) SERIES	4.122	0.757	0.184	-0.319	2.426

X(MIN)= 99.000
X(MAX)= 271.000
LOWER OUTLIER LIMIT OF X= 71.719

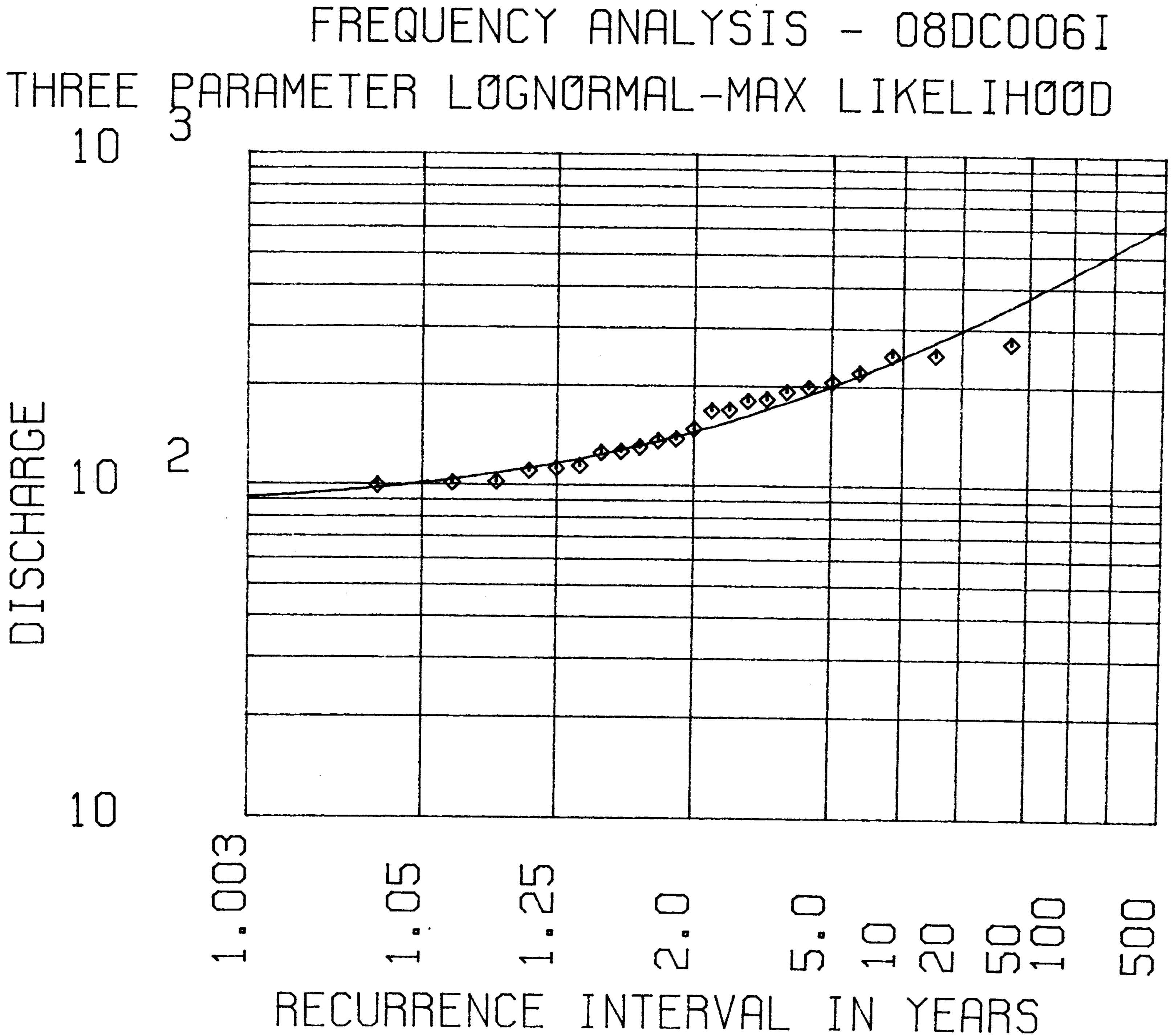
TOTAL SAMPLE SIZE= 23
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= 83.180 M= 4.122 S= 0.757

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	90.90
1.050	0.952	101.00
1.250	0.800	116.00
2.000	0.500	145.00
5.000	0.200	200.00
10.000	0.100	246.00
20.000	0.050	297.00
50.000	0.020	375.00
100.000	0.010	442.00
200.000	0.005	516.00
500.000	0.002	628.00


FREQUENCY ANALYSIS - 08DC006I
THREE PARAMETER LØGNØRMAL-MAX LIKELIHØØD
10 3
10 2
10
DISCHARGE
1.003
1.05
1.25
2.0
5.0
10
20
50
100
500
RECURRENCE INTERVAL IN YEARS

HAYCO

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
08DC006I BEAR RIVER ABOVE BITTER CREEK (MAX. INSTANTANEOUS)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	161.913	51.824	0.320	0.622	2.803
LN X SERIES	5.040	0.313	0.062	0.218	2.303

X(MIN)= 99.000
X(MAX)= 271.000
LOWER OUTLIER LIMIT OF X= 71.719

TOTAL SAMPLE SIZE= 23
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MOMENTS

LP3 PARAMETERS: A= 0.3421E-01 B= 83.84 LOG(M)= 2.171
M = 8.769

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	70.30
1.050	0.952	93.50
1.250	0.800	118.00
2.000	0.500	153.00
5.000	0.200	200.00
10.000	0.100	232.00
20.000	0.050	263.00
50.000	0.020	305.00
100.000	0.010	336.00
200.000	0.005	369.00
500.000	0.002	414.00

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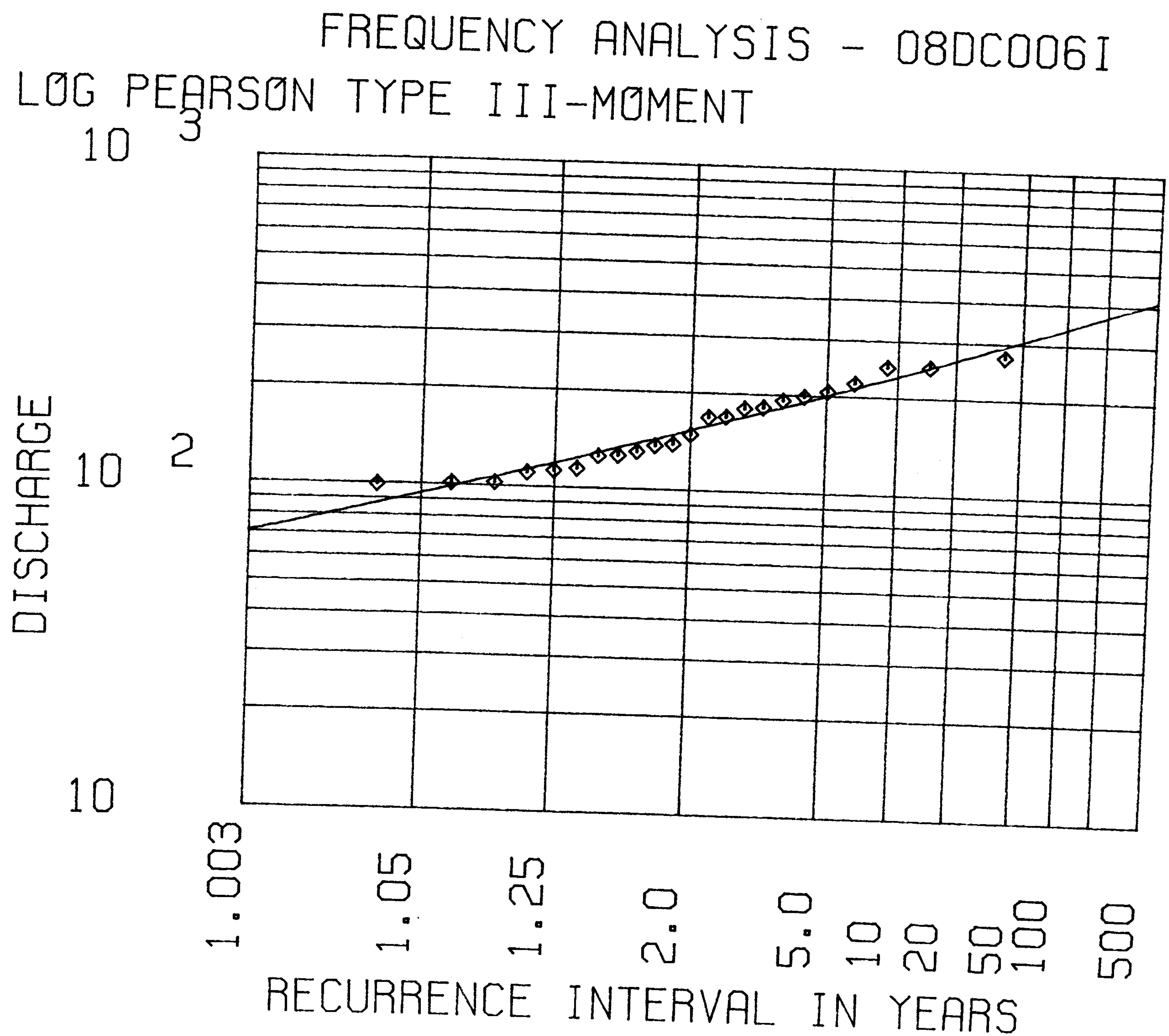

FREQUENCY ANALYSIS - 08DC006I
LØG PEARSØN TYPE III-MØMENT
10 3
10 2
10
DISCHARGE
1.003
1.05
1.25
2.0
5.0
10
20
50
100
500
RECURRENCE INTERVAL IN YEARS

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APPENDIX 3

Tabulated Flood Level Profiles (Freeboard Included)

Flood Level Profile (Freeboard Included)

Cross Section No.	Designated Flood Level (Freeboard Included) m	Crest Elevation m	Crest Level above Designated Flood Level m
1	5.4 a	NA	NA
2	5.4 a	4.44 c	-0.94
3	5.4 a	4.55 c	-0.83
4	5.4 a	4.73 c	-0.65
6	5.4 a	3.98 c	-1.41
5	5.4 a	4.23 c	-1.16
7	5.4 a	5.30 c	-0.08
8	5.4 a	5.73 c	0.34
9	5.45	5.87 d	0.42
10	5.48	6.07 d	0.59
11	6.60	7.04 d	0.44
12	6.94	7.87 d	0.93
13	7.36	8.63 d	1.27
14	8.01	9.32 d	1.31
15	8.98	9.87 d	0.89
16	9.60	10.51 d	0.91
17	10.18	11.35 d	1.17
18	11.05	11.77 d	0.72
19	11.70	12.43 d	0.73
20	12.64	13.32 d	0.68
21	13.28	13.92 d	0.64
22	13.97	14.21 d	0.24
23	14.72	14.84 d	0.12
24	15.37	15.74 d	0.37

Bear River: Flood Level Profile (Freeboard Included)

Cross Section No.	Designated Flood Level (Freeboard Included) m	Crest Elevation m	Crest Level above Designated Flood Level
25	15.41 (EG* 16.12)	~15.74 b	0.33
26	15.59 (EG* 16.27)	16.31 b	0.72 (-0.17)**
27	16.73 (EG* 16.77)	17.04 h	0.31
28	17.63	17.93 h	0.30
29	19.71	19.47 h	-0.24
30	21.78	21.97 h	0.19
31	23.78	23.72 h	-0.06
32	26.10	25.52 h	-0.58

* EG = Total energy grade plus freeboard.
** Interpolated from EG levels and H_v
a = Ocean Flood Level
b = Bridge
c = Causeway
d = Dyke
h = Highway

APPENDIX 4

Aggradation Rate Analysis

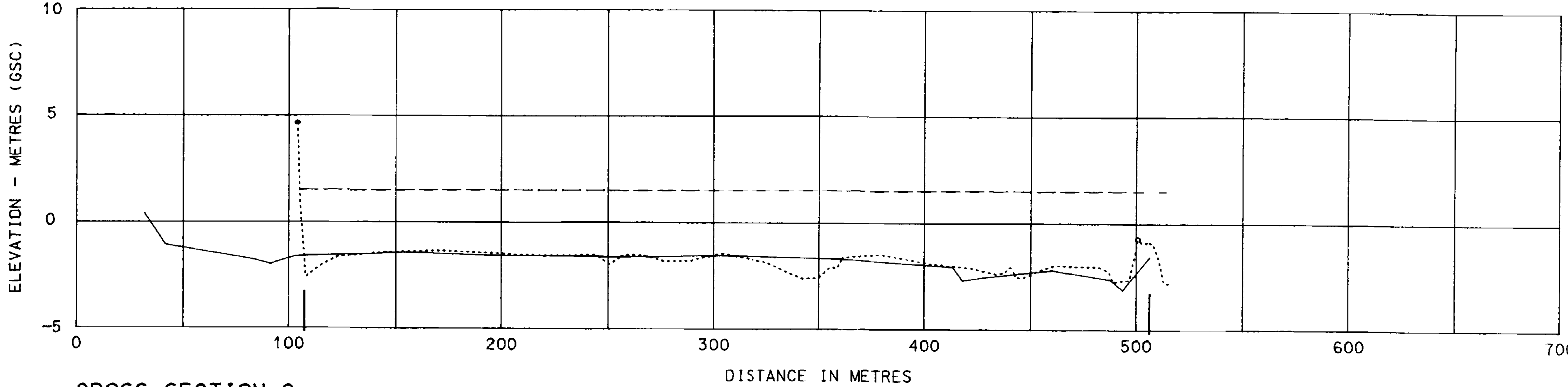
Aggradation Rate Analysis (1980 - 1991)

