CANADA/BRITISH COLUMBIA
FLOODPLAIN MAPPING AGREEMENT
Ministry of Environment, Lands and Parks
Water Management Division

A Review of the Floodplain Mapping for the Lillooet River near Pemberton, B.C.

Hydrology Branch
Victoria, British Columbia
January 1995
File: 35100-30/119-0000

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FLOODPLAIN MAPPING REVIEW
LILLOOET RIVER

PREFACE

This review has been undertaken by the writer under the direction of Mr. R.W. Nichols, P.Eng., Head, Floodplain Mapping Program, Hydrology Branch.

The review was undertaken to assess the adequacy of the floodplain mapping for the Lillooet River, Drawing No. 88-44, Sheets 1 through 11. Figure 1 is the Key Plan from the floodplain mapping project catalogue which indicates the location of the mapsheets.

The review was based on information obtained as a result of the major flood which occurred on August 30, 1991 in the study area. This information is summarized below:

1) High water marks from the flood were recorded and documented throughout the study area (Appendix 1.1),

2) A hydrology study utilizing the flow data from the August 30, 1991 flood event was completed (Appendix 2),

3) River monitoring cross sections were obtained in July 1993 and compared with data obtained in 1969, 1978 and 1985 (Appendix 1.2).

Other detailed information sources which were used in the review are listed in Appendix 1.

1. BACKGROUND TO REVIEW

1.1 Previous Studies

Floodplain mapping was originally produced for the Lillooet River in December 1973, as drawing number 5022 sheets 1 to 10, and further revised in 1980. The orthophoto mapping was at 1:5000 scale and utilized 5 foot contour intervals.

In October of 1984, major flooding occurred in the Pemberton valley resulting in major damages to the dyking system, rail lines, roads, bridges and other infrastructure. Following this event, field reconnaissance surveys were undertaken to identify high water mark locations and elevations. Subsequently, a two volume report was prepared by H. Nesbitt-Porter P. Eng of B.C. Environment entitled "Pemberton Valley Flood Protection - 1985 Study" (Appendix 1.3).

Volume 1 of the report outlines historical riverine activities in the Pemberton Valley, damage assessments from the 1984 event and proposed remedial works, improvements and alternatives to the dyking system. Volume 2 contains a series of mosaics which provide the location of river cross sections, proposed and existing bank protection, dykes, culverts etc. Also contained in Volume 2 are thalweg and flood profiles for the various watercourses in the study area. Upon release of the report, major works to extend and upgrade portions of the dyking system to a 1:200 year standard were undertaken.

As a result of the 1984 flood event, new base contour mapping was requested for the preparation of updated floodplain mapping for the area. The base mapping prepared was 1:5000 scale with 1 metre contour intervals. Surveys were undertaken to determine high water mark elevations and to document the "as constructed" works and channel configurations. Hydrology studies were updated to reflect the recent data. This new information was then combined to produce the September 1990, Lillooet River floodplain mapping, Drawing Number 88-44, sheets 1-11, currently in use. Details of the studies undertaken to produce the floodplain mapping are contained in "A Design Brief on the Floodplain Mapping study - Lillooet River" (Appendix 1.4)

1.2 1991 Flood

During August of 1991 unusually heavy rains fell upon the southwest corner of the province. The area known as the "Sea to Sky" Corridor (Howe Sound to Lillooet), received major flood damages on August 30, 1991. Particularly hard hit, were the communities of Britannia, Squamish, Whistler and Pemberton (Figure 2) where heavy rains falling in early August left ground conditions primed for the subsequent event of August 30, 1991. Peak flows for the year were recorded on a number of watercourses within those areas.

Staff members of the Flood Hazard Identification Section (FHIS), Flood Control and Response Sections (FCRS) and the Major Projects Section (MPS) along with Regional Water Management staff of B.C. Environment responded to the flooding reports. Videotape footage filmed from a helicopter during the event was obtained and transferred to VHS format videotape (Appendix 1.5). Details of the flood damages in the corridor area can be found in a report by Mr. A.A. Brown of the Flood Control and Response Section entitled "Squamish Area Flooding - Proposed Restoration Works" (Appendix 1.6). Following is a summary of the incidents which occurred along the "Sea to Sky Corridor":

1.2.1 Britannia

At Britannia, a small community located on the eastern shore of Howe Sound, landslides in the upper watershed of Britannia Creek triggered debris flows through the lower reach which resulted in inundation of the main community area. Residents within the alluvial fan area were evacuated as flood waters deposited gravel and debris to an average depth of approximately 1 metre over the fan area. A major channel avulsion occurred, resulting in damage to sewer and water services.

1.2.2 Squamish

At the head of Howe Sound, the District of Squamish experienced high water conditions on the Squamish, Mamquam and Cheakamus Rivers and their tributaries. Damages were sustained to roads, bridges, dykes and bank protection works. A main water supply intake on Mashiter Creek was cutoff when upstream slope failures resulted in inundation of the structure. On the Cheakamus River, damages occurred to the abutments of the "Bailey Bridge" on the road leading to Paradise Valley and the dyke at the upstream end of the North Vancouver Outdoor School was overtopped.

1.2.3 Whistler

Further up the corridor, severe flooding, erosion and debris flows occurred on Fitzsimmons Creek which flows through the ski resort area of the District of Whistler. Major damages occurred to bridges, rail lines and utility services. Emergency personnel were put on alert as a major potential landslip was identified along Fitzsimmons Creek above the townsite.

Fitzsimmons Creek is a tributary to the Green River which flows into the Lillooet River near Pemberton (Figure 2). Green Lake which Fitzsimmons Creek flows into, reached the highest level experienced since 1956. Alta Lake, another headwaters lake in the Green River watershed, experienced the highest observed levels in 52 years (Appendix 1.7).

1.2.4 Pemberton

Farther north, the farming and logging community of Pemberton experienced major flood flows on the Lillooet, Green and Ryan Rivers. High water marks were obtained along the Lillooet River from the airport upstream to the vicinity of Wolverine Creek near the upper limits of the floodplain mapping (Appendix 1.1).

Lillooet Lake reached its highest level on record and it was reported that the road along the lake leading to Duffey Lake was submerged cutting off access to the Village of Lillooet (Figure 2) from the west.

Just above the confluence of the Lillooet and Green Rivers, floodwater totally inundated the municipal airport facility and a temporary trailer camp for the Ministry of Forests "Rap Attack" (forest fire suppression) crew. Airplanes, vehicles and trailers at these locations were damaged, equipment and supplies lost. Floodproofing of the airport electrical, weather and control facilities proved effective.

Upstream on the Lillooet River floodwater eroded through and old agricultural berm in the vicinity of the "McKenzie Cut". This resulted in flooding of pasture lands as the waters passed through to the confluence with the Ryan River and Miller Creek.

Floodwater from the Ryan River overtopped the Pemberton Meadows road and the dyke on the Ryan River was breached in the vicinity of the rock quarry. This resulted in many acres of crops being flooded. In an effort to minimize the damage to the crops, the Pemberton Meadows road was purposely breached to accelerate the release of impounded floodwater as culverts in place proved to be inadequate to relieve the floodwater quickly. A temporary bridge at this site was made utilizing and old flatdeck railcar to allow traffic to continue through the area. The road has since been restored.

Further upstream on the Lillooet River, at the forestry bridge near the upper limits of the floodplain mapping, flood damages were minimal. Upstream of the bridge, the right bank is dyked to ministry standards. Flood waters at this location barely reached the toe of the dyke. On the downstream side of the bridge some flooding of the fields occurred when floodwater exceeded bank full conditions and entered the fields through a low swale. Damages at this location were minimal.

2. FLOOD MAGNITUDES

2.1 Lillooet River

Water Survey of Canada (WSC) has been operating Gauge 08MG005, Lillooet River near Pemberton, from 1914 to 1918 and 1923 to date. This gauge provides 74 years of daily flow records and 40 years of instantaneous records (Appendix 1.8). Major flows (>700 m^3/s daily) have occurred 7 times during the period of record, 5 of which occurred in the last 20 years, 4 have occurred since 1980. The August 30, 1991 flow is the highest flow on record at 1260 m^3/s daily. October 19, 1940 ranks as the third largest flow during the period of record at 900 m^3/s daily.

The designated 1:200 year flood flow utilized in the 1989 floodplain mapping study at this gauge was 992 m^3/s daily and 1170 m^3/s instantaneous. At the time of the 1989 studies, the October 1984 event was the greatest flow experienced during the period of record at this gauge at 1110 m^3/s daily and 1310 m^3/s instantaneous. During the 1984 event, flood waters bypassed this gauge because of the Miller Creek dyke breach. The flow for this event was estimated based upon the gauged flow plus the calculated flow through the dyke breach. Hydrology studies conducted for the 1989 floodplain mapping project concluded the October 8, 1984 flow to be greater than a 1:200 year frequency (Appendix 1.9).

As a result of the August 30, 1991 event, hydrology studies were again requested to determine the effects of this flood on the 1:200 year discharge estimate. Table 1 (from Appendix 2) indicates the adopted 1:200 year flows and revised flows at the various locations along the watercourses in the study area. Also included in Table 1, is the 1989 estimate used to produce the floodplain mapping sheets. The most recent estimates at the WSC gauge 08MG005 are approximately 20% higher than used in the 1989 floodplain mapping study.

The recorded flow for the 1991 event at the gauge was 1260 m^3/s daily and 1410 m^3/s instantaneous. The updated studies by the Hydrology Section (Appendix 2) has now determined the 1:200 year flows to be increased to 1230 m^3/s daily and 1400 m^3/s instantaneous thereby giving the August 30, 1991 event about a 1:200 year frequency.

2.2 Lillooet Lake

WSC also operates a water level recorder on Lillooet Lake. This gauge, 08MG020, has been in operation since 1971, except 1977, and provides both daily and instantaneous measurements.

The August 30, 1991 event produced the highest lake levels recorded during the period of record at 199.70 metres GSC. The updated estimates of the 1:200 year instantaneous (I) level is 200.34 m GSC. The 1:200 year daily (D) level is 200.15 m GSC (Appendix 2). The flood level for Lillooet Lake used for administrative purposes by the Ministry since October 1976 is 201.0 m GSC or 1.3 metres above the highest recorded level.

2.3 Pemberton Creek

WSC Gauge 08MG025 has been in operation since 1987 and provides daily and instantaneous readings. The 1:200 year estimate has been updated from the 1990 study for this small drainage basin (31.9 km^2).

2.4 Green River

There are no gauges currently in operation on the Green River. August 30, 1991 flow estimates are based upon studies done previously for the Whistler area (Appendix 1.7). Local residents indicated the Green Lake (at the head of Green River) level to be the highest since 1956. The outlet flow (I) from Green Lake for the August 30, 1991 flood was estimated to be 163 m^3/s. This corresponds to a 50 year return period flow based on the recent hydrology estimates (Table 1).

Gauge 08MG003 Green River near Pemberton was in operation from 1914 through 1951 providing daily flow records during the period and instantaneous records from 1932 to 1951 except 1940. The greatest daily flow on record was estimated at 402 m^3/s and occurred on Oct. 19, 1940 coincidently with the largest flow on record to that date on the Lillooet River at gauge 08MG005.

3. HYDROMETRIC REVIEW

In addition to the hydrometric stations listed in Section 2 a review of other stations, both active and inactive, within the Lillooet River watershed was conducted. Figure 3 (from WSC streamflow data) indicates the location of these stations. As stated previously, October 19, 1940 was a significant event on the Lillooet system, where major flows were recorded on tributary watersheds. Similarly, October 16, 1926 produced simultaneous peaks on Lillooet River tributaries.

Following are additional stations that were active during the 1940 and 1926 events:

3.1 Rutherford Creek

Rutherford Creek is tributary to the Green River and drains 179 km^2 to the west of the Lillooet River. WSC Station 08MG006 Rutherford Creek near Pemberton was active during the period 1914 through 1947 providing daily discharge records only. Maximum daily discharge for the October 19, 1940 event is published by WSC at 141 m^3/s.

3.2 Soo River

WSC station 08MG007 Soo River near Pemberton was in operation during the period of 1925 through 1947 and provided daily discharge readings. The Soo River watershed is tributary to the Green River lying to the west of the Rutherford Creek watershed and drains 283 km^2. Daily discharge for the October 19, 1940 event is published by WSC at 184 m^3/s and is the flood event of record.

3.3 Green River near Rainbow

WSC Station 08MG004 was in operation in 1913 and 1924 through 1947 and provided daily discharge readings. Peak flow during this period occurred on October 19, 1940 at 77.3 m^3/s.

Graphs of the October 19, 1940 and October 1926 events indicating the concurrent peaks is shown in Figure 4 and 5. The graphs indicate that peak daily flows can and have occurred simultaneously within the Lillooet River watershed.

Table 2 indicates the concurrent flows of the watersheds contributing to the Lillooet system during the 1940 event. The table indicates that the combined flow at Lillooet Lake may have been in excess of 1300 m^3/s daily and would rank as about a 1:50 year event based on current hydrology estimates.

4. HYDRAULIC ANALYSIS

4.1 High Water Mark Data

High water mark data was obtained by the writer at 45 locations along the Lillooet River for the August 30, 1991 event (Appendix 1.1). These locations were photo identified for later survey by members of the Technical Support Section (TSS). Results of this survey are summarized in Table 3. As indicated, the 1991 instantaneous flood levels were less than or equal to the flood levels as shown on the floodplain mapping sheets which include an allowance for hydrologic and hydraulic uncertainties.

4.2 Survey Data

At the request of the Flood Control and Response Section (FC&R) and the Water Management Branch in Surrey, survey data was obtained by TSS in July 1993 for cross sections 6 through 16.1 along the Lillooet River to monitor the possibility of channel aggradation in this area. The reach extends from approximately 1.2 km downstream of Gravell Creek (Sheet 2) upstream to approximately 0.9 km above the highway bridge (Sheet 5) a distance of about 8.5 km. The survey data was compared to data obtained from previous surveys in 1985, 1978 and 1969. Plots of these cross sections are contained in Appendix 1.2. Figure 6 shows a typical cross section plot in this reach.

4.3 HEC-2 Analysis

4.3.1 Channel Conveyance

High Water mark data and flow estimates for the August 30, 1991 event were utilized in the HEC-2 analysis. Original modelling for the 1989 floodplain mapping project was performed using HEC-2 on an IBM mainframe computer. The existing HEC-2 model was converted for use on a "PC" microcomputer utilizing the Haestad Methods version of HEC-2 currently in use by FHIS. Output from the converted model compared favourably with the original study results.

Comparisons of the 8.5 km long reach of the Lillooet River for cross sections 6 through 16.1 were made utilizing HEC-2. The computer analyses provided cross sectional areas for the comparative years of 1969, 1978, 1985 and 1993. The top of bank stations were selected as cutoff points, water surface elevations were set for each cross section and flow specified. The results indicate that an enlargening of the channel by about 14% has occurred in this reach during the period of 1969 to 1978. During the period 1978 to 1985 the channel continued to gain some additional capacity, increasing on average 14.8% over 1969. Some fluctuation in channel area has occurred in the successive years however, overall, the channel capacity remains increased approximately 12% on average over 1969 for this reach (Table 4).

4.3.2 Sensitivity Studies

As a matter of standard practice, sensitivity studies are undertaken during the course of modelling. Once the model has been calibrated, the Q200 flows (daily and instantaneous) are run. From these results an allowance of 0.61 metres is added to the calculated daily flood level and compared to the calculated instantaneous level with 0.3 metres added to it. The highest of the two levels is selected as the designated flood level. The allowance is a factor to account for hydraulic and hydrologic uncertainties. Sensitivity studies regarding changes in discharge and Manning's "n" values are then undertaken to determine the adequacy of the selected flood level with freeboard allowance.

The 1989 sensitivity studies found that the freeboard allowance was sufficient to withstand a 25% increase in discharge or a 22% increase to Manning's "n" values (Appendix 1.4). The August 30, 1991 event was of a similar magnitude as the maximum discharge modelled during the 1989 sensitivity studies (ie: approximately 20% greater than the estimated Q200 flow).

As discussed in Section 4.2, high water marks gathered from the event indicate the model to be more conservative for the upper reaches of the study area over the downstream reach (Table 3).

Aerial reconnaissance during the peak of the event indicated a portion of the eastern (left bank) floodplain area in the lower reach, downstream of the Miller Creek confluence, was not inundated. A larger flow would result in a greater area of the floodplain being inundated with minimum increase in the flood level.

The general accuracy of the 1989 floodplain mapping model and the estimated discharge for the 1991 event have been verified by these sensitivity studies and field observations.

5. CONCLUSIONS

1. Hydrology studies conducted as a result of the August 30, 1991 event indicate that the estimated 1:200 year discharge for the Lillooet River at WSC gauge 08MG005 have increased from 992 m^3/s daily and 1170 m^3/s instantaneous to 1230 m^3/s daily and 1400 m^3/s instantaneous. The August 30, 1991 event discharge is equivalent to the recent 1:200 year flood estimates which exceeded the designated flood utilized in the floodplain mapping studies by approximately 20%.

2. The flood levels shown on the October 1990 floodplain mapping sheets (which includes an allowance for uncertainties) proved to be greater than the flood levels which occurred during the 1991 event upstream of the Miller Creek confluence (Table 3).

3. In the area from Lillooet Lake to the Miller Creek confluence, which is affected by the Green River flows, the 1991 flood levels are virtually equal to the flood levels shown on the mapping sheet (Table 3). High water marks and visual observations gathered from the August 30, 1991 event indicate a significant (but ungauged) tributary inflow to the Lillooet River from the Green River system.

4. The hydrology studies also indicate that the 1:200 year estimate for WSC gauge 08MG020 Lillooet Lake has increased to 200.34 m GSC. The designated flood level for Lillooet Lake of 201.0 m GSC adopted by the Ministry in 1976, is 1.3 metres above the highest recorded lake level which occurred on August 30, 1991.

5. The comparison of cross sections 6 through 16 for the years 1969, 1978, 1985 and 1993 indicate the reach to be stable, with little change in channel capacity having taken place since 1978.

6. RECOMMENDATIONS

1. The flood levels as determined from the 1989 studies be retained as shown on the floodplain mapping for the Lillooet River Drawing Number 88-44, sheets 1 through 11. The flood levels have been determined to be adequate, accurate and useful pursuant to clause 7 (3) (i) (I) of the Canada/British Columbia Agreement Respecting Floodplain Mapping. The drawings should be modified to indicate that a review of the mapping has taken

place as a result of the August 30, 1991 flood event.

2. The Ministry should review the floodplain mapping to maintain the adequacy, accuracy and usefulness of the existing information when significant floods, erosion rates, floodplain development or other situations occur.

3. The Village of Pemberton, Squamish Lillooet Regional District, Pemberton Dyking District and the Hydrology Section of the Ministry of Environment, Lands and Parks should actively seek the cooperation of Water Survey of Canada in the re-establishment of hydrometric station 08MG003 Green River near Pemberton.

4. The Ministry should continue to encourage local authorities to educate landowners within their jurisdiction regarding the flood threat.

Steve Corner
Project Technician
Flood Hazard Identification Section

Appendix 1

Detailed Information Sources

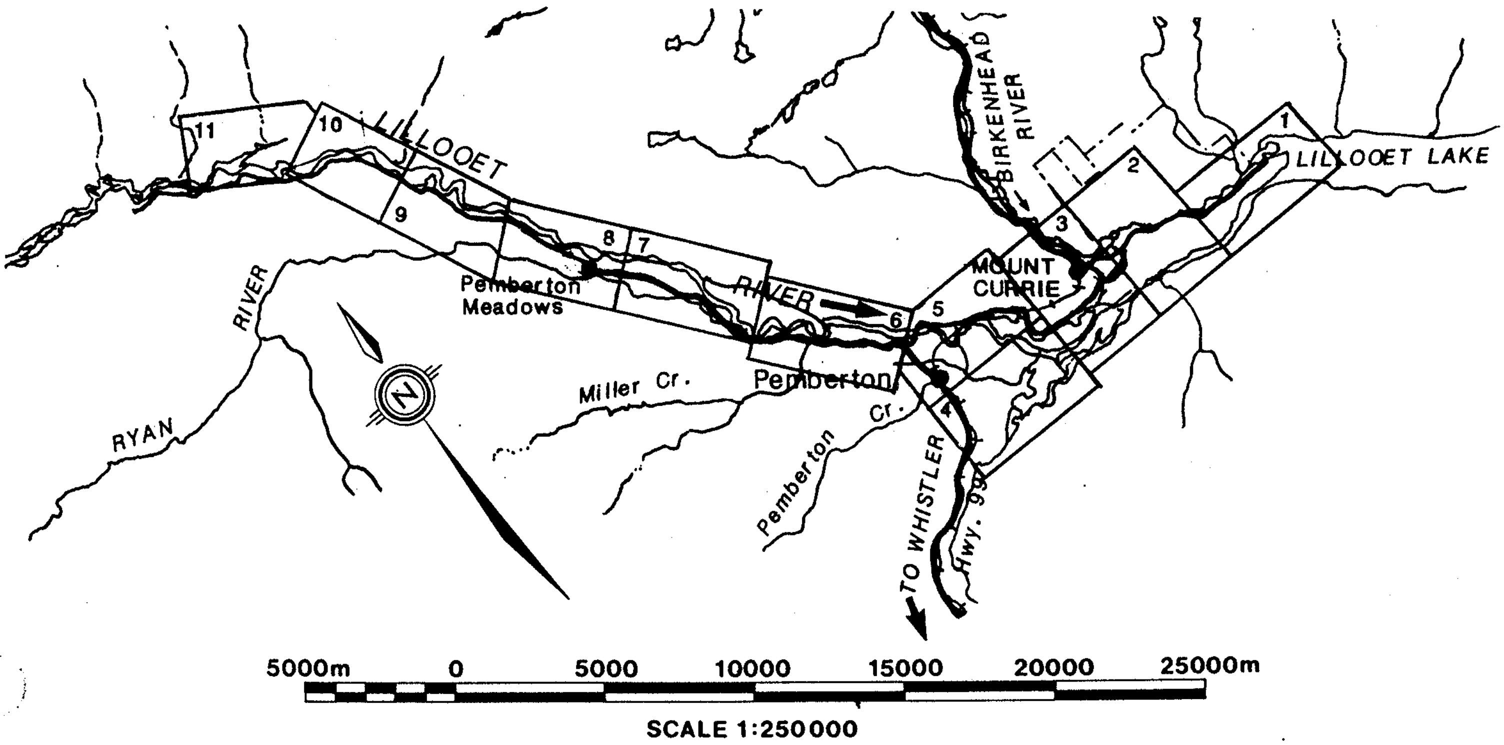
No.	Source	Contents
1.	Project No. 91 29F 022, Whistler-Pemberton High Water Marks, September 1991.	45 high water marks and photographs along the Lillooet River derived from the August 30, 1991 flood event
2.	Project No. 93 18R 038, Lillooet River, dated July 1993.	1993 Survey data for Lillooet River Cross Sections 6 through 16.1 including comparison plots for 1969, 1978 and 1985.
3.	Flood Control and Response Section - Pemberton Valley Flood Protection - 1985 Study, H. Nesbitt Porter, P.Eng.	History of riverine activities in the Lillooet River watershed, includes proposed remedial works and alternatives
4.	Flood Hazard Identification Section, Water Management Division - A Design Brief on the Floodplain Mapping Study - Lillooet River, R.W. Nichols, P.Eng.	An overview of the studies undertaken to produce floodplain mapping for the Lillooet River
5.	Flood Hazard Identification Section: Flooding - Britannia, Squamish, Whistler and Pemberton, August 30, 1991	Helicopter footage by S.Corner, Technician, FHI Section, on VHS videotape of flood locations and damages
6.	Flood Control and Response Section: Squamish Area Flooding - Proposed Restoration Works; A.A. Brown, P.Eng.	Details of the August 30, 1991 Flood Damages and Restoration Works for Britannia, Squamish, Whistler and Pemberton
7.	Flood Hazard Identification Section: A Design Brief on the Floodplain Mapping Study - Whistler Area, R.W. Nichols, P.Eng.	An overview of the studies undertaken to produce floodplain mapping for the Resort Municipality of Whistler

Appendix 1
Detailed Information Sources

No.	Source	Contents
8.	Water Survey of Canada - Historical Streamflow Summary - British Columbia	Listings of recorded daily and instantaneous discharges for streams throughout the province.
9.	Hydrology Division, Water Management Branch: Study S2105 dated June 26, 1985	Results of studies to predict the 1:200 flood frequencies and peak flows for the October 1984 event.

CANADA - BRITISH COLUMBIA

FLOODPLAIN MAPPING PROGRAM



KEY PLAN

LILLOOET RIVER

DRAWING NO. 88-44 SHEETS 1 TO 11

NTS REF. 92J

ISSUED OCTOBER 1990

For ordering information see Page B17-18 in the MAPS-BC Catalogue or contact:

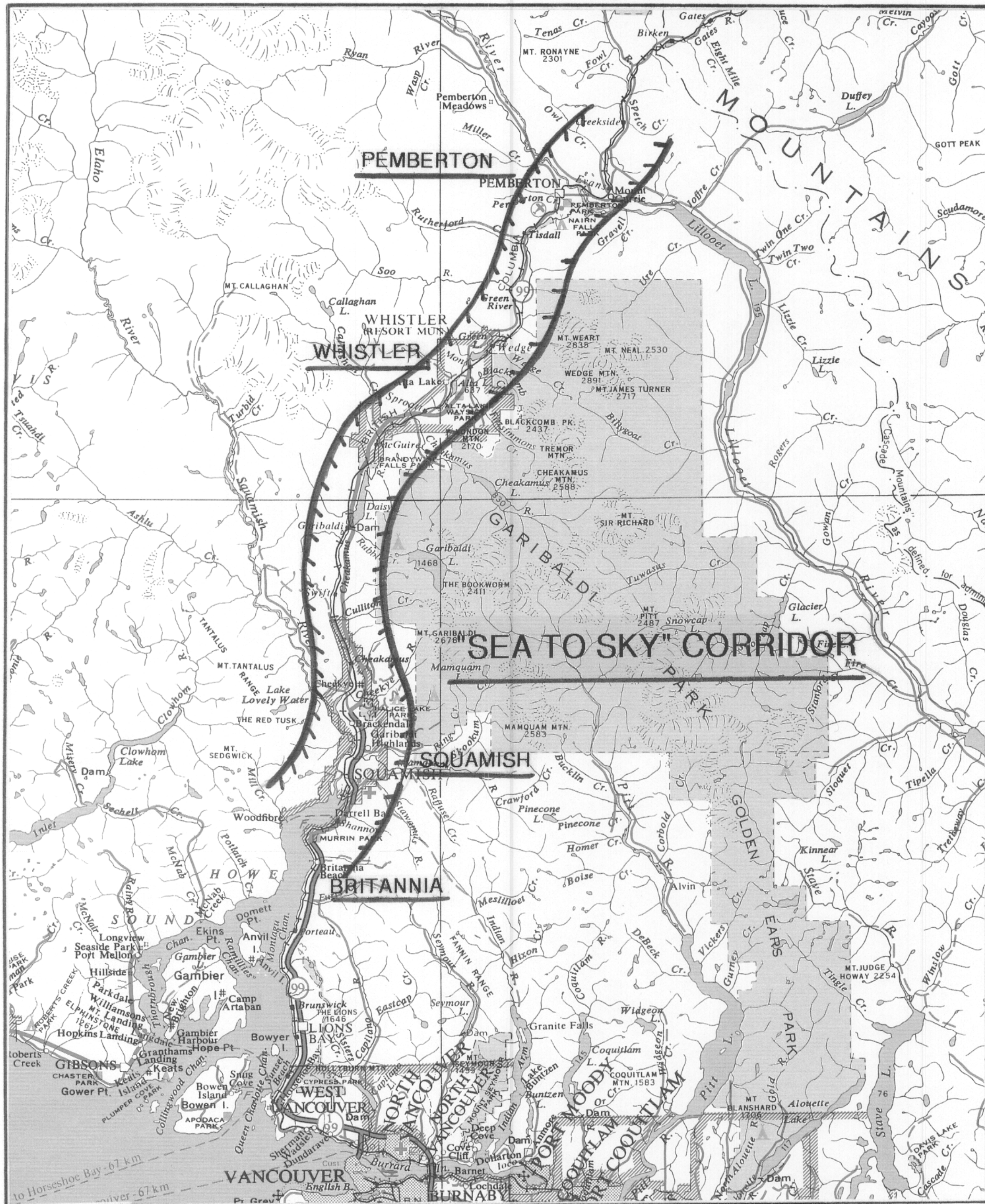
MAPS-BC
FLOODPLAIN MAPS
SURVEYS AND RESOURCE MAPPING BRANCH
B.C. MINISTRY OF CROWN LANDS
1802 DOUGLAS STREET
VICTORIA, B.C.
V8V 1X5
Telephone: (604) 387-1441
FAX: (604) 387-3022

Note: Be sure to include both the Drawing Number and Sheet Number

Environment Canada   Environnement Canada

BC Environment

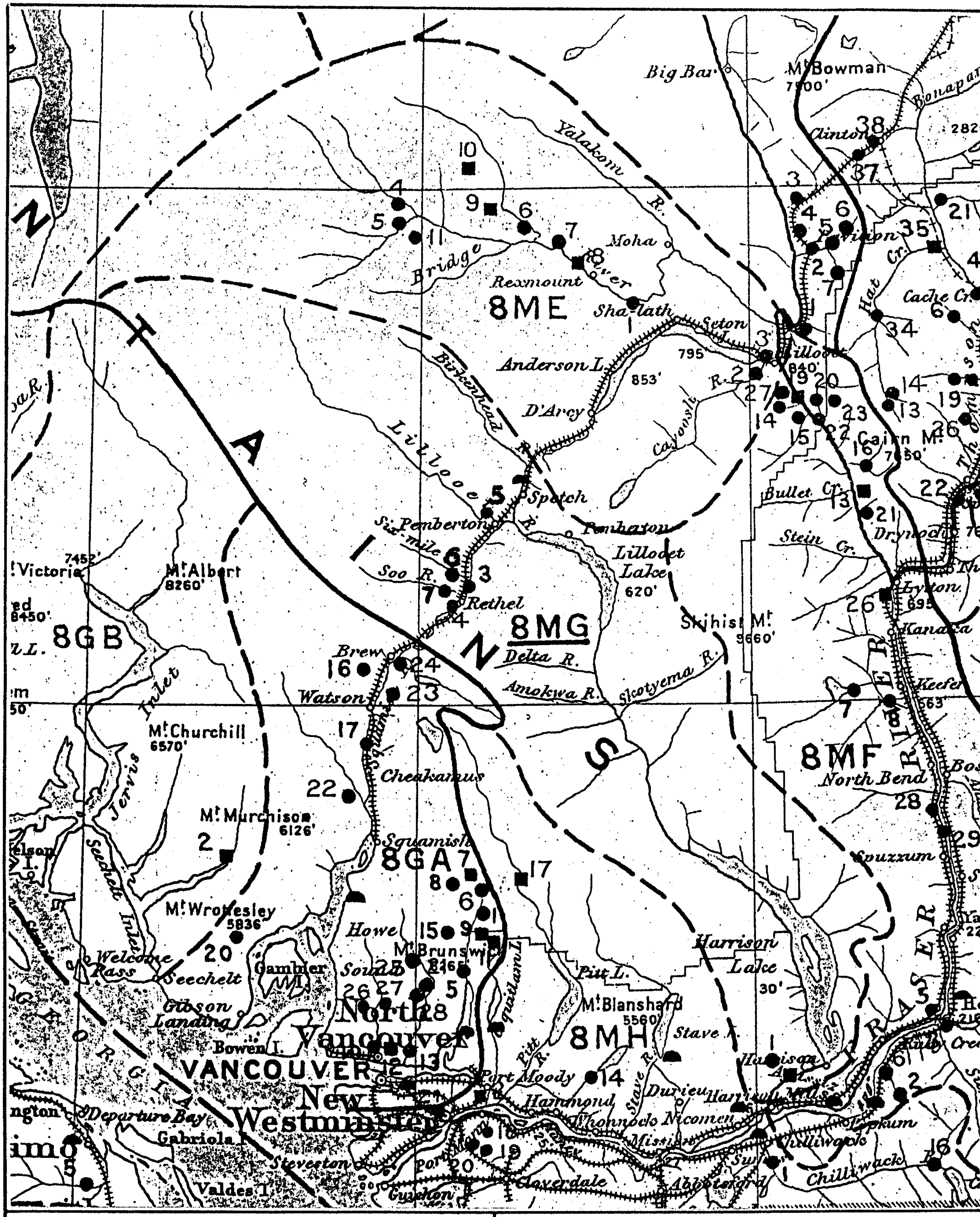
FIGURE 1



Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON
LILLOOET RIVER
FLOODPLAIN MAPPING REVIEW
"SEA TO SKY" CORRIDOR

SCALE: VERT. HOR. NOT TO SCALE	DATE OCTOBER 1994	S. CORNER TECHNICIAN
		FILE No. 35100-30/119-0000 DWG. No. FIGURE 2



TO ACCOMPANY REPORT ON

LILLOOET RIVER FLOODPLAIN MAPPING REVIEW

HYDROMETRIC STATION LOCATIONS

Province of British Columbia

Ministry of Environment

WATER MANAGEMENT BRANCH

SCALE: VERT. HOR. NOT TO SCALE	DATE OCTOBER 1994	S. CORNER TECHNICIAN FILE No. 35100-30/119-0000 DWG. No. FIGURE 3

VAN CAL 15712

FIGURE 4

LILLOOET RIVER WATERSHED GAUGES
OCTOBER 1940 EVENT

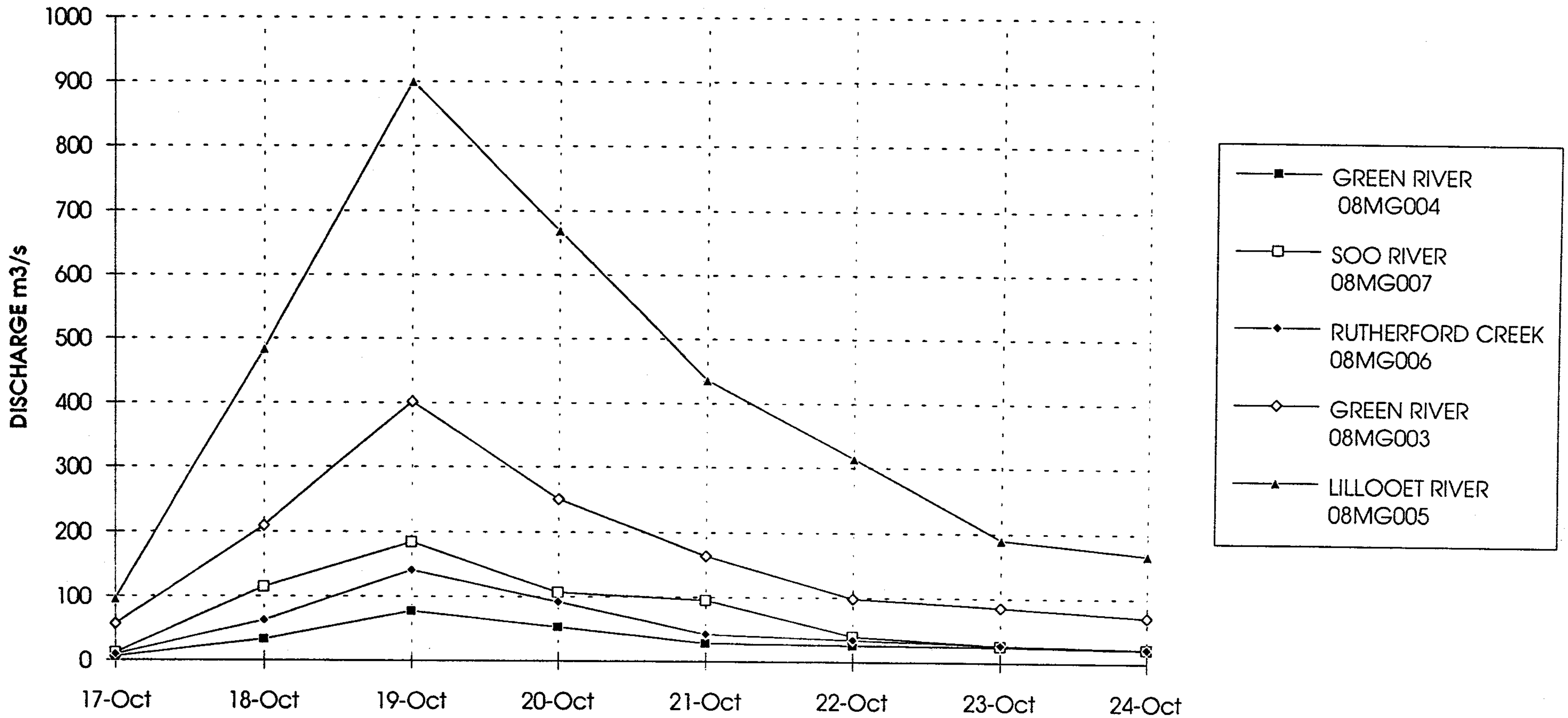
