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FLOODPLAIN MAPPING PROGRAM

LITTLE QUALICUM RIVER

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 mapping for the Little Qualicum River near Qualicum Beach on Vancouver Island. This work is covered under the 1987 joint Federal/Provincial Agreement on Floodplain Mapping.

The floodplain mapping program is a joint initiative by the federal and British Columbia governments to provide information which will help to minimize future flood damage. The program identifies and maps areas that are highly susceptible to flooding. These areas may be designated as floodplains by the federal and provincial environment Ministers. Designated floodplains are subject to development restrictions. Subdivisions within a floodplain require the approval of the Regional Water Manager, BC Environment. Crown agencies such as Canada Mortgage and Housing Corporation do not support development on designated floodplains unless adequate floodproofing measures are taken. As well, disaster assistance is available only if new developments have incorporated adequate floodproofing measures. Local governments may impose further restrictions.

The Little Qualicum River drains the eastern slopes of the Beaufort Range on Vancouver Island, Figure 1. The river has its headwaters in Cameron Lake situated roughly midway between Port Alberni and Qualicum Beach. This river is known as the Cameron River above the lake. The study area is located in the Nanaimo Regional District. The town of Qualicum Beach and the unincorporated settlement of Dashwood are located in the study area near the estuary east and west of the Little Qualicum River respectively. The Qualicum National Wildlife area occupies fifty-six hectares at the mouth of the Little Qualicum.

The Little Qualicum River is a gravel/cobble bed stream which is poorly incised in the study area except for the middle reach near the Esquimalt & Nanaimo Railroad crossing. The lower reach favours the left (west) side of an alluvial fan. Some bank erosion is evident on the left bank above the highway bridge. The upper reach includes a relatively wide floodplain which has been developed as a Federal fish hatchery on the right side with a network of spawning channels. A dyke has been built to isolate the hatchery from the river. There are no standard dykes on the river.

The floodplain mapping studies described herein cover a 6.9 kilometre reach of the river extending upstream from the river mouth in Georgia Strait. A single map sheet covers the entire study reach. The mapping also depicts the areas subject to ocean flooding along the shoreline.

Representative site photos of the study area are included in the report with locations referenced to the surveyed cross sections or principal features.

2 SOURCES OF INFORMATION

This study made use of extensive river 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, photographs of cross sections, bridge sketches and bridge road profiles, 1:5000 base mapping and drawings of the fish hatchery. High water mark data pertaining to the February 27-28, 1994 flood was also supplied. The river surveys were conducted in July 1995. Base mapping is dated April 1996 based on air photography flown July 12, 1990. In addition, Water Survey of Canada streamflow records were utilized as well as stage records pertaining to floods. A complete listing of data sources and references is included in Appendix III.

3 FIELD INSPECTIONS

A field inspection was conducted by Mr. R.J. Wallwork on October 30, 1996 in order to establish the adequacy of the survey data base. The field inspection allowed Mr. Wallwork to become familiar with the study area and any changes which might have occurred subsequent to compilation of the river survey package. Mr. Wallwork also took site photos for possible inclusion in this report.

Prior to the site visit, Mr. Wallwork spoke to Mr. Jim Card at the Ministry's regional office in Nanaimo. River and ocean levels were discussed with respect to bylaws governing building construction. It was reported that the flood construction level with respect to ocean levels is 1.5 m above the natural boundary while for river levels the value is 3 m above the natural boundary. It was stressed by Mr. Card that these were "rules of thumb" only and he indicated the rationale for such levels would be revised as a result of the present study.

Mr. Wallwork met with a number of property owners during the site visit. Mrs. J. Miller at 1021 Surfside Drive reported that waves regularly overtop the seawall and pour into her back yard during high tides. She also said that water inundated her solarium to a depth of four inches during a December storm about 10 years ago. Observations of some of the properties at the western end of Surfside Drive revealed similar conditions. The floor level of the most westerly residence on Surfside Drive was observed using a hand level and found to be approximately 1.6 m above the ocean level at the time of the site visit (9:57 a.m.). A high tide of 4.8 m would have occurred at 8:48 a.m. based on Point Atkinson tides. The range of tides is approximately 5.1 m at Qualicum Beach so high tides could be at least 0.4 m higher than the observed water level which was viewed more than one hour after high tide. It is therefore unlikely that this particular residence has been sited 1.5 m above the natural boundary of the ocean. Rather, field measurements suggest this residence is, at most, 1.2 m above the natural boundary.

The owner of the camp ground on the right bank above the highway bridge reported that flood water had overtopped the river banks near cross section 8 during a recent flood. This water ponded but did not flow out of the area. The right bank is relatively low in this area and the Ministry added riprap to the bank several years ago.

An inspection was made of the reach near the pump station at cross section 11. Staff doing repairs at the pump station reported that floods are confined to the channel at the pump station. A flood in 1980 was reported to have overtopped the road at the east bridge approach resulting in 0.6 m of water in the south bound lane and 0.20 - 0.25 m of water in the north bound lane, the difference was reportedly due to superelevation of the bend.

Staff at the fish hatchery reported that the dyke had not been overtopped since the hatchery opened in October 1979 with the exception of some minor overbank flow near the outlet structure between cross sections 17 and 18. Copies of Floodplain Mapping Program literature were left at the hatchery.

A final field inspection was undertaken by Mr. Wallwork on March 13, 1997, in order to check the final draft of the floodplain maps.

4 HYDROLOGY

4.1 Flood Frequency Studies - Methodology

Flood data for analysis was exported from HYDAT Version 4.93 which included all of the available station records for the Little Qualicum River.

Environment Canada's Consolidated Frequency Analysis computer program, CFA Ver. 3.1, was utilized for the flood frequency analyses. 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 (3-PLN)
3. Log Pearson Type III Distribution (LPIII)

The selection of the most appropriate distribution for this study was based on a number of considerations including the observed fit, consistency of instantaneous to daily flood estimates, and relative consistency of flood estimates between the two stations on the Little Qualicum River as described below.

4.2 Streamflow Records

There are two Water Survey of Canada (WSC) stream gauging stations on the Little Qualicum River. These stations are listed in Table 1.

Table 1
Hydrometric Stations in the Study Area

Station	Name	Drainage Area km^2	Record
08HB004	Little Qualicum River at Outlet of Cameron Lake	135	13-22 MC 60-87 MC 88-93 RC 42 yr (d) 5 yr (i) Reg
08HB029	Little Qualicum River near Qualicum Beach	237	60-86 RC 26 yr (d) 25 yr (i) Reg
(d) = maximum daily flow (i) = maximum instantaneous flow			

The upper gauge (08HB004) was discontinued on September 2, 1993 while the lower gauge (08HB029) was in operation until January 1987 when the recorder was stolen.

4.3 Linear Regression Analysis

The upper gauge records were used to extend the record for the lower station which is representative of conditions through the study reach. There are 26 pairs of published annual daily flood peaks on the river. Mr. Hal Coulson, MoELP Hydrology Branch, provided an estimate of 250 m^3/s for the 1961 maximum daily flood at the mouth, bringing the number of flood pairs to 27. A linear regression analysis was carried out on these daily flood records with the y-intercept set to zero. The regression equation obtained is as follows:

$y = mx + b$ where:
y = flow at lower station (08HB029)
x = flow at upper station (08HB004)
b = y-intercept = 0
m = slope = 1.23501

The correlation coefficient R was determined to be 0.928 for the above analysis (R squared = 0.86075). This value indicates reasonably good correlation exists between the two sets of flood values.

The above equation was used to extend the lower station records from 27 years to 42 years. Results of the correlation analysis are included in Appendix II as spreadsheet output. Frequency analyses were then carried out on the various sets of records. It should be noted that, while it is possible to extend the daily flood record at the lower station in this manner, it is not possible to extend the maximum instantaneous flood record as the upper station had only 5 years of maximum instantaneous floods.

4.4 Flood Frequency Analysis

The maximum daily flood frequency estimates for the upper and lower stations are given in Table 2 below. The Qualicum Beach estimates are given for both the 27 years of recorded flows, including the 1961 flood estimate from Hal Coulson, plus the 42 years of extended record based on correlation with the upper station.

It can be seen from Table 2 that the mean floods during the shorter period (1960-1986) were greater than they were for the longer period (1913-1921 and 1960-1992). The LPIII frequency distribution provided a good fit to the data and MoELP reported that this distribution provided the best fit to the regional data for this area. Consequently, the LPIII frequency distribution was adopted for the study analyses. The extended record (42 years) resulted in larger flood estimates at both the upper and lower stations.

Table 2
Maximum Daily Flood Estimates - Little Qualicum River

Return Period years	Cameron Lake (upper station) m^3/s		Qualicum Beach (lower station) m^3/s	
	N = 42 years	N = 27 years	N = 27 years	N = 42 years
2	59.8	70.2	91.7	78.0
mean	70.095	77.881	99.956	89.000
5	95.0	111	139	120
10	122	137	168	150
20	151	160	195	182
50	193	187	227	226
100	228	206	249	261
200	266	223	269	299
500	321	244	295	352

The maximum instantaneous flood frequency estimates were determined for the lower station based on the 25 years of available record plus estimated floods for 1960 and 1961 (total of 27 years). These estimates were compared to the maximum daily flood estimates for the corresponding 27 year period at the lower station and I/D flood ratios were determined for each flood return period. These ratios were found to decrease with increasing return period which is contrary to the expected trend. It was therefore decided to take the average I/D ratio from the largest three daily floods (1.18) and apply this to the maximum daily flood estimates corresponding to the extended 42 year record at the lower station. In this manner, maximum instantaneous flood estimates were determined for the lower station based on the 42 year period of extended records. Results of this analysis are given in Table 3.

It should be noted that all of the flood data on the Little Qualicum River are reported to be regulated. Enquiries were made with WSC staff in Nanaimo and Mr. Ed Meyer reported that regulation involved controlled releases from Cameron Lake during the summer months to limit low flows. This minor regulation was for fisheries enhancement and would have no impact whatsoever on fall and winter floods.

Table 3
Little Qualicum River near Qualicum Beach - Flood Estimates

Return Period years	Little Qualicum River m^3/s		I/D Flood Ratio	Maximum Daily Flood N=42 m^3/s	Max. Inst. Flood m^3/s 1.18xDaily
	N=27 Max. Daily	N=27 Max. Inst.			
2	91.7	111	1.210	78.0	92.0
mean	99.956	119.500	1.196	89.000	105
5	139	168	1.209	120	142
10	168	202	1.202	150	177
20	195	231	1.185	182	215
50	227	264	1.163	226	267
100	249	286	1.149	261	308
200	269	306	1.138	299	353
500	295	329	1.115	352	415

The flood of record on the Little Qualicum River occurred in 1961 based on records for the upper gauge. This flood was initially reported by WSC for the lower gauge, according to Mr. Coulson, however the flood was later removed from the record. The 1961 flood would have a return period of approximately 50 years based on records for the upper gauge. Using the extended record for the lower gauge, the return period for this flood would have been in excess of 50 years.

The design flood estimates for the project are therefore estimated as follows:

200	-	year maximum daily flood	=	299 m^3/s
200	-	year maximum instantaneous flood	=	353 m^3/s
20	-	year maximum daily flood	=	182 m^3/s
20	-	year maximum instantaneous flood	=	215 m^3/s

4.5 Historical Data

The 1961 flood is the flood of record on the Little Qualicum River, as measured at the outlet of Cameron Lake. The maximum daily flood discharge was 189 m^3/s on January 16, however, no maximum instantaneous flows were available. The lower gauge, at Qualicum Beach, was in operation at this time but WSC did not report this flood event. As previously mentioned, Mr. Hal Coulson, MoELP Hydrology Branch, provided an estimate of 250 m^3/s for this flood at the mouth.

Apart from some high water marks in the upper study reach, dating from the 1970's, the only other data was the high water levels pertaining to the February 27-28, 1994 flood.

5 OCEAN WATER LEVELS

5.1 Tide Levels

Tide levels at the mouth of the Little Qualicum River were determined using standard correction factors applied to the tides at Point Atkinson, which is the applicable Canadian Hydrographic Service (CHS) reference port. The tide estimation procedure is detailed in the Canadian Tide and Current Tables, published annually by CHS. Table 4 lists HHW large tide estimates for Point Atkinson and the Little Qualicum River, as well as the large tide range for both stations.

Table 4
Tide Levels at Point Atkinson and Little Qualicum River

Station	HHW, Large Tide m above chart datum	Large Tide Range (m)
Point Atkinson	5.0	4.9
Little Qualicum River	5.2	5.1

Geodetic datum at Qualicum Beach is 3.16 meters 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. The pressure effect on storm surge at the Little Qualicum River was estimated based upon the results of an extreme water level analysis carried out for Boundary Bay, for which extreme storm surge levels were estimated for Point Atkinson (Seaconsult, 1990). It was assumed that the transfer function from Point Atkinson was linear, and thus the estimates were transferred directly. The estimates obtained for the 1:50 and 1:200 year storm surges are listed in Table 5.

Table 5
Storm Surge Levels

Return Period	Surge Estimates (m above SWL) Generalized Extreme Value Distribution
1 in 50 years	1.03
1 in 100 years	1.15

The effects of wind stress at the site were evaluated using the standard bathostrophic theory found in the Shore Protection Manual (1977, 1984) and related methodologies. Winds recorded at the AES station in Balleenas 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 various direction quadrants.

For the 50 year return period event, storm surges were estimated to be between 0.01 and 0.19 m depending upon the incident wind direction. For the 200 year return period event, estimated storm surges ranged between 0.01 and 0.20 m, again depending upon the incident wind direction.

5.3 Wave Runup

To estimate wave runup, a hindcast was undertaken to determine the deepwater wave climate in Georgia Strait using the modified SMB procedure (Shore Protection Manual, 1984). A shallow (1:20) nearshore slope was assumed for the runup calculations, based upon in house survey data collected at adjacent sites for previous projects.

Wave runup was estimated using the method of Hunt (1959), which has been found to apply to moderately shallow, cobble or gravel beaches. The estimated runups for the hindcast deepwater wave conditions are given in Table 6.

Table 6
Deepwater Wave Height and Runup Estimates at Qualicum Beach

Return Period	Wave Height (m)	Wave Runup (m)
1 in 1 year	3.3	0.5
1 in 20 year	4.7	0.65
1 in 50 year	5.0	0.67
1 in 200 year	5.2	0.7

5.4 Ocean Flood Levels

The 200 year and 50 year levels for the ocean at the Little Qualicum River 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 the mouth of the Little Qualicum River:

a) HHW Large Tide + 200 year storm surge + 200 year wave runup
= 1.90 + 1.15 + 0.70
= 3.75 m GSC

b) HHW Large Tide + 50 year storm surge + 50 year wave runup
= 1.90 + 1.03 + 0.67
= 3.60 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 year Storm surge
= 1.90 + 1.03
= 2.93 m GSC

d) 20 Year Event:
HHW Large Tide
= 1.90 m GSC

The above water levels would be applicable to cross section 1 at the mouth of the Little Qualicum River.

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 outer B.C. coast from tsunamis generated by potential undersea earthquakes in the Pacific, including a recurrence of the 1964 Alaska earthquake. No evaluation of the potential sea level rise in the Strait of Georgia was undertaken in this study. Seismically generated waves can occur within the Strait of Georgia, however, a detailed study of the potential increase in the water levels along the coast has not been carried out.

Water level rise due to tsunamis cannot be assigned a probability, as the data base of seismic events and related rise in coastal levels is extremely sparse. It is possible only to estimate maximum levels due to seismic events, which was done in Seaconsult's 1988 report. The most appropriate course of action is to broadcast a warning to evacuate all coastal areas should a seismic event occur.

Tsunami is not a criteria for Designation under the Federal/Provincial Agreement although a note is made regarding this potential on floodplain mapping drawings when historic tsunami data is available in a study area.

6 HYDRAULIC ANALYSIS - LITTLE QUALICUM RIVER

6.1 Model Calibration

The U.S. Army Corps of Engineers HEC-2 Water Surface Profiles computer program, Version 4.6.2, May 1991, was utilized in the water surface profile analysis, as implemented by Haestad Methods. The Haestad Methods implementation of the program, HM Version 6.52, is an extended version which allows up to 400 ground points (GR points) in each cross section.

The HEC-2 water surface profile model of the Little Qualicum River was developed from 32 surveyed cross sections on the river. There is one bridge crossing of Highway 19 in the lower reach plus a railway bridge crossing of the Esquimalt and Nanaimo Railway (Canadian Pacific) in the middle reach of the study area. In addition, there were 18 surveyed cross sections of Highway 19, together with a road profile, commencing at the bridge and extending east approximately 1.7 kilometres to Qualicum Beach. A road dyke profile was also provided in the upper reach in the vicinity of the side channels for the fish hatchery.

High water mark data was available for model calibration. This data included 12 high water marks on the Little Qualicum River below the railway bridge which are attributable to the February 27-28, 1994 flood event. These marks were surveyed by Ministry staff on March 4, 1994. Three trash line marks above the bridge are also attributable to this flood. A single high water mark near cross section 28 is attributed to a flood event which occurred in the 1970's.

Finally, the abandoned WSC gauge below the railway bridge provided rating curve information at the location of one of the high water marks. The bench mark for this gauge was tied in during the course of the surveys for this study.

A skew adjustment factor was applied to cross sections 3 and 4 at the highway bridge crossing as the bridge was not oriented perpendicular to the flow. Likewise, a similar skew adjustment factor was applied to cross section 11. Cross sections were extended to the limit of the floodplain using the 1:5000 base mapping.

The model included bridge data, namely, lower chord and minimum road elevations. The highway bridge was not rigorously modelled as floods were expected to pass without contacting the lower chord. Subsequent analysis proved this assumption to be correct. The contraction and expansion coefficients, 0.1 and 0.3, were increased to 0.5 and 0.8, respectively, in the vicinity of this bridge. The railway bridge would have no appreciable impact on the flow as only the lower piers were in the water at the river margins.

The split flow option was used to model the reach immediately upstream of the highway bridge, cross sections 6 to 9 inclusive. It was assumed that right overbank flow would be governed by the highest surveyed point on the right bank, at each cross section, or by the elevation of the highway opposite the section, whichever elevation is higher. Water lost from this reach of the channel would not re-enter the channel again until cross section 1 at the mouth of the river. At this point, lost flow would be redirected into the main channel from a side channel connecting up with swampy ground in the estuary.

Model calibration was begun using estimated values of channel and overbank roughness, as determined from the site photos taken during the cross section surveys, in conjunction with reference literature (Barnes). In addition, it was necessary to estimate the flood flow corresponding to the February 27-28, 1994 flood event. A flood estimate of 95.3 m^3/s was determined from the surveyed high water mark (HWM 12) at the site of the abandoned gauge. The elevation of this high water mark was 7.85 m which corresponds to a gauge height reading of 2.103 m. This gauge height translates into the above listed flow according to rating table no. 21. It was found that the resulting water levels predicted by the HEC-2 model were substantially lower than the observed high water mark data. An attempt was made to achieve model calibration by increasing the Manning's n values but a calibration could not be affected with realistic n values.

Following discussions with Ministry staff, it was determined that perhaps there had been significant channel changes at the site of the former WSC gauge such that the rating curve is no longer valid. The rating table was dated February 9, 1987 and there was some evidence of bank erosion near the gauge during the recent surveys. Bench mark 6 was reportedly in unstable ground when tied in.

In addition to the above, there was another reason for suspecting the calibration flow was low. Based on the flood frequency analysis, the flow of 95.3 m^3/s would have been less than the annual average flood, yet, indications in terms of high water mark data suggested this to be an above average flood event. It was therefore decided to arbitrarily increase the calibration discharge until a reasonable calibration could be achieved. The adjusted calibration flow was determined to be 160 m^3/s, which is less than the 1:20 year instantaneous design flow estimate of 215 m^3/s.

Even with the higher flow, substantial increases in the Manning's n values were still required in order to achieve a semblance of calibration. The resulting model had deviations of 0.25 m or less at most cross sections with the following exceptions:

- the computed water level at cross section 20 was 1.49 m lower than the extrapolated Trash line 1 value of 16.22 m (Trash line 1 = 16.80 m);

- the computed water level was 0.88 m higher than the trash line value at section 25 where the trash line was on the inside of the bend;

- the computed water level was 0.34 m higher than the trash line data at section 31 where the trash line was on the inside of a bend.

It should be noted that Trash line 1 was higher than the value for Trash line 2 which was further upstream but on the hatchery side of the dyke. Consequently, there is some uncertainty in this calibration data and no guarantee that the trash line data applies to the same flood as the other data, namely, the February 27-28, 1994 event. For these reasons, the large discrepancy at cross section 20 was largely ignored. The Manning's n value at this section was 0.070 which was considered the maximum realistic value which could be justified at this location. The discrepancy at section 25 was attributed to superelevation of the flow in the bend as well as uncertainty in the flood event. Likewise, the discrepancy at section 31 was downplayed for similar reasons.

The adopted Manning's n values varied from 0.030 to 0.070 in the channel. A constant n value of 0.150 was used in the overbanks except at the first cross section at the river mouth where an n value of 0.050 was used.

The model did not result in critical depth at any of the cross sections for the adjusted calibration discharge. Also, there was no flow escapement from the channel in the split flow reach upstream from the highway bridge.

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%. Results of this analysis are presented in the HEC-2 Study File - Little Qualicum River. The starting water level in each case was 2.93 m GSC which is equivalent to a higher high water, large tide (HHWLT) value of 1.90 m plus the 50 year storm surge component of 1.03 m.

The sensitivity analysis resulted in critical depth at cross section 28 which is upstream of the fish hatchery. This was the only cross section where critical depth was predicted by the model.

The model was fairly sensitive to discharge, a 30% increase in flow resulted in stage increases ranging from 0.07 m at cross section 7 to 0.79 m at cross section 15 which is in a highly confined reach.

Typically, stage increases were in the 0.3 m to 0.6 m range for a 30% increase in flow. Flow escapement occurred in the split flow reach, sections 6 to 9, for each of the sensitivity discharges.

6.2.2 Roughness

The sensitivity of the calibrated model to changes in bed roughness was also investigated by means of a multiple Manning's n run. The calibrated model roughness values were increased by 20% and 40% in conjunction with the 200-year mean daily flood. Starting water levels were 2.93 m GSC as per the previous discharge sensitivity tests.

The roughness sensitivity tests indicated subcritical flow for all cross sections over the full range of roughness values. There was flow escapement from the channel in the split flow reach, sections 6 to 9, for each of the roughness sensitivity tests.

The model was fairly sensitive to channel roughness, a 40% increase in Manning's n values resulted in stage increases which ranged from 0.02 m at cross section 4 to 0.69 m at cross section 15. Once again, the maximum stage increase occurred in the most confined reach of the river.

6.2.3 Starting Water Surface Elevation

An additional multiple profile run was undertaken to investigate the sensitivity of the calibrated model to starting water surface level in Georgia Strait. Water surface profiles along the river axis were derived for starting water surface elevations of 2.73, 3.13 and 3.33 m GSC which represents a water surface decrease of 0.2 m as well as water surface increases of 0.2 m and 0.4 m, respectively, from the elevation utilized in the calibrated model.

The model was completely insensitive to starting water surface elevation for the river reach upstream of the campground at cross section 7.

Within the reach downstream of the campground, the impact of the imposed adjustments to starting water surface elevation was inversely proportional to distance upstream from the mouth.

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 freeboard, or the computed 200-year mean daily peak profile plus 0.6 m 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 in the flood profile calculations and for changing conditions such as bed aggradation.

The 200-year mean daily flood profile plus 0.6 m freeboard allowance was found to govern the flood profile determination throughout the entire reach below the railway bridge as well as at about half the reach above the bridge. Tabulated values for the flood profile on the Little Qualicum River, including freeboard, are listed in Appendix I. The flood profile on the Little Qualicum River, including freeboard, is shown on Figure 2.

The freeboard allowance added to the designated flood level therefore appears adequate to accommodate a 200-year instantaneous flow increase of approximately 12% or more. The freeboard allowance, in conjunction with the 200-year mean daily flood, would also be able to accommodate an increase in roughness of 40% or more at most locations.

Interpolated flood levels at one metre spacing were derived from the designated flood profile including freeboard, Figure 2, and used to draw flood level isograms on the enclosed floodplain map. As there were no standard dykes along the study reach, there was no need to undertake a dyke breach analysis for these studies. The dyke adjacent the fish hatchery channel could result in elevated ponding levels at the lower end of the channel and this has been noted on the floodplain map.

Twenty year flood levels, including freeboard, were derived in a similar manner and noted on the floodplain map.

7 SPECIAL FLOOD CONDITIONS

The lower portion of the study reach involves flow on an alluvial fan. The river presently occupies the left side of the fan, the apex of which is just upstream of the pump station at cross section 11. There does not appear to be any great threat of a channel avulsion occurring, nevertheless, the potential remains. If an avulsion were to occur near the pump station, say due to a logjam, overland flow could carry on down the fan and cross the highway near Seacroft Road which happens to be the low point in the highway profile. There is some evidence of a flow path between the pump station and this low point on the highway according to the contours on the base map. Floodwaters, should they cross the highway as described, would put at risk many residences near the shoreline.

The lower portion of the fan has been subject to active overbank flows in recent years. These flows cross the highway to the east of the bridge and enter the estuary where they are picked up by the channel network. Fortunately, there are no residences in the path of these overland flows once they cross the highway. Buildings in the vicinity of the campground would be subject to flood damage.

8 FLOODPLAIN MAPS

The floodplain map for the Little Qualicum River is enclosed, Drawing No. 93-11-1 (sheet 1 of 1). The limits of the floodplain are shown together with flood level isograms showing approximate lines of equal 200-year flood level (freeboard included) to the edge of the floodplain.

Floodplain maps are administrative tools to provide information which will help to minimize future flood damages. They are not comprehensive floodplain management plans, nor do they provide site specific solutions to hazards such as land erosion, sudden channel shifts during flooding or tsunami hazards.

As noted on the drawing, the floodplain limits have not been established on the ground by legal survey and the map depicts open water conditions only. Flooding may occur outside the designated floodplain due to a variety of reasons including tributary flooding, ponding behind transportation routes, floods that exceed the design event, channel obstructions or tsunamis. These limitations are noted on the maps where appropriate.

9 CONCLUSIONS AND RECOMMENDATIONS

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

1. The floodplain map prepared for the Little Qualicum River, as presented herein, should be designated under the terms of the joint Federal/Provincial Floodplain Mapping Agreement.

2. The drawings may be used for administrative purposes related to the preparation of hazard map schedules for official plans; floodproofing requirements in zoning and building bylaws; and the identification of floodable lands by Subdivision Approving Officers.

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

4. Water Survey of Canada (WSC), the BC Ministry of Environment and the local government should collectively endeavour to re-establish a gauging station within the study area.

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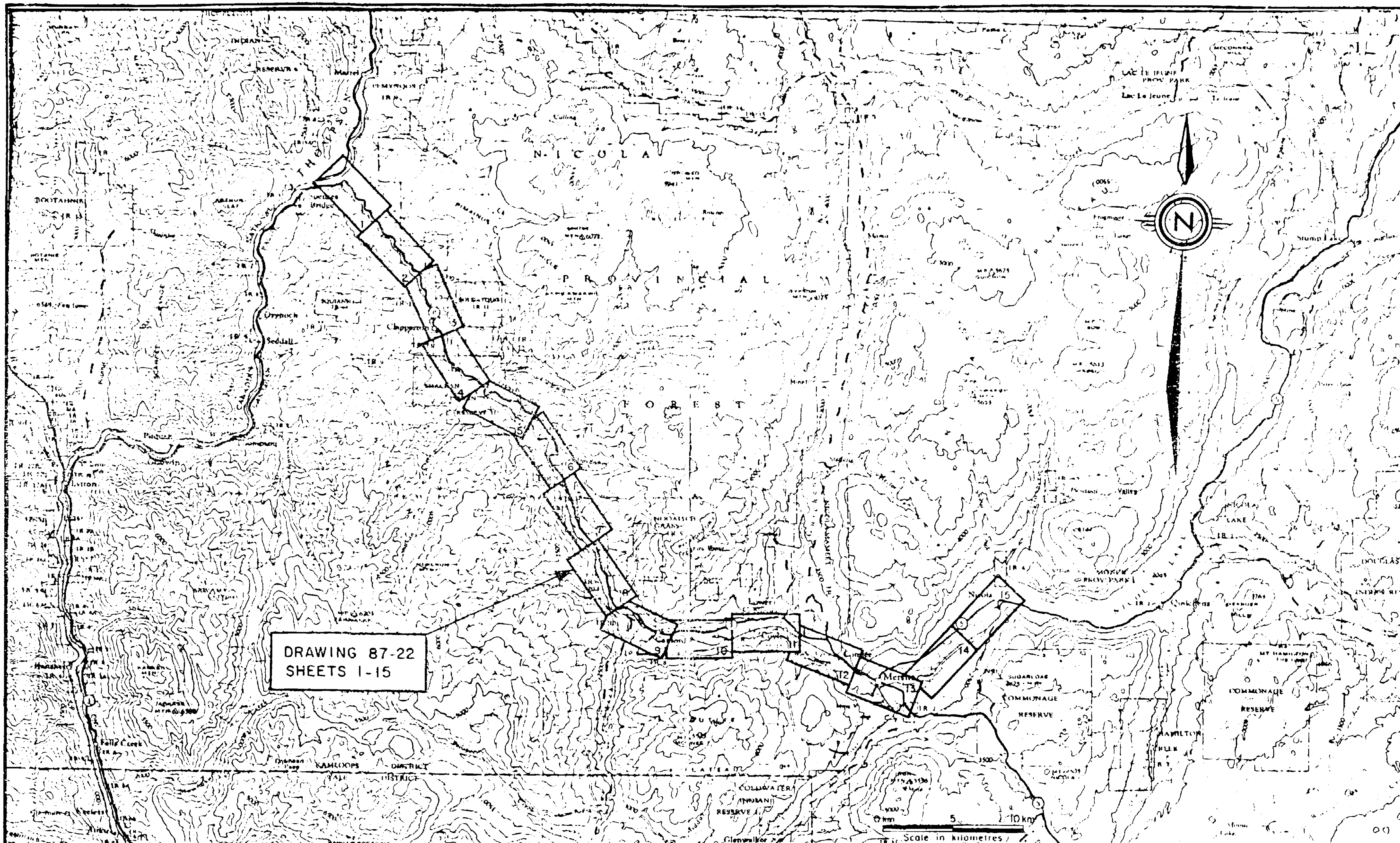
Dr. S.R.M. Gardiner, P.Eng.

APPENDIX I

TABULATED FLOOD LEVEL PROFILES (FREEBOARD INCLUDED) LITTLE QUALICUM RIVER

LITTLE QUALICUM RIVER			
Section Number	**Flood Level* m**	**Section Number**	**Flood Level* m**
1	3.53	17	13.38
2	3.70	18	13.51
3	4.08	19	14.18
4	4.23	20	16.04
5	4.24	21	17.52
6	4.44	22	18.67
7	5.01	23	19.96
8	5.76	24	21.82
9	6.64	25	22.31
10	7.00	26	23.11
11	7.54	27	23.66
12	8.62	28	24.41
13	9.52	29	25.76
14	9.46	30	25.95
15	10.62	31	27.05
16	12.75	32	28.02

* Flood levels as shown on the Floodplain Mapping Drawing. Includes freeboard allowance.

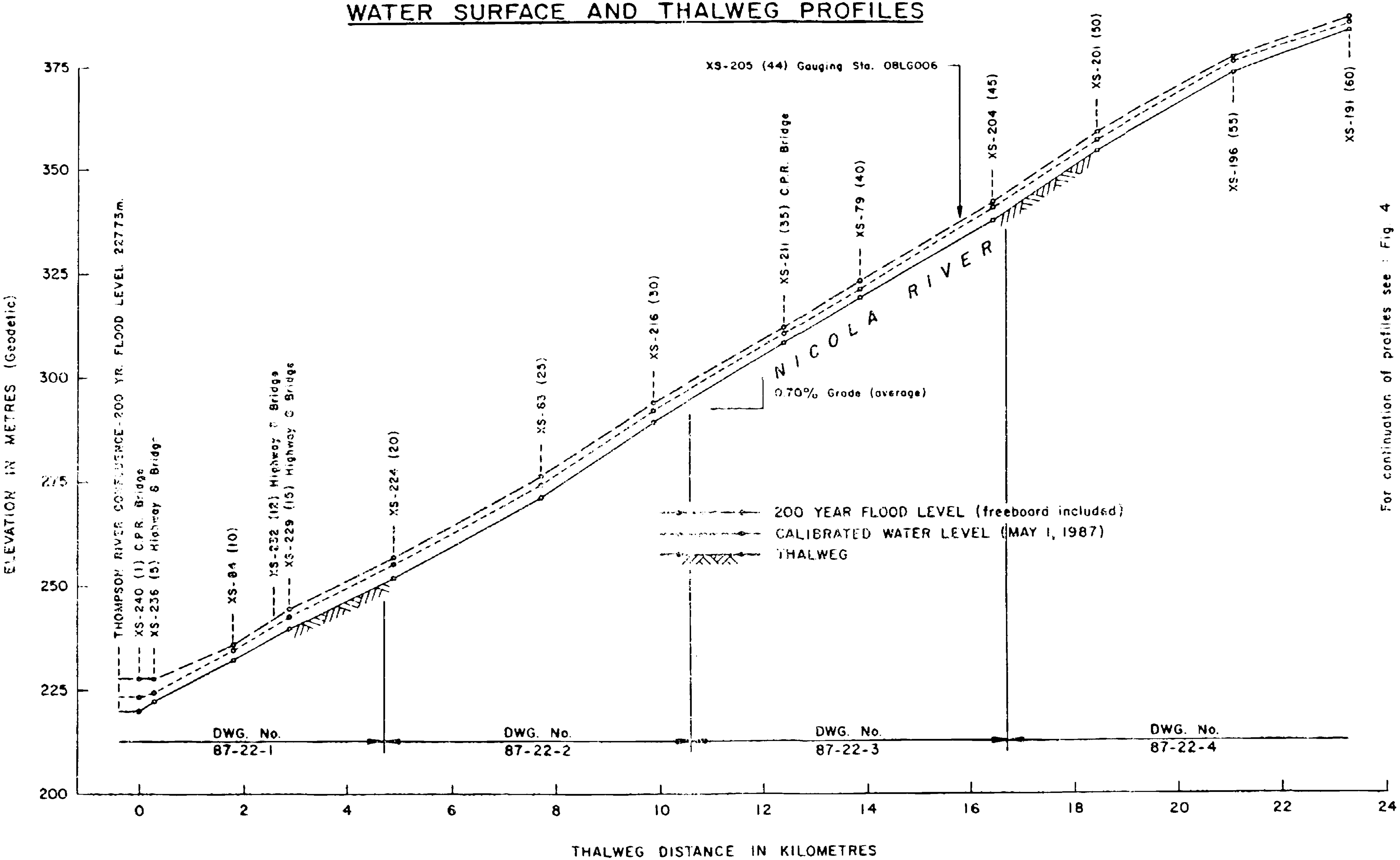


Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

FLOODPLAIN MAPPING STUDY
NICOLA RIVER
KEY MAP

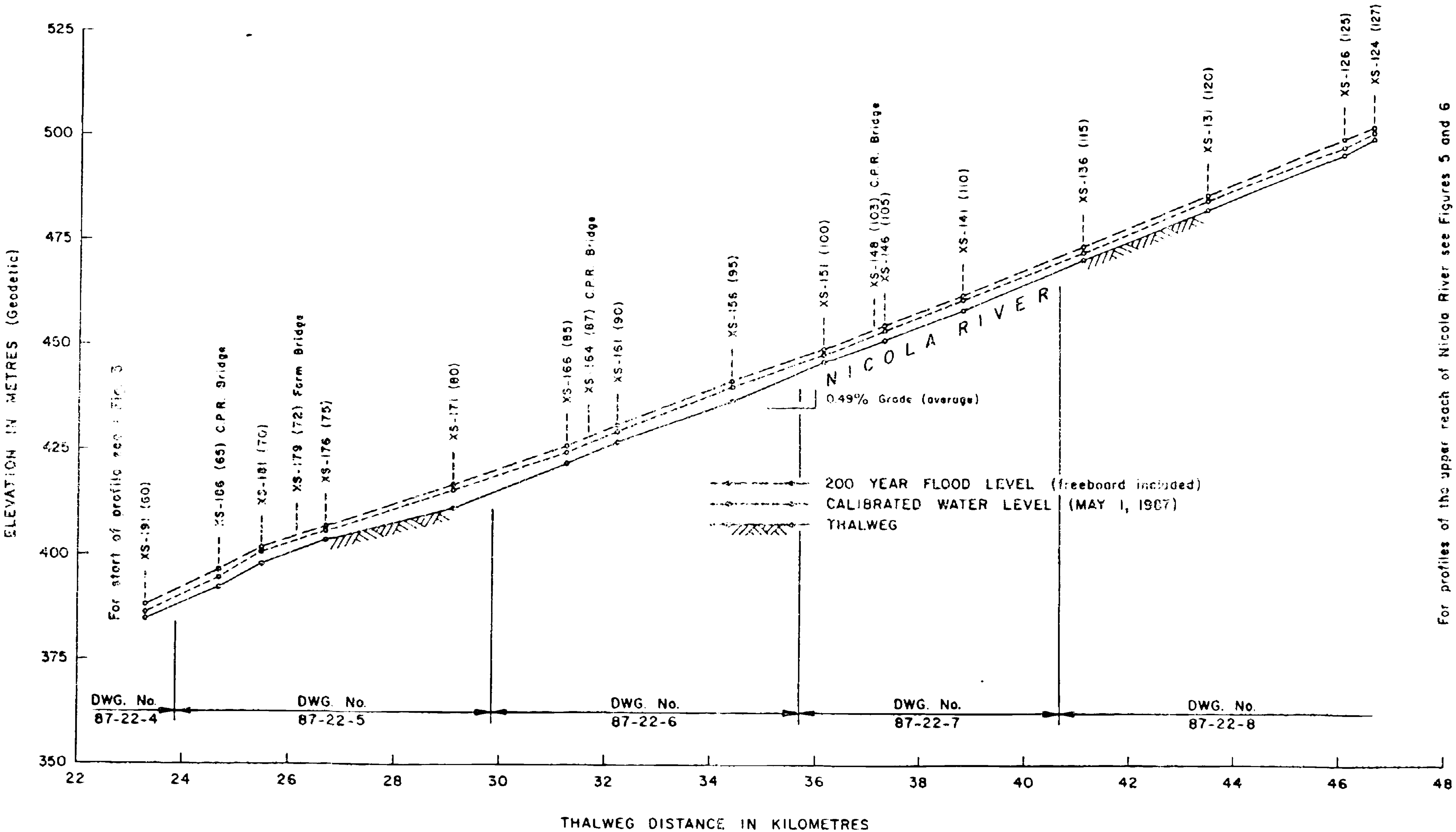
SCALE: VERT.	DATE
HOR 1:250 000	JULY, 1988
R. W. NICHOLS	ENGINEER
FILE No. 02-2500-S.1	FIG. No. 2

WATER SURFACE AND THALWEG PROFILES



Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	FLOODPLAIN MAPPING STUDY NICOLA RIVER SPENCES BRIDGE TO CANFORD	SCALE: VERT. AS SHOWN HOR. AS SHOWN	DATE JULY, 1988
		R. W. NICHOLS ENGINEER	
		FILE No. 02-2500-S.1	FIGURE No. 3

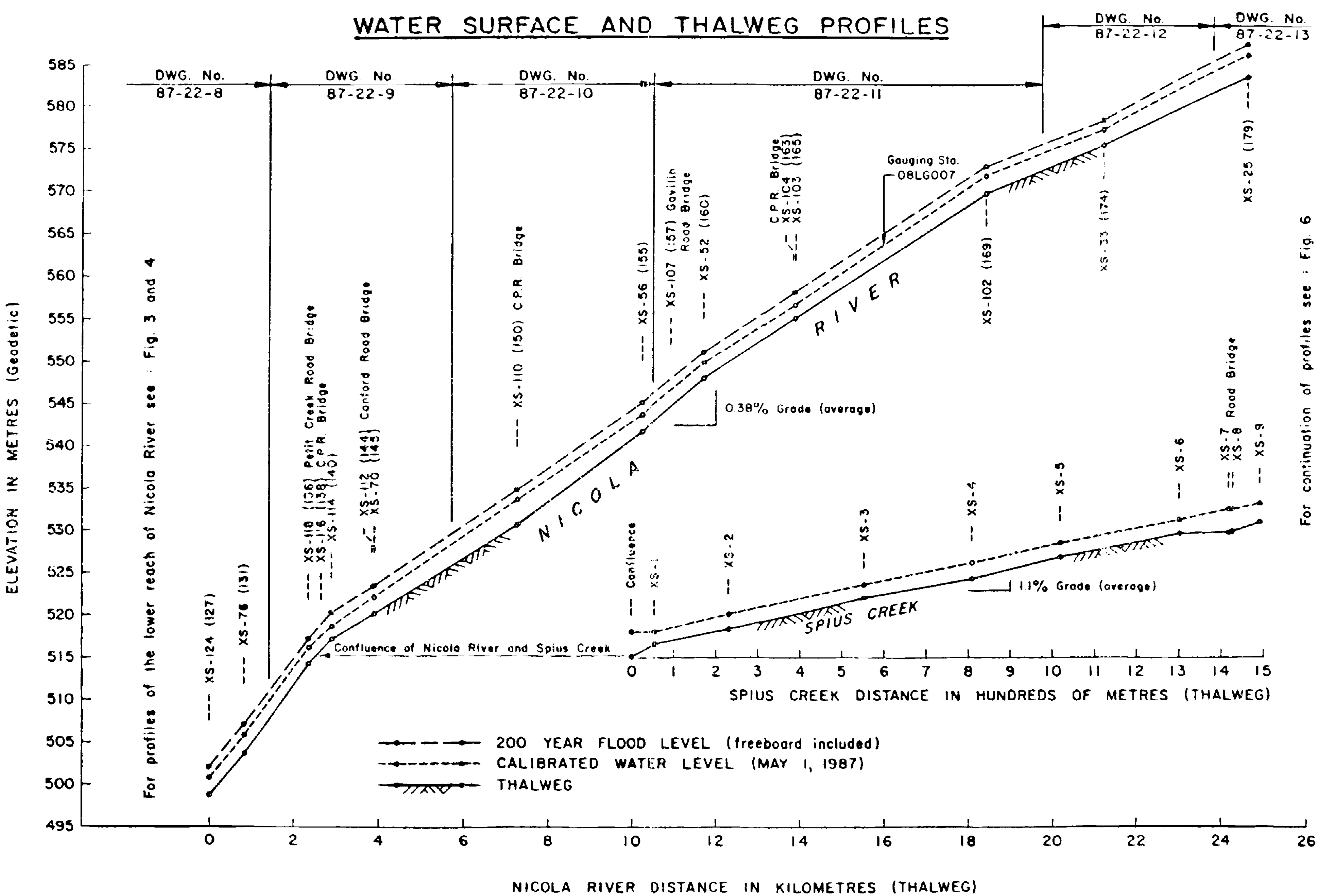
WATER SURFACE AND THALWEG PROFILES



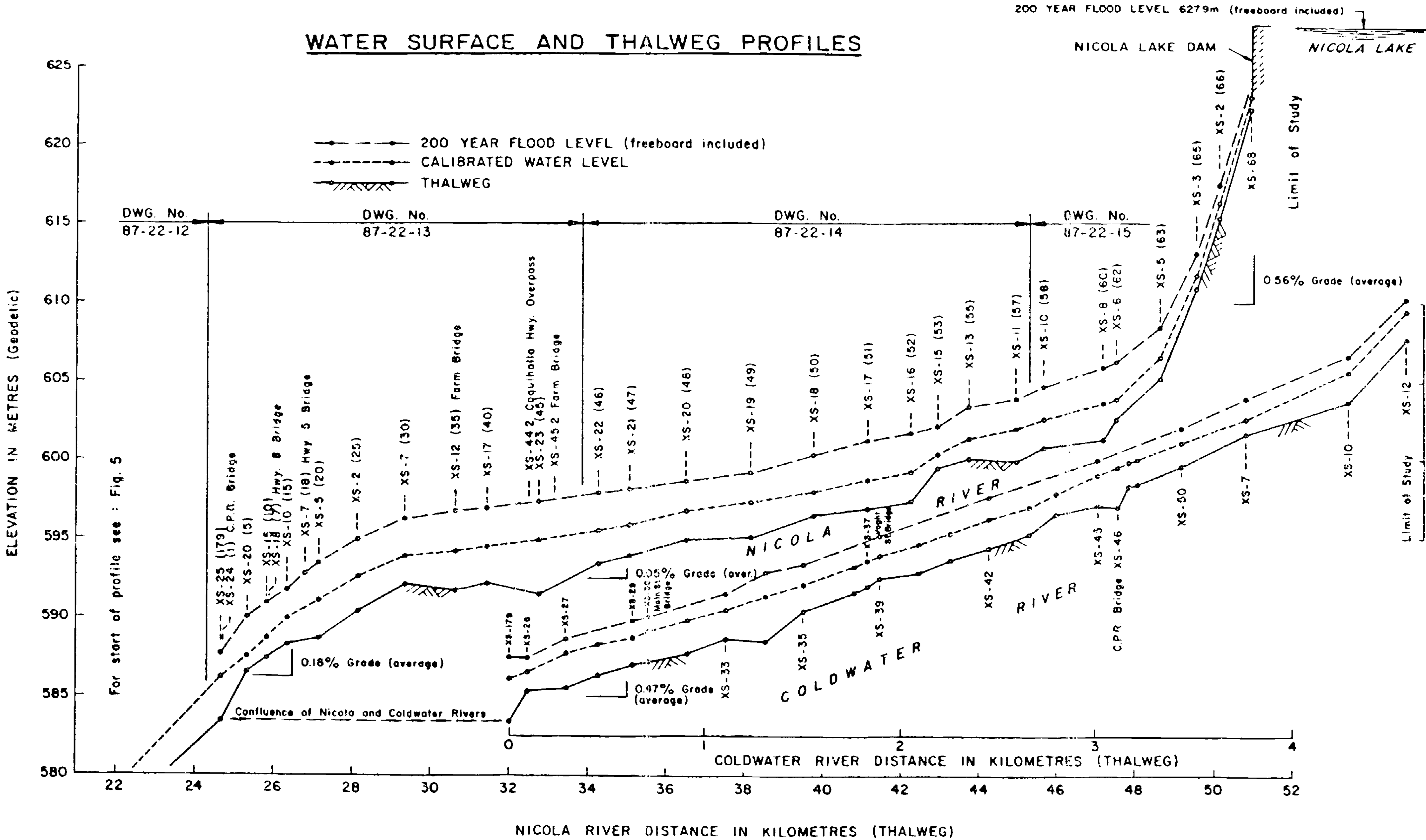
Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

FLOODPLAIN MAPPING STUDY
NICOLA RIVER
SPENCES BRIDGE TO CANFORD

SCALE: VERT AS SHOWN		DATE
HOR AS SHOWN		JULY, 1988
R. W. NICHOLS		ENGINEER
FILE No. 02-2500-S.1	FIGURE No.	4



Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	FLOODPLAIN MAPPING STUDY NICOLA RIVER CANFORD TO NICOLA LAKE	SCALE: VERT. AS SHOWN HOR. AS SHOWN	DATE JULY, 1988
		R. W. NICHOLS ENGINEER	
		FILE No. 02-2500-S.1	FIGURE No. 5



Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

FLOODPLAIN MAPPING STUDY
NICOLA RIVER
CANFORD TO NICOLA LAKE

SCALE: VERT. AS SHOWN
HOR. AS SHOWN
DATE JULY, 1988
R. W. NICHOLS ENGINEER
FILE No. 02-2500-S1 FIGURE No. 6

APPENDIX II

LITTLE QUALICUM RIVER
LINEAR REGRESSION ANALYSIS

LITTLE QUALICUM RIVER - REGRESSION ANALYSIS (MAXIMUM DAILY FLOODS)			
			LINEAR REGRESSION ESTIMATE
YEAR	CAMERON LAKE	QUALICUM BEACH	QUALICUM BEACH
	M3/S	M3/S	M3/S
1913	41.9		51.7
1914	57.5		71.0
1915	43.3		53.5
1916	31.7		39.1
1917	41.6		51.4
1918	73.6		90.9
1919	45.9		56.7
1920	33.4		41.2
1921	85		105.0
1960	59.7	131	73.7
1961	189	250	233.4
1962	69.1	91.2	85.3
1963	125	140	154.4
1964	42.5	68	52.5
1965	41.6	56.1	51.4
1966	87.2	92.3	107.7
1967	46.7	57.8	57.7
1968	131	154	161.8
1969	30	46.2	37.1
1970	23.2	37.1	28.7
1971	42.8	66.8	52.9
1972	85	99.7	105.0
1973	101	138	124.7
1974	132	136	163.0
1975	128	140	158.1
1976	31.7	44.5	39.1
1977	45.6	58.9	56.3
1978	23	33.4	28.4
1979	104	131	128.4
1980	162	166	200.1
1981	71.1	85.5	87.8
1982	71.6	85.6	88.4
1983	90.1	155	111.3
1984	55.5	88.7	68.5
1985	23.4	29	28.9
1986	91	117	112.4
1987	61.1		75.5
1988	44.9		55.5
1989	34.4		42.5
1990	77.9		96.2
1991	68		84.0
1992	101		124.7
	Regression Output:		
Constant			0
Std Err of Y Est			19.162475121083
R Squared			0.86074911088835
No. of Observations			27
Degrees of Freedom			26
X Coefficient(s)		1.2350125741487	
Std Err of Coef.		0.041273776256415	

APPENDIX III

DATA SOURCES AND REFERENCES

APPENDIX D

LIST OF AVAILABLE INFORMATION

LITTLE QUALICUM RIVER

1. River Survey - Project 9508F058 (July and November 1995)

   A. List of Contents (Attached)

2. Drawings

   A. Drawing 96-1-1, "Topographic Plan Showing Cross Section Locations"(attached)

   B. Drawing 93-11-1, "Little Qualicum River", base map sheet at 1:5000 scale, 1 meter contour intervals prepared for delineation of the designated floodplain.

3. Miscellaneous

   A. One ring binder entitled "Little Qualicum River-February 27/28 1994- High Water Marks". Binder contains a listing, photographs and a map showing the high water mark data collected by Hydrology Branch staff. Also included is information on WSC Gauge 08HB029.

   B. File 35000-20/21-120, available through the Regional Office from Mr. Jim Card, Head Engineering (Telephone 751-3139 / Nanaimo) has reports and notes about flooding in the study area from 1967 to date.

   C. Ministry of Transportation and Highways , Peter Wightman, District Highways Manager, Richard Crossley, Area Manager (alternate contact) , may have information on Dec.1980 and Nov. 1990 floods.(Telephone 390-6295/ Nanaimo).

   D. Water Management Branch, British Columbia Ministry of Environment, "Coastal Environment and Coastal Construction - A Discussion Paper" by B.J. Holden, Victoria, 1987.

Little Qualicum River

Project # 9508F058

Code # 497058

Requested by: R.W. Nichols, P. Eng.
Senior Hydraulic Engineer
Flood Hazard Identification

Field : July 15 - 26 and November 27-28, 1995
Office : November, 1995 - February, 1996

The field survey was carried out in favourable conditions by a four man crew under the supervision of M.B. Pronk. Standard Floodplain survey practices were observed throughout. Initial field reconnaissance carried out July 15, with layout and cross sections commencing the following day. Additional data was acquired on Highway 19 on November 27 and 28 in heavy rain.

SURVEY LOGISTICS:

Little Qualicum River; Thirty two cross sections were run, commencing at Georgia Strait and extending upstream approximately 6.9 kilometres.
Highway #19; Eighteen cross sections and a profile were run, commencing at Little Qualicum River bridge and extending west approximately 1.7 kilometres to Qualicum Beach.
Cross section locations are shown on drawing 96 - 1 - 1.

SURVEY DATA:

Horizontal control for cross sections and profiles were established by EDM traverse using a total station theodolite. Vertical control was established by reciprocal height traversing, using a total station theodolite and confirmed by standard differential levelling. Data recorded in Field Book #2653-L1 and on disc labelled #2653-D. Data reduced, compiled and plotted using PC/Vax and HP Table Plotter by M. Spencer. Reduced data was also compiled in a program written by Co-op. student M. Humphries for Excel 5.0. This program includes the project photographs, with the negatives first burned onto a PhotoCD laser disk, and then incorporated digitally into the job package. Points plots, cross sections and site plans were also produced on AutoCad.

DATUM:

Horizontal control referred to British Columbia Survey Control Posts 80H2805 & 81H4333, obtained from Surveys and Resource Mapping Branch data bank listing dated May 12, 1995. NAD83 coordinates were used throughout. Vertical control is based on Geodetic Datum (CVD28) and referred to Geodetic Survey of Canada Bench Mark 77C541 and British Columbia Control Survey Bench Marks 90HA080 and 90HA081. Elevations are in metres and were obtained from Surveys and Resource Mapping Branch listing dated May 12, 1995. This listing was last updated November 3, 1993.

DATA RETURNS:

Flood Hazard Identification Section: one volume containing;
-Chart and graph of water level profile, including February 27-28, 1994 high water marks;
-Copy of Water Survey of Canada description for station number 08HB029;
-Profile statements and plots of Cross Sections 1 thru 32;
-Photographs of channel and bank conditions;
-Profile and 19 cross sections on Highway 19
-Site plans of structures at cross sections 3/4, 14, 17 and 25.
-Listing of G.R. Data for all cross sections;
-One copy of drawing #96 - 1 - 1, scale 1:5,000, showing location of cross sections and bench marks;
-3.5 inch computer disk with decimal and non-decimal G.Rs. for all cross section data obtained for this project.

REFERENCES

1. Barnes, H.H., 1967. Roughness Characteristics of Natural Channels, U.S. Geological Survey. Water Supply Paper No. 1849.

2. Fax transmittal (November 13, 1996) from Ms. Shelley Bradford, Water Survey of Canada, re: rating table 21 for Little Qualicum River (Sta. 08HB029).

3. Hay and Company, November 4, 1996 letter to Water Management Division, re: Little Qualicum River Project, Site Visit - Survey Data Base.

4. Hay and Company, November 21, 1996 letter to Water Management Division, re: Little Qualicum River Project, Flood Frequency Analysis.

5. Fax transmittal, November 27, 1996, from Water Management Division, re: comments on Flood Frequency Analysis.

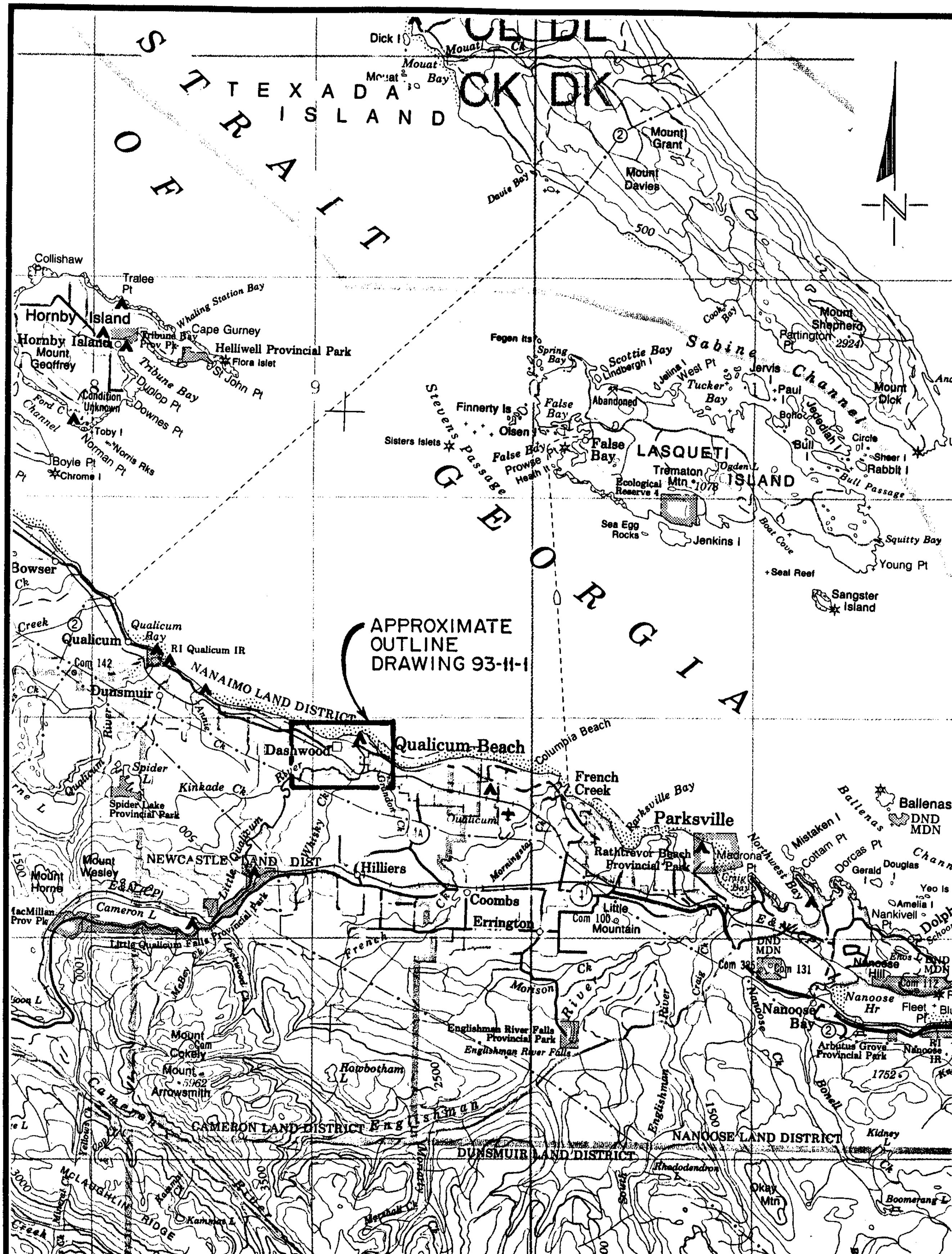
6. Pilon, P.J., et al., Environment Canada, Consolidated Frequency Analysis Package, Ver. 3.1.

7. Environment Canada, Atmospheric Environment Service, HYDAT CD-ROM, Ver. 4.93

8. Environment Canada — British Columbia Floodplain Mapping Program, A Users Guide to Floodplain Maps in British Columbia.

FIGURES

HAYCO



HAY & COMPANY CONSULTANTS INC.

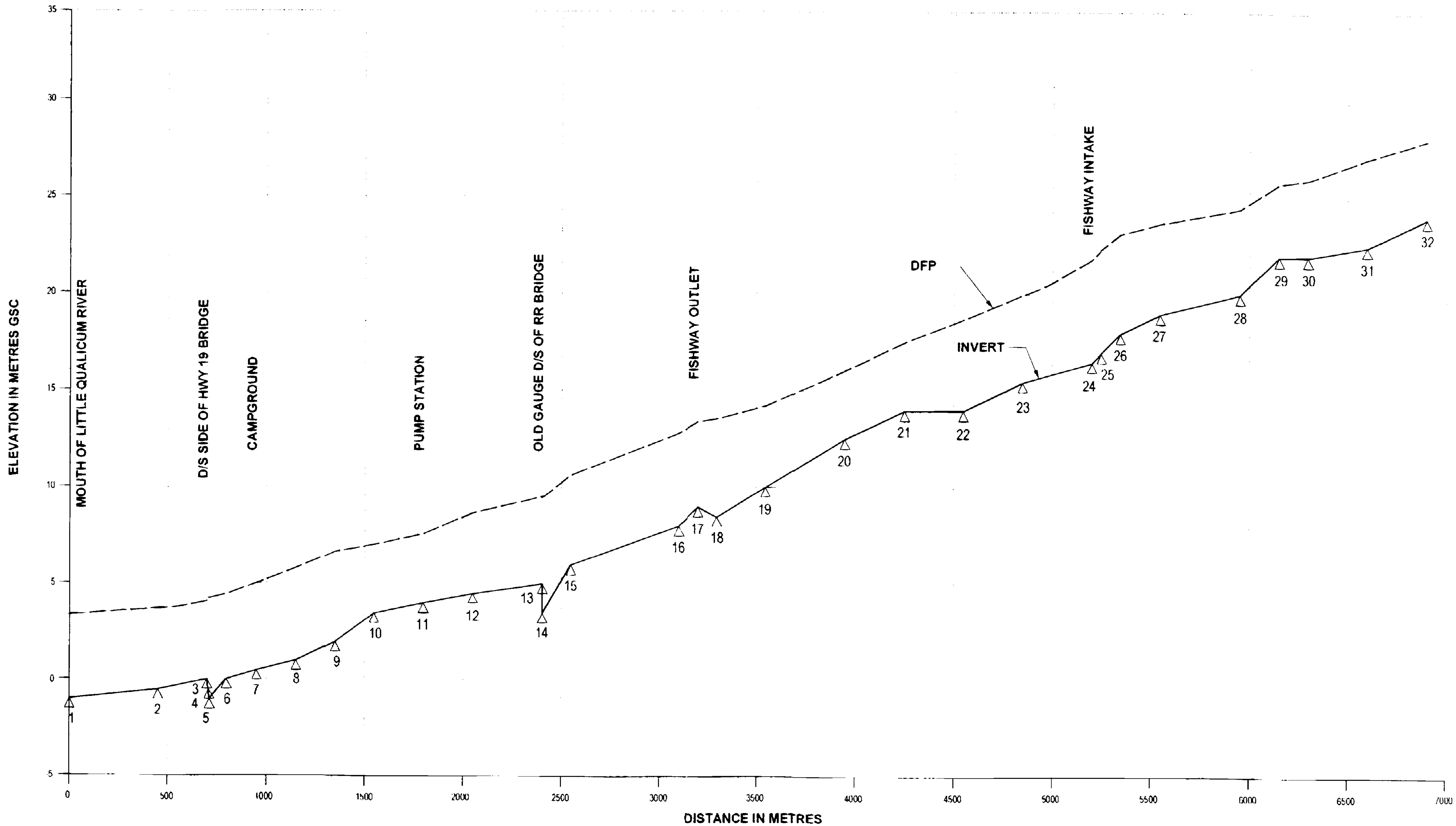
B. C. ENVIRONMENT

FLOODPLAIN MAPPING
LITTLE QUALICUM RIVER

LOCATION MAP

FIG. 1

CAD FILE : MENV-018 / MENV18FIG.DGN / 1997 FEB. 14



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B. C. ENVIRONMENT

FLOODPLAIN MAPPING
LITTLE QUALICUM RIVER

DESIGNATED FLOOD PROFILE
LITTLE QUALICUM RIVER

FIG. 2

CAD FILE : MENV 018 / MENV18FIG.DGN / 1997 FEB. 14

PHOTOGRAPHS

PHOTO 1 SHORELINE AT WEST END OF SURFSIDE DRIVE - LOOKING EAST

PHOTO 2 SHORELINE AT 1021 SURFSIDE DRIVE - LOOKING WEST

HAY & COMPANY CONSULTANTS INC.

B. C. ENVIRONMENT

FLOODPLAIN MAPPING
LITTLE QUALICUM RIVER

PHOTOS 1 AND 2

CAD FILE : MENV-018 / MENV18FIG.DGN / 1997 FEB. 14

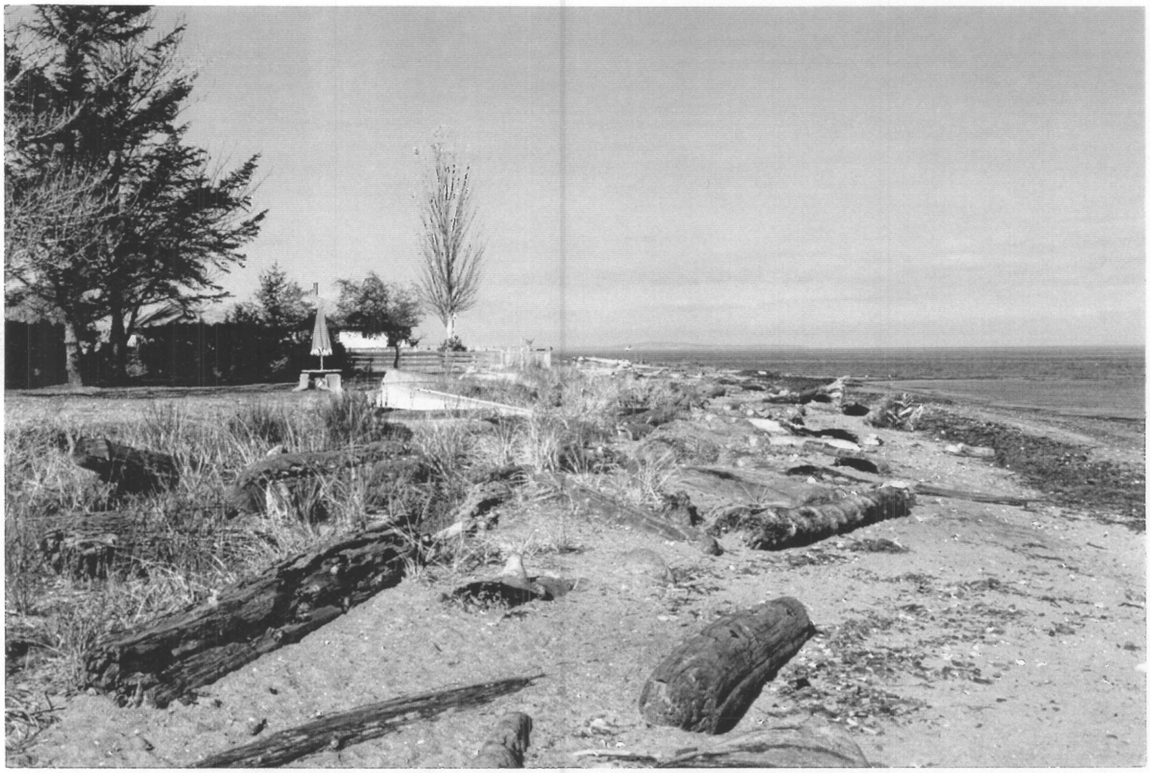

PHOTO 3 SHORELINE NEAR MCFEELY DRIVE AND KINKADE ROAD - LOOKING WEST

PHOTO 4 SHORELINE AT NORTH END OF SEACROFT ROAD - LOOKING WEST

HAY & COMPANY CONSULTANTS INC.

B. C. ENVIRONMENT

FLOODPLAIN MAPPING

LITTLE QUALICUM RIVER

PHOTOS 3 AND 4

CAD FILE : MENV-018 / MENV18FIG.DGN / 1997 FEB. 14

PHOTO 5 LITTLE QUALICUM RIVER ESTUARY - LOOKING UPSTREAM FROM CROSS SECTION 1

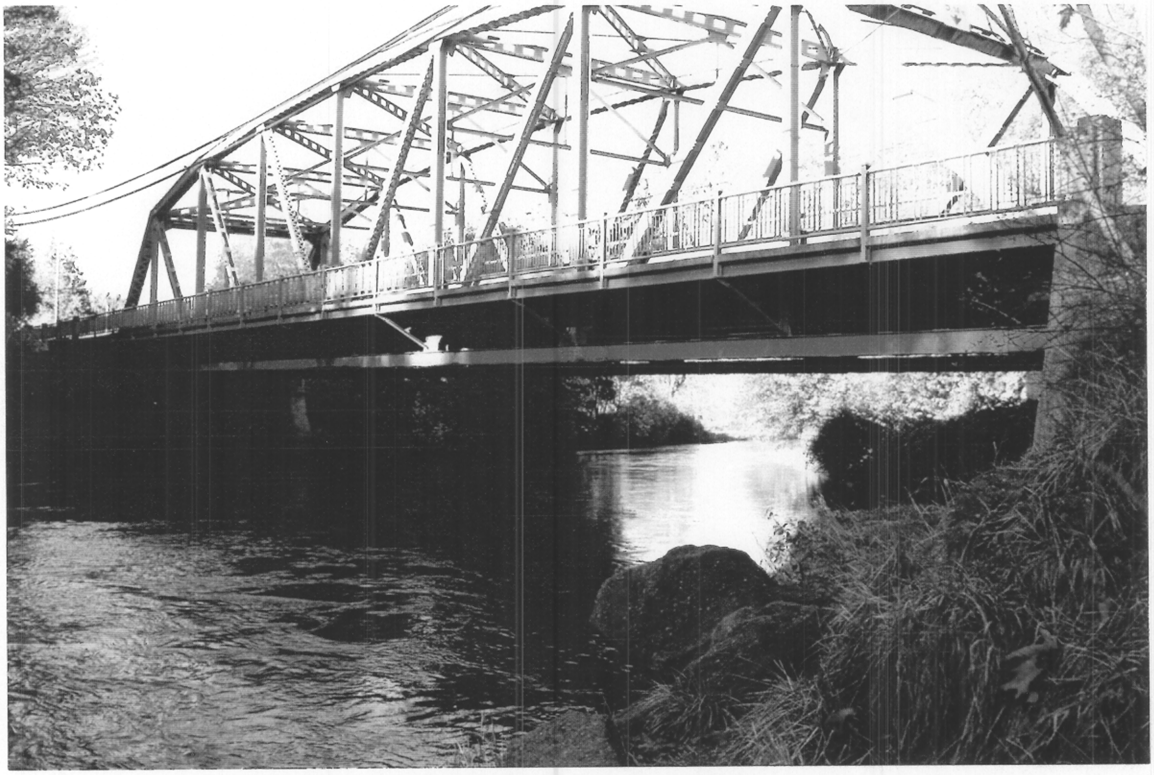

PHOTO 6 LITTLE QUALICUM RIVER - LOOKING DOWNSTREAM AT HIGHWAY 19 BRIDGE

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FLOODPLAIN MAPPING

LITTLE QUALICUM RIVER

PHOTOS 5 AND 6

CAD FILE : MENV-018 / MENV18FIG.DGN / 1997 FEB. 14

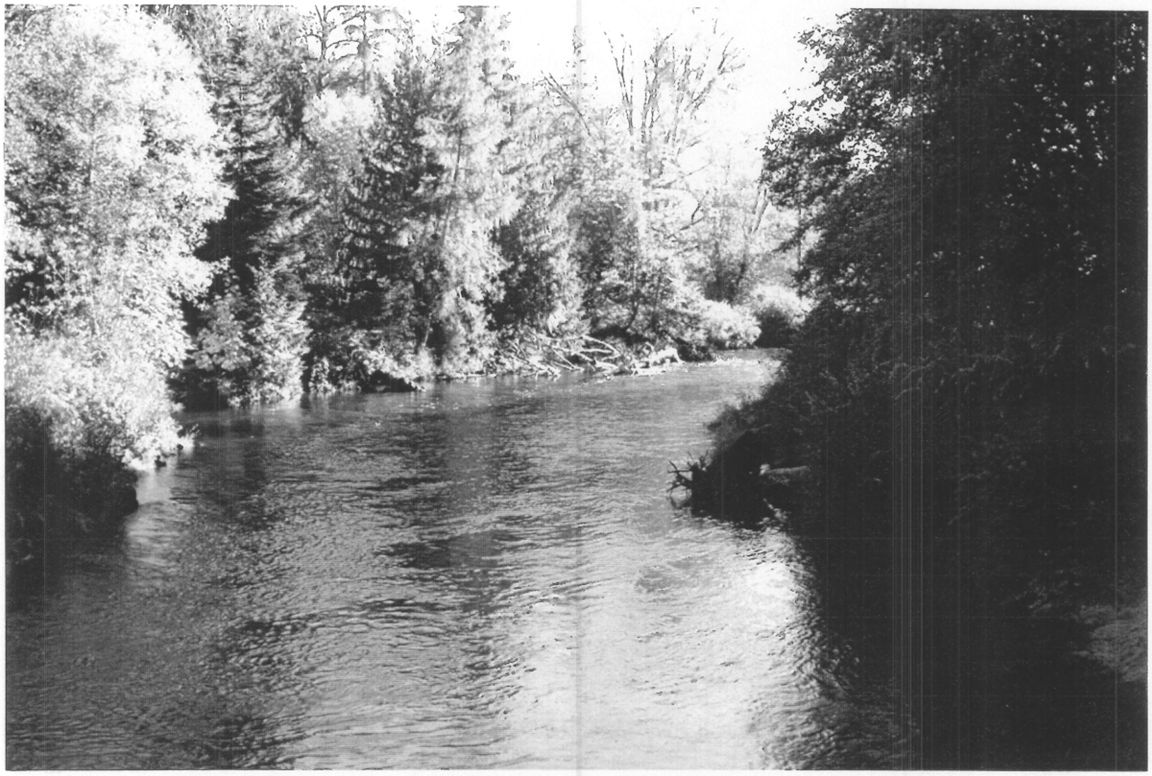

PHOTO 7 LITTLE QUALICUM RIVER - LOOKING UPSTREAM FROM HIGHWAY 19 BRIDGE

PHOTO 8 LITTLE QUALICUM RIVER - ERODING LEFT BANK BETWEEN CROSS SECTIONS 6 AND 7

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B. C. ENVIRONMENT

FLOODPLAIN MAPPING
LITTLE QUALICUM RIVER

PHOTOS 7 AND 8

CAD FILE : MENV-018 / MENV18FIG.DGN / 1997 FEB. 14

PHOTO 9 LITTLE QUALICUM RIVER - LOOKING UPSTREAM NEAR CROSS SECTION 8

PHOTO 10 LITTLE QUALICUM RIVER - LOOKING DOWNSTREAM FROM CROSS SECTION 11 (PUMP STATION)

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FLOODPLAIN MAPPING
LITTLE QUALICUM RIVER

PHOTOS 9 AND 10

CAD FILE : MENV-018 / MENV18FIG.DGN / 1997 FEB. 14

PHOTO 11 LITTLE QUALICUM RIVER - LOOKING DOWNSTREAM FROM FISHWAY OUTLET STRUCTURE

PHOTO 12 LITTLE QUALICUM RIVER - LOOKING UPSTREAM FROM FISHWAY OUTLET STRUCTURE

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FLOODPLAIN MAPPING
LITTLE QUALICUM RIVER

PHOTOS 11 AND 12

CAD FILE : MENV-018 / MENV18FIG.DGN / 1997 FEB. 14

PHOTO 13 LITTLE QUALICUM RIVER - LOOKING UPSTREAM NEAR CROSS SECTION 23

PHOTO 14 LITTLE QUALICUM RIVER - LOOKING UPSTREAM AT FISHWAY INTAKE STRUCTURE

HAY & COMPANY CONSULTANTS INC.

B. C. ENVIRONMENT

FLOODPLAIN MAPPING

LITTLE QUALICUM RIVER

PHOTOS 13 AND 14

CAD FILE : MENV-018 / MENV18FIG.DGN / 1997 FEB. 14

DRAWINGS

HAYCO