Cross Section	Cut m^2	Fill m^2	Net Change m^2	Width m	Average Bed Change m
1	41.6	50.2	+ 8.6	399.2	+ 0.02
2	16.7	322.0	+ 305.3	442.7	+ 0.69
3	61.2	75.5	+ 14.3	408.9	+ 0.03
4	157.0	126.2	- 30.8	424.1	- 0.07
6	620.2	53.5	- 566.7	471.3	- 1.20
5	394.4	180.3	- 214.1	456.1	- 0.47
7	259.7	630.8	+ 371.1	425.5	+ 0.87
8	193.6	415.8	+ 222.2	323.3	+ 0.69
9	147.5	58.7	- 88.8	180.7	- 0.49
10	37.5	67.5	+ 30.0	127.5	+ 0.23
11	45.2	33.1	- 12.1	222.5	- 0.05
12	82.3	86.8	+ 4.5	269.1	+ 0.02
13	65.2	57.1	- 8.1	262.2	- 0.03
14	41.4	36.5	- 4.9	186.7	- 0.03
15	32.5	112.4	+ 79.9	211.1	+ 0.38
16	103.7	97.7	- 6.0	360.6	- 0.02
17	69.1	147.3	+ 78.3	311.6	+ 0.25
18	92.4	88.4	- 4.0	209.5	- 0.02
19	43.1	105.6	+ 62.5	234.6	+ 0.27
20	27.9	102.6	+ 74.7	189.8	+ 0.39
21	20.9	96.5	+ 75.6	177.8	+ 0.43
22	24.5	77.6	+ 53.1	143.5	+ 0.37
23	4.1	46.1	+ 42.0	101.8	+ 0.41
24	2.0	30.4	+ 28.4	65.1	+ 0.44

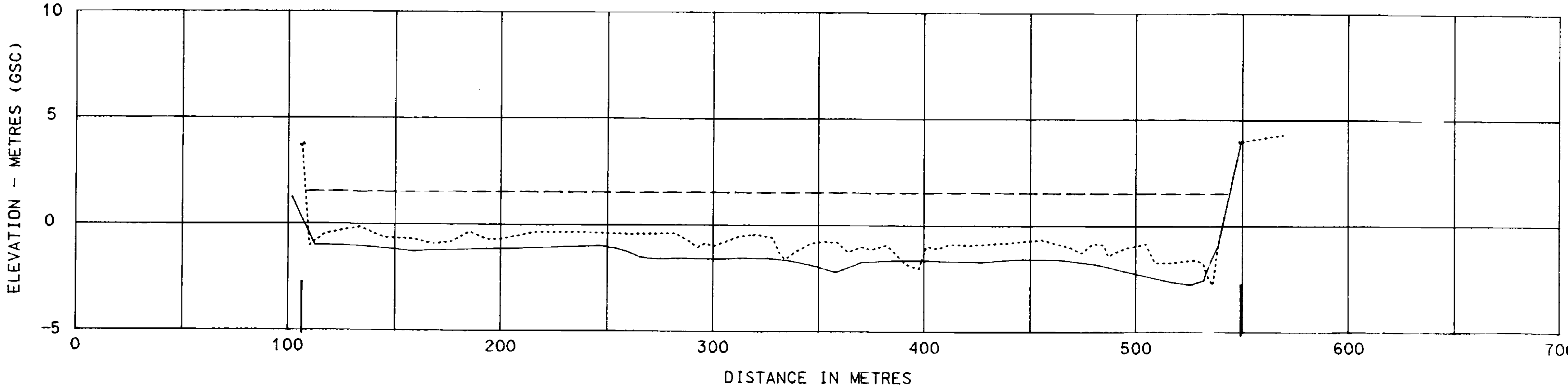
$$\text{Average Bed Change } XS\ -1 \rightarrow 24 = \frac{+3.11}{24} = +0.13\ m\ (+0.012\ m/yr)$$

$$\text{Average Bed Change } XS\ -19 \rightarrow 24 = \frac{+2.31}{6} = +0.38\ m\ (+0.035\ m/yr)$$

CROSS SECTION 1



CROSS SECTION 2



McELHANNEY SURVEY (1980)
WMB SURVEY (1991)

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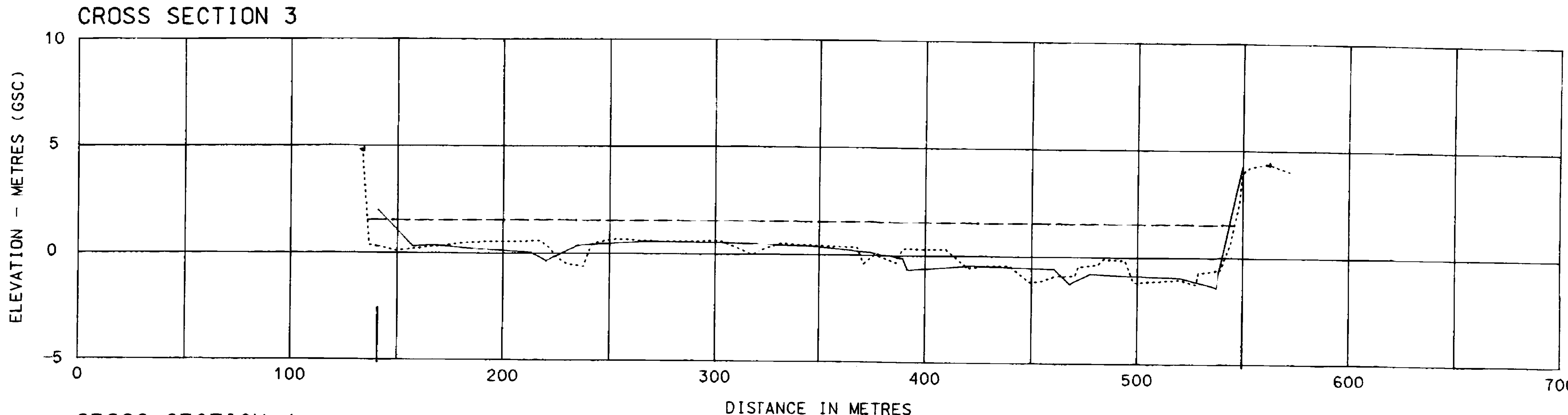
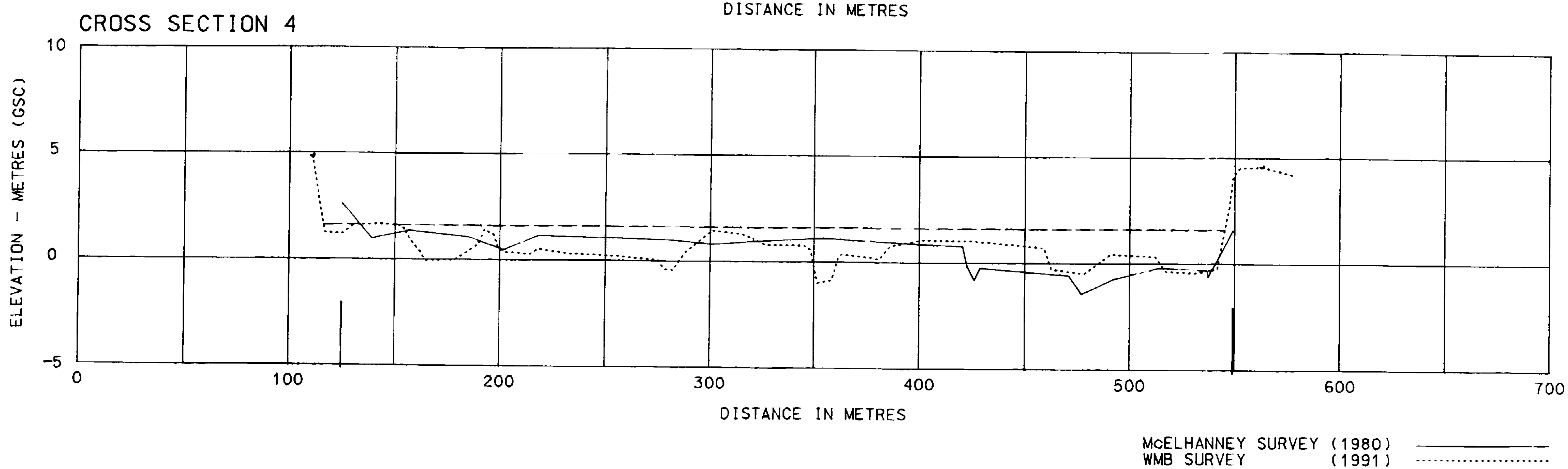
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 1 & 2

FIG. A4.1

MENV-0134PROFILE.DGN@RF=n11@JAN 92





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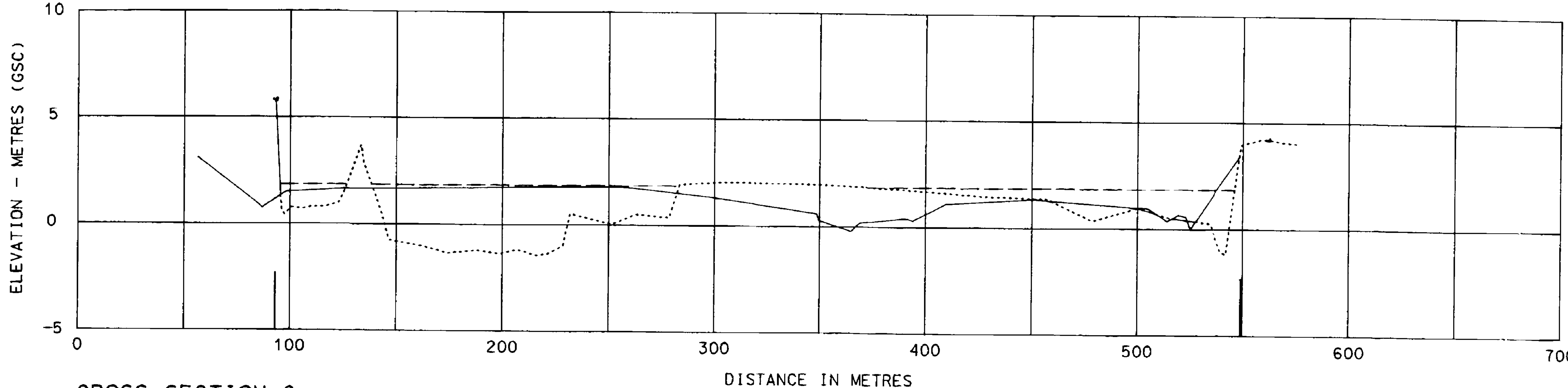
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 3 & 4

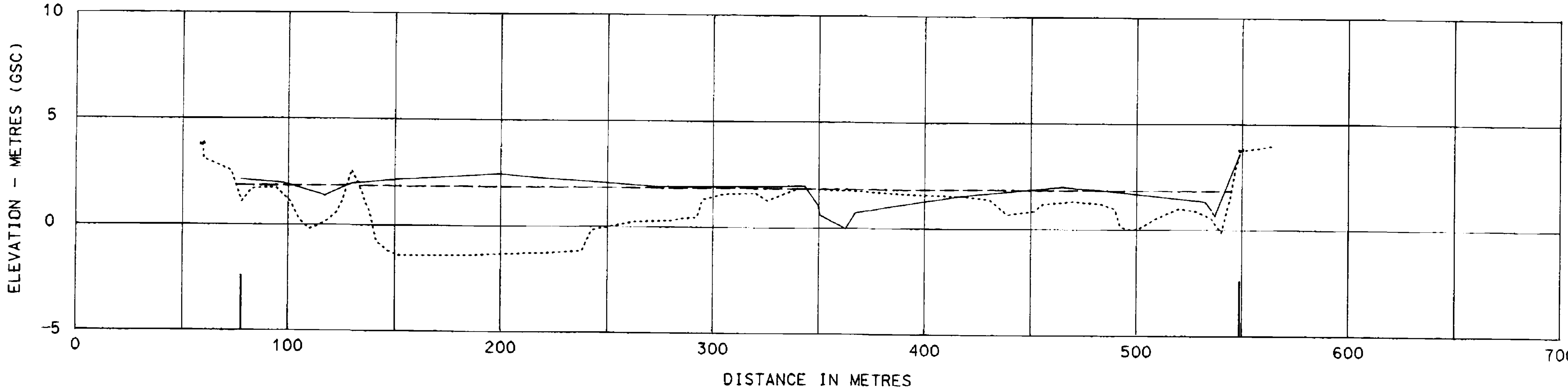
FIG. A4.2

MENV-0134PROFILE.DGN=RF=n!!=JAN 92

CROSS SECTION 5



CROSS SECTION 6



McELHANNEY SURVEY (1980) ————
WMB SURVEY (1991) ············

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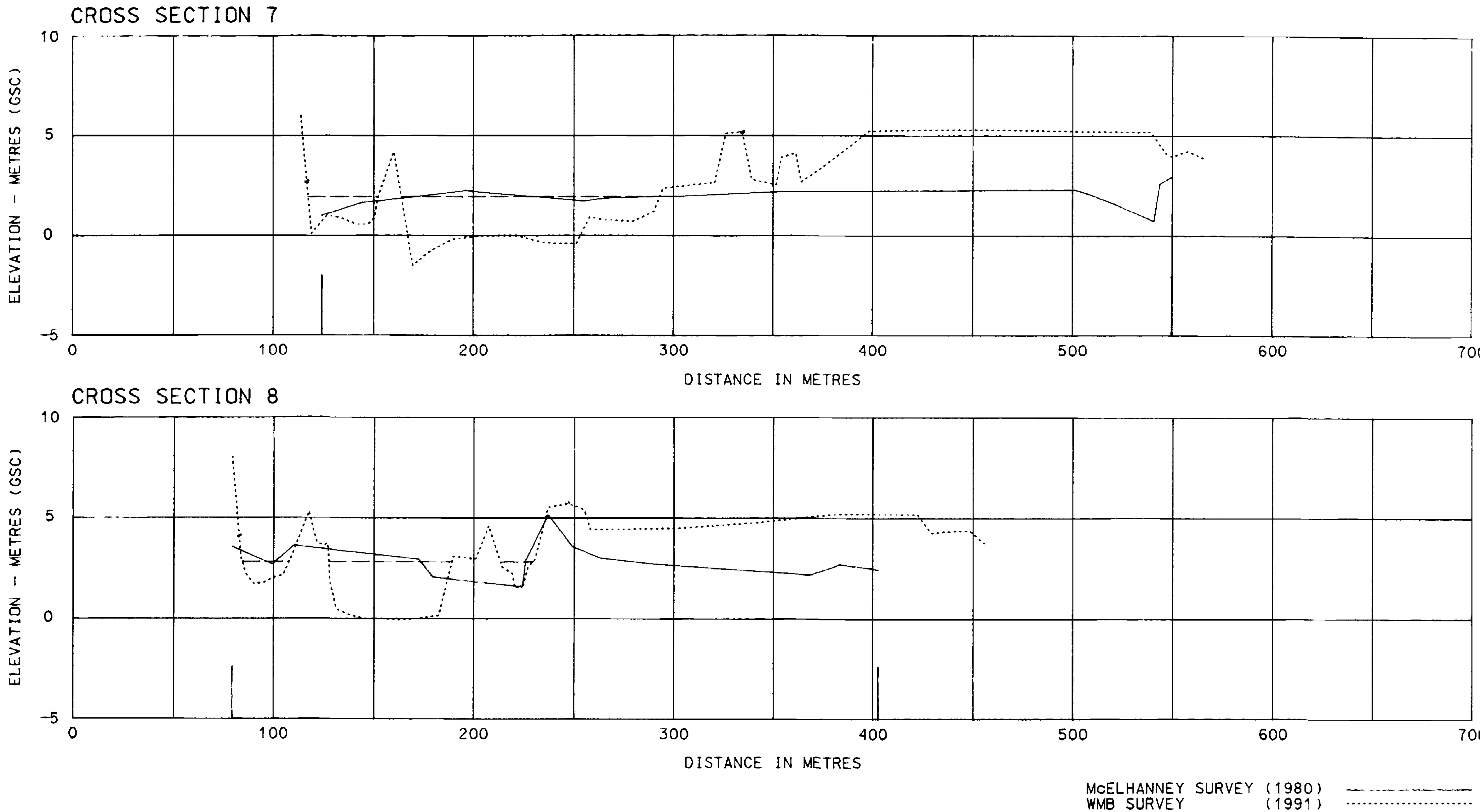
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 5 & 6

FIG.
A4.3

MENV-0134PROFILE.DGN@RF=n11@JAN 92



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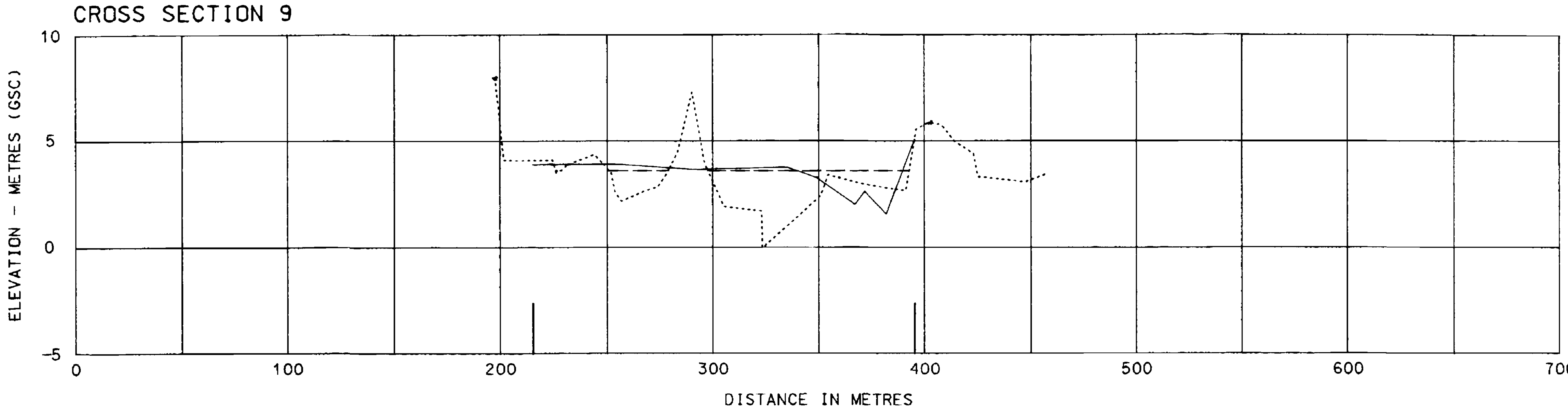
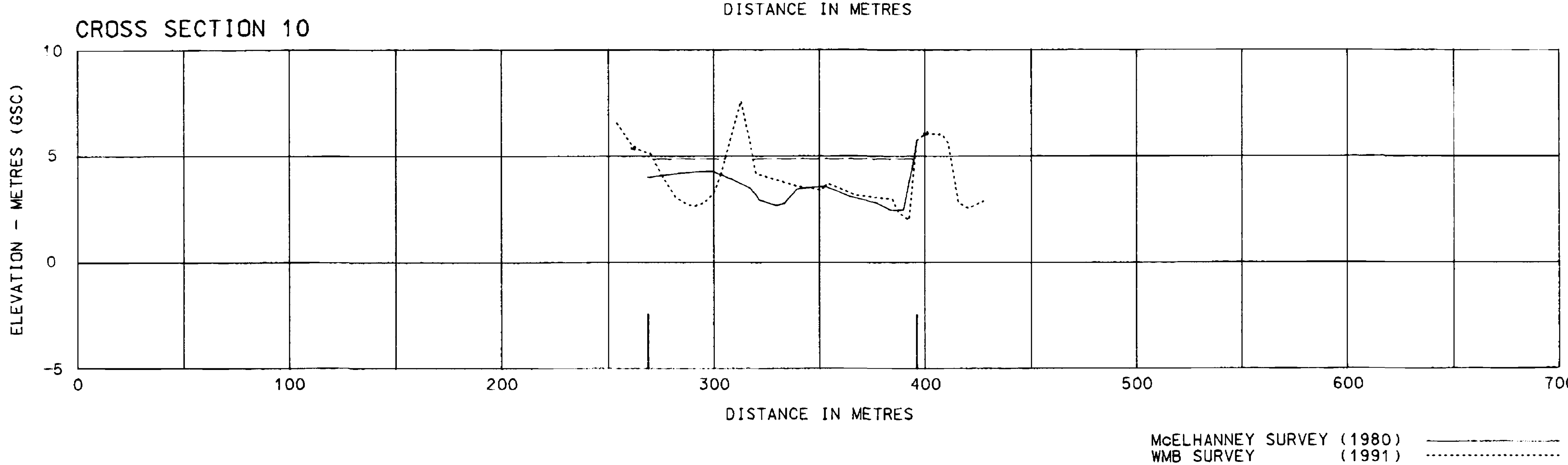
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 7 & 8

FIG. A4.4

MENV-0134PROFILE.DGN@RF-n11@JAN 92





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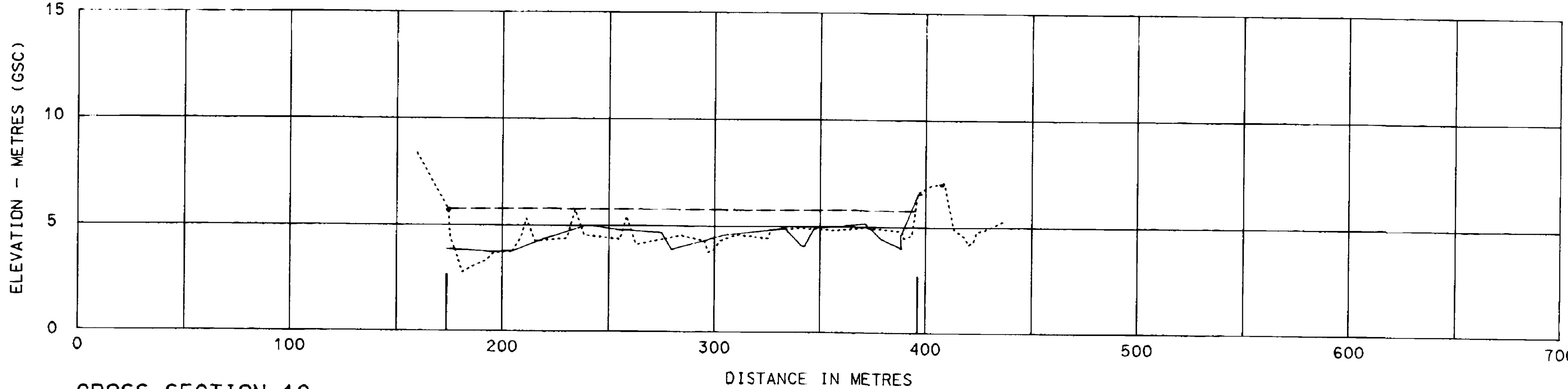
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 9 & 10

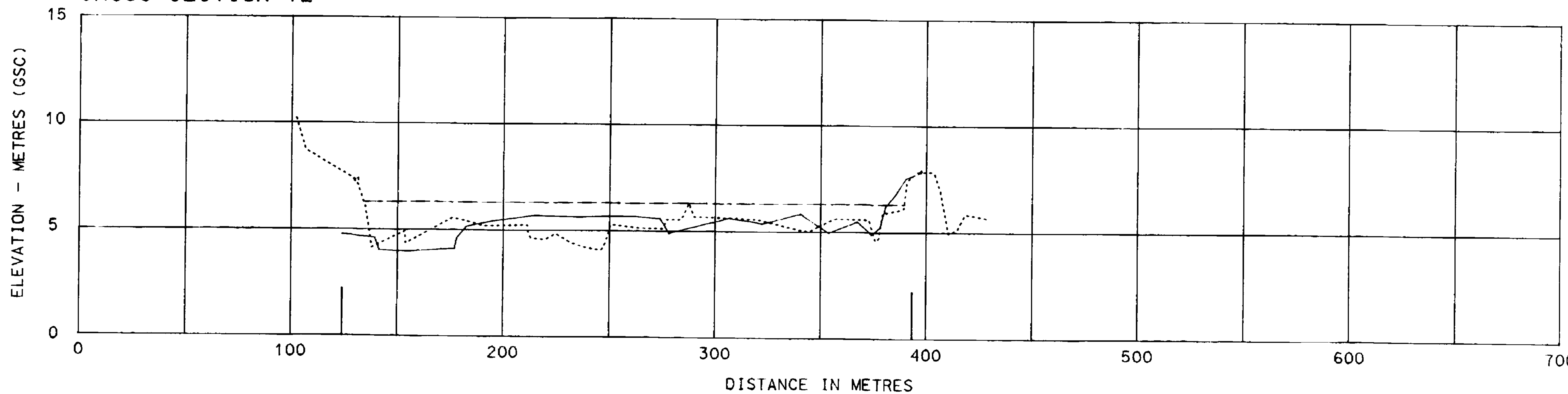
FIG. A4.5

MENV-013@PROFILE.DGN@RF=n11@JAN 92

CROSS SECTION 11



CROSS SECTION 12



McELHANNEY SURVEY (1980) ————
WMB SURVEY (1991) ....

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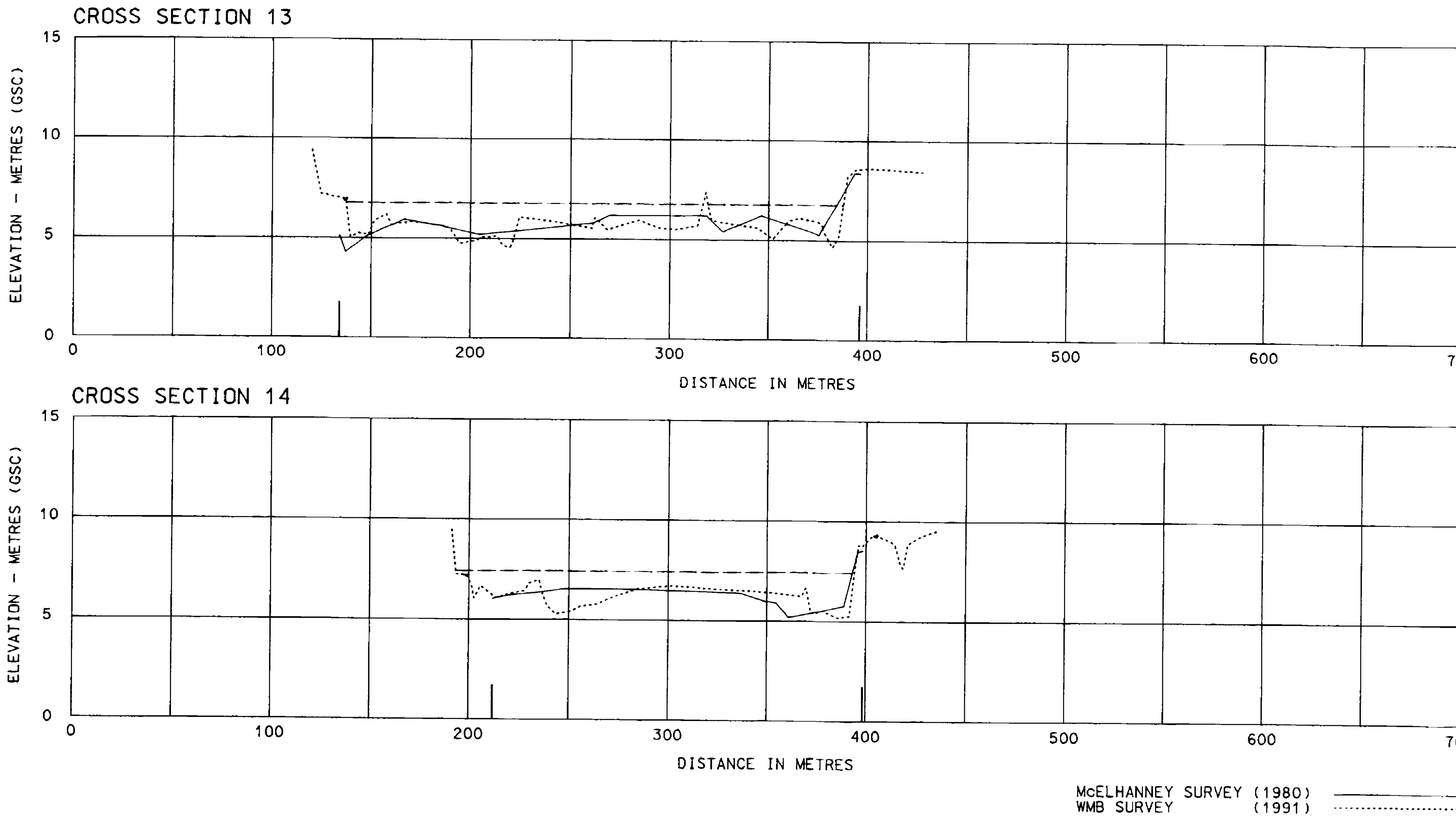
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 11 & 12

FIG. A4.6

MENV-013*PROFILE.DGN*RF-n11*JAN 92



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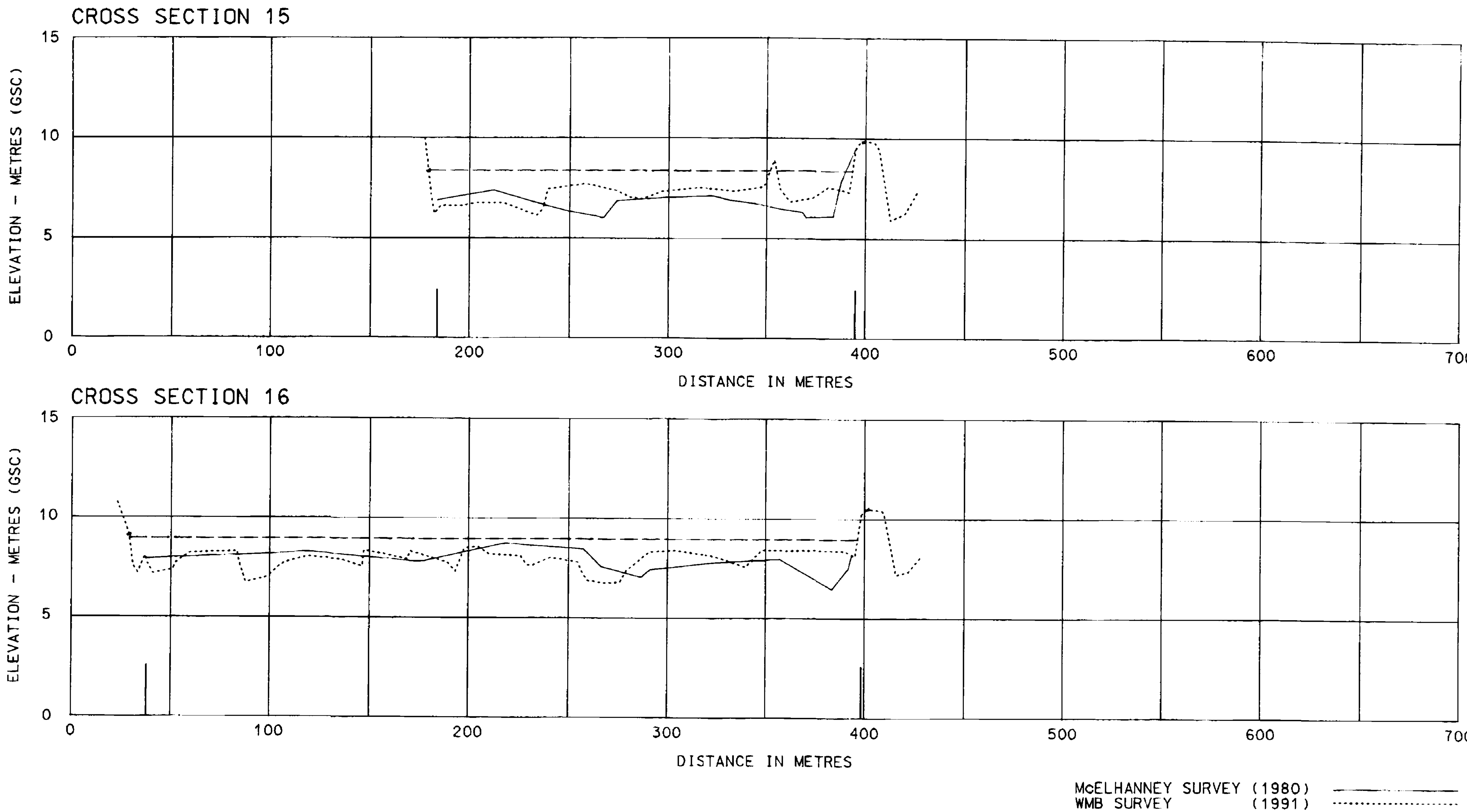
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 13 & 14

FIG. A4.7

MENV-0134PROFILE.DGN@RF=n11@JAN 92



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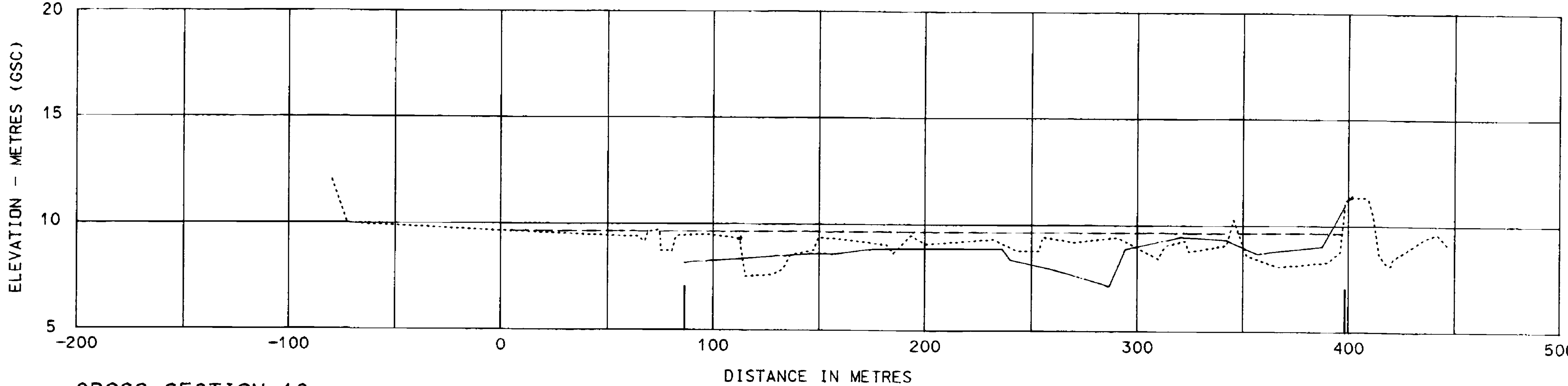
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 15 & 16

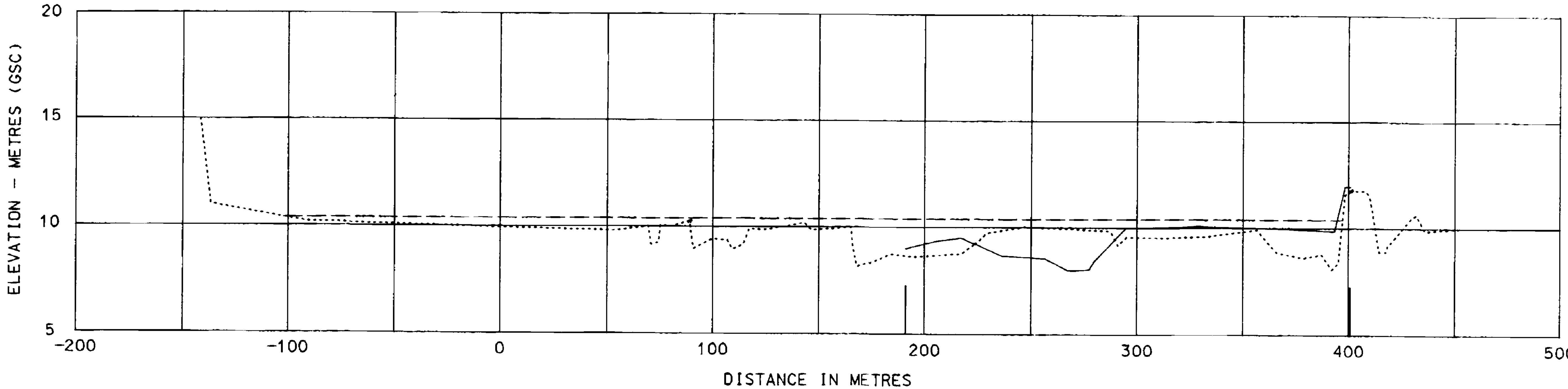
FIG. A4.8

MENV-013@PROFILE.DGN@RF=n11@JAN 92

CROSS SECTION 17



CROSS SECTION 18



McELHANNEY SURVEY (1980) ————
WMB SURVEY (1991) ....

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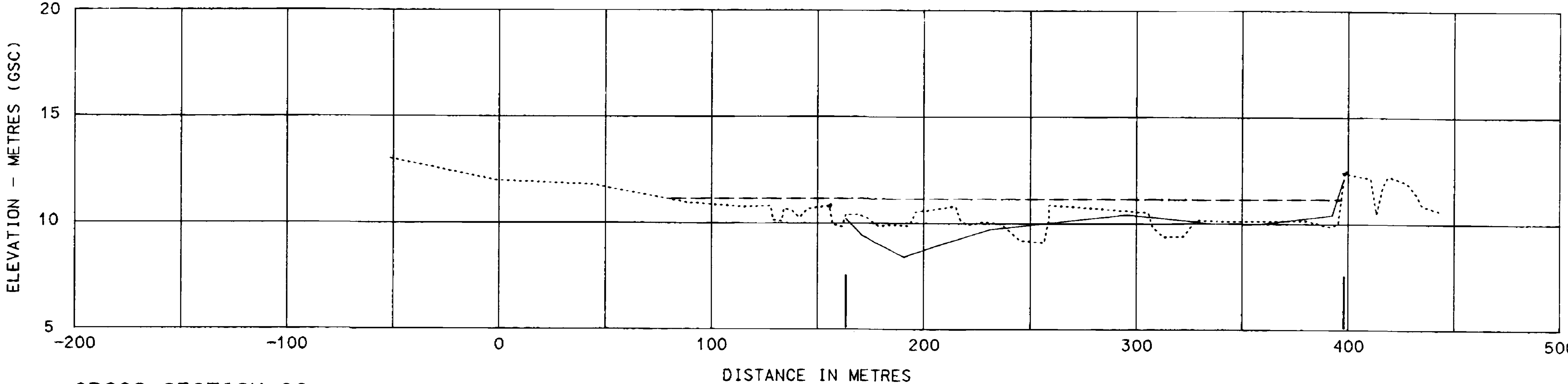
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 17 & 18

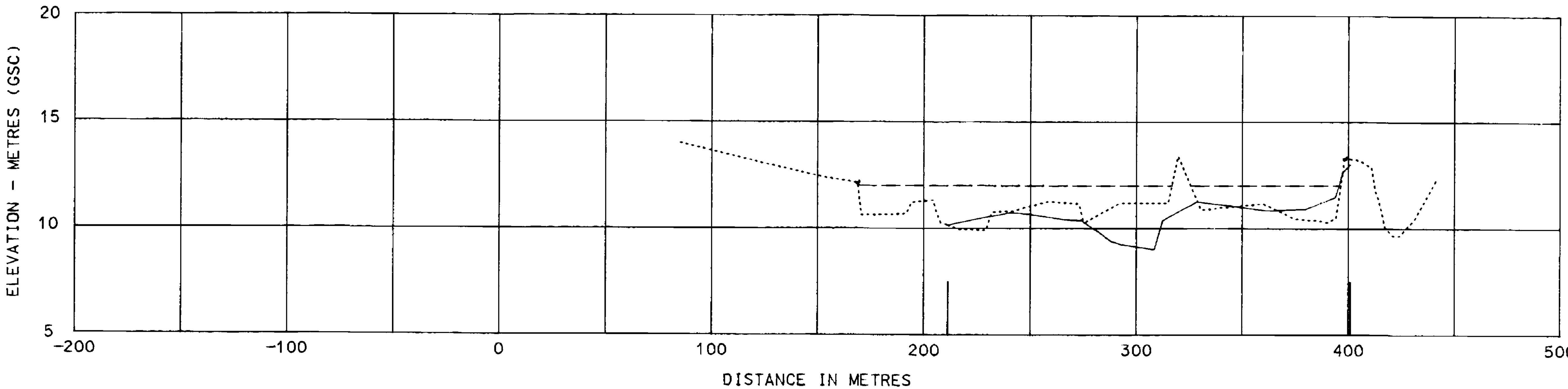
FIG. A4.9

MENV-0134PROFILE.DGN=RF-n11@JAN 92

CROSS SECTION 19



CROSS SECTION 20



McELHANNEY SURVEY (1980)
WMB SURVEY (1991)

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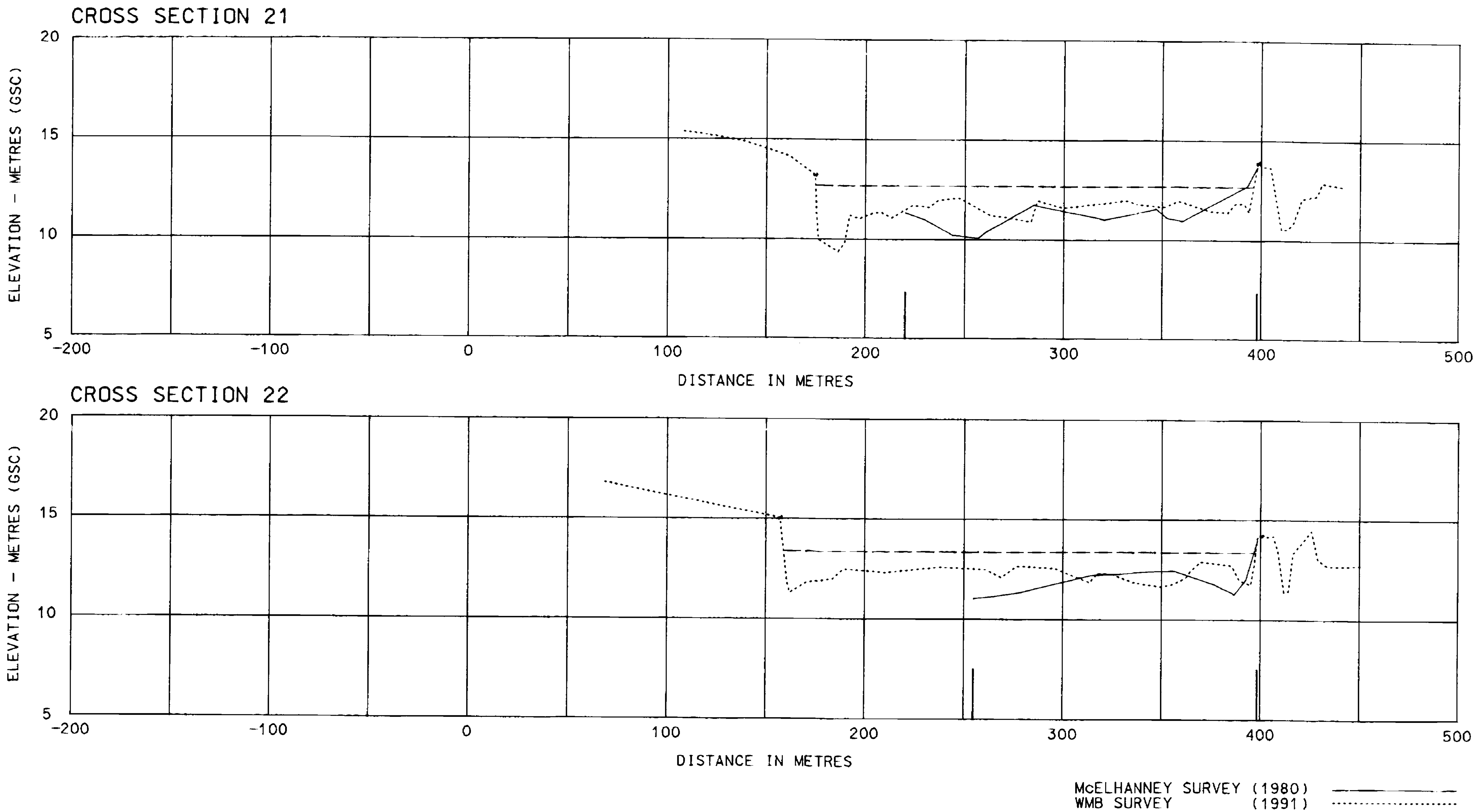
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 19 & 20

FIG. A4.10

MENV-0134PROFILE.DGN RF=n11 JAN 92



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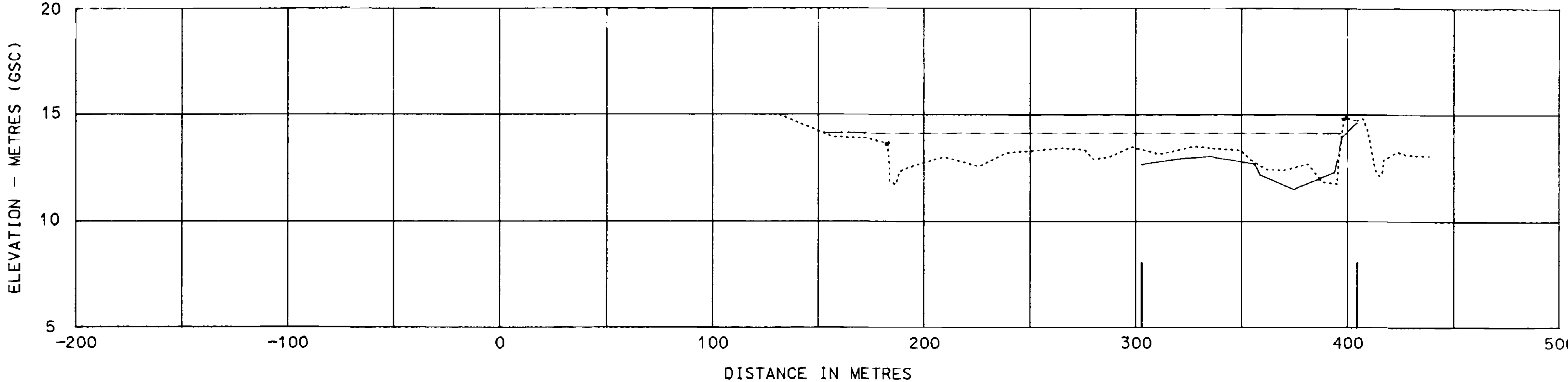
FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 21 & 22

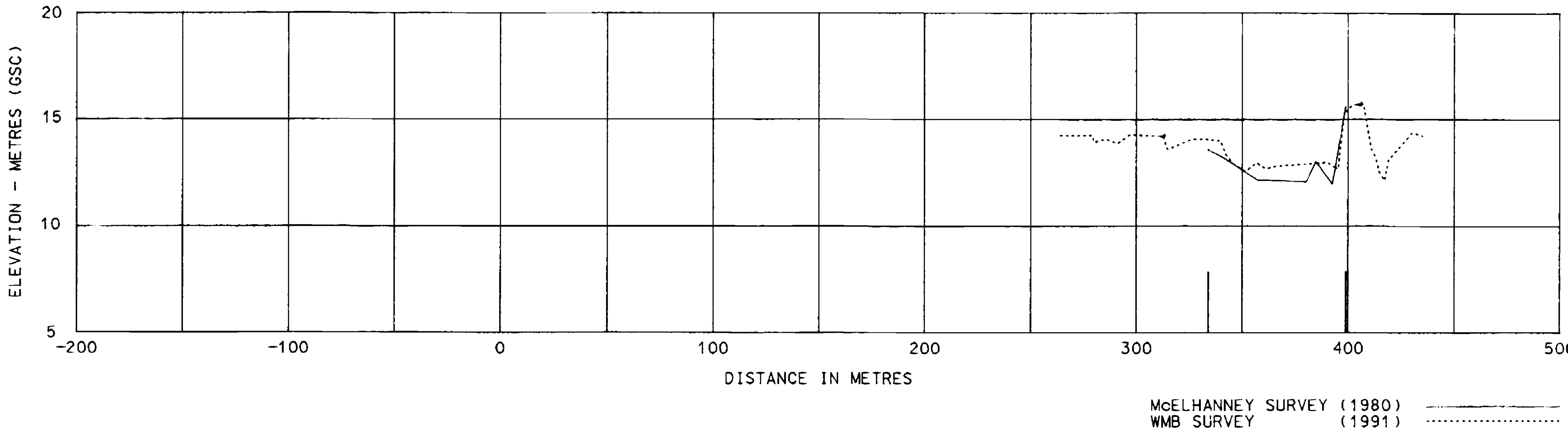
FIG.
A4.11

MENV-013#PROFILE.DGN#RF=n11#JAN 92

CROSS SECTION 23



CROSS SECTION 24



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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

AGGRADATION RATE ANALYSIS
CROSS SECTIONS 23 & 24

FIG. A4.12

MENV-013=PROFILE.DGN=RF=n11=JAN 92

APPENDIX 5

DATA SOURCES AND REFERENCES

A. Information Supplied by Water Management Branch

APPENDIX D

List of Available Information

BEAR RIVER AT STEWART

1. River Survey - Project 91 09 F037 (April-May 1991) - 1 Volume

   A. One VHS video tape showing cross section locations and conditions of the Bear River at Stewart. Tape does not show detail for all cross sections but no still photographs were taken at time of survey. Video taken at "garbage dump bridge" shows cross sections 34 and 35 on Winachee Creek (see drawing 92-6-2).
   B. List of contents.
   C. Survey request dated April 11, 1990, and survey requirements dated April 3, 1990.
   D. Photocopy of portion of air photograph BC77066:166.
   E. Copy of a portion of photo mosaic "Figure 8", Hay & Company, March 1986, showing location of 3 cross sections surveyed by Hay (A, B and C) plus the location of 14 of 24 cross sections surveyed by McElhanney (see "survey requirements" memo referred to in "C" above).
   F. Pouch containing prints of Drawings 92-6-1 and 92-6-2 titled "Bear River at Stewart, Plan Showing Cross Section Locations".
   G. Pouch containing one 3.5" double-sided disk containing HEC-2 GR data with and without decimals.
   H. Listings of GR data with and without decimals.
   I. Left-to-right written profiles and plots of cross sections 1 through 32 on the Bear River and 33 through 36 on Winachee Creek. Includes additional plotted profile of XS 26 with bridge and comparison of 1988 and 1991 channels, plotted plan and profile of Highway 37A bridge detail with 1988 channel and 1991 XS 25 and 26 channels, and plotted plan and profile of Winachee Creek road bridge detail showing channel at XS 34 and 35.
   J. Written and plotted centerline road profile of Highway 37A bridge.
   K. Cross reference list of cross section identification for McElhanney and Water Mangement surveys.
   L. Pouch containing a print of McElhanney drawings 1 and 2 of 2 titled "Plan and Profile, Bear River Cross Sections" and dated May 7, 1980.

2. Matte films of floodplain mapping base drawing #91-30, sheets 1 & 2.

3. Ministry of Environment Survey Project 88MSP-5, "Bear River (Stewart) Cross Sections and Dyke Profile" by M. Pronk, dated May, 1988.

4. Report entitled "Evaluation of Tsunami Levels Along the British Columbia Coast" by Seaconsult Marine Research Ltd., dated March, 1988.

5. Reports by Hay & Company entitled "Bear River Estuary, Hydrology & Geomorphology" dated December 1984 and "Bear River Estuary Phase 2 Studies, Hydrology & Geomorphology" dated March, 1986.

6. Report entitled "General Purpose Wharf Study, Stewart B. C." by Swan Wooster Engineering Co. Ltd. dated October, 1985.

7. Prints of District of Stewart boundary maps:
   - Municipal Affairs negative #185072, 1:40,000 scale with 1:5000 scale detail of townsite, dated 1983
   - unnumbered mapsheet at 1"=2 mile scale, dated 1968

8. "Bear River Training Dyke Operation & Maintenance Manual" by P. J. Woods, P. Eng., dated February, 1978.

9. Report entitled "Bear River Dyking, Stewart B. C." by P. J. Woods, P. Eng., dated September, 1976.

10. Canadian Hydrographic Service chart 3794, dated 1973.

11. "Coastal Environment and Coastal Construction - A Discussion Paper", B. J. Holden, Ministry of Environment and Parks, 1987.

12. "Guide to Peak Flow Estimation for Ungauged Watersheds in the Skeena Region (Smithers)", A. Chapman, D. Reksten, R. Nyhof, Ministry of Environment, Lands and Parks, March 1992.

13. Hydrology Study #22, August 12, 1976 (file 0256957), November 26, 1984 (file (S2104-6), Hydrology Section, Ministry of Environment, Lands and Parks.

B. Other Data Sources and References

1. Water Management Branch, October 1992, Drawings, 92-15-1 to 4 entitled "Bear River Dyking at Stewart, Plan and Profile".

2. Water Management Branch, December 18, 1992, Hydrometric data and photocopies of gauge installation photographs, supplied by Mr. Gordon McG. Clark.

3. Water Survey Canada, Surface Water Data - Reference Index - Canada 1990.

4. Water Survey of Canada, Historical Streamflow Summary - British Columbia - to 1990.

5. Personal communication with Ms. Shelly Bradford, Water Survey of Canada, re: streamflow data to 1991.

6. Water Resources Branch, Inland Waters Directorate, Environment Canada, July 1985, "Consolidated Frequency Analysis Package - CFA88", by Paul J. Pilon et al.

7. U.S. Geological Survey, Water Supply Paper 1849, "Roughness Characteristics of Natural Channels", by Henry H. Barnes, Jr.

8. Hay and Company, October 2, 1992 letter to Water Management Branch, re: Survey Data Base, Bear River at Stewart - Floodplain Mapping.

9. Hay and Company, November 20, 1992 letter report to Water Management Branch, re: Extreme Water Level Analysis.

10. Hay and Company, November 30, 1992 letter to Water Management Branch, re: addendum to November 20, 1992 letter.

11. Hay and Company, December 2, 1992 letter report to Water Management Branch, re: Flood Frequency Analysis.

12. Hay and Company, December 4, 1992 letter to Water Management Branch, re: WMD comments on November 20, 1992 letter report on Extreme Water Level Analysis.

13. Hay and Company, December 17, 1992 letter to Water Management Branch, re: addendum to December 2, 1992 letter.

14. U.S. Army Corps of Engineers, 1984, Shore Protection Manual.

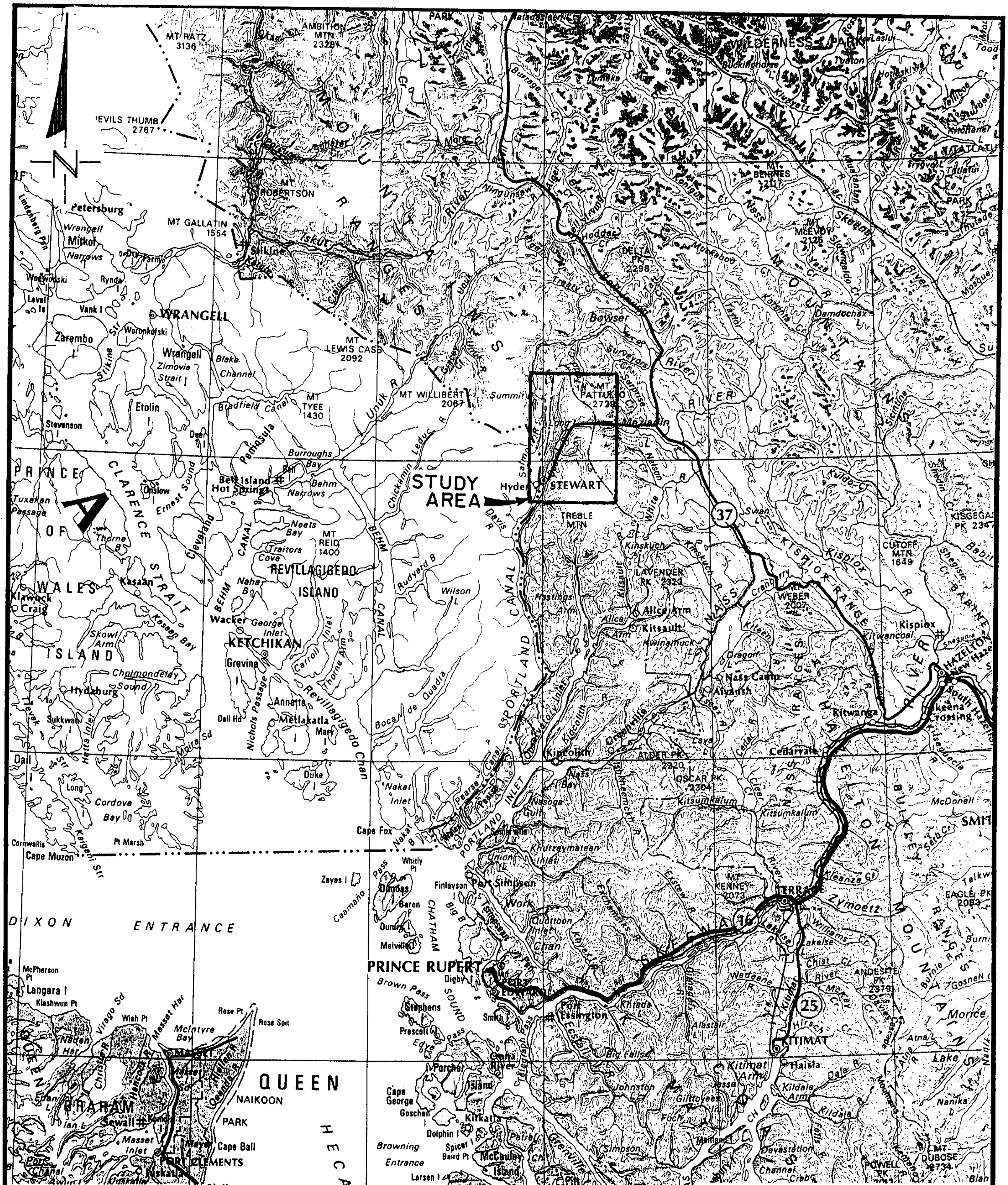
15. Canadian Hydrographic Service, 1991 Canadian Tide and Current Tables, Volume 6.

16. National Topographic Mapping, Energy, Mines and Resources, Canada

1:50,000 Maps

Advanced Print	103O/16	Edition 1
Stewart	103P/13	Edition 1
Bear River	104A/4	Edition 3
Bowser Lake	104A/5	Edition 2
Leduc Glacier	104B/1	Edition 1

FIGURES



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SCALE ~1 : 2,000,000

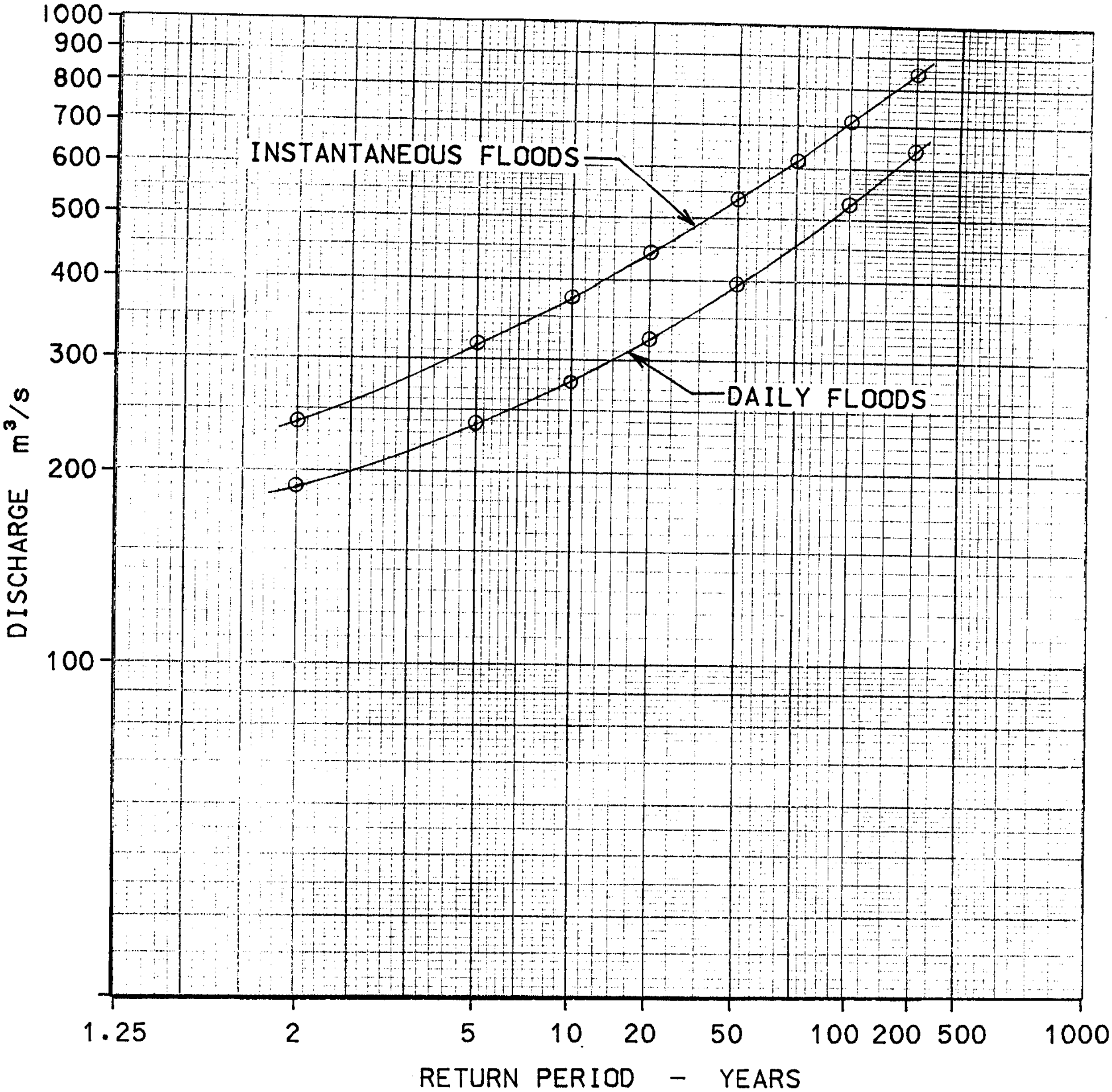
B.C. MINISTRY OF ENVIRONMENT

FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

LOCATION MAP

FIG. 1

MENV-013/BOBPHOTO.DGN/1993 JAN 14



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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

FLOW Vs RETURN PERIOD

FIG. **2**

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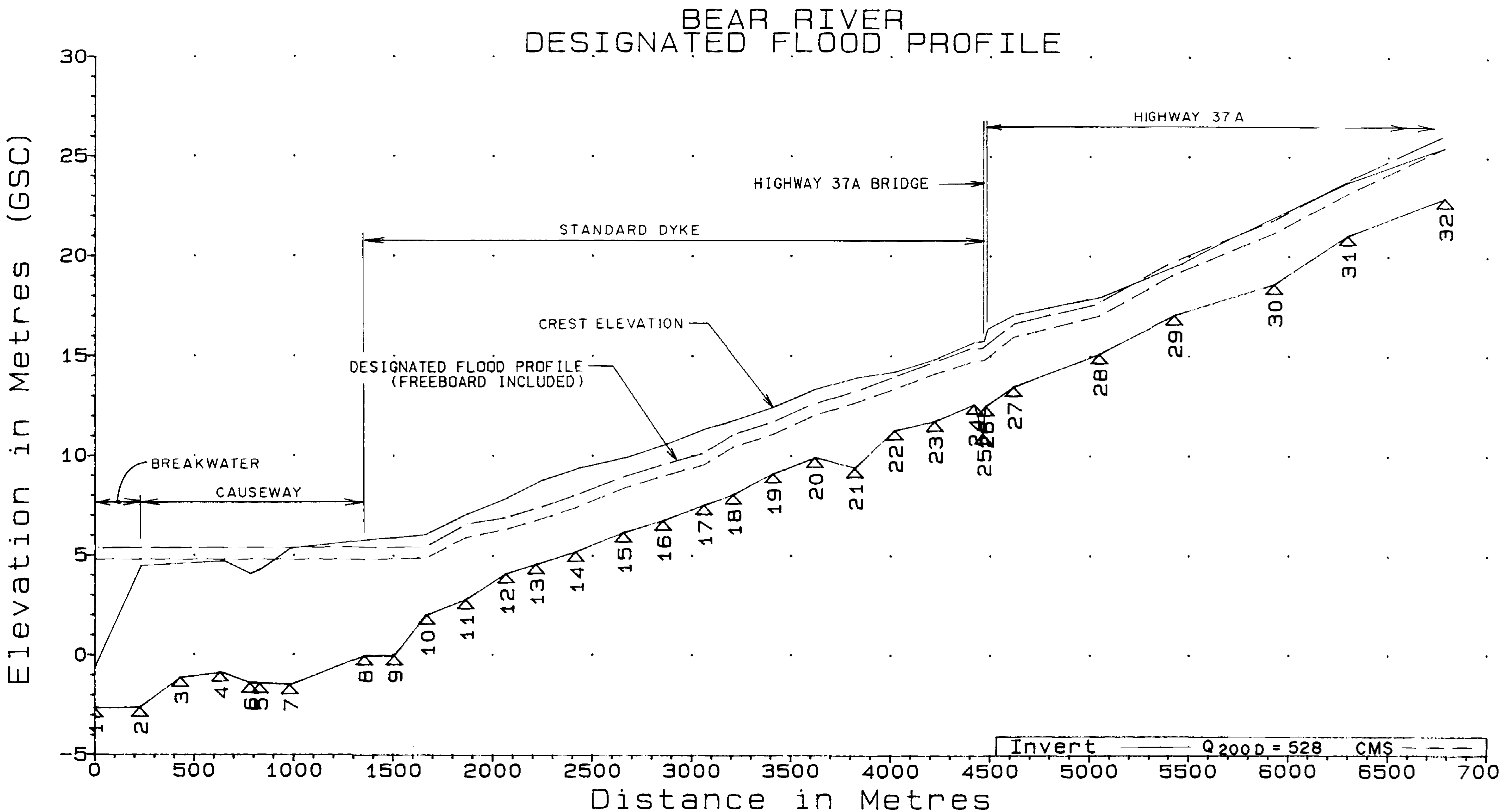
PHOTOGRAPHS

HAYCO



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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

DESIGNATED FLOOD PROFILE

FIG. 3

MENV-013/BOBPHOTO.DGN/1993 JAN 14

PHOTO 1: STEWART FORESHORE (TIDAL ZONE)

PHOTO 2: PORTLAND CANAL LOOKING SOUTH FROM BREAKWATER AT END OF CAUSEWAY (NEAR SECTION 1)

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 1 & 2

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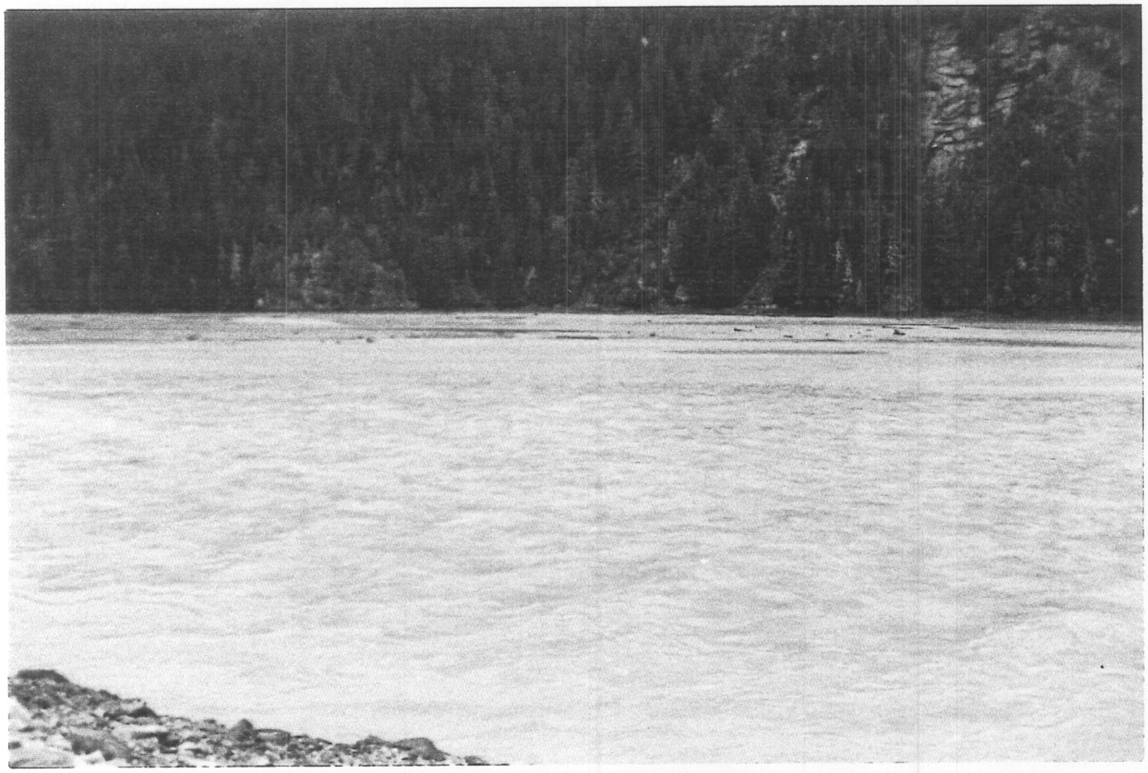

PHOTO 3: BEAR RIVER LOOKING TOWARD LEFT BANK NEAR CROSS SECTION 2

PHOTO 4: BEAR RIVER LOOKING UPSTREAM TOWARD LEFT BANK NEAR CROSS SECTION 5

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 3 & 4

MENV-013/BODPHOTO.DGN/1993 JAN 14

PHOTO 5: BEAR RIVER LOOKING DOWNSTREAM FROM CROSS SECTION 8

PHOTO 6: BEAR RIVER LOOKING UPSTREAM FROM CROSS SECTION 8

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FLOODPLAIN MAPPING BEAR RIVER AT STEWART

PHOTOS 5 & 6

MENV-013/BODPHOTO.DGN/1993 JAN 14

PHOTO 7: BEAR RIVER LOOKING DOWNSTREAM FROM CROSS SECTION 11

PHOTO 8: BEAR RIVER LOOKING UPSTREAM FROM CROSS SECTION 11

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 7 & 8

MENV-013/BODPHOTO.DGN/1993 JAN 14

PHOTO 9: BEAR RIVER LOOKING DOWNSTREAM FROM CROSS SECTION 14

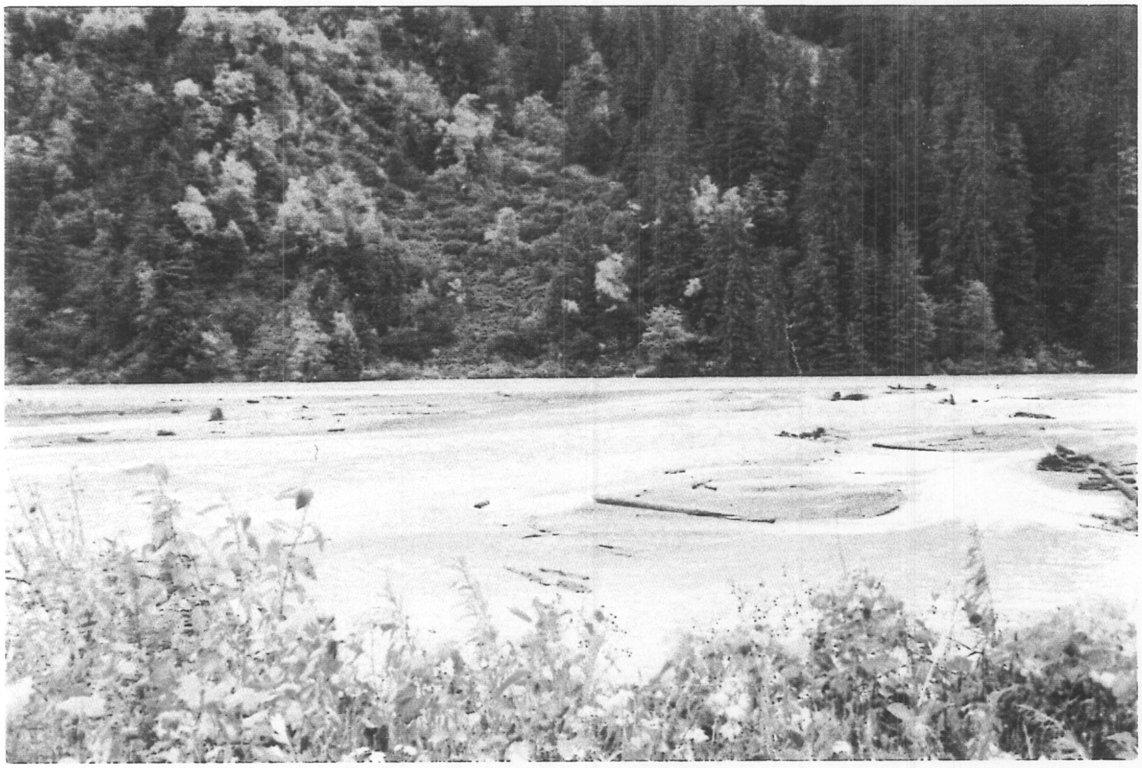

PHOTO 10: BEAR RIVER LOOKING TOWARD LEFT BANK AT CROSS SECTION 14

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 9 & 10

MENV-013/BODPHOTO.DGN/1993 JAN 14

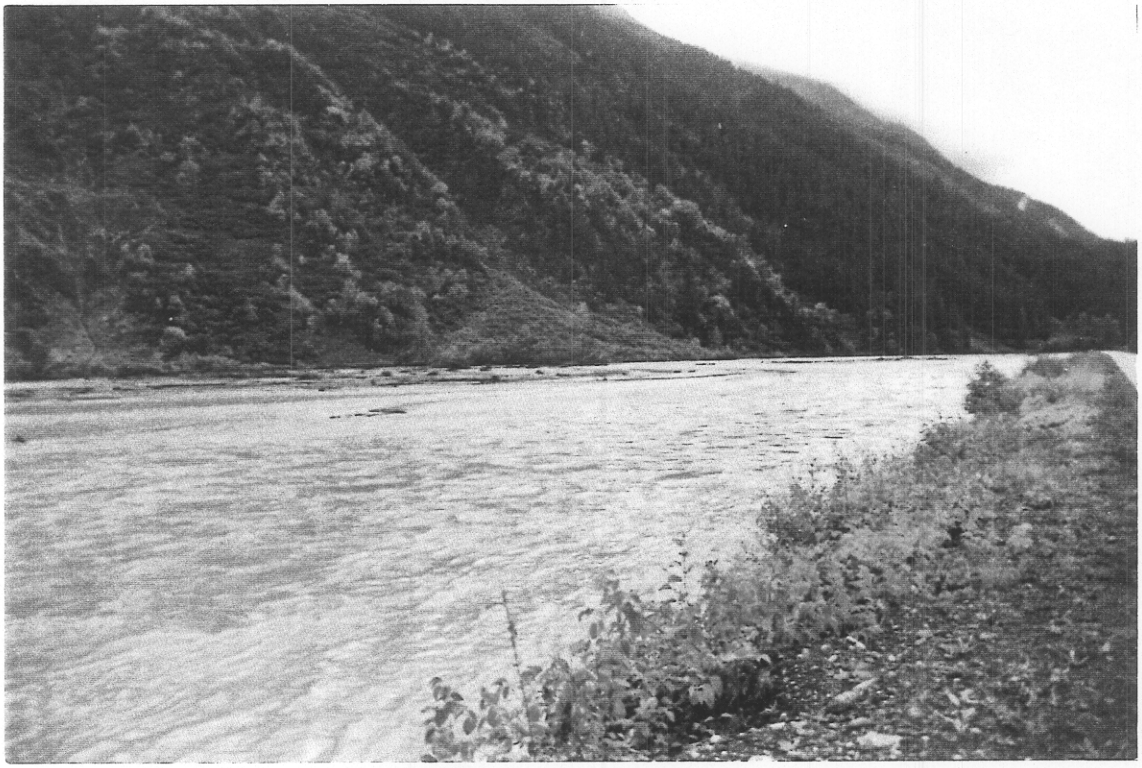

PHOTO 11: BEAR RIVER LOOKING DOWNSTREAM FROM CROSS SECTION 18

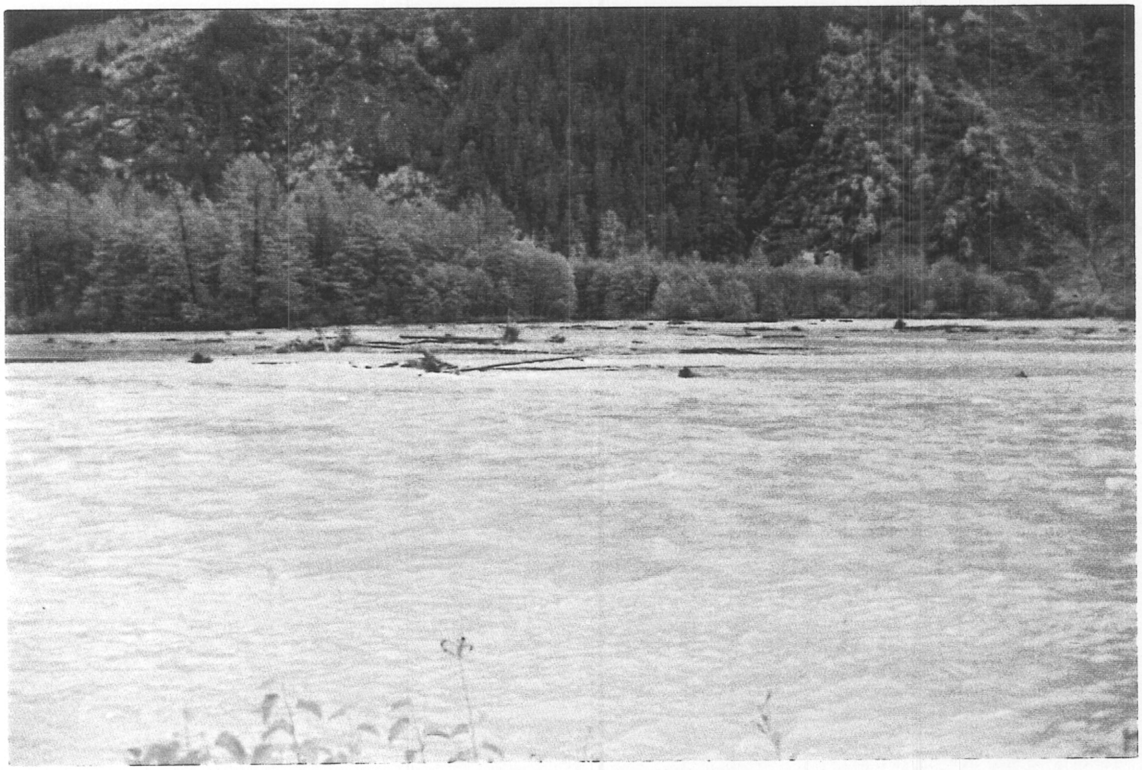

PHOTO 12: BEAR RIVER LOOKING TOWARD LEFT BANK AT CROSS SECTION 18

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 11 & 12

MENV-013/BODPHOTO.DGN/1993 JAN 14

PHOTO 13: BEAR RIVER LOOKING TOWARD LEFT BANK AT CROSS SECTION 21

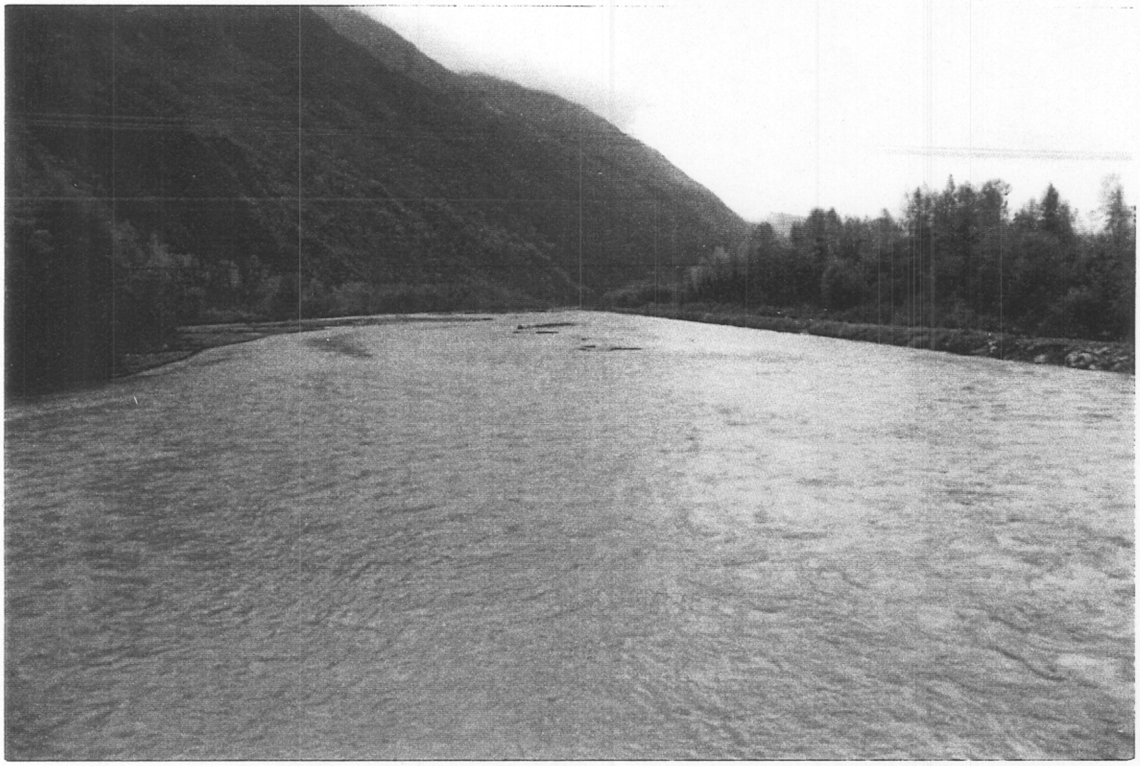

PHOTO 14: BEAR RIVER LOOKING DOWNSTREAM FROM BRIDGE

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 13 & 14

MENV-013/BODPHOTO.DGN/1993 JAN 14

PHOTO 15: BEAR RIVER BRIDGE WITH WATER MANAGEMENT DIVISION GAUGE ON DOWNSTREAM FACE

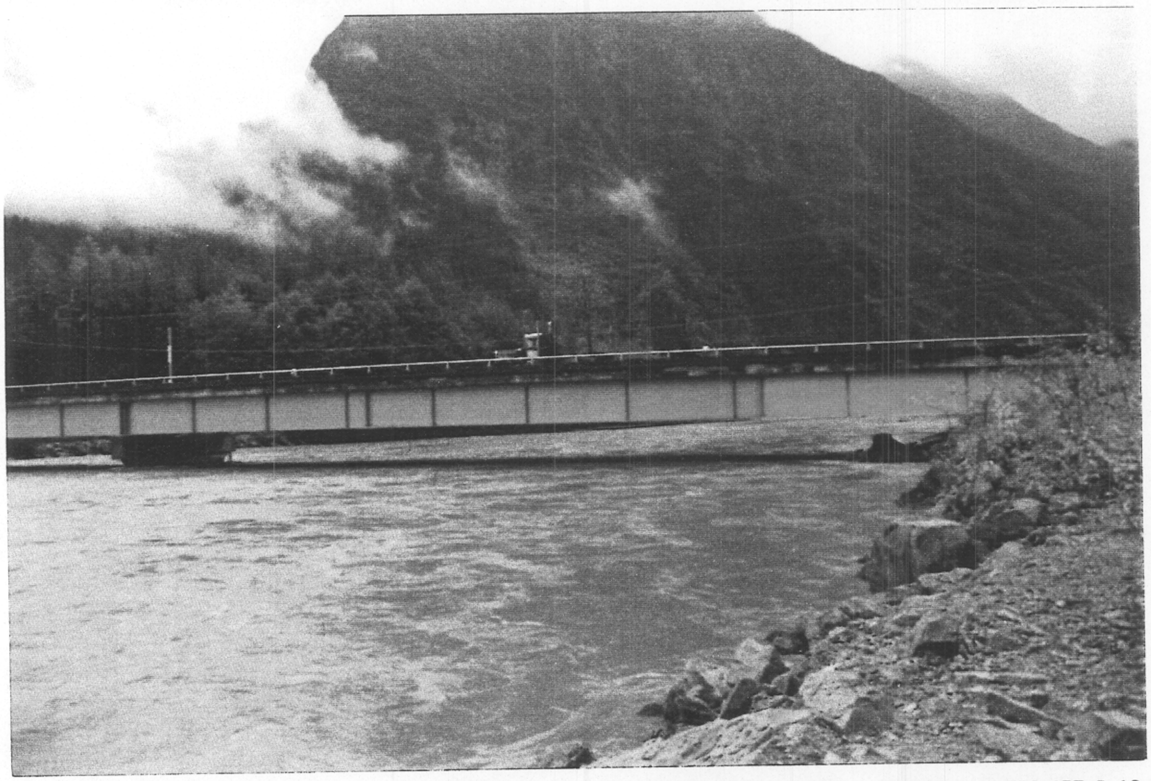

PHOTO 16: BEAR RIVER BRIDGE LOOKING DOWNSTREAM FROM RIGHT BANK ROCK GROYNE. BRIDGE GIRDERS ARE 2.18 M DEEP

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B.C. MINISTRY OF ENVIRONMENT

FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 15 & 16

MENV-013/BODPHOTO.DGN/1993 JAN 14

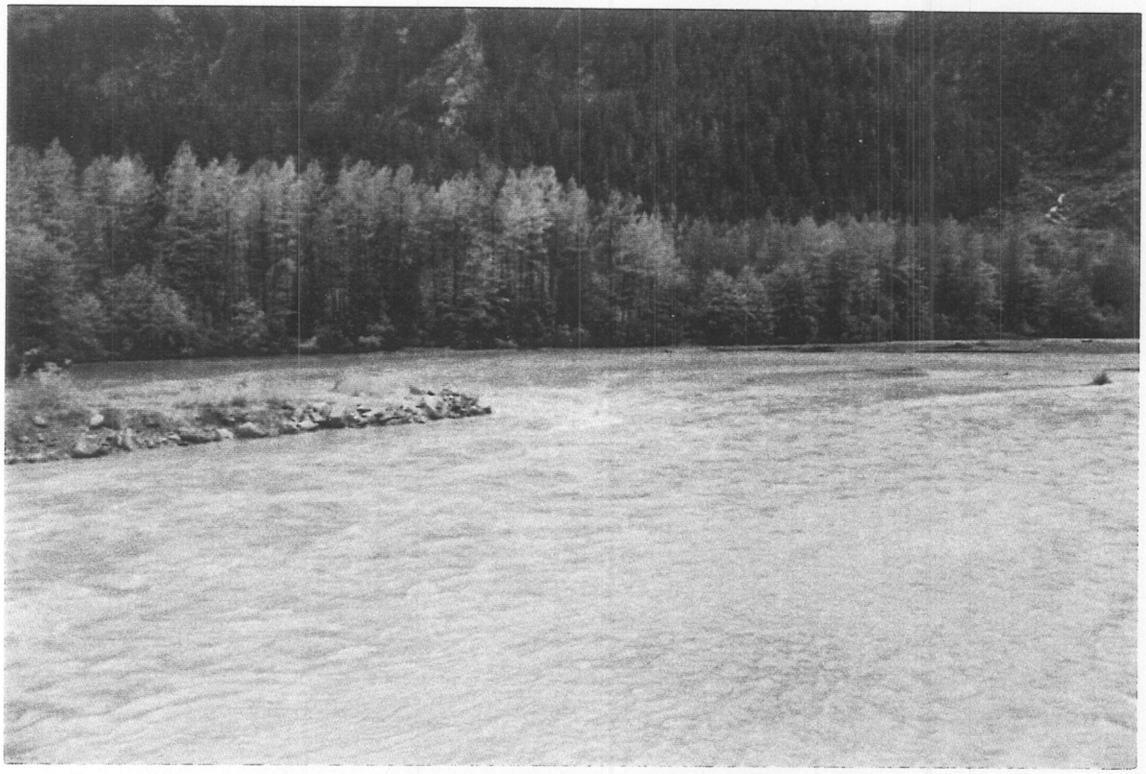

PHOTO 17: BEAR RIVER LOOKING UPSTREAM FROM BRIDGE AT RIGHT BANK ROCK GROYNE

PHOTO 18: HIGHWAY 37A - WEST BRIDGE APPROACH WITH CUTOFF DYKE INTERSECTION NEAR SPEED SIGN

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 17 & 18

MENV-013/BODPHOTO.DGN/1993 JAN 14

PHOTO 19: BEAR RIVER LOOKING UPSTREAM FROM CULVERT CROSSING. 70 M DOWNSTREAM OF CROSS SECTION 29

PHOTO 20: FLOW REVERSAL AT CULVERT CROSSING OF HIGHWAY 37A, 70 M DOWNSTREAM OF CROSS SECTION 29

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 19 & 20

MENV-013/BODPHOTO.DGN/1993 JAN 14

PHOTO 21: WINACHEE CREEK LOOKING DOWNSTREAM AT BRIDGE TO GARBAGE DUMP (NEAR CROSS SECTION 35)

PHOTO 22: BEAR RIVER AT OUTLET FROM STROHN LAKE (BEAR GLACIER)

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FLOODPLAIN MAPPING
BEAR RIVER AT STEWART

PHOTOS 21 & 22

MENV-013/BODPHOTO.DGN/1993 JAN 14

DRAWINGS

NOTES	
Produced by:	British Columbia Water Management Branch, Special Projects Section, Floodplain Mapping Program.
Survey:	River survey done by Surveys Section, Water Management Branch, Project 91 09 F037, April 1991 a) Horizontal control based on provincial network. b) Elevations are in metres and are referred to Geodetic Survey of Canada datum. (◉ indicates Survey Monument).
Mapping:	Base mapping done by Map Production Division, Surveys and Resource Mapping Branch, Project 89-008, dated February 1991. NAD 27. Air Photography 1989. a) Contour interval 1 metre and greater; spot elevations shown to 0.1 metres, with accuracy to ± 0.3 metres, except where noted. b) Grid origin referred to U.T.M. Projection Zone 9 .

FLOODPLAIN DATA

1. The floodplain areas as depicted on this map have been designated pursuant to the Canada/British Columbia Floodplain Mapping Agreement (1988) by the Minister of the Environment for Canada and the Minister of Environment, Lands and Parks for British Columbia.

   Flooding may still occur outside of the designated floodplain areas. The Ministers do not assume any liability by reason of the designation or failure to designate areas on this map.
2. The Designated Flood has a statistical frequency of occurrence of once every 200 years.
3. The flood levels were computed using a standard step method modelling technique, assuming open water flow conditions.
4. The floodplain limits assume the absence of all dykes.
5. The floodplain limits and flood levels include an allowance for freeboard.
6. The floodplain limits are not established on the ground by legal survey.
7. The floodplain limits are not delineated for side streams and tributaries.
8. The required setback of buildings from the natural boundaries of lakes and watercourses to allow for the passage of floodwaters and possible bank erosion is not shown. This information is available either through local municipalities or the Ministry of Environment, Lands and Parks.
9. MAPS AVAILABLE FROM MAPS B.C. MAP AND AIR PHOTO SALES, VICTORIA, B. C.

LEGEND

DESIGNATED FLOODPLAIN LIMIT

FLOOD LEVEL

200 Year Frequency

20 Year Frequency

(METRES G.S.C. DATUM)

KEY MAP

SCALE 1 : 250 000

REVISIONS

No.	DESCRIPTION	DATE

DRAFT

Environment Canada Inland Waters / Environnement Canada Eaux Intérieures

British Columbia Ministry of Environment / Colombie-Britannique Ministère de l'Environnement

Canada British Columbia Floodplain Mapping Agreement / L'Accord Canada Colombie-Britannique sur la cartographie des plaines d'inondation

HAY & COMPANY CONSULTANTS INC.
One West 7th Avenue
Vancouver, B.C.
Canada V5Y 1L5
(604) 875-6391

FLOODPLAIN MAPPING

BEAR RIVER AT STEWART

100m 0 100 200 300 400 500m
Scale in metres

DRAWN	HNC
CHECKED	
RIVER SURVEY	M. P.
DESIGNED	
ENGINEER	R.J. Wallwork
RECOMMENDED	
APPROVED	
FILE No.	910-9994
N.T.S. MAP No.	1030/P, 104A
SCALE	1 : 5 000
NEGATIVE No.	
DRAWING No.	91-30-1
REV.	
SHEET	1 of 2

DDflmg

NOTES	
Produced by:	British Columbia Water Management Branch, Special Projects Section, Floodplain Mapping Program.
Survey:	River survey done by Surveys Section, Water Management Branch, Project 91 09 F037, April 1991. a) Horizontal control based on provincial network. b) Elevations are in metres and are referred to Geodetic Survey of Canada datum. (◉ indicates Survey Monument).
Mapping:	Base mapping done by Map Production Division, Surveys and Resource Mapping Branch, Project 89-008, dated February 1991. NAD 27. Air Photography 1989. a) Contour interval 1 metre and greater; spot elevations shown to 0.1 metres, with accuracy to ± 0.3 metres, except where noted. b) Grid origin referred to U.T.M. Projection Zone 9.

FLOODPLAIN DATA

1. The floodplain areas as depicted on this map have been designated pursuant to the Canada/British Columbia Floodplain Mapping Agreement (1988) by the Minister of the Environment for Canada and the Minister of Environment, Lands and Parks for British Columbia.

   Flooding may still occur outside of the designated floodplain areas. The Ministers do not assume any liability by reason of the designation or failure to designate areas on this map.
2. The Designated Flood has a statistical frequency of occurrence of once every 200 years.
3. The flood levels were computed using a standard step method modelling technique, assuming open water flow conditions.
4. The floodplain limits assume the absence of all dykes.
5. The floodplain limits and flood levels include an allowance for freeboard.
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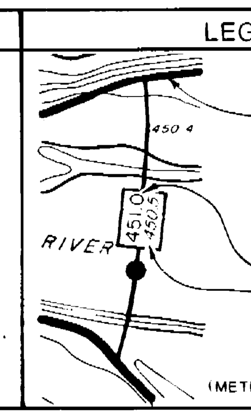
9. MAPS AVAILABLE FROM MAPS B.C. MAP AND AIR PHOTO SALES, VICTORIA, B. C.

LEGEND



DESIGNATED FLOODPLAIN LIMIT

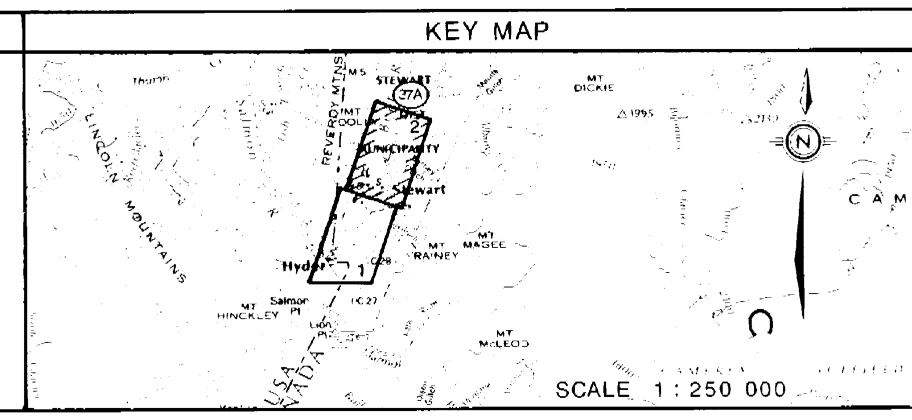
FLOOD LEVEL

200 Year Frequency

20 Year Frequency

(METRES G.S.C. DATUM)

KEY MAP



SCALE 1 : 250 000

REVISIONS

No.	DESCRIPTION	DATE

DRAFT

ENVIRONMENT CANADA INLAND WATERS / ENVIRONNEMENT CANADA EAUX INTÉRIEURES

BRITISH COLUMBIA MINISTRY OF ENVIRONMENT / COLOMBIE-BRITANNIQUE MINISTÈRE DE L'ENVIRONNEMENT

CANADA BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT / L'ACCORD CANADA COLOMBIE-BRITANNIQUE SUR LA CARTOGRAPHIE DES PLAINES D'INONDATION

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FLOODPLAIN MAPPING

BEAR RIVER AT STEWART

100m 0 100 200 300 400 500m
Scale in metres

DRAWN: HNC
CHECKED:
RIVER SURVEY: M. P.
DESIGNED:
ENGINEER: R. J. Wollwork.
RECOMMENDED:
APPROVED:

FILE No. 910-9994
N.T.S. MAP No. 1030/P, 104A
SCALE 1 : 5 000
NEGATIVE No.
DRAWING No. 91-30-2
REV.
SHEET 2 of 2

DDflmg