CANADA / BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT

Ministry of Environment, Lands and Parks
Resource Inventory Branch

A Design Brief
on the
Floodplain Mapping Project
Cowichan and Koksilah Rivers near Duncan
and the
Cowichan River (Riverbottom Road Area)

Water Inventory Section
Victoria, British Columbia
March, 1997
File: 35100-30/920-2577

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Preface

The purpose of this design brief is to present a description of the methodologies used and the results of the study undertaken to delineate the floodplains of the Cowichan and Koksilah Rivers and tributaries near Duncan, British Columbia.

1. Introduction

This floodplain mapping was prepared by the Water Inventory Section of the B. C. Ministry of Environment, Lands and Parks, under the terms of the Canada/British Columbia agreement dated December, 1987 and entitled "An Agreement Respecting Floodplain Mapping in the Province of British Columbia" (Amended August 2, 1994).

The study area is located on southern Vancouver Island near Duncan, which is located between Victoria and Nanaimo, as shown on Figure 1. The locations of Drawing 93-19, Sheets 1 to 6, and Drawing 91-33, Sheets 1 and 2, are shown on Figures 2 and 3, respectively.

Areas covered by this mapping project are within the boundaries of the City of Duncan, the District of North Cowichan, the Cowichan Tribes and the Cowichan Valley Regional District.

The Cowichan River has its headwaters in Cowichan Lake, from which it flows in an easterly direction for approximately 46 kilometers and empties into Cowichan Bay. Cowichan Lake covers an area of 62 square kilometers and is fed by numerous watercourses including the Robertson River and Sutton, Shaw, Cottonwood and Meade Creeks. As published by Water Survey of Canada (WSC), the Cowichan River at the gauge near Duncan has a drainage area of 826 square kilometers, 596 of which are above the Cowichan Lake outlet. Mountain peaks in the drainage area range between 800 and 1500 meters in elevation.

The headwaters of the Koksilah River, like the Cowichan, are located in the mountainous region of southern Vancouver Island with mountain peaks between 500 and 1100 meters in elevation. Flow is southeast, northeast and north a distance of 44 kilometers to its confluence with the south branch of the Cowichan River approximately one kilometer from Cowichan Bay. The drainage area of the Koksilah River is 281 square kilometers.

2. Background

Flooding on the lower Cowichan and Koksilah Rivers has been a problem for many years. A map of the Cowichan Valley and Chemainus dated 1860 (Figure 4) shows the natural river regime before the existence of built-up roads and bridges. Old channels of the Cowichan River flowed southeasterly from upstream and downstream of the present location of the E & N Railway bridge. Channels of both the Cowichan and Koksilah interconnected at several locations. Small tributaries, which formerly flowed into the Cowichan River, now drain to Somenos Lake.

As early as 1866, bridges were built across channels near the mouth of the Cowichan River where the Pembury and Clem Clem bridges are located today. In a report prepared for the Environmental Land Use Committee (ELUC) (Appendix 1.21) it was noted that, because of the small area under the Pembury bridge and the local dykes, a new channel became activated prior to 1930 about 2 km. above the bridge. The new channel diverted flow to the Koksilah channel and under the Clem Clem

bridge. This "new" channel is what is now the Cowichan south channel. In 1948-49, the river was diverted into an artificial channel so as to pass under the new "Silver" bridge on Highway 1. Figure 1 in the ELUC report shows south and middle channels of the Koksilah to be active. These channels are not shown as active on the current mapping.

Since 1961, a number of activities have been carried out in the study area as follows:

- When extensive flooding occurred on January 15, 1961, a report by E. Pigott, et al. (Appendix 1.25) proposed the construction of dykes. A plan from this report showing the limit of the 1961 flood is shown as Figure 5. Recommendations for flood control in a 1968 report entitled "Cowichan-Koksilah Rivers, Preliminary Flood Control Proposals," (Appendix 1.24) were not implemented due to financial constraints and objections by fisheries' agencies (Appendix 1.23).

- The Cowichan Estuary Task Force was formed in 1978 with one of its tasks being to develop a flood control plan. The plan was produced in the "Cowichan Estuary Task Force Report" in 1980 (Appendix 1.20).

- River surveys were carried out in 1978 (Appendix 1.5) and floodplain mapping was issued in May 1981 (Appendix 1.9) by the Province's Floodplain Mapping Program. This mapping was designated under the terms of the Canada/British Columbia Floodplain Mapping Agreement in December 1987.

- In 1983, with the assistance of a Provincial Public Works Program, the District of North Cowichan constructed a 1000 meter long dyke on the right bank downstream from the Silver Bridge. A "Preliminary Report on Cowichan River Flood Control Proposals - 1984" by A. A. Brown of the Ministry of Environment (Appendix 1.19) offered three alternatives for dyking on the left bank in the same area. A left bank dyke was constructed by November, 1987.

- In a report prepared for the Cowichan Valley Regional District (CVRD) in 1989, Hardy BBT Limited (Appendix 1.15) stated that in their area of study (upstream from Duncan), much of the Cowichan River was "laterally unstable" and "characterized by significant lateral erosion and channel switching". Earlier mapping indicates the Koksilah River has also changed course during the past century.

- Several dykes have been constructed on lands of the Cowichan Tribes at various times. Many have been rebuilt with assistance from senior governments and they are maintained by the Cowichan Band Council (Appendix 1.14).

3. Present Floodplain Mapping Study

Floodplain Mapping for the Cowichan and Koksilah Rivers was originally produced and issued by the Ministry of Environment in May 1981, using an orthophoto base produced from 1977 air photography. This 1981 mapping was designated under the terms of the 1987 Federal/Provincial Agreement on Floodplain Mapping. In the years following the production of the 1981 floodplain mapping, the Ministry recognized that significant changes in the river regime had occurred due to dyking, land filling for development purposes and road construction (Appendix 1.17). Additional years of discharge records also indicated estimated peak flows used in the earlier study may be conservative (Appendix 1.16).

The 1989 Hardy BBT report, an assessment of the flooding and erosion potential in the River Bottom Road area, was prepared for the Cowichan Valley Regional District. The report, which recommended the establishment of 200 year flood levels, was forwarded to the Ministry by the Regional District in conjunction with their request for assistance in the preparation of a floodplain management plan.

One-meter topographic mapping extending from the River Bottom Road area to the mouth of the Cowichan was produced by the Ministry's Surveys and Resource Mapping Branch in 1991, under the Provincial Large Scale Mapping Program. This mapping also covered the Koksilah River and Somenos and Quamichan Lakes, and was used as a basis for the new floodplain mapping sheets. Under the floodplain mapping agreement, approval was obtained for producing floodplain mapping for the River Bottom Road area and the updating and extending of the existing mapping in the Duncan area.

The 1996/1997 studies undertaken to delineate the floodplains for the Cowichan and Koksilah Rivers utilized the following information:

- Survey data obtained by the Technical Support Section, Hydrology Branch, Water Management Division, Project 93 01 F024, March 1993, Volumes 1 to 5, which include channel cross section data with plots and photographs, bridge details, road profiles, and plans showing cross section and profile locations (Appendix 1.1).

- Topographic base mapping of the study area issued in February 1991 by the Mapping Section, Surveys and Resource Mapping Branch, Project 89-001, NAD 27. This mapping is based on 1987 and 1989 air photography and is 1:5000 scale with 1 meter contour intervals (Appendix 1.6).

- High water mark data, with descriptions, elevations, photographs and location plans, obtained following the flood event of December 4, 1990, Project 91 14 F024, January 1992 (Appendix 1.2).

- Drawings showing the location and elevation of high water marks obtained in 1974, 1986 and 1990 (Appendix 1.29).

- Hydrology studies of the Cowichan and Koksilah Rivers and Somenos Creek carried out by the Surface Water Section, Hydrology Branch, Study No. 417, May 1996 (Appendix 2).

- Coastal Flood Level Report for Cowichan Bay (Appendix 1.7).

- Files from the former Rivers Section of the Ministry of Environment dealing with dyking (Appendices 1.18, 1.19, 1.21, 1.22, 1.23, 1.26, 1.27).

- Files from the Floodplain Mapping Section including photocopies of maps and newspaper clippings obtained from the Provincial Archives.

4. Flood Magnitudes

Annual peak flows for the Cowichan and Koksilah Rivers generally occur in November, December or January, and are the result of heavy rainfall or rain combined with a melting snowpack. Both watersheds drain mountainous areas with similar median elevations (Appendix 2). Annual daily extremes for Water Survey of Canada (WSC) gauging stations on both watercourses are available from published data. The Water Surface Section Hydrology Report (Appendix 2) contains details of frequency analyses carried out for the present study. Earlier hydrology reports are contained in the current and previous floodplain mapping design files (Appendix 1.8, 1.10).

4.1 Cowichan River

WSC operate two gauges on the Cowichan River, one at Cowichan Lake (08HA002), the other near Duncan (08HA011). The Cowichan Lake gauge was in place during 1914 to 1918 and has currently been continuously operated since 1940. The gauge near Duncan has been in operation since 1960. Maximum daily and instantaneous recorded discharges of 326 and 331 meters cubed per second (m^3s) respectively occurred on January 21, 1968 at the Cowichan Lake site. At the Duncan location, a maximum daily flow of 558 m^3s was recorded on January 15, 1961, but instantaneous discharges at this station were not recorded until 1977. The highest recorded instantaneous discharge since 1961 is lower than the aforementioned daily figure.

The Cowichan River flows used in the present study are listed in Table 1 as follows:

TABLE 1

FLOWS USED IN THE COWICHAN RIVER STUDY

FLOOD EVENT	FLOW (M^3S)
Q 200 I	700
Q 200 D	600
Q 20 I	523
Q 20 D	453

4.2 Koksilah River

The only gauge on the Koksilah River (08HA003) is situated at Cowichan Station and was operated during 1915/16 and then continuously from 1960. January 18, 1986 is the date of the maximum daily recorded discharge of 271 m^3s. Available data only show maximum instantaneous discharges for 1990, 1993 and 1994, and these instantaneous flows are exceeded by the maximum recorded daily flow noted above.

Flows used on the Koksilah River in the present study are listed in Table 2 as follows:

TABLE 2

FLOWS USED IN THE KOKSILAH RIVER STUDY

Flood Event	Flow (m^3s) Tidewater to Kelvin Creek Confluence	Flow (m^3s) Upstream of Kelvin Creek Confluence
Q 200 I	396	312
Q 200 D	350	276
Q 20 I	360	284
Q 20 D	284	224

5. Coastal Flood Level

The 1981 mapping project adopted a coastal flood level of 3.6 meters based on the practice of the Ministry at that time (not a site specific study) of assuming the coastal flood level to be equal to 1.5 meters above the recorded extreme highest high water (Appendix 1.10).

The coastal flood level adopted for this study is 3.2 meters GSC datum. This level is for Cowichan Bay at the mouth of the Cowichan River and includes higher high water large tide, a 1:200 year storm surge allowance based on an analysis of historical data, and an allowance for uncertainty which includes local wind chop, seiche and unit conversion factors.

The coastal flood level for Cowichan Bay at the mouth of the Cowichan River was determined by B. J. Holden, P. Eng. (Appendix 1.7). The coastal flood level does not include wave runup and assumes that buildings will be set back from the natural boundary of the sea pursuant to Ministry policy. Coastal building setbacks are site specific and are dependent on the nature of the coast and its exposure to wave action.

6. Hydraulic Analysis

6.1 General

Information sources listed in Appendices 1 and 2 were utilized in the HEC-2 water surface profile computer program version 6.4, developed by the Hydrologic Engineering Centre, US Army Corps of Engineers in Davis, California and currently administered by Haestad Methods, Inc. The profile calculations employ a standard step method and assume open flow channel conditions.

Flood profiles for the Cowichan and Koksilah Rivers were all executed in a similar sequence. An assessment was made of the surveyed river sections incorporating extensions obtained from the 1 meter contour topographic mapping in the cross section plot run. This run was also used to review other data such as flow regime, loss coefficients, reach lengths, overbank information and relative Manning's "n" values. Manning's "n" values

were selected using the color photographs included in the survey project, experience gained in other studies and a review of the information provided in the book "Roughness Characteristics of Natural Channels" (Appendix 1.31).

The model was calibrated using known high water marks (Appendix 1.2) observed in the field and the flows recorded on December 4, 1990 (Appendix 2). Once a satisfactory match was obtained for the calibration model, estimated 200 and 20 year daily and instantaneous flow profiles were obtained. Sensitivity to flow (Q) and Manning's "n" values were also undertaken as outlined below.

Information from the 1981 study was used to assist in the study including the floodplain mapping worksheets, the HEC-2 computer output, and a sketch of the different channels noting various flows and starting level elevations used in the 1981 study.

The lower Cowichan River was divided into individual reaches, as follows:

- the lower "north" channel upstream from Cowichan Bay to just beyond the confluence of the "south" channel (XS 15-24)
- the lower "south" channel upstream from Cowichan Bay to just beyond the confluence with the "north" channel (XS 1-14 & 24)
- the main channel upstream from the "north" and "south" channel confluence to the upper limit of the lower Cowichan study (XS 24-63)

Both the Koksilah River and the River Bottom Road reach of the Cowichan River were run following the procedure noted previously, with the Koksilah River including the Cowichan River south channel XS-8, located just downstream of the confluence of the two rivers. A summary of all computer runs is included as Appendix 3.

In accordance with standard Ministry practice, an allowance for hydraulic and hydrologic uncertainties was applied to the water surface elevations computed by the model for each cross section. An allowance of 0.3 meters and 0.6 meters was applied to the instantaneous and daily levels respectively, and the higher flood level selected. For both the Cowichan and Koksilah Rivers, the daily flood levels were found to dominate at the majority of the cross sections using this criteria.

6.2 Cowichan River Flood Levels

The Cowichan River in the north and south channels from tidewater to X-S 24 is shown on Drawing 91-19-1. Appendix 4, photos 20 to 29, show typical views of the river channels in this area, areas of active bank erosion and floodproofed residences under construction. The north channel was estimated to carry about 85% of the 371 m^3s calibration flow. A log jam at the confluence area of the north/south channels was attributed to the flow distribution for the calibration event.

Flow magnitude in the north channel during a 200-year flood event was limited to an amount such that the resulting flood levels did not exceed the existing dyke freeboard allowance. The remaining flow was assumed to be directed into the south channel.

The Cowichan River model in the Duncan area (Drawing 91-19-3) was calibrated to match the 16 high water marks obtained in the reach between X-Sections 24 to 63 obtained from the December 4, 1990 flood. Appendix 4, photos 9 to 19, show typical views of the river channel in this area, areas of active bank erosion or gravel deposition, existing dykes, an area where high water mark data was obtained and examples of floodproofed buildings.

The flood levels shown on the floodplain mapping drawing of this reach, which include the allowance for uncertainties outlined in Section 6.1, average 1.2 meters above the calibrated profile for the 1990 high flow event.

Channel flood levels determined in the 1996 study average about 0.3 meters above the 1981 study results, except in the Somenos Creek confluence area where 1996 flood levels in the river channel average 0.8 meters above the 1981 results. This level increase is mainly due to the constriction of the floodway by the dyking system located downstream of the confluence area as discussed in Section 7.2

Figure 6 is the stage-discharge curve for WSC 08HA011 at X-Section 56 based on data provided by WSC and the calculated levels for the calibration flow and the estimated 200 year daily and instantaneous flows.

The River Bottom Road section (Drawings 91-33-1&2) was calibrated based on the 8 high water marks obtained after the December 4, 1990 flood event. Appendix 4, photos 1 to 8, show typical views of the river channel in this area, areas of active bank erosion or gravel deposition and areas where bank protection works have been placed.

The slope/area method was used to estimate the starting water surface elevation in this reach. Flood levels for the 1:20 and 1:200 year flows were selected based on the uncertainty allowances outlined in Section 6.2.

Summaries of the computer runs for the Cowichan River are listed in Appendix 3.

6.3 Koksilah River Flood Levels

The Koksilah River was calibrated to match the 5 high-water marks obtained as a result of the December 1990 flood event. Appendix 4, photos 30 to 41, show typical views of the river channel in this area, areas of active bank erosion, log jam areas and an example of a floodproofed home in the Koksilah floodplain.

The flood level data extended from near tidewater (Drawing 91-19-1) to X-Section 12 located near the Koksilah Village Dyke (Drawing 91-19-2). Flood levels obtained from the Cowichan River south channel study near the Koksilah River confluence were used as starting levels for the Koksilah model. A total of 32 river cross sections were utilized in the study to determine the flood levels for this area.

Summaries of the computer runs for the Koksilah River are listed in Appendix 3.

6.4 Sensitivity Studies

Calculations were undertaken to determine the sensitivity of the models developed for the study area to flood level increases resulting from flows which exceed the 1:200 year event. Increases in assumed Manning's "n" values were also assessed to determine the effects on flood levels. Results of the sensitivity studies varied in the study area depending on the confinement of the floodway area.

Summaries of the computer sensitivity runs for the study area are listed in Appendix 3.

7. Lake Levels

7.1 Quamichan Lake

Quamichan Lake is shown on Drawings 91-19-5&6. Quamichan Creek drains into Somenos Creek near the confluence with the Cowichan River as shown on Figure 2. Weed growth has been observed near the outlet (Appendix 4, photo 51) which may restrict Quamichan Lake outflows.

The highest recorded lake level of 26.5 meters GSC occurred on January 19, 1968. A 1:200 year flood level of 27.4 meters geodetic was estimated for the 1981 floodplain mapping study based on an allowance for uncertainties of 0.9 meters added to the highest observed level.

Daily records of Quamichan Lake water levels were provided to BC Environment in 1993. These levels have been recorded since September 1, 1958 by Mr. Allan Stewart, a lakeside property owner. Copies of Mr. Stewart's records are included in volume 5 of the survey project (Appendix 1.1) and in the design file (Appendix 1.8).

Using the maximum annual peak level data, a frequency analysis was performed by staff of the Surface Water Section (Appendix 1.8, item 27). An estimated 1:200 year flood level of 26.7 meters geodetic was determined, based on the 20 years of available data. An allowance for hydraulic and hydrologic uncertainties of 0.7 meters results in a flood level of 27.4 meters. The flood level of 27.4 meters GSC, equal to that adopted in the 1981 mapping, has been retained for administrative purposes.

7.2 Somenos Lake

At Somenos Lake (Drawing 91-19-4) the 1961 flood level reached 7.3 meters GSC. The profile was virtually level from the lake to the bridge over Trunk Road near the Cowichan River confluence, where the flood level was recorded at 7.2 meters GSC. Following the January, 1961 flood event on the Cowichan-Koksilah system, several reports were prepared (Appendix 1.24 to 1.27). Drawing 4084-34 (file 0206435, #5), indicates the 1961 flood profile on Somenos Creek. A copy of the above-noted drawing is on the 1980 design file (Appendix 1.10).

Appendix 4, photos 42 to 49, show typical views of Somenos Creek, areas of active weed growth, log jam areas and examples of floodproofed buildings in the Somenos/Cowichan

floodplain. Photos O1 to O4 show flooding of Somenos Lake and Creek during a flood event in the 1960's.

The 1979 report by Hardy & Jackson (Appendix 1.22) concluded that weeds, undergrowth and brush buildup at both the lake outlet and in the creek channel were restricting runoff.

High water marks of 7.4 meters (1972), 7.3 meters (1974) and 7.5 meters (1990) were recorded at Somenos Lake with level profiles along Somenos Creek to the Cowichan River similar to that observed in 1961. A survey of Somenos Creek undertaken in March 1993 (Appendix 1.1) indicated that the Somenos Creek thalweg elevation of 3.2 meters was the same as the thalweg elevation of the Cowichan River channel in the Cowichan River/Somenos Creek confluence area. The water levels taken during the survey (5.5 meters approximately) exhibited the flat profile noted under higher flow conditions.

Downstream of the Cowichan/Somenos confluence, the Cowichan River floodway is constricted by the Hatchery and Quamichan dykes. During the 1:200 year flood event, calculated flood levels exceed the existing dyke crest elevations by about 0.2 meters. The calculated 1:200 year water surface elevation on the Cowichan River near the Cowichan/Somenos confluence is approximately 8.2 meters. The downstream dykes will be overtopped before the 8.2 meter level is achieved in the confluence area. The flood level for Somenos Lake of 8.8 meters GSC (includes an allowance for uncertainty), adopted by BC Environment in the early 1970's, has been retained for administrative purposes.

8. Floodplain Mapping

8.1 General

The flood levels determined in the study were used to delineate the floodplain limits onto the existing 1 meter contour mapping it the study area. The studies were based on the information noted in Section 3. As noted under "Revisions" on the title block, Drawings 91-19-1 to 91-19-6 replace the previously issued drawings A5293-1 to A5293-6, dated May 1981.

In accordance with the policy of the Ministry of Environment, Lands and Parks, the flood levels and floodplain limits shown on floodplain mapping sheets are based on a designated (1:200 year frequency) flood level plus an allowance for hydraulic and hydrologic uncertainties.

The mapping indicates the location of the floodplain limits, cross section and monument locations, and flood level isograms. Roads and dykes are also identified. Particular attention should be paid to the "Notes" on the mapsheets with regard to ponding and debris jamming.

As noted on the mapping sheets (under "Floodplain Data" Item 4) the floodplain limits assume the absence of all dykes. The flood level isograms (lines of equal 200 year flood levels) were extended across the floodplain taking cognizance of topographic conditions, high water levels from the 1974, 1986 and 1990 floods (Appendix 1.29) and the existing transportation routes and dyke locations in the area. In addition, Ministry experience in

transportation routes and dyke locations in the area. In addition, Ministry experience in reviewing flood levels from significant flooding in the province, including the event that occurred on the Lillooet River in 1984 (Appendix 1.32) involving the overtopping of a portion of an existing dyking system, was utilized in the location of the isograms in the floodplain areas.

Field inspections were undertaken prior to the release of the new mapping to verify the location of the floodplain boundary shown on the drawings. The newly dedicated provincial park located on the left bank at the upstream end of the study area near River Bottom Road was noted.

Areas of concern in the lower Cowichan were visited during January 1997 in the company of Arvid Charlie of the Cowichan Tribes and Jim Card of BC Environment's regional office in Nanaimo. The assistance of Arvid Charlie in locating and flagging high water marks during the December 1990 flood event and of his knowledge of the study area is greatly appreciated.

8.2 Comparison With 1981 Mapping

Changes in the floodplain area had occurred since the issuance of the 1981 mapping as a result of a number of dyke and road construction or improvement projects, land fill placement for development purposes and changes in the river regime.

The floodplain mapping sheets issued in 1981 (Drawings A5293-1 to 5) were reviewed and compared to the mapping sheets covering the same area which are scheduled for issuance in September 1997 (Drawings 91-19-1 to 6).

Sheet 1 covers the Cowichan Bay area and the lower tidal reaches of the Koksilah River and the Cowichan River (north and south channels). A large portion of Sheet 1 is within Indian Reserve Lands. The coastal flood level for Cowichan Bay has been lowered by 0.4 meters. Flood levels in the Cowichan River north channel increased by approximately 0.7 meters in the area upstream of the north and south channel confluence. This increase is attributed to dyke reconstruction and/or changes to the river regime in the confluence area which results in higher flows in the north channel. Flood levels in the south channel of the Cowichan River and in the Koksilah river channel are essentially unchanged. The existing road/rail system influences flood levels in the tidal confluence area.

Flood level isogram extensions from the existing channel flood level locations across the floodplain have been based on the mapping contour data, high water data, transportation routes, dyke locations and experience in reviewing flood levels in other mapped areas in the province. The locations of the 1997 isograms on Sheet 1 differ from the 1981 mapping but appear to be within the uncertainty allowance applied to the flood levels shown on the mapping sheets.

The floodplain limits shown on Sheet 1 have not changed appreciably since 1981 due to the relatively steep slope of the topography in the floodplain limit areas.

Sheet 2 covers the area of the Koksilah River upstream of the tidewater confluence area and portions of Koksilah/Cowichan floodplains. There are no significant changes to the flood levels, the isogram locations across the floodplain area or the floodplain limits since the 1981 mapping was issued. There have not been any apparent changes to transportation routes or dyking projects or to the river regime in this area. The floodplain limits were extended further upstream on the Koksilah River in the 1997 mapping study.

Sheet 3 covers the main channel of the Cowichan River from near tidewater to the Somenos Creek confluence area, upstream on Somenos Creek and on the Cowichan River to just beyond the limits of the City of Duncan. Channel flood levels in the Somenos Creek confluence area average approximately 0.8 meters above the 1981 study results due to the confinement of the floodway as a result of the downstream dykes. The channel flood level increase extends to just upstream of the Highway 1 bridge. The City of Duncan dyke was constructed on the north bank since the 1981 mapping was issued. Between the Highway and the E&N railway bridge, road crests appear to have been raised and landfill placed for developments constructed in the floodplain since 1981.

The southern boundary of the floodplain limits on Sheet 3 have not changed appreciably due to the relatively steep slope of the topography in the floodplain limit area. The northern boundary of the floodplain limits has increased in the area between the bridges where changes have occurred in the floodplain since 1981 as noted above. Downstream of Highway 1 bridge, changes in the floodplain limits appear to be due to more detailed topographic information available from the newer mapping of the area.

Sheets 4 and 5/6 cover the Somenos and Quamichan Lake floodplains respectively. The flood levels have not changed in these areas since 1981 and any changes in the floodplain limits appears to be due to more detailed topographic information available from the newer mapping of the area. As noted on the mapping sheets, the floodplain limits are not established on the ground by legal survey. Contour accuracy is +/- 0.5 meters with spot height accuracy to +/- 0.3 meters.

9. Conclusions

1. This design brief presents and overview of the studies undertaken to produce the floodplain mapping sheets for the Cowichan and Koksilah Rivers at Duncan and the River Bottom Road section of the Cowichan River. The floodplain limits outline the area which would be inundated by the designated flood.

2. The study area has a documented history of flooding and erosion problems.

3. The 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 solutions to site specific problems.

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

10. Recommendations

1. It is recommended that the floodplains delineated on Drawing 91-19, Sheets 1 to 6, and on Drawing 91-33, Sheets 1 and 2, be Designated under the terms of the 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; flood proofing requirements in zoning and building bylaws; and the identification of lands by Subdivision Approving Officers.

3. The Cowichan Valley Regional District, Municipality of North Cowichan, City of Duncan, Cowichan Indian Band, BC Ministry of Transportation and Highways and staff of BC Environment should be aware that the raising of an existing transportation route or dyke crest within the floodplain may adversely impact adjacent or upstream properties by increasing flood velocities and levels in the study area.

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

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Water Inventory Section

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R.W. Nichols
Head
Floodplain Mapping Program

Province of British Columbia
Ministry of Environment, Lands and Parks
WATER MANAGEMENT DIVISION

TO ACCOMPANY A DESIGN BRIEF ON THE
FLOODPLAIN MAPPING

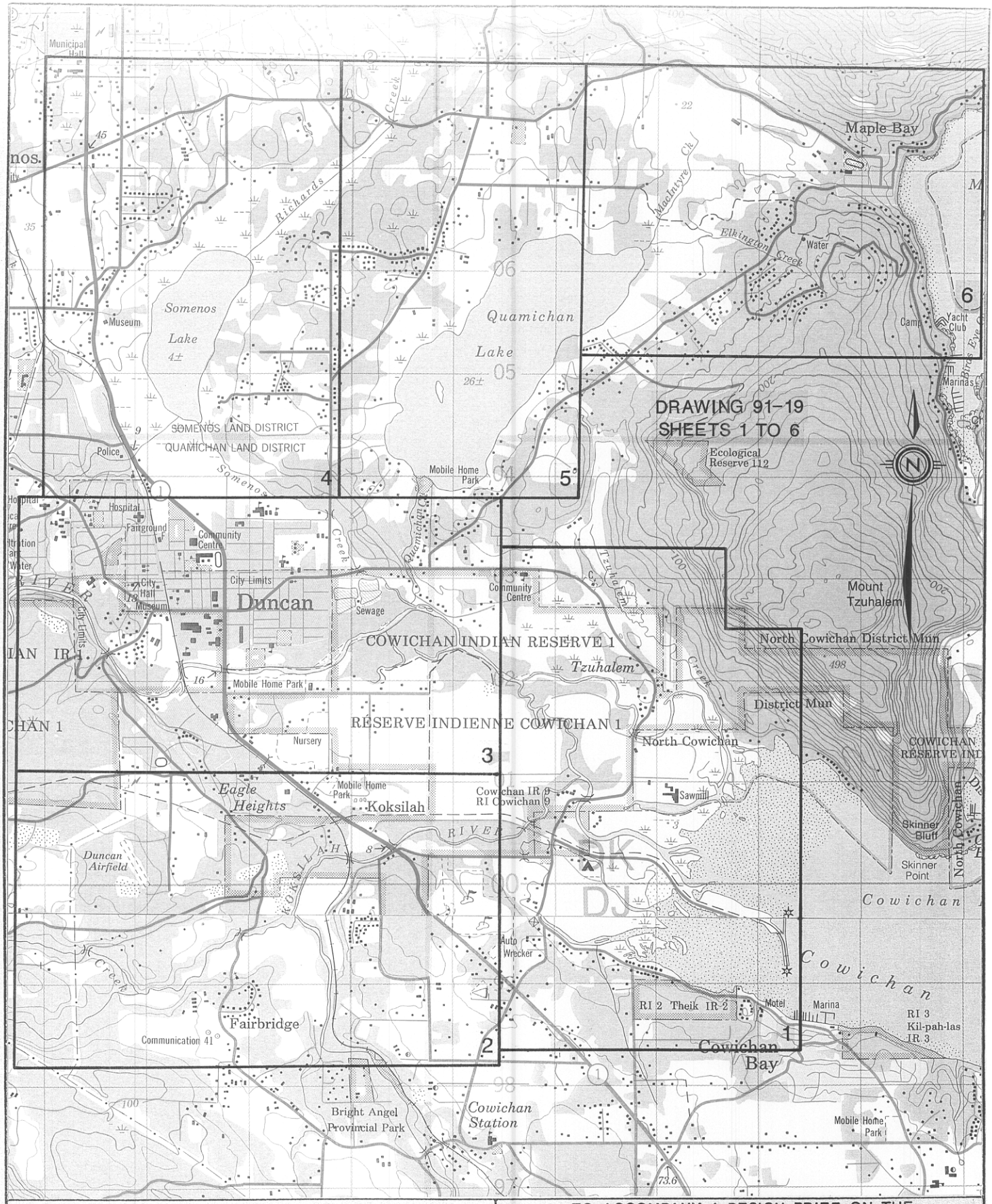
COWICHAN AND KOKSILAH RIVERS
STUDY AREA LOCATION

SCALE: VERT
HOR NOT TO SCALE

DATE
DECEMBER 1996

R.W. NICHOLS ENGINEER

FILE No. 35100-30/920-2577 DWG. No. FIGURE 1



Province of British Columbia

Ministry of Environment, Lands and Parks

WATER MANAGEMENT DIVISION

TO ACCOMPANY A DESIGN BRIEF ON THE

FLOODPLAIN MAPPING

COWICHAN AND KOKSILAH RIVERS

STUDY AREA LOCATION

SCALE: VERT.

HOR. 1 : 50 000

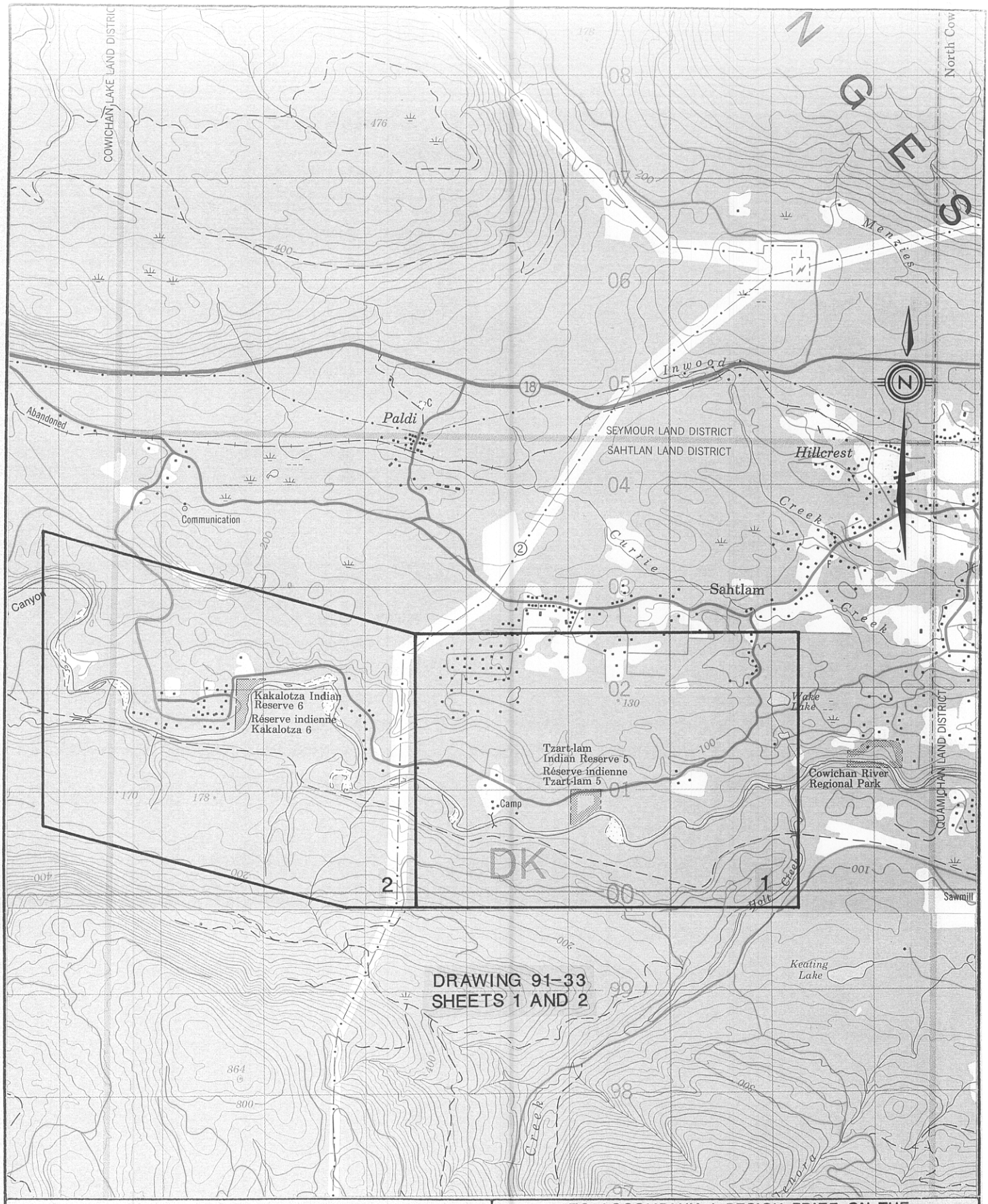
DATE

DECEMBER 1996

R.W. NICHOLS ENGINEER

FILE No. 35100-30/920-2577 DWG No. FIGURE 2

VAN CAL 15712



Province of British Columbia

Ministry of Environment, Lands and Parks

WATER MANAGEMENT DIVISION

TO ACCOMPANY A DESIGN BRIEF ON THE FLOODPLAIN MAPPING

COWICHAN AND KOKSILAH RIVERS
STUDY AREA LOCATION

SCALE: VERT. .....

HOR. 1 : 50 000

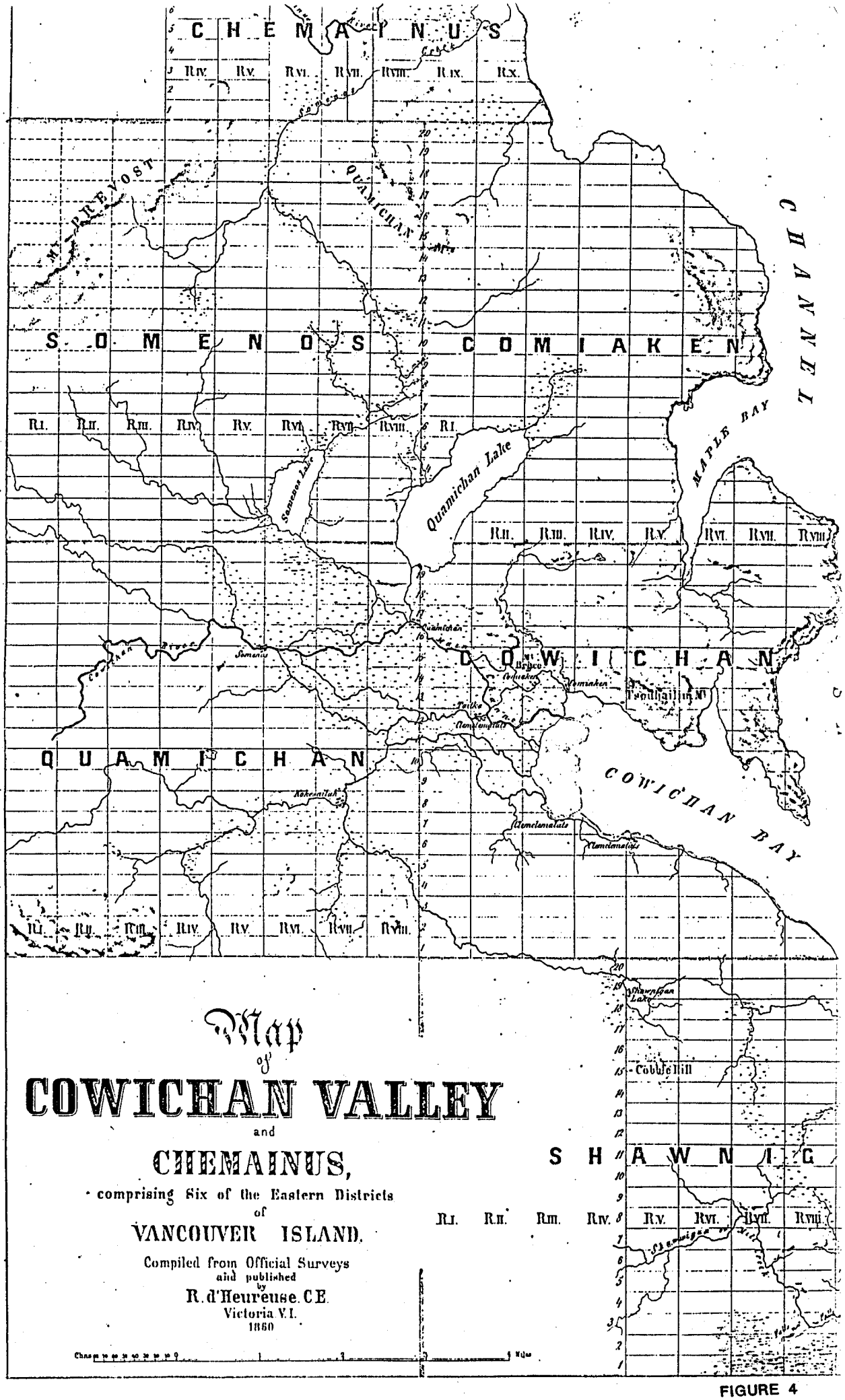
DATE

DECEMBER 1996

R.W. NICHOLS ENGINEER

FILE No. 35100-30/920-2577 DWG No. FIGURE 3

VAN CAL 15712



Map of COWICHAN VALLEY and CHEMAINUS,

comprising Six of the Eastern Districts of

VANCOUVER ISLAND.

Compiled from Official Surveys and published by

R. d'Heureuse. C.E.

Victoria V.I.

1860

FIGURE 4

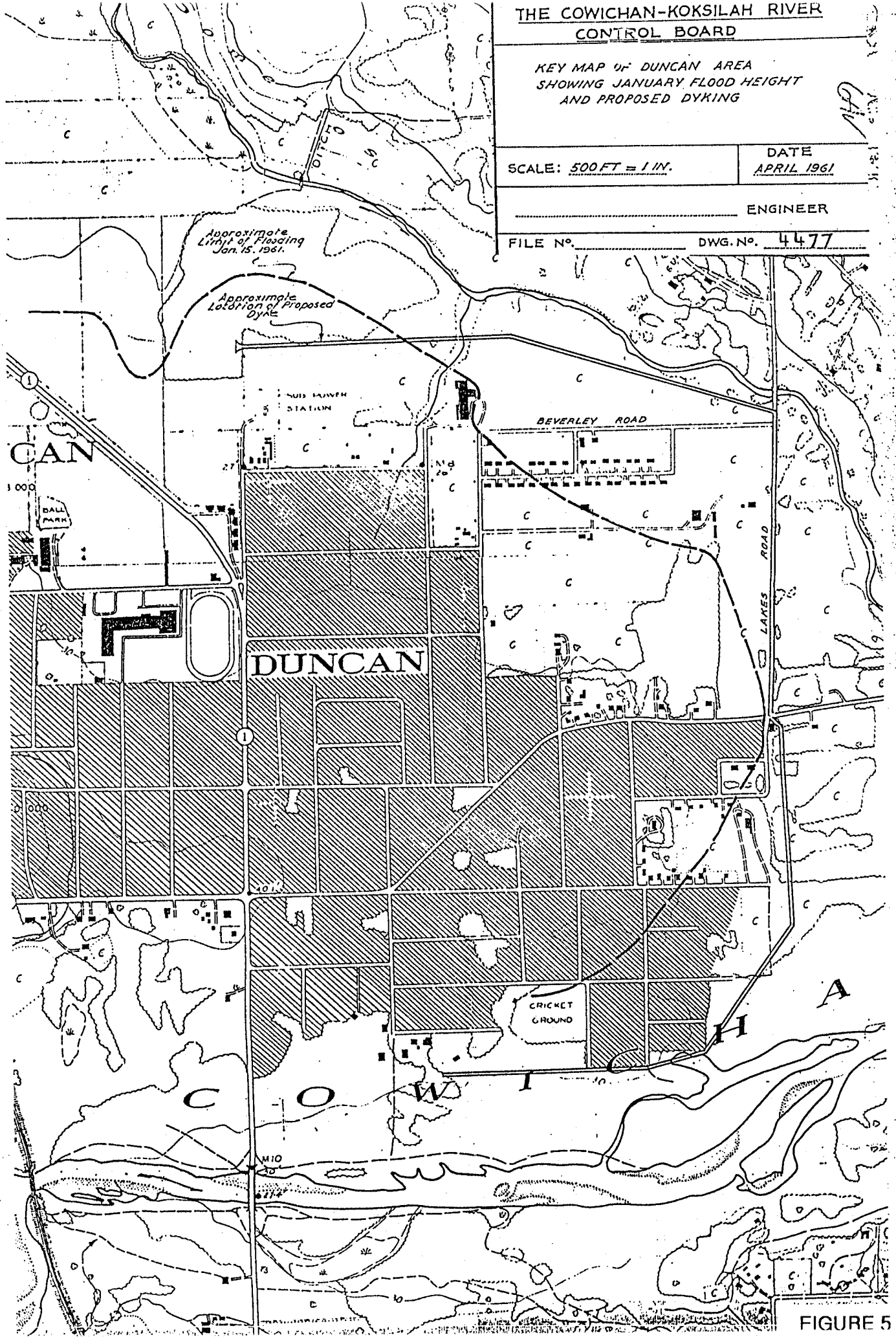
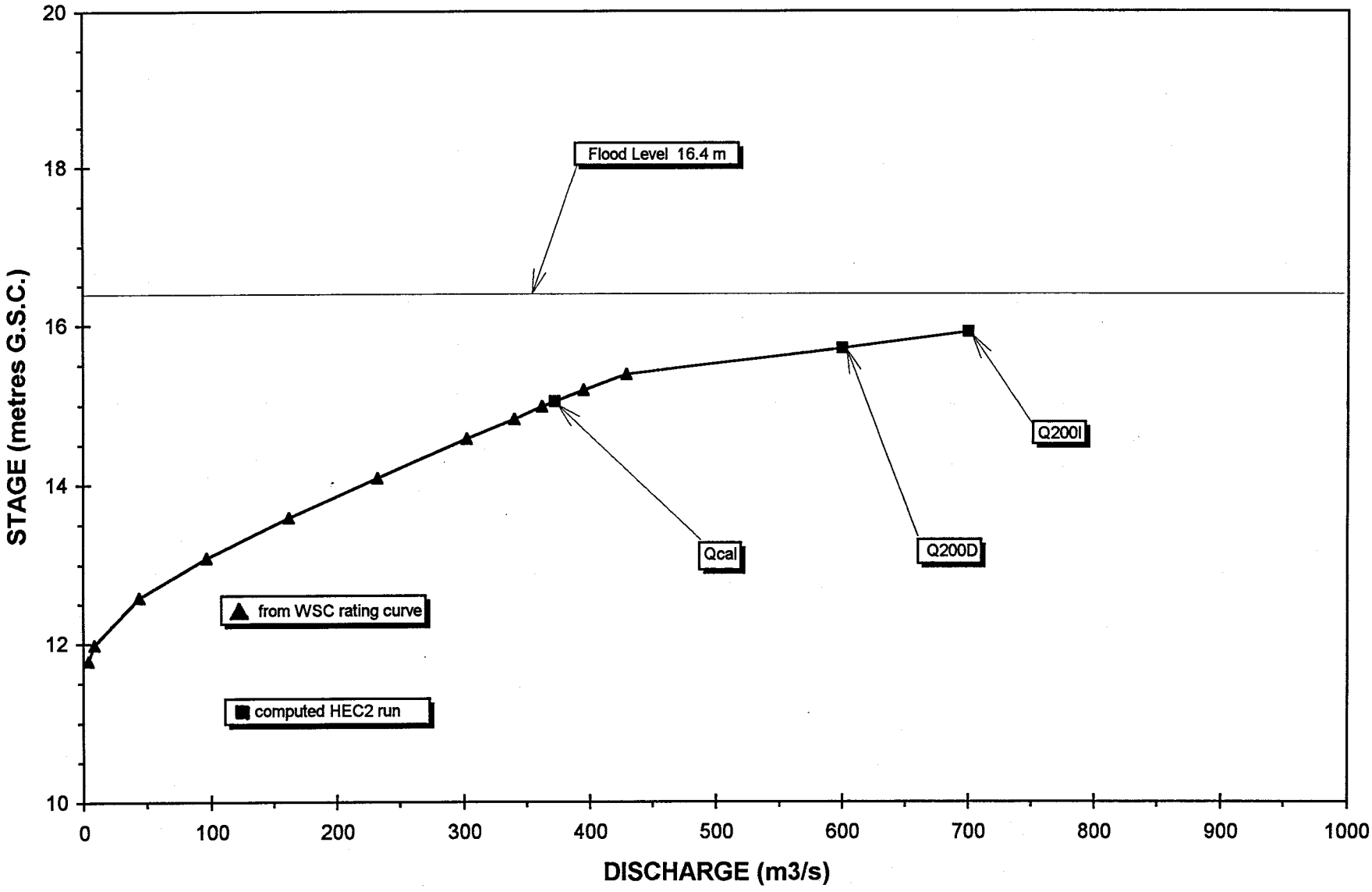

THE COWICHAN-KOKSILAH RIVER CONTROL BOARD
KEY MAP of DUNCAN AREA SHOWING JANUARY FLOOD HEIGHT AND PROPOSED DYKING
SCALE: 500 FT = 1 IN.
DATE APRIL 1961
ENGINEER
FILE No.
DWG. No. 4477
Approximate Limit of Flooding Jan. 15. 1961.
Approximate Location of Proposed Dyke
BEVERLEY ROAD
LAKES ROAD
DUNCAN
BALL PARK
CRICKET GROUND
COWICHAN

FIGURE 5

FIGURE 6

COWICHAN RIVER
STAGE DISCHARGE CURVE
XS-56 (WSC 08HA011)



APPENDIX 1

Detailed Information Sources

APPENDIX 1

Detailed Information Sources

No.	Source	Contents
1.	Technical Support Section, Water Management Division, Project 93 01 F024, Volumes 1 to 5, March 1993	130 cross sections with plots and photographs (Lower Cowichan River 63, River Bottom Road area 24, Koksilah River 31, Somenos Creek 12); 7 road profiles; bridge details; drawings 94-2-1 through 94-1-6 showing locations of cross sections, Temporary Bench Marks, and monuments; Quamichan Lake water levels 1958-1992; HEC-2 GR data on a 3.5" floppy disc and hard copy
2.	Technical Support Section, Water Management Division, Project 91 14 F024, January 1992	High water mark data with descriptions, elevations, photographs and location plans, following the flood event of December 4, 1990
3.	Somenos Lake Gauge Levels & Spot Heights, January 1992, Project 92 01 H010	Includes map showing 2 areas adjacent to Somenos Lake
4.	Surveys Section, Water Management Branch, Project 88FDC6, August 1988	4 Cowichan River cross sections with plots, topography, HEC-2 GR data listing, and mosaic showing locations
5.	Surveys Section, Planning & Surveys Division, Water Investigations Branch, Project 75 F2, 2 Volumes, March 1978	45 Cowichan River cross sections, 37 Koksilah River cross sections, Cowichan River thalweg profile
6.	Lands Services Division, Surveys and Resource Mapping Branch, Topo/GIS Section, Project 89-001	1:5000 scale 1 meter interval topographic mapping based on 1987 and 1989 air photography, NAD 27, dated February 1991
7.	"Coastal Flood Level, Cowichan Bay" by Brendan Holden, May 1996	A determination of the coastal flood level in Cowichan Bay
8.	Cowichan-Koksilah Rivers floodplain mapping design file, 1995-96	Assorted accumulated data relating to the 1995/6 Cowichan-Koksilah floodplain mapping study (includes Appendix 1 items 7, 11, 12, 13, 16, 17 and Appendix 2)
9.	Floodplain mapping drawing A5293, sheets 1 to 5, issued May 1981	1:5000 scale 1m topographic orthophoto maps showing flood levels, floodplain boundary
10.	Cowichan-Koksilah Rivers floodplain mapping design file, 1980	Assorted accumulated data relating to the preparation of the 1981 issue floodplain mapping

APPENDIX 1 (Continued)

11.	Newspaper article from Victoria Times-Colonist dated September 24, 1996	Cowichan River designated heritage river status provides some benefits but not complete protection from environmentally harmful development
12.	"Geomatics and the Law" by Alec McEwen, from Geomatica, Vol. 50, No. 2, 1996, pp.202 to 204	Magazine article on a court action involving the location of the south bank of the Cowichan River at Duncan
13.	Quamichan Lake Frequency Analysis, July 23, 1996	
14.	"Inventory and Inspection Report, Cowichan River Estuary, Cowichan Indian Band Dyking" by R. J. Henry, May 1992, FHI file 920-2577V	Contains drawings, design considerations, funding agreements, photographs and other pertinent data
15.	"Assessment of Flooding and Erosion Potential of Cowichan River near River Bottom Road" by Hardy BBT Limited, April 1989, file 920-2577V	A report with recommendations for the Cowichan Valley Regional District to assist in development applications
16.	Memo by W. J. Wyngaards regarding Duncan Floodplain Management Plan and Cowichan River estimated flows, Nov. 8, 1988, file 92-4800-S.4	Frequency analysis based on additional years of discharge records indicate higher maximum flows should now be used for flood flow calculations
17.	Memo by W. J. Wyngaards regarding Duncan Floodplain Management Plan Technical Study dated Nov. 2, 1988, file 92-4800-S.4	Recommends new survey, discharge estimates, computer modeling and base mapping to replace 1981 floodplain mapping outdated by dyke construction
18.	"Cowichan Estuary Environmental Management Plan" by G. K. Lambertsen, Planning & Assessment Branch, Ministry of Environment & Parks, February 1987 (revised 1992), file P82-003/C	Intended to provide a framework for environmental decisions and to balance environmental priorities and concerns with those of other interests and organizations.
19.	"Preliminary Report on Cowichan River Flood Control Proposals, 1984" by A. A. Brown, Rivers Section, Water Management Branch, February 1984, file P82-3	Proposed remedial works with alternatives for flood protection in the Duncan area
20.	"Cowichan Estuary Task Force Report", 1980	Report containing an outline flood control program

APPENDIX 1 (Continued)

21.	"The Cowichan Estuary, Hydraulics and Hydrology" by Western Canada Hydraulics Laboratories, October 1979, Rivers Section file P73-60:2	Discusses the impact of flooding and delta dynamics; recommends improved log handling at at Doman's, improvements to road bridges and Cowichan River bifurcation
22.	"Preliminary Drainage Observations, Richards Creek, Somenos Lake, Somenos Creek Areas," by R. Hardy and J. Jackson, May 30, 1979, files P73-60:4, P74-6	Observations of flooding and recommendations to remove weed growth
23.	"Conservation of Fish and Wildlife of the Cowichan-Koksilah Flood Plain", by A. F. Lill et al, Environment Canada, circa 1973, file P73-60:3	Fisheries concerns regarding the impact of flood control works
24.	"Cowichan-Koksilah Rivers, Preliminary Flood Control Proposals" by J. Wester, Water Resource Service, 1968, file 0238056	Flood control recommendations made following flooding in January, 1961
25.	Cowichan-Koksilah Rivers Flood Control Committee "Preliminary Report by Engineers on Flood Protection," by E. Pigott, et al, April 20, 1961	Discussion and recommendations for flood protection works
26.	Cowichan and Koksilah Rivers, Flooding on Jan. 16, 1961, and subsequent formation of the FLOOD CONTROL COMMITTEE, file P73-60	Minutes of meetings, progress reports, correspondence and other material from the Flood Control Committee following the 1961 flood
27.	"North Cowichan Municipality, Flooding on Jan. 15, 1961" by R. G. Fernyhough, January, 1961, file P74-6	Profiles, photographs, map showing flood locations, and Somenos Creek plan and sounding profile
28.	Flooding & Erosion files 35100-30/920-2577D and 35100-30/920-2577V	
29.	Working copy of drawing 91-19, sheets 1-6	Show location and elevation of all high water marks obtained during flooding in 1974, 1986 and 1990
30.	Canadian Tide and Current Tables, Volume 5, published under the authority of the Canadian Hydrographic Service, Fisheries and Oceans Canada	Annual publication of daily tides and currents

APPENDIX 1 (Continued)

31.	Roughness Characteristics of Natural Channels, Geological Survey Water-Supply Paper 1849, by H. H. Barnes, Jr., US Department of the Interior, Geological Survey	Photographs and descriptive data including Manning's "n" values for stream channels for which roughness coefficients have been determined.
32.	"A Design Brief on the Floodplain Mapping Study, Lillooet River", April 1989, file 01-0000-S.1	An overview of the studies undertaken to produce floodplain mapping for the Lillooet River following the October 8, 1984 flood.

APPENDIX 2

Hydrology Report

Cowichan & Koksilah Rivers and Somenos Creek

Study No. 417
May 1996
file: 76840-40

SURFACE WATER SECTION REPORT

COWICHAN & KOKSILAH RIVERS

DETERMINATION OF 20 AND 200 YEAR PEAK FLOWS

At the request of the Floodplain Mapping Unit, a hydrology study was carried out to determine the 20-year and 200-year peak flows on the Cowichan and Koksilah rivers and Somenos Creek near Duncan.

The Cowichan River flows in an easterly direction from Cowichan Lake to its mouth near Duncan. Its watershed drains the mountainous area of southern Vancouver Island. Cowichan Lake has a control structure but has limited control during high flow events. Koksilah River is a major tributary to the Cowichan River entering approximately 1 km above the mouth. Its watershed is similar to that of the Cowichan River with a similar median elevation. Somenos Creek is a smaller tributary of the Cowichan River entering 3 km above the mouth. Somenos Creek drains Somenos Lake which has no control structure. The watershed is mixed with some low elevation flatlands and some steep drainage but at a lower median elevation than either Cowichan or Koksilah. Bings Creek is tributary to Somenos Lake.

The major portion of the annual runoff is the result of fall rainfall and melting of the mountain snowpack with more than 80% of the annual runoff occurring during the six months, November to April. The annual peak flows are the result of heavy rainfall or rain combined with melting of a shallow snowpack with the annual peaks occurring in November, December or January.

Long term hydrometric data are available from two gauges on the Cowichan River, one on the Koksilah River and one on Bings Creek. These gauges with their period of record of annual daily peak flows used in this study are shown below.

Cowichan River at Lake Cowichan	8HA002	1914 to 1918 & 1940 to 1993
Cowichan River near Duncan	8HA011	1960 to 1993
Koksilah River at Cowichan Station	8HA003	1915 to 1916 &1960 to 1993
Bings Creek near the mouth	8HA016	1962 to 1993

Somenos Creek was measured June 1961 to May 1963 only at gauge:

Somenos Creek near Duncan	8HA014

1. Frequency Analysis

Frequency analysis was carried out on peak daily and instantaneous flows for the above long term stations. The analysis was carried out by the River Forecast Centre and is described in the attached memorandum dated February 14, 1995. Observed peak flows were used for the Cowichan River,

no attempt was made to adjust for storage effects on Cowichan Lake. Instantaneous peak flows for both Koksilah River and Bings Creek were determined from regional hydrologic studies, the two datasheets are attached. The results for the 20 and 200-year return periods are as follows.

Station	20-year		200-year		
	daily	inst	daily	inst	
8HA002	284	290	371	380	m^3/s
8HA011	453	523	600	700	
8HA003	224	284	276	312	
8HA016	13.4	21.7	18.4	33.9	

2. Somenos Creek Peak Flows

During the 24 months of operation of this gauge five individual peak flow events were observed these are listed below. (As this was a manual gauge, only daily values are available.) Daily flows at the Bings Creek station corresponding to these peak flows are shown for comparison.

	Somenos	Bings	
1961 Dec 04	3.14	1.40	m^3/s
1962 Jan 03	5.69	3.17	
1962 Nov 26	11.8	5.92	
1963 Jan 01	13.4	4.76	
1963 Feb 07	9.20	2.59	

The data on Somenos Creek are insufficient to carry out frequency analysis, however a relationship using the available data on Somenos Creek and Bings Creek was developed in 1981. The results and discussion of uncertainty are described in the attached memo report (Study 123) dated January 23, 1981. This study was reviewed based on the additional years of data available for Bings Creek, however no significant difference was found. The daily peak flows for Somenos Creek, from Study 123 are: 20-year 16.5 m^3/s
200-year 18.5

As, stated in the January 1981 memorandum, backwater and temporary storage make the higher flow figures somewhat uncertain and quite impossible to estimate instantaneous peak flow.

3. Koksilah River Peak Flows

The above frequency analysis provides the peak flows at the streamgauge at Cowichan Station. The drainage area to this point is 209 km^2 while the drainage area at the mouth of the Koksilah is 281 km^2. Using the regional relationship of peak flow versus drainage area would give a peak flow increase of 27% for this increase in drainage area. The resulting peak flows at the mouth of the Koksilah River are:

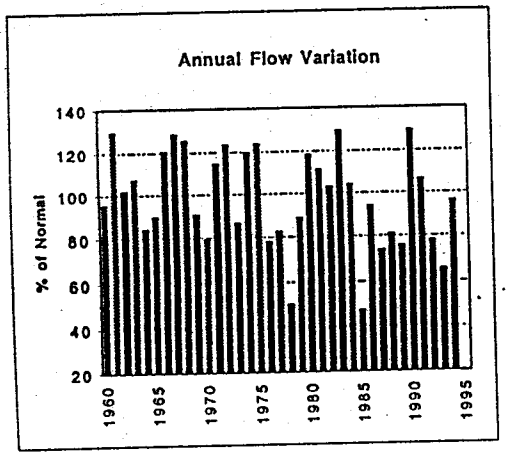
20-year daily	284	m^3/s
inst	360	
200-year daily	350	
inst	396	

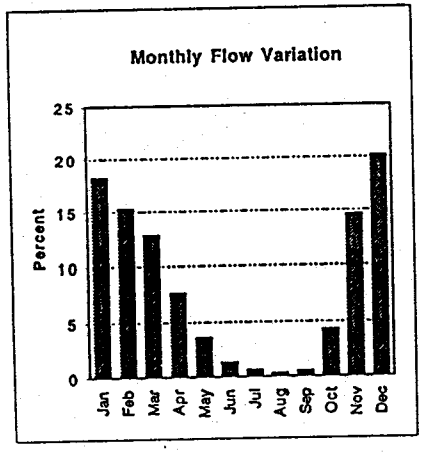
C.H. Coulson
Surface Water Section

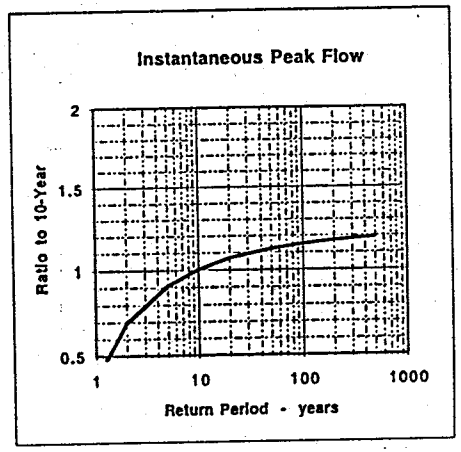
KOKSILAH RIVER AT COWICHAN STATION 8HA003

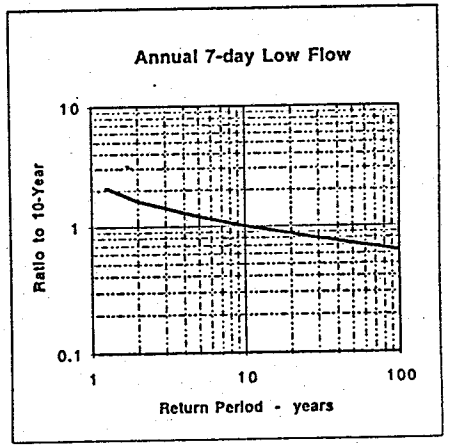
Monthly and Annual Discharge in m3/s — d.a. = 221 km2 — median elevation= 510 m

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Instantaneous Peak Flow date	Instantaneous Peak Flow m3/s	7-Day Low Flow Jun-Sep	7-Day Low Flow Annual	Year
1960	16.5	22.6	11.5	16.0	4.3	1.6	0.6	0.4	0.5	4.0	15.6	16.5	9.1	Jan 29	204	0.313	0.313	1960
1961	34.6	37.4	23.6	6.7	5.3	1.2	0.5	0.2	0.4	4.6	10.8	24.4	12.4	Jan 15	247	0.233	0.233	1961
1962	15.6	5.9	7.6	9.0	7.2	2.2	0.8	0.6	0.4	7.0	28.8	31.2	9.7	Nov 19	140	0.296	0.296	1962
1963	14.5	19.0	7.2	8.3	4.6	0.8	0.9	0.4	0.3	12.7	28.5	26.7	10.3	Dec 23	174	0.274	0.274	1963
1964	30.7	16.7	15.4	8.4	3.6	1.7	0.8	0.5	0.8	2.8	6.6	8.3	8.0	Jan 16	124	0.387	0.387	1964
1965	13.9	27.8	8.1	8.0	4.5	1.2	0.5	0.4	0.4	5.9	13.7	20.2	8.6	Jan 30	100	0.310	0.310	1965
1966	26.0	13.2	17.2	10.6	3.5	1.1	0.9	0.4	0.4	4.8	13.5	46.2	11.5	Dec 13	192	0.338	0.338	1966
1967	35.0	18.4	18.3	6.2	3.6	0.9	0.3	0.2	0.3	20.2	13.1	30.6	12.3	Dec 10	169	0.212	0.212	1967
1968	38.8	23.8	17.6	6.7	2.5	1.3	0.6	0.5	2.0	10.2	17.6	22.6	12.0	Jan 19	237	0.417	0.417	1968
1969	9.6	10.9	19.9	20.4	6.0	1.4	0.7	0.5	1.9	3.1	6.1	23.5	8.7	Dec 13	135	0.459	0.459	1969
1970	18.1	14.0	8.9	12.1	2.5	0.8	0.3	0.2	0.4	2.1	9.8	22.1	7.6	Jan 23	130	0.183	0.183	1970
1971	29.9	22.0	20.6	15.5	8.8	2.3	1.1	0.4	0.6	3.8	15.3	11.8	10.9	Jan 19	140	0.327	0.327	1971
1972	23.7	29.4	27.2	10.4	4.1	1.0	1.4	0.5	1.4	1.0	7.0	35.0	11.8	Dec 25	238	0.319	0.319	1972
1973	21.4	7.7	7.0	2.9	2.4	1.4	0.6	0.3	0.3	3.2	19.5	32.5	8.3	Nov 28	216	0.220	0.220	1973
1974	30.3	24.8	24.9	11.2	4.7	3.4	1.2	0.5	0.4	0.5	14.6	21.7	11.4	Jan 14	238	0.416	0.416	1974
1975	16.0	11.0	13.8	10.2	6.3	1.0	0.4	1.0	0.8	19.8	33.1	28.5	11.8	Dec 26	161	0.267	0.267	1975
1976	24.4	17.4	14.0	13.1	5.6	2.0	0.7	0.5	0.5	0.7	2.8	7.9	7.5	Jan 15	101	0.343	0.343	1976
1977	7.8	11.2	17.0	5.9	1.8	0.9	0.3	0.2	0.6	3.2	24.6	21.6	7.9	Nov 01	163	0.132	0.132	1977
1978	13.5	11.0	8.5	4.2	3.1	1.2	0.4	0.3	1.5	1.2	4.0	8.9	4.8	Jan 08	57	0.216	0.216	1978
1979	3.2	26.5	15.1	5.1	2.2	0.7	0.5	0.3	1.0	5.7	3.2	39.2	8.5	Dec 14	276	0.252	0.252	1979
1980	16.5	27.3	13.1	8.1	2.1	1.9	1.3	0.5	0.6	0.8	26.6	37.8	11.3	Dec 26	269	0.462	0.462	1980
1981	12.3	27.4	4.6	11.9	4.8	3.3	1.3	0.5	1.4	9.8	23.4	28.5	10.6	Dec 05	165	0.428	0.428	1981
1982	21.6	28.5	11.2	8.5	3.9	0.9	0.8	0.3	0.3	4.1	8.9	30.3	9.9	Dec 03	221	0.233	0.233	1982
1983	26.2	35.7	18.0	5.9	1.5	0.9	2.0	0.5	0.9	1.1	46.3	11.8	12.4	Nov 15	254	0.319	0.319	1983
1984	21.5	14.3	14.2	7.6	9.0	2.7	0.8	0.4	0.5	4.4	28.0	16.4	10.0	Jan 04	222	0.329	0.329	1984
1985	4.8	8.1	6.8	9.9	4.1	1.5	0.2	0.2	0.3	5.2	7.5	6.3	4.5	Dec 08	44	0.116	0.116	1985
1986	27.7	23.1	11.4	4.3	5.9	1.7	0.6	0.2	0.3	0.6	19.1	14.1	9.0	Jan 18	352	0.203	0.203	1986
1987	23.5	13.1	15.0	4.9	2.0	1.6	0.3	0.2	0.2	0.3	4.4	19.3	7.1	Dec 10	126	0.155	0.155	1987
1988	16.1	10.1	14.5	12.2	2.6	2.4	0.5	0.3	0.5	1.4	20.0	12.6	7.7	Jan 14	130	0.251	0.251	1988
1989	20.1	9.0	18.3	12.2	1.8	0.6	0.5	0.3	0.2	1.0	8.5	14.2	7.2	Dec 04	152	0.209	0.209	1989
1990	19.7	23.4	13.6	6.9	2.4	3.0	0.6	0.3	0.3	5.2	45.9	28.6	12.4	Nov 23	202	0.236	0.236	1990
1991	22.7	37.6	9.6	12.3	2.0	1.1	0.5	2.3	1.7	0.7	17.7	16.3	10.2	Feb 02	221	0.242	0.242	1991
1992	37.0	19.3	4.1	3.6	2.5	0.8	0.6	0.3	0.3	1.7	10.4	9.2	7.5	Jan 30	199	0.247	0.247	1992
1993	19.8	6.8	9.4	9.8	5.5	2.6	1.0	0.6	0.3	0.8	2.4	15.8	6.3	Dec 10	185	0.314	0.314	1993
1994	13.1	18.4	21.0	6.4	1.7	1.0	0.5	0.3	0.4	1.4	11.4	35.4	9.2	Dec 19	197	0.275	0.275	1994
1995																		1995
normal	20.6	18.9	14.4	8.9	4.1	1.6	0.7	0.4	0.7	4.9	17.0	22.8	9.5	average	182	0.284	0.284	average
mm	249	209	175	105	49	18	9	5	8	59	200	276	1362	10-year	266	0.173	0.173	10-year









BINGS CREEK NEAR THE MOUTH 8HA016

monthly and annual flow in m3/s — d.a. = 17.5 km2 — median elevation= 180 m

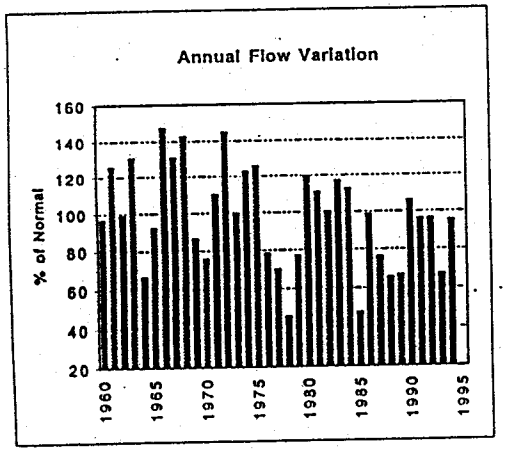
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1960													0.464
1961	1.970	2.080	1.340	0.242	0.166	0.088	0.045	0.018	0.021	0.048	0.270	1.050	0.604
1962	0.878	0.292	0.471	0.333	0.224	0.090	0.052	0.043	0.057	0.123	1.380	1.740	0.475
1963	1.050	0.952	0.364	0.366	0.261	0.080	0.058	0.053	0.056	0.475	1.520	2.330	0.629
1964	1.960	0.627	0.661	0.128	0.026	0.017	0.025	0.031	0.016	0.037	0.052	0.234	0.319
1965	0.803	2.120	0.427	0.332	0.140	0.054	0.021	0.021	0.018	0.035	0.507	0.979	0.444
1966	2.318	1.090	1.340	0.252	0.095	0.057	0.036	0.020	0.021	0.080	0.432	2.730	0.708
1967	2.060	1.020	1.040	0.223	0.442	0.031	0.014	0.014	0.031	0.296	0.631	1.740	0.630
1968	3.050	1.210	1.000	0.290	0.129	0.063	0.031	0.033	0.041	0.149	0.661	1.560	0.686
1969	0.639	0.871	1.150	0.738	0.138	0.038	0.025	0.028	0.032	0.028	0.060	1.250	0.415
1970	1.010	0.804	0.482	0.450	0.097	0.037	0.023	0.018	0.022	0.035	0.141	1.260	0.364
1971	1.320	1.160	1.890	0.634	0.128	0.058	0.034	0.030	0.032	0.043	0.333	0.718	0.529
1972	1.170	2.050	1.690	0.611	0.127	0.055	0.034	0.029	0.028	0.025	0.075	2.480	0.696
1973	1.350	0.456	0.339	0.125	0.060	0.031	0.023	0.020	0.021	0.098	1.100	2.100	0.479
1974	1.480	1.500	1.540	0.554	0.156	0.070	0.044	0.026	0.019	0.023	0.295	1.420	0.590
1975	1.130	0.809	0.931	0.319	0.111	0.040	0.021	0.083	0.024	0.440	1.270	2.090	0.606
1976	1.960	0.893	0.858	0.358	0.094	0.056	0.029	0.022	0.025	0.031	0.046	0.140	0.376
1977	0.407	0.463	1.300	0.124	0.084	0.035	0.018	0.016	0.022	0.032	0.464	1.060	0.336
1978	0.785	0.585	0.398	0.229	0.154	0.065	0.029	0.021	0.037	0.033	0.059	0.278	0.221
1979	0.228	1.210	0.534	0.200	0.141	0.074	0.035	0.016	0.052	0.070	0.095	1.840	0.371
1980	0.953	1.580	0.647	0.252	0.112	0.084	0.056	0.031	0.034	0.033	0.989	2.180	0.576
1981	0.790	1.330	0.286	0.334	0.202	0.122	0.050	0.028	0.035	0.088	1.120	2.090	0.535
1982	1.400	1.430	0.567	0.387	0.112	0.045	0.031	0.020	0.022	0.036	0.109	1.670	0.482
1983	1.070	1.940	1.030	0.362	0.109	0.046	0.028	0.018	0.071	0.029	1.480	0.700	0.563
1984	1.230	0.966	0.795	0.321	0.511	0.151	0.057	0.036	0.027	0.055	1.470	0.908	0.542
1985	0.356	0.689	0.504	0.391	0.139	0.067	0.033	0.016	0.014	0.077	0.151	0.355	0.230
1986	1.510	1.330	0.775	0.281	0.275	0.101	0.060	0.034	0.021	0.033	0.474	0.833	0.473
1987	1.460	0.996	0.894	0.190	0.110	0.069	0.033	0.009	0.004	0.009	0.069	0.579	0.366
1988	0.797	0.295	0.509	0.538	0.081	0.058	0.011	0.014	0.014	0.034	0.796	0.646	0.316
1989	0.872	0.605	1.140	0.479	0.085	0.043	0.025	0.018	0.009	0.026	0.054	0.490	0.320
1990	0.945	1.270	0.685	0.168	0.099	0.111	0.041	0.021	0.018	0.062	1.280	1.470	0.509
1991	0.919	1.880	0.610	0.545	0.136	0.072	0.039	0.044	0.024	0.022	0.565	0.809	0.462
1992	2.570	1.420	0.275	0.205	0.144	0.039	0.025	0.013	0.016	0.045	0.367	0.463	0.463
1993	0.937	0.353	0.895	0.404	0.274	0.083	0.042	0.031	0.021	0.033	0.05	0.726	0.322
1994	0.844	1.070	1.030	0.300	0.090	0.049	0.030	0.015	0.021	0.030	0.312	1.740	0.459
1995													
normal	1.232	1.087	0.853	0.340	0.154	0.065	0.034	0.026	0.028	0.086	0.579	1.297	0.480
mm	189	152	131	50	24	10	5	4	4	13	86	199	865

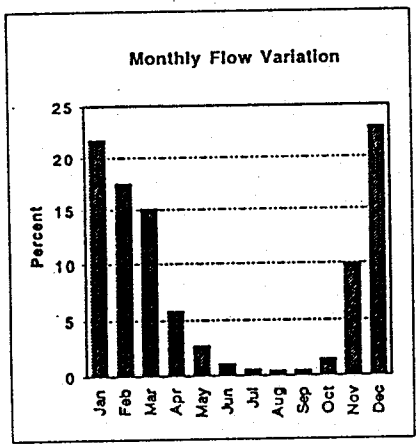
Instantaneous Peak Flow

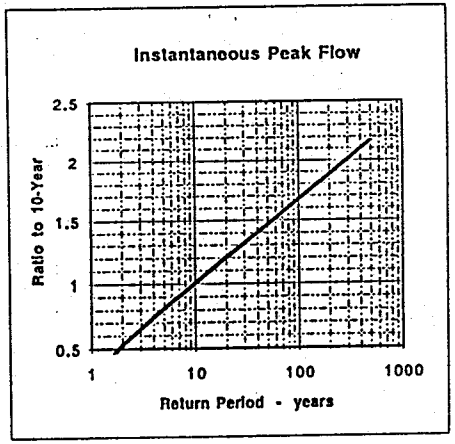
date	m3/s
Nov 26	7.5
Dec 23	8.8
Jan 16	8.1
Feb 08	7.0
Jan 13	10.0
Dec 23	8.5
Jan 14	22.9
Dec 22	5.4
Dec 16	6.5
Mar 12	8.8
Dec 26	15.7
Jan 14	7.7
Jan 14	11.3
Dec 03	9.9
Jan 04	8.6
Mar 08	24.5
Jan 08	7.4
Dec 17	17.4
Dec 26	14.1
Feb 19	11.3
Dec 03	7.9
Feb 10	6.7
Feb 11	2.7
Feb 25	10.6
Jan 27	6.6
Jan 14	8.1
Mar 10	3.3
Dec 04	13.9
Jan 31	22.9
Jan 22	20.0
Mar 21	7.0
Dec 20	11.9
average	10.7
10-year	18.1

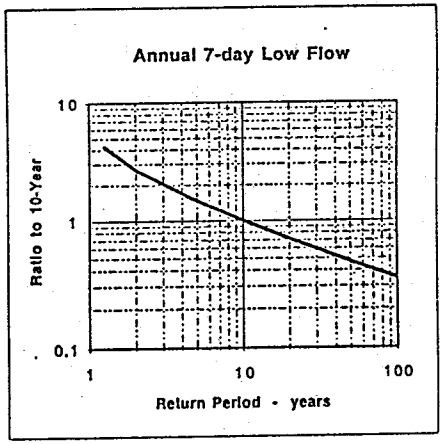
7-Day Low Flow

Jun-Sep	Annual	Year
		1960
0.015	0.015	1961
0.032	0.032	1962
0.035	0.035	1963
0.011	0.008	1964
0.013	0.005	1965
0.017		1966
		1967
0.023	0.023	1968
0.022	0.022	1969
0.014	0.014	1970
0.023	0.023	1971
0.023	0.023	1972
0.008	0.008	1973
0.015	0.015	1974
0.013	0.013	1975
0.019	0.019	1976
0.013	0.013	1977
0.011	0.011	1978
0.013	0.013	1979
0.026	0.026	1980
0.020	0.020	1981
0.014	0.014	1982
0.015	0.015	1983
0.023	0.023	1984
0.008	0.008	1985
0.012	0.012	1986
0.003	0.003	1987
0.003	0.003	1988
0.003	0.003	1989
0.014	0.014	1990
0.019	0.016	1991
0.006	0.006	1992
0.015	0.015	1993
0.012	0.012	1994
		1995
0.016	0.015	average
0.006	0.005	10-year









Province of British Columbia

BC Environment
WATER MANAGEMENT DIVISION

MEMORANDUM

To:
C.H. Coulson, Manager,
Surface Water Section

Date:
February 14, 1995

Files: 42500-40

Re: Frequency Analysis, Cowichan area

As requested in Brian Board's January 25, 1995 memorandum, I have analyzed the recorded peak flows on the three gauges using our FFAME frequency analysis program. The results are as follows:

	Cowichan Lake @ Lake Cowichan 08HA002		Cowichan River near Duncan 08HA011		Koksilah River at Cowichan Station 08HA003	
	m^3/s		m^3/s		m^3/s	
Q_{20D}	284		435		224	
Q_{200D}	371		600		276	
Q_{20I}	290		523		N/A	
Q_{200I}	380		700		N/A	
	Return Period					
Jan 20, 1986						
Daily	154 m^3/s	< 2 yrs	400 e m^3/s	8.5 yrs	271 m^3/s	155 yrs
Instantaneous	157 m^3/s	< 2 yrs	447 m^3/s	8.5 yrs		
Dec 4, 1990						
Daily	238 m^3/s	7 yrs	326 m^3/s	4 yrs	191 m^3/s	7 yrs
Instantaneous	243 m^3/s	7 yrs	371 m^3/s	4 yrs		

These analyses are based on the available data through 1993, namely:

Gauge # 08HA002 Daily 59 years, instantaneous 50 years
Gauge # 08HA011 Daily 33 years, instantaneous 17 years
Gauge # 08HA003 Daily 36 years, instantaneous 2 years

For gauge 08HA011, the instantaneous flows were correlated with the corresponding daily flows (r^2=0.98) and the data set extended to 33 years to give more confidence in the frequency

curves. With only 2 years of instantaneous data for gauge # 08HA003, it is not possible to estimate the flow frequency by numerical means.

The flow figures for the two gauges computed in 1980 are not greatly different from those now calculated using the longer period of record.

R.Y. McNeil, P. Eng., Head
River Forecast Centre
Hydrology Section
387-9472

APPENDIX 3

HEC-2 Computer Run Summaries

Cowichan River - Riverbottom Road

Hec-2 Run Summary

Run #	Comments
1.	Plot run with extensions
2.	Calibration run to match Dec. 4/90 flood
3.	Work file
4.	Multiple "Q" run: Q200D = 600 cms **FL's seclected** Q200 I = 700 cms Start by slope/area method
5.	Multlple "Q" run, sensitivity to "n" (x 1.0, 1.15, 1.30) Q200D = 600 cms, start WSEL = 41.30m "n" x 1.15: mean W/L increase of 0.18 m (max. 0.38) "n" x 1.30: mean W/L increase of 0.34 m (max. 0.59) FL exceeded once by 0.01 m
6.	Multiple "Q" run, sensitivity to "Q" (x 1.0, 1.16, 1.30, 1.45) (Q x 1.16 ≅ Q200I) Q200D = 600 cms, start WSEL = 41.30m Q x 1.16: average W/L increase of 0.22 m (all within FL) Q x 1.30: " " " " 0.40 m (2 exceed FL by max. 0.20) Q x 1.45: " " " " 0.58 m (7 exceed FL by a mean of 0.23m; max. 0.59)
7.	Multiple run, sensitivity to starting water surface level Q200D = 600 cms, start WSEL = 40.30m, 42.30m Matches by XS-218 (7th of 24) when start reduced by 1 metre Matches by XS-222 (3rd of 24) when start increased by 1 metre
8.	Multiple "Q" run starting upstream at XS-222 using slope/area method Q200D = 600 cms, Q200I = 700cms
9.	Multiple run - Q20 Daily & Instantaneous - **FL's selected** Q20D = 453 cms, slope/area method start Q20I = 523 cms, " " " "

Cowichan Main

Hec-2 Run Summary

Run #	Comments
1.	Plot run
2.	Calibration/Check run, 90-12-04 flood
3.	Calibration run: Q = 371 cms, start WSEL = 4.90m Q200 Daily = 600 cms Q200 Instantaneous = 700 cms (Q200D + 0.6 averages 1.22 m above 1990 observed Q of 375 cms)
4.	Multiple Q run: Q200D = 600 cms, start WSEL = 5.00m, "n" x 0.8, 0.9, 1.0. Flood level based on "n" x 0.9
5.	Q200 Instantaneous = 700 cms, start WSEL = 5.10m, "n" x 0.9 **FL selected** (FL=Q200I + 0.3 m or Q200D + 0.6 m)
6.	Multiple Q run: Q20D & I Q20 Daily = 453 cms **FL's selected** Q20 Instantaneous = 523 cms Starting water levels from Lower Cowichan north, run 7
7.	Multiple "Q" run, slope/area method start "Q" = 100, 200, 300, 400, 500, 600 & 700 cms

Lower Cowichan South

Hec-2 Run Summary

Run #	Comments
1.	Plot and check run
2.	Work file with corrections noted.
3.	Repeat of run 2 with corrections
4.	Multiple Q run; 6 profiles with Q ranging from 200 to 450 cms, start WSEL = 2.60m
5.	Multiple Q run, "n" x 1.0; 8 profiles with Q ranging from 200 to 600 cms, start WSEL = 2.60m
6.	Multiple Q run, "n" x 1.2; 8 profiles with Q ranging from 200 to 600 cms, start WSEL = 2.60m
7.	Multiple Q run, "n" x 1.3; same as 6 above
8.	**Flood levels selected.** Q200 daily = 660/300 cms. (tidal to Koksilah/Koksilah to bifurcation) Q200 instantaneous = 710/350 cms (as above) start WSEL = 2.60m
9.	Multiple Q20 run, **flood levels selected.** Q20 daily = 507/223 cms Q20 instantaneous = 469/185 cms start WSEL = 2.60m

Lower Cowichan North

Hec-2 Run Summary

Run #	Comments
1.	Plot run
2.	Check run
3.	Multiple "Q" run to determine stage/Q at XS- 22 and 23. Start WSEL = 2.60m. Stage of 4.22 @ XS-22 = Q of ≅ 315 cms. Sensitivity: -at 400m3s (14% increase) 4 of 10 exceed FCL by a mean of 0.12m -at 500 " (43% ") all above tidal exceed FCL by an average of 1.09m (min. 0.64)
3A.*	Repeat of run 3 with left bank cutoff removed at XS-17 & 18 [Flow over road allowed]. Q = 315 cms @ XS-22 for WL to = 4.22 m (1990 observed). Sensitivity: -at 400m3s (14% increase) all within FL -at 500m3s (43% increase) all above tidal exceed FL by a mean of 0.26m (max. 0.43)
4.	Same as run 3 with "n" x 1.2 Sensitivity: -at 300m3s, all within FL -at 400m3s, exceed FL by an average of 0.57m (max. 0.70) -at 500m3s, " " " " " " 1.35m (max. 1.52)
5.	Same as run 3 with "n" x 1.3. Sensitivity: -at 300m3s, all within FL -at 400m3s, exceed FL by an average of 0.71m (max. 0.87) -at 500m3s, " " " " " " 1.43m (max. 1.60)
6.	Q200I = 350 cms, "n" x 1.0, start WSEL = 2.60m. **FL's selected**.
7.	Multiple Q run: Q20 I & D Q20I = 300 cms **FL's selected **** Start WSEL = 2.60m. Q20D = 268 cms

* Used to select Q = 350 cms as Q200 Daily and Instantaneous flows for north channel.

** Starting water surface elevations for Cowichan main Q20 runs taken from XS-23.

Koksilah River

Hec-2 Run Summary

Run #	Comments
1.	Plot run
2.	Work file
3.	Calibration (preliminary), 90/12/04 flood, Q= 356/308/243 (Cowichan/Koksilah/upstream Kelvin Cr) Start WSEL = 2.90m
4.	Calibration (final), same as above
5.	Q200 Daily: Q = 356 cms **this run only**, start WSEL = 2.90m 356/350/276 (Lower Cowichan Main/Koksilah/upstream Kelvin Cr)
6.	Multiple Q run - Q200 D & I, Q20 D & I - **FL's Selected** Q200D = 360 cms Q200 I = 396 cms Q20D = 284 cms Q20I = 360 cms
7.	Sensitivity to "n" - Q200D, "n" x 1.0 - 1.1 - All CWSEL's 1.2 - within FL 1.3 - I NOTE: Starting "Q" = 360 cms this run
8.	Sensitivity to "Q" - Q200D x 1.2 - All within FL 1.4 - 11 exceed FL's by 0.10m average (0.18 max) 1.6 - 27 of 33 exceed FL's NOTE: Starting "Q" = 360 cms this run

APPENDIX 4

PHOTOS

Cowichan River, Riverbottom Road Area	**Photos 1 through 8**
Cowichan River, Main Channel	**Photos 9 through 19**
Cowichan River, South Channel	**Photos 20 through 25**
Cowichan River, North Channel	**Photos 26 through 29**
Koksilah River	**Photos 30 through 41**
Somenos Creek	**Photos 42 through 50**
Quamichan Lake	**Photos 51 and 52**
Aerial obliques of Somas Creek area flooding (circa 1961)	**Photos O1 through O4**

COWICHAN RIVER - RIVERBOTTOM

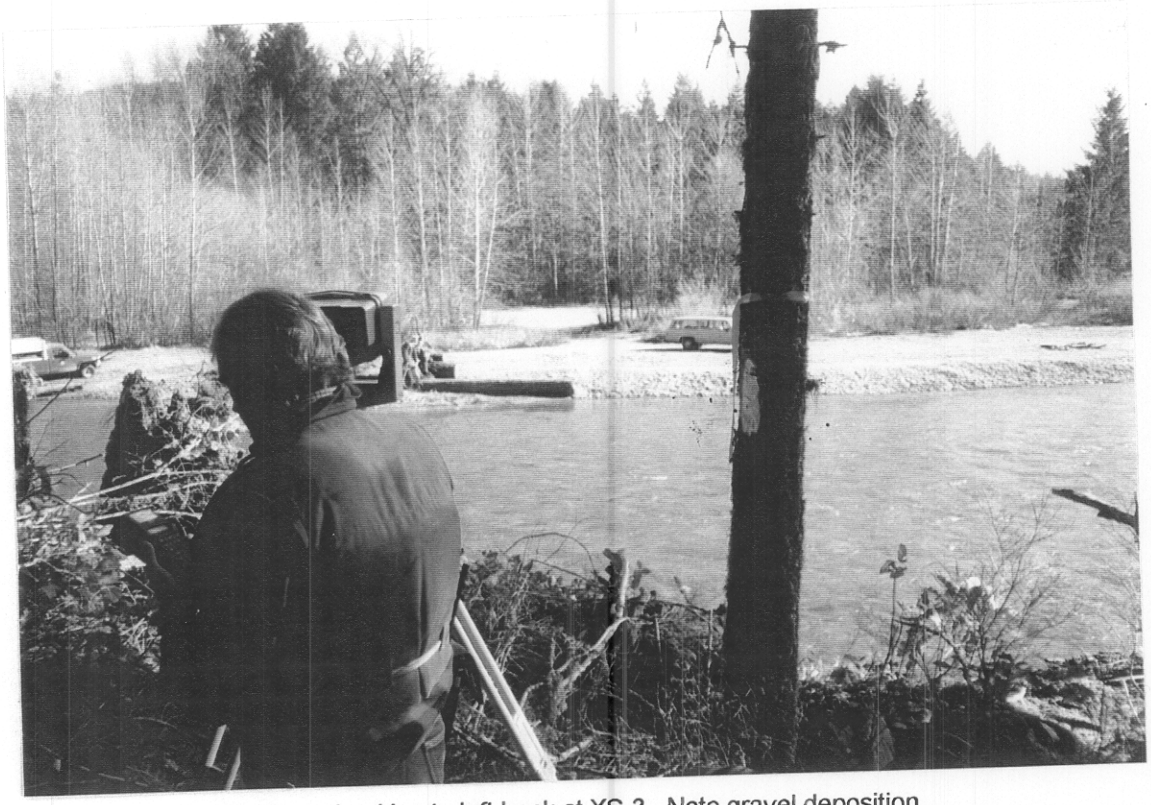


Photo 1 Looking to left bank at XS-3. Note gravel deposition.

Photo 2 Looking at the right bank at XS-3. Note severe erosion.

COWICHAN RIVER - RIVERBOTTOM

Photo 3 Looking to left bank at XS-9. Flood boundary near top of bench where houses are situated.

Photo 4 Looking downstream, left bank, between XS-10 and XS-11. Note erosion and rootball of fallen tree in foreground, bank protection in background.

COWICHAN RIVER - RIVERBOTTOM

Photo 5 Close-up of bank protection on left bank between XS-10 and XS-11.

Photo 6 Looking at the right bank at XS-12. Note severe erosion, exposed tree roots.

COWICHAN RIVER - RIVERBOTTOM

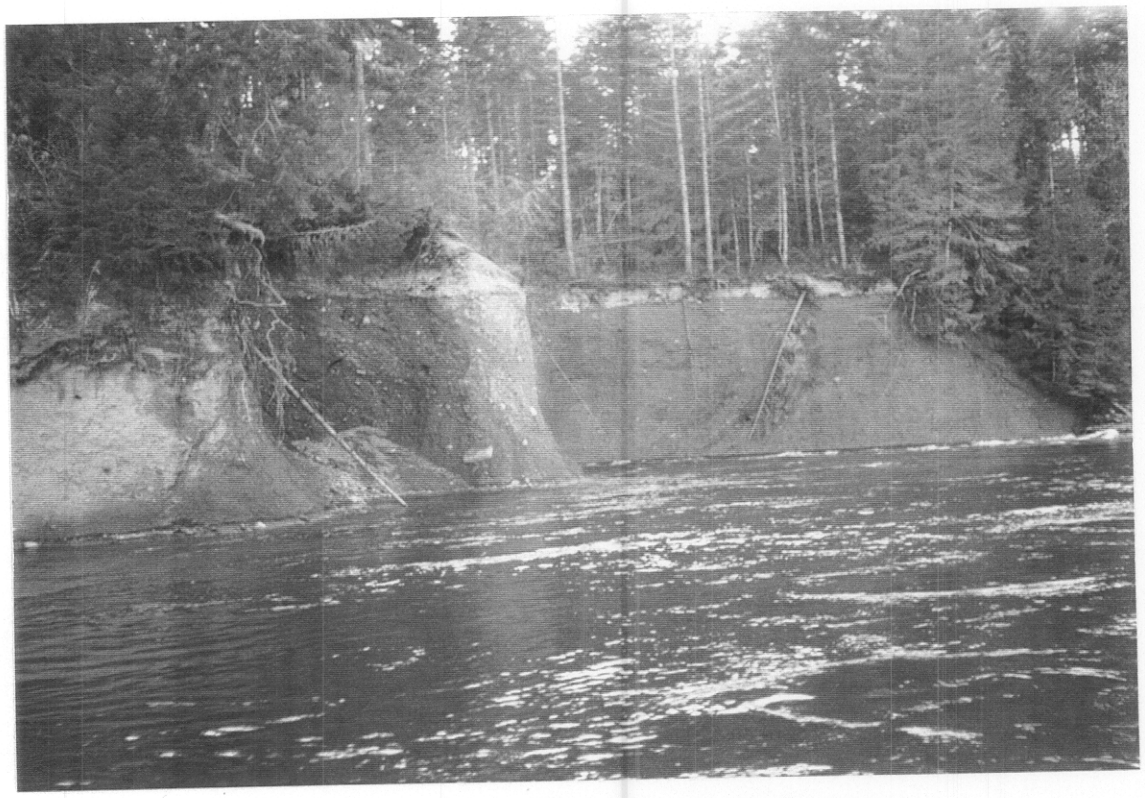


Photo 7 Erosion on the left bank between XS-13 and XS-14.

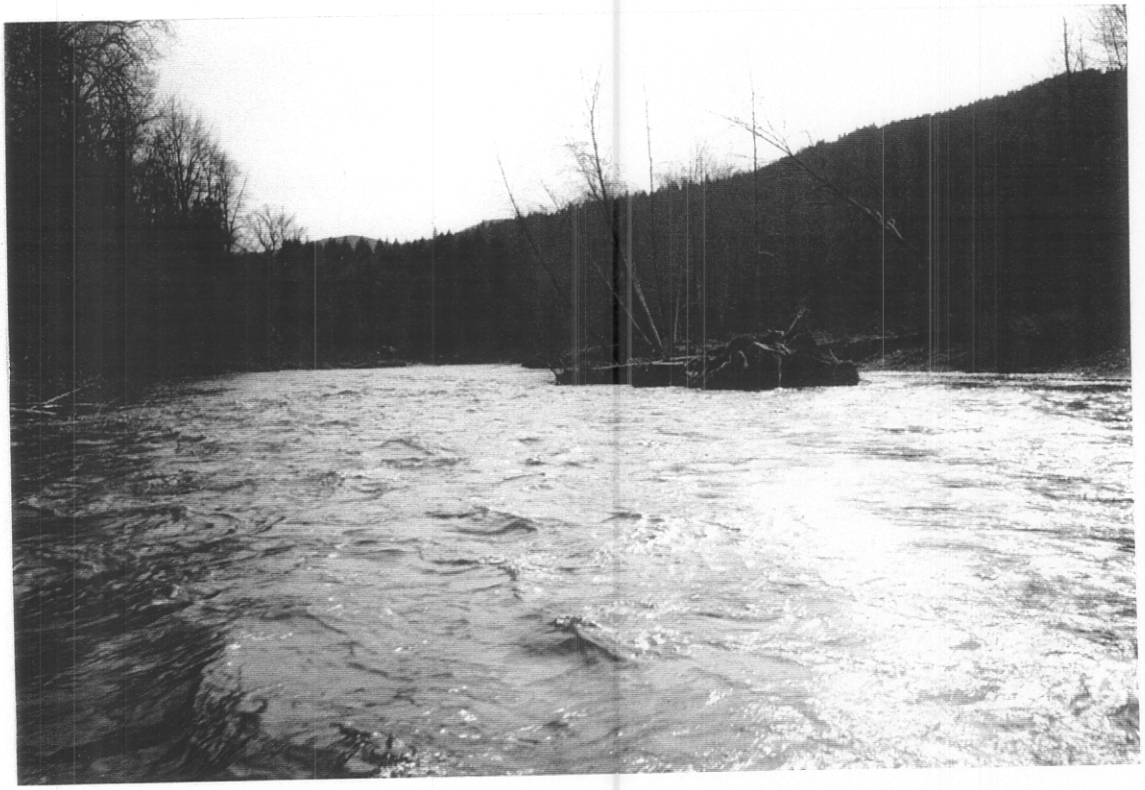


Photo 8 Looking downstream from XS-17. Note fallen tree in channel and leaning trees on eroded right bank.

COWICHAN RIVER - MAIN CHANNEL

Photo 9 Looking downstream from XS-62. Typical of main channel upstream of Allenby Road.

Photo 10 Floodproofed building in Cowichan floodplain west of Highway 1.

COWICHAN RIVER - MAIN CHANNEL

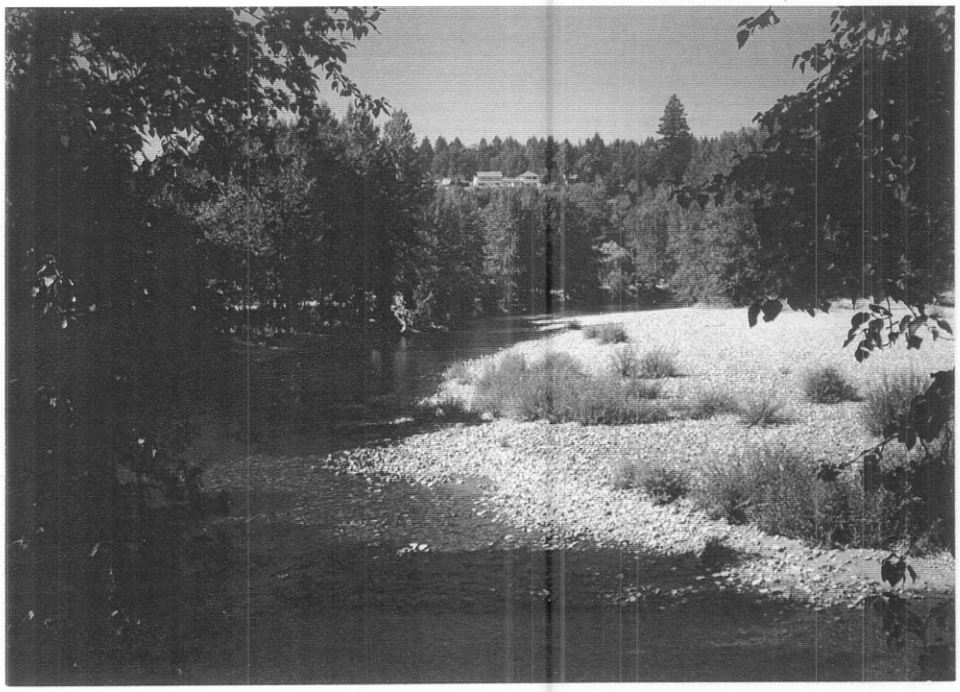


Photo 11 Looking upstream from E&N railway west of the black bridge (XS-48). Note large gravel bar on left bank side.

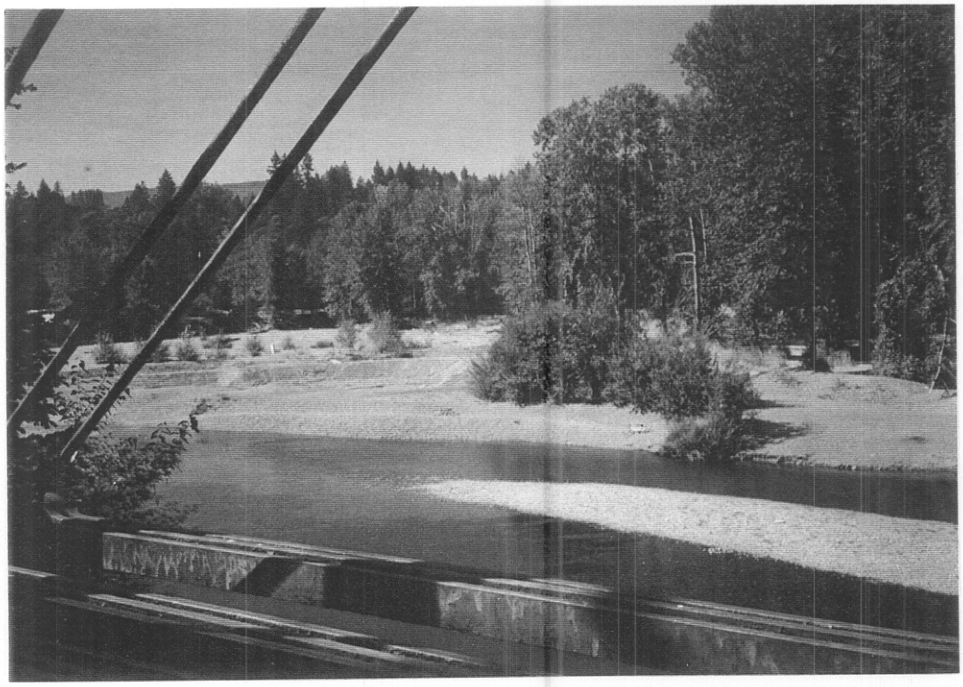


Photo 12 Another view of the gravel bar upstream of XS-48 taken from the E&N Bridge.

COWICHAN RIVER - MAIN CHANNEL

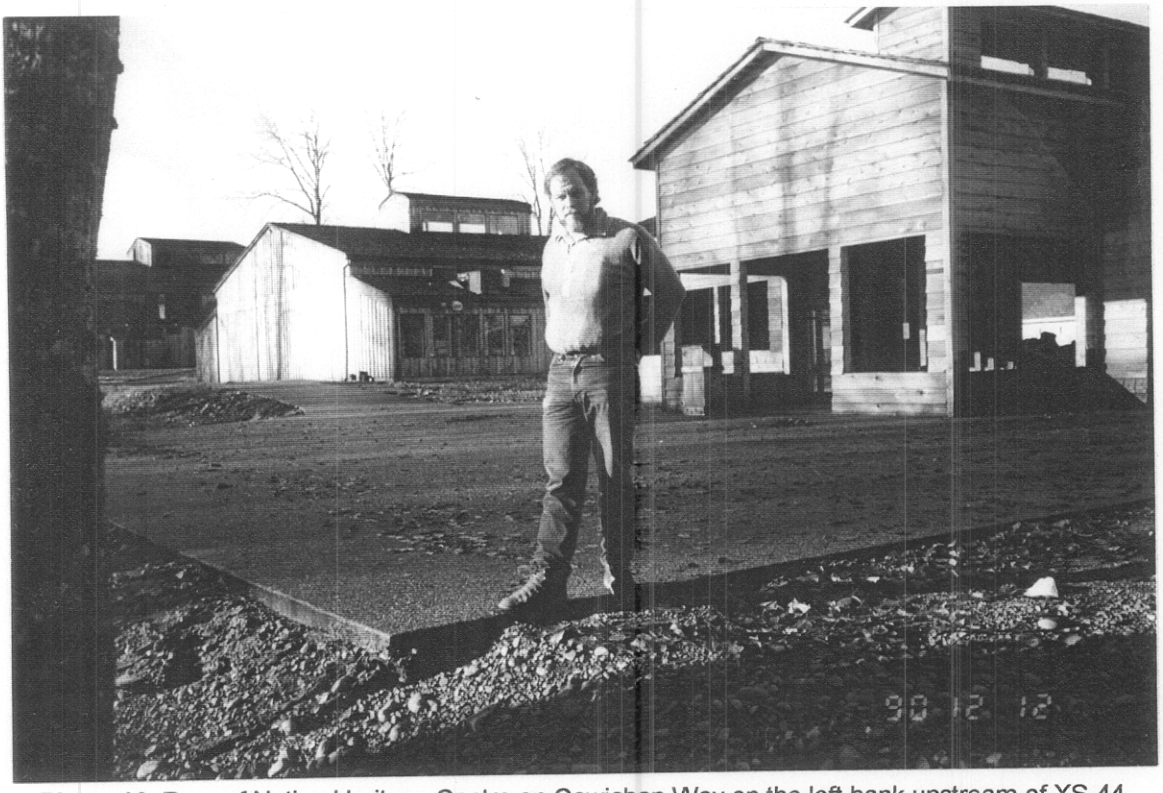


Photo 13 Rear of Native Heritage Centre on Cowichan Way on the left bank upstream of XS-44. December 4, 1990 high water mark indicated by toe of right boot and trash line beyond.

Photo 14 Looking upstream from the Silver Bridge on Highway 1 (XS-43). Native Heritage Centre property is to the right of the photo.

COWICHAN RIVER - MAIN CHANNEL

Photo 15 Looking downstream from the Silver Bridge (XS-42). Crest of Duncan City Dyke is at base of gray wall in front of buildings to left side of photo. District of North Cowichan South Dyke is just behind vegetation on right.

Photo 16 Looking upstream to the Silver Bridge on Highway 1 (XS-43) from the top of the left bank. City of Duncan Dyke is out of the photo to the right.

APPENDIX 4 - PHOTOGRAPHS

COWICHAN RIVER - MAIN CHANNEL

Photo 17 Looking upstream to XS-27. Main channel at left and centre, old Somenos Creek channel at right. Note debris in main channel.

COWICHAN RIVER - MAIN CHANNEL

Photo 18 High water mark (nail in power pole) from December 4, 1990 flooding. This is on the left bank just downstream of XS-26.

Photo 19 Looking upstream to the bifurcation (centre of photo) from the left bank between XS-23 and XS-24.

COWICHAN RIVER - SOUTH CHANNEL

Photo 20 XS-14 main south channel looking downstream.

Photo 21 Looking downstream XS-14 backchannel.

APPENDIX 4 - PHOTOGRAPHS

COWICHAN RIVER - SOUTH CHANNEL

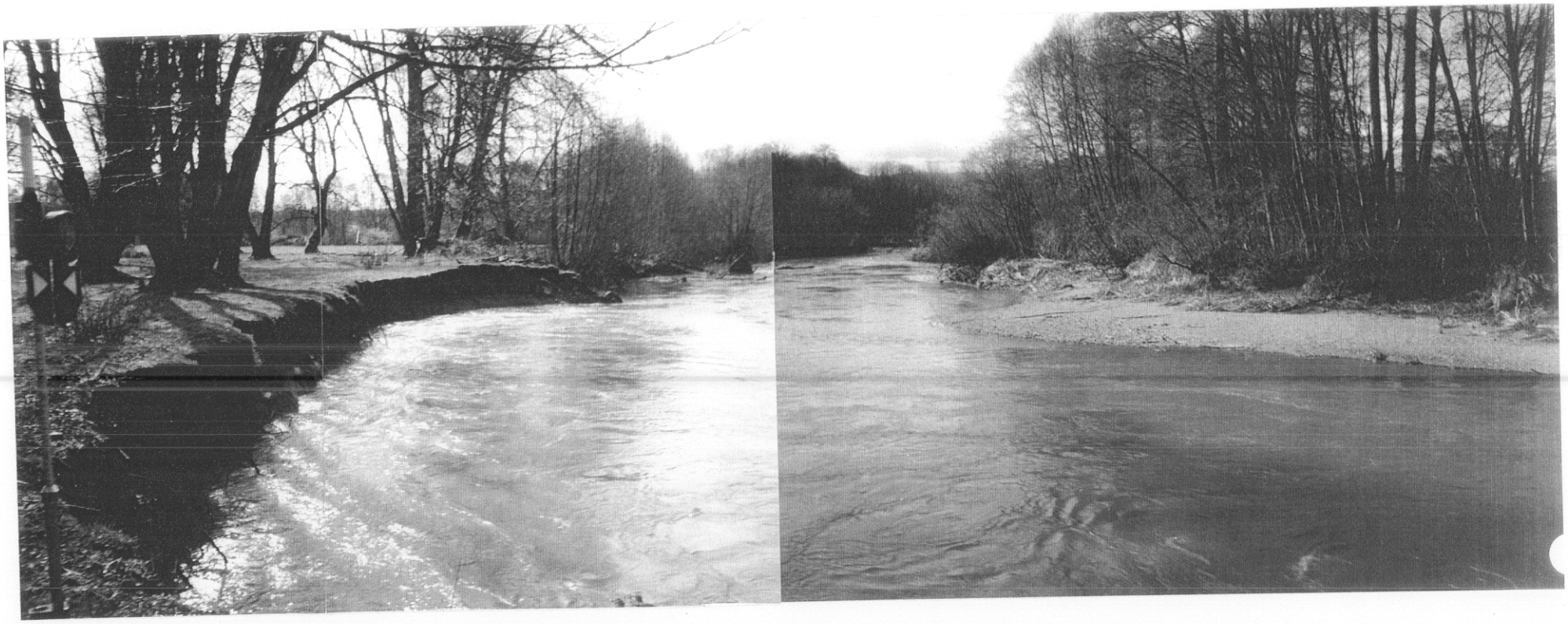


Photo 22 Looking downstream from XS-11. Note severe erosion on left bank, gravel deposition on left bank.

COWICHAN RIVER - SOUTH CHANNEL

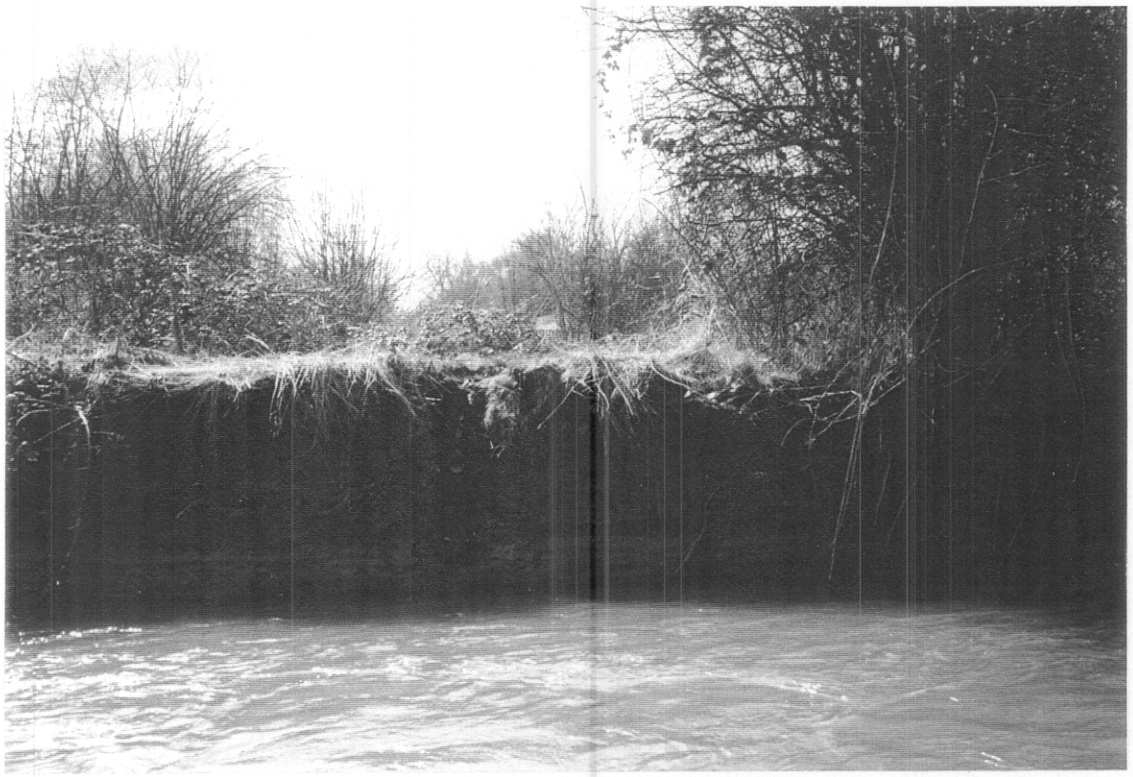


Photo 23 Severe erosion on the right bank at XS-9, south channel.

Photo 24 Looking upstream from XS-8. Koksilah River mouth on left, Cowichan River south channel on right.

COWICHAN RIVER - SOUTH CHANNEL

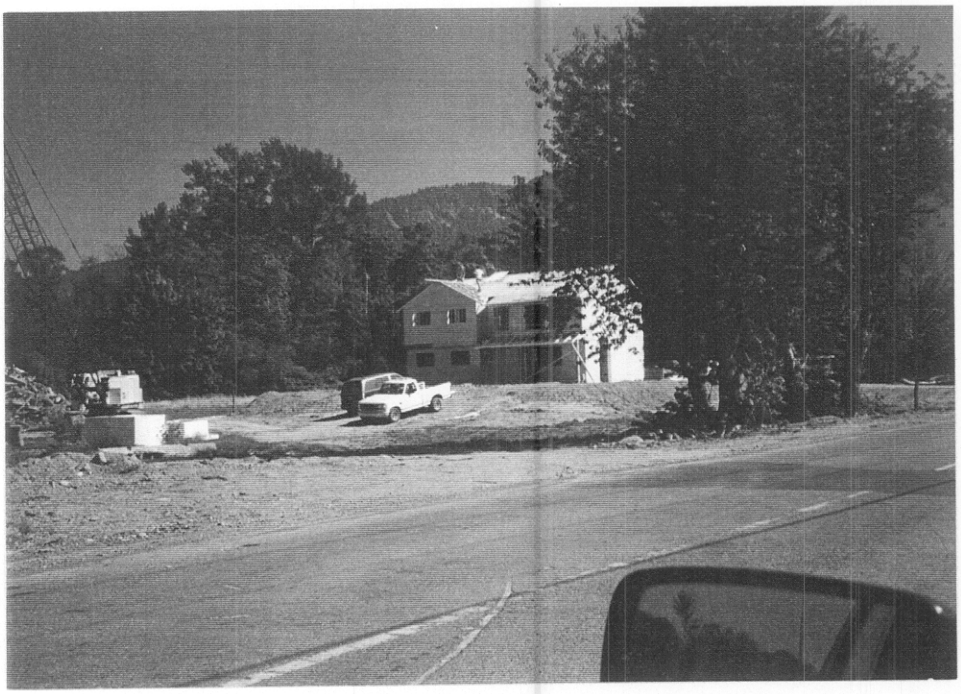


Photo 25 Floodproofed residential construction on the left bank at XS-7, south channel, just north of Tzouhalem Road.

COWICHAN RIVER - NORTH CHANNEL

Photo 26 Looking to the right bank from the end of the Quamichan Dyke downstream of XS-23. High water overtops the right bank and flows southwesterly to the south channel.

COWICHAN RIVER - NORTH CHANNEL

Photo 27 Looking downstream from XS-22. Typical of main and north channel in this area.

Photo 28 Recent erosion (autumn 1996) on the right bank just upstream of the Pembury Bridge and XS-18.

COWICHAN RIVER - NORTH CHANNEL

Photo 29 Looking downstream from XS-21. Note debris on both sides of channel.

KOKSILAH RIVER

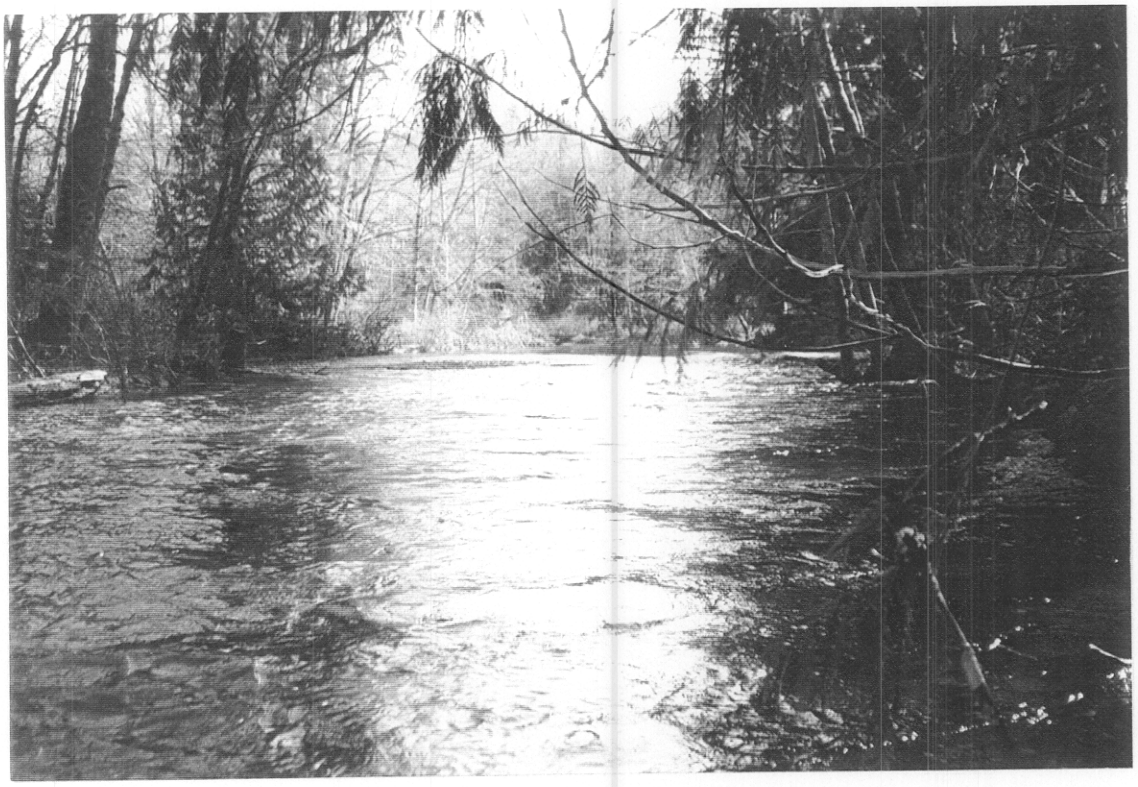


Photo 30 Typical of upstream Koksilah channel, looking upstream from XS-6.

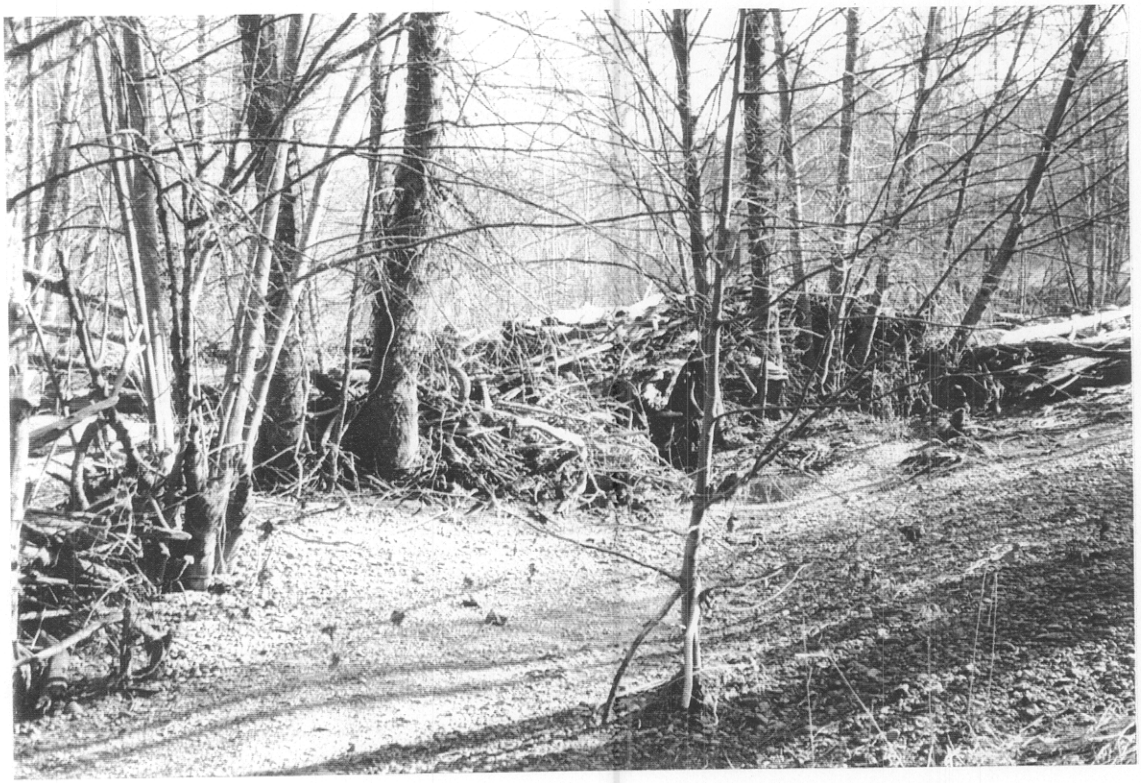


Photo 31 Looking upstream at XS-6 backchannel. Note large log jam.

KOKSILAH RIVER

Photo 32 Looking upstream at XS-10. Kelvin Creek flow can be seen on the extreme right of the photo.

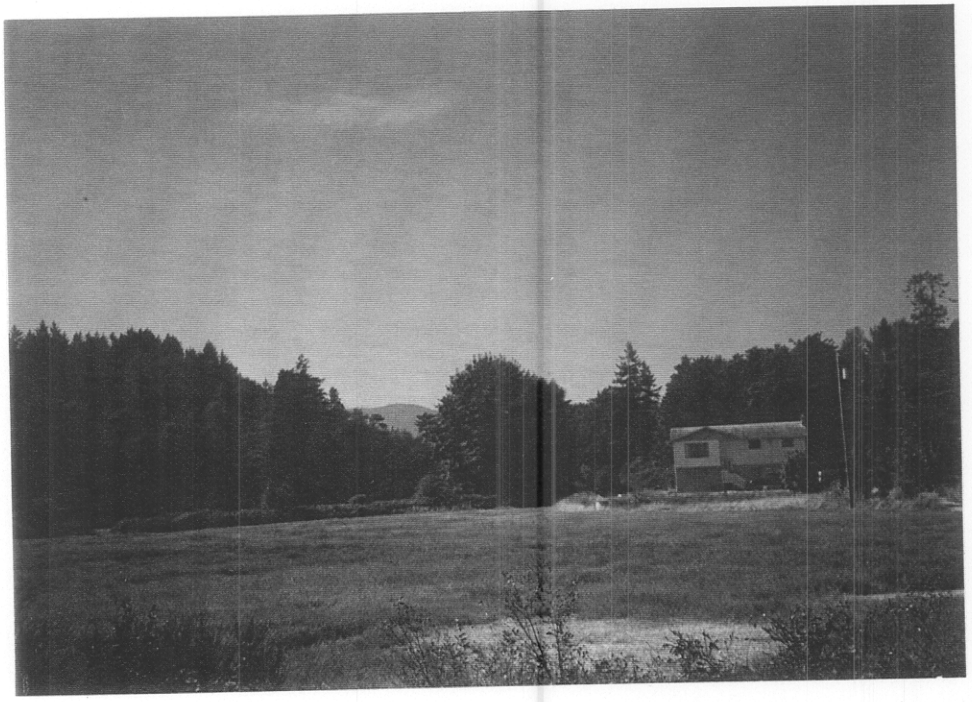


Photo 33 Looking southwest from Highway 1. Cross sections 13 to 15 at the CP Rail bridge over the Koksilah River are beyond the floodproofed house.

KOKSILAH RIVER

Photo 34 Looking downstream from XS-14. Note debris on both banks and mid-channel.

Photo 35 Erosion and debris on the right bank at XS-22..

KOKSILAH RIVER

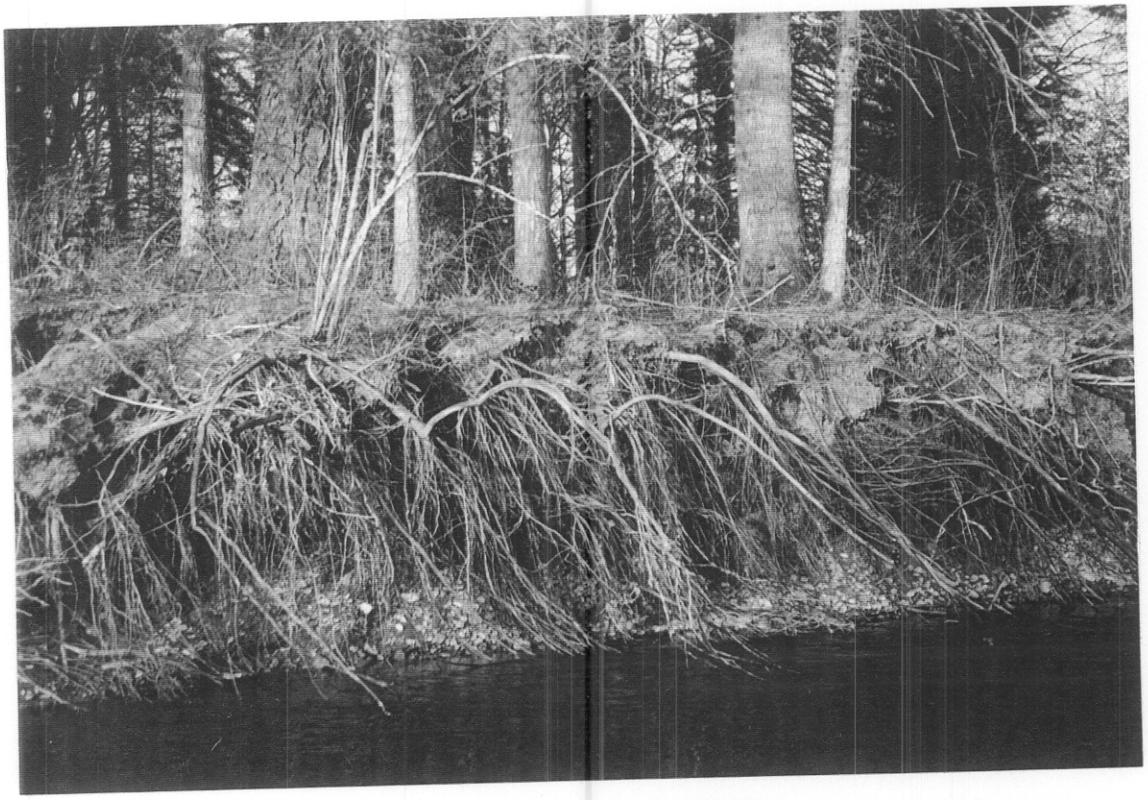


Photo 36 Undercut left bank at XS-23.

Photo 37 Looking downstream below XS-24. Side channel which flows under easternmost bridge on Cowichan Bay Road is at the right edge of log jam.

KOKSILAH RIVER

Photo 38 Looking upstream on side channel noted in photo 37.

Photo 39 Looking upstream above XS-25. Side channel which flows under Tsouhalem Road immediately north of Cowichan Bay Road is under fallen tree.

KOKSILAH RIVER

Photo 40 Looking upstream near XS-25. During high flows, water overtops area where men are standing and flows to side channel noted in photo 39.

Photo 41 Looking downstream from abandoned M&B haul bridge to XS-27 along upstream edge of former rail bridge. Note debris buildup.

SOMENOS CREEK

Photo 42 Typical weed growth in creek channel near XS-3.

Photo 43 Floodproofed residence near XS-3.

SOMENOS CREEK

Photo 44 Looking downstream from XS-6. Note flat overbank area.

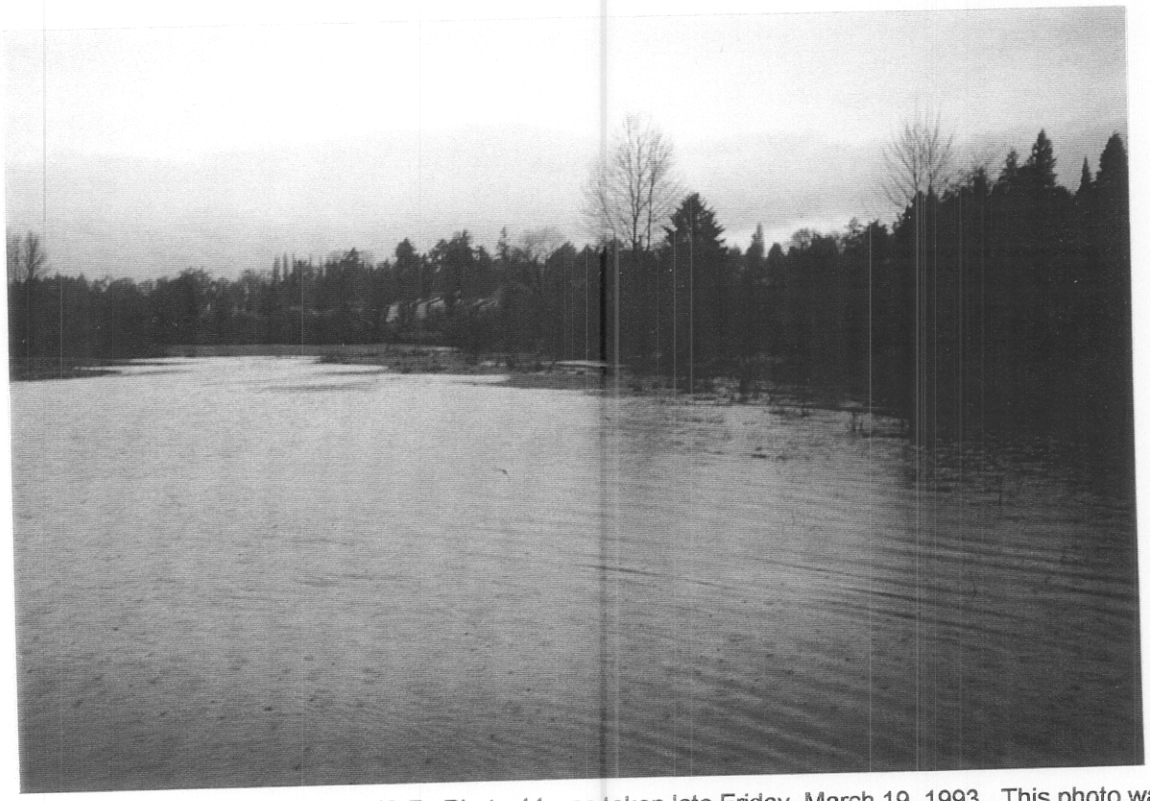


Photo 45 Looking upstream from XS-7. Photo 44 was taken late Friday, March 19, 1993. This photo was taken the following Monday morning after heavy weekend rain. XS-6 is downstream of white residences near centre of photo.

SOMENOS CREEK

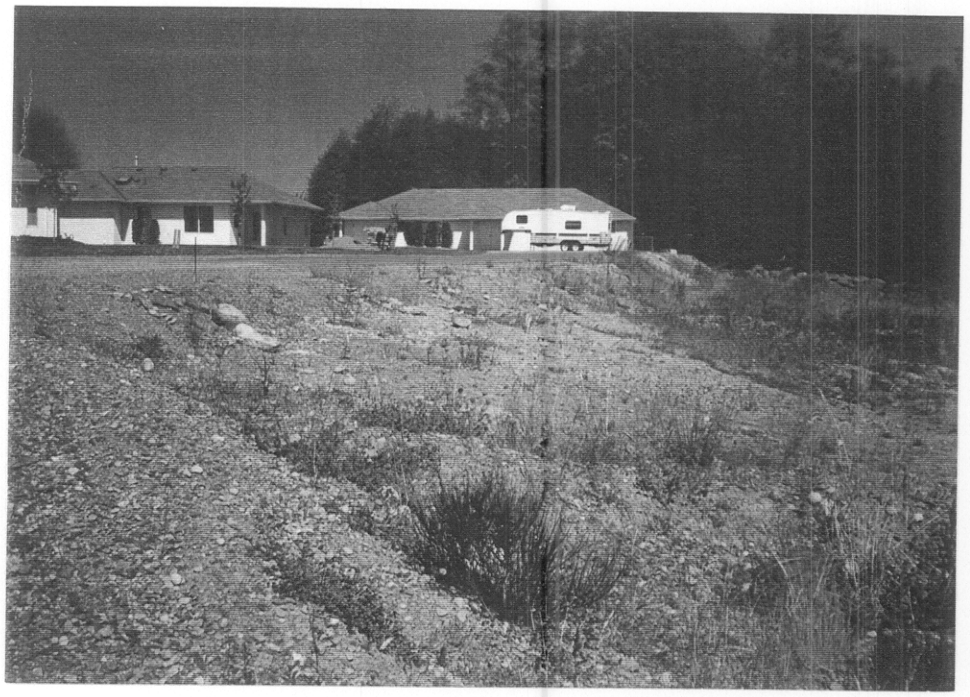


Photo 46 Floodproofed residential development west of Lakes Road, north of Tzouhalem Road.

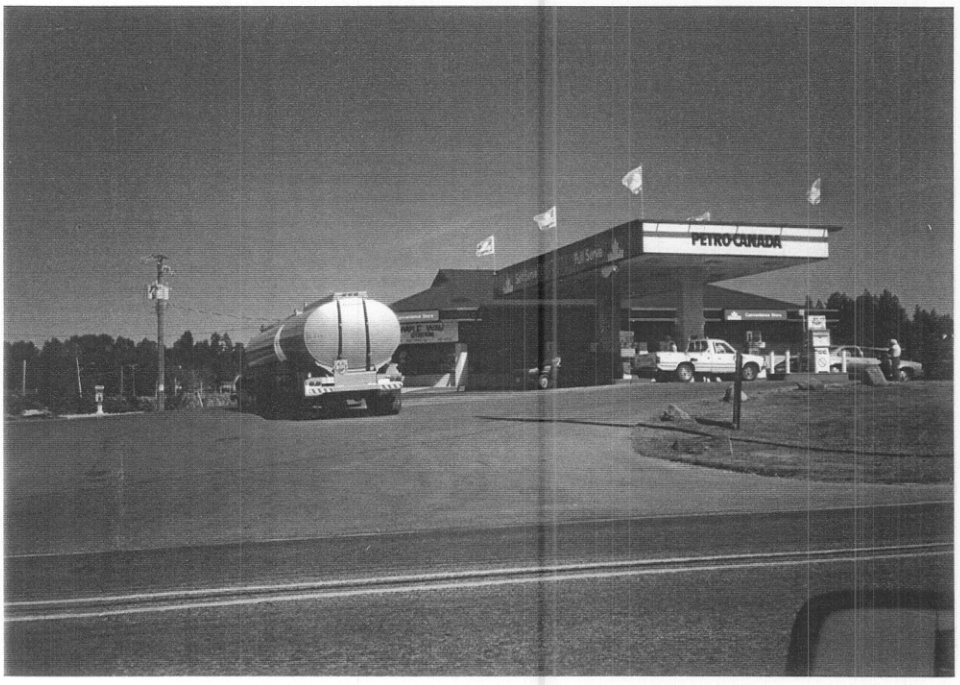


Photo 47 Floodproofed service station at Tzouhalem and Lakes Road intersection.

SOMENOS CREEK

Photo 48 Looking to the right bank and upstream at XS-10. Note overflow extending to sewage lagoon dyke and overflow at the upstream left bank.

SOMENOS CREEK

Photo 49 Looking downstream from XS-11. Normal incised channel is between grassy top by boat and grassy clump opposite, flowing to brown bush at left of photo.

Photo 50 Looking downstream to XS-12 (Somenos)/XS-28 (Cowichan). High Cowichan flow is preventing Somenos outflow causing upstream flooding depicted in photos 45, 48 and 49.

QUAMICHAN LAKE

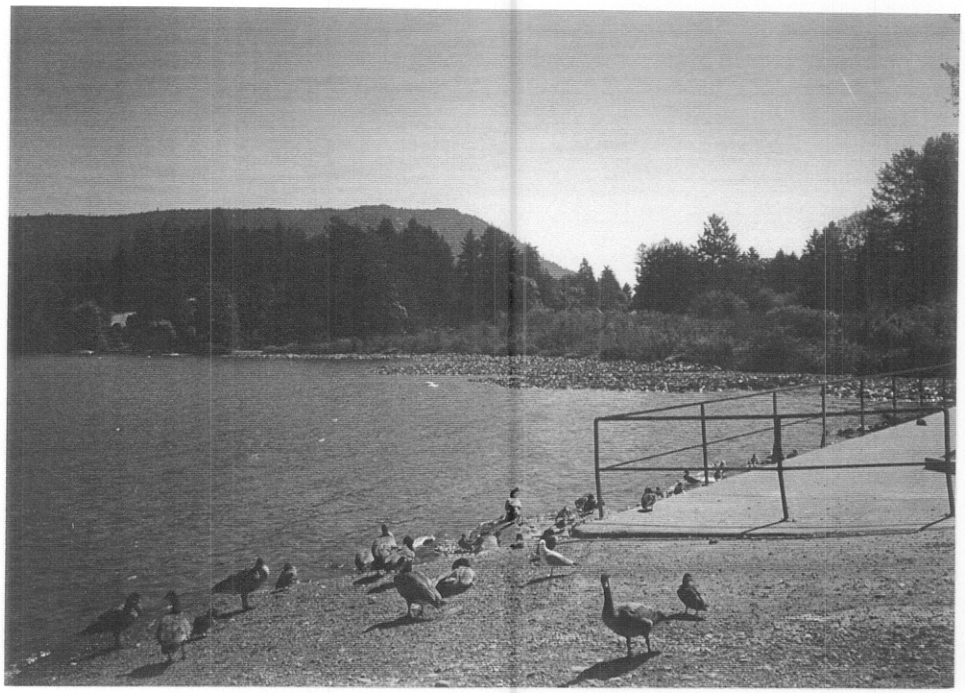


Photo 51 South end of Quamichan Lake east of the parking area at the end of Indian Road. Note weed growth.

Photo 52 New floodproofed residential development on Indian Road just south of Quamichan Lake.

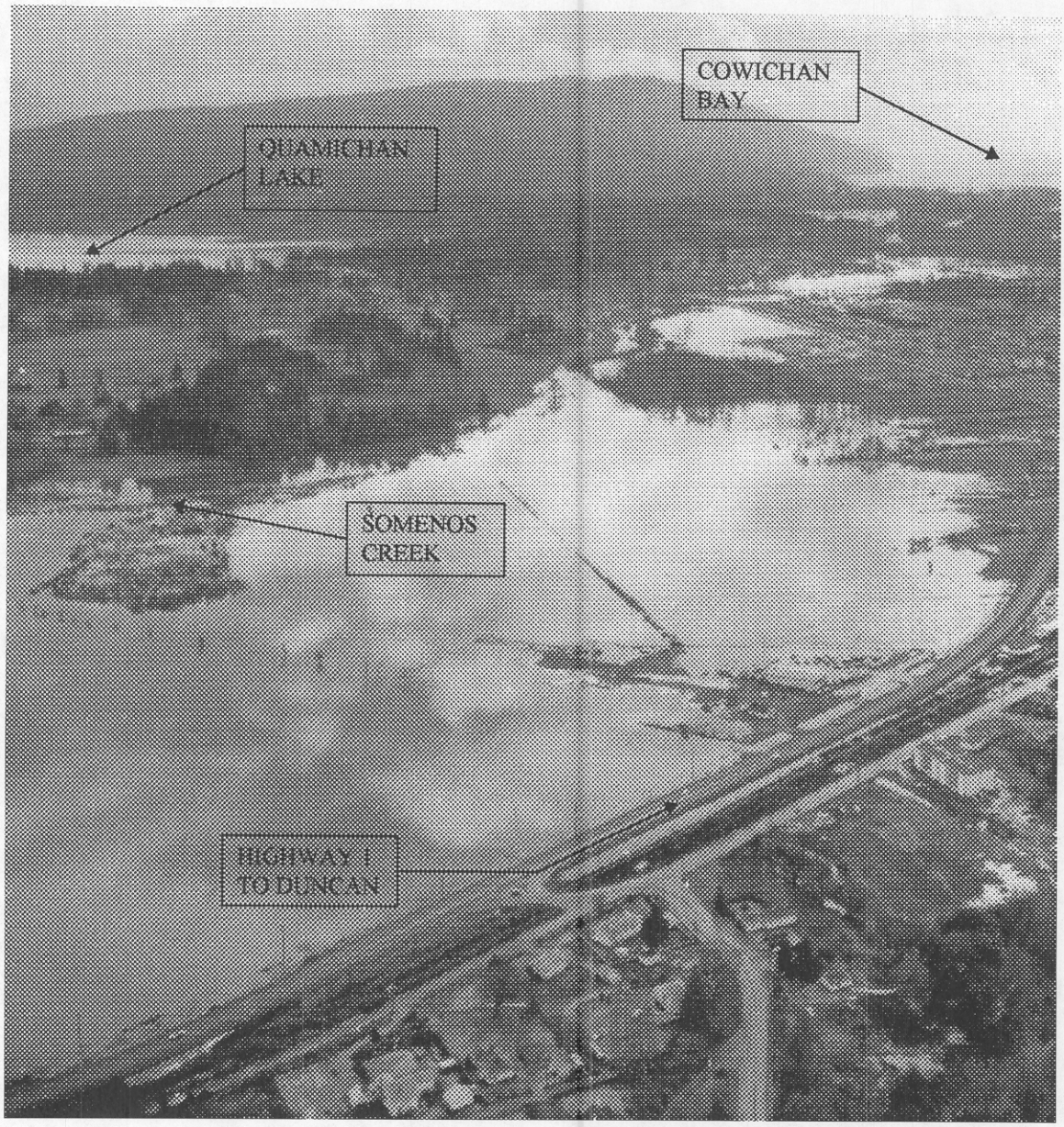


Photo O1 Looking east southeast from Highway 1 and Canada Avenue.

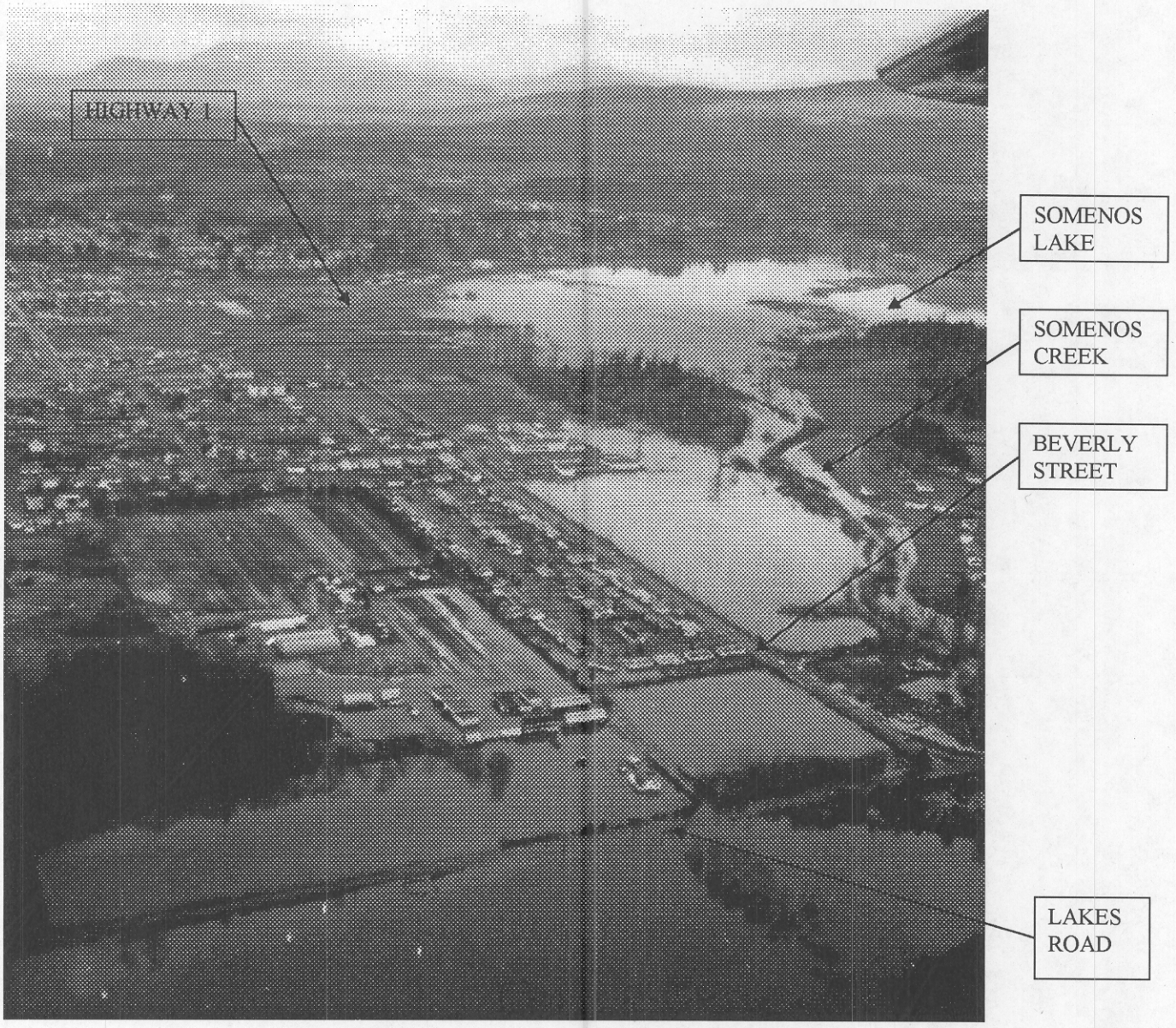


Photo O2 Looking northwest from Lakes Road

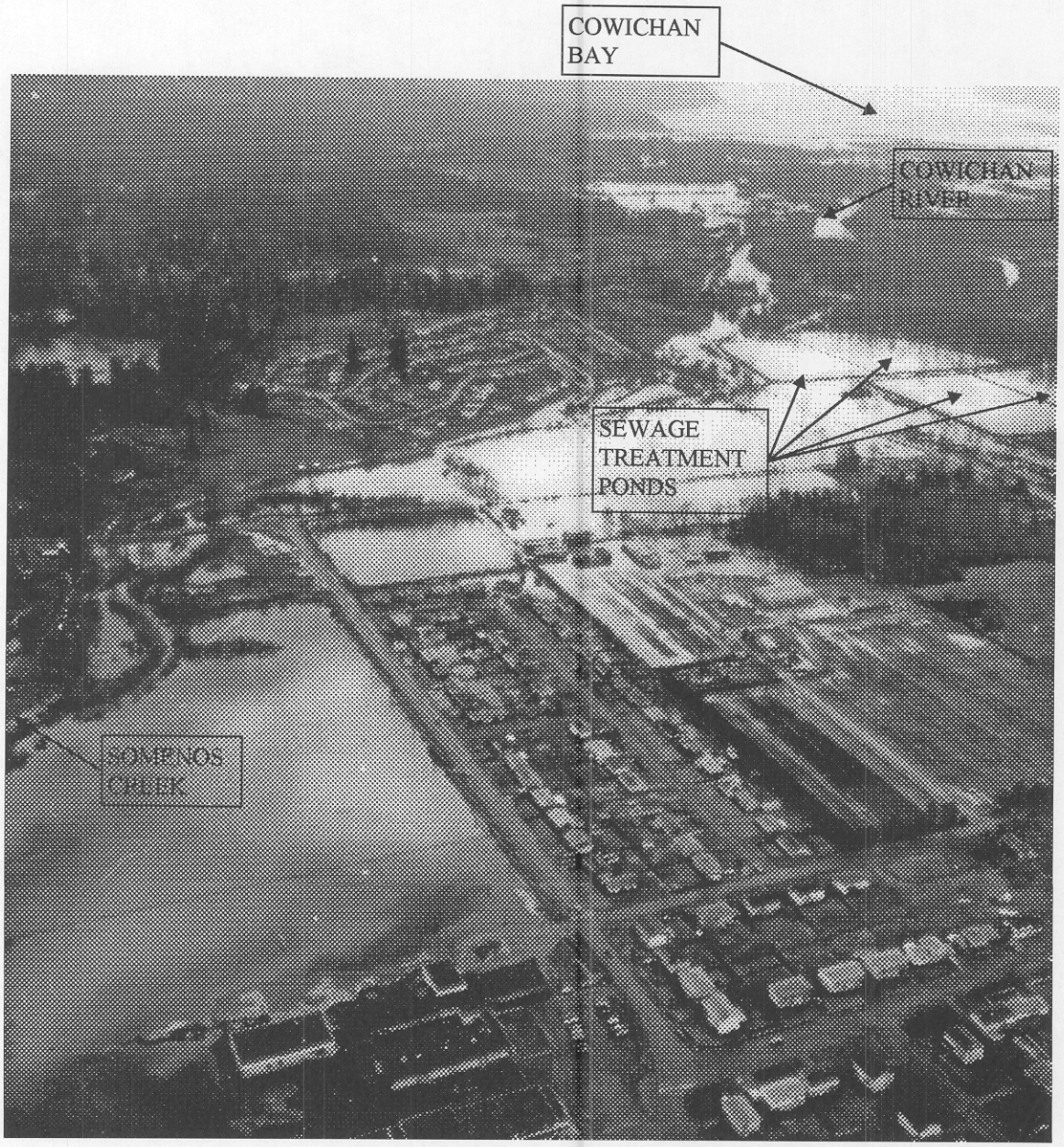


Photo O3 Looking southeast

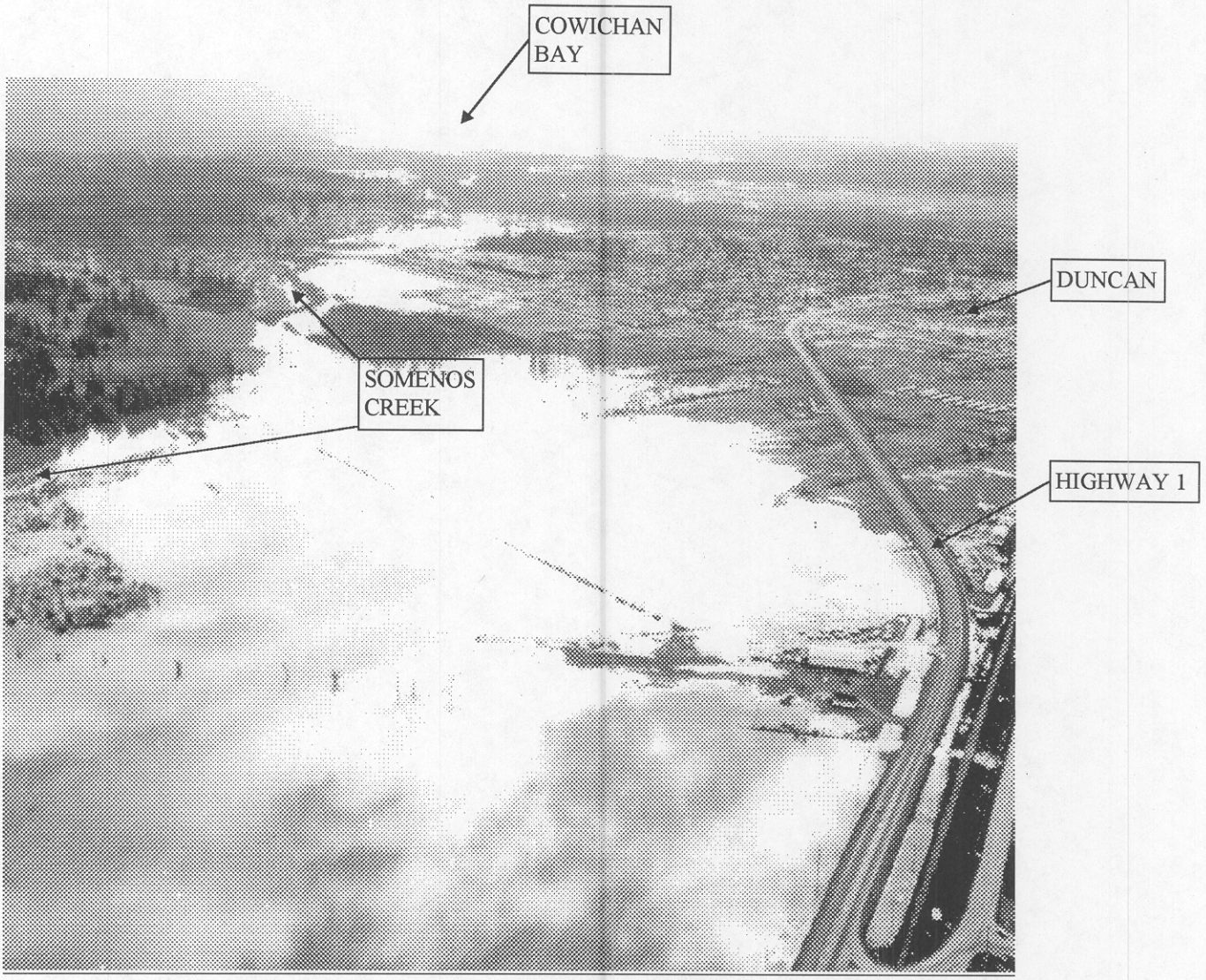


Photo O4 Looking southeast from Highway 1 and Canada Avenue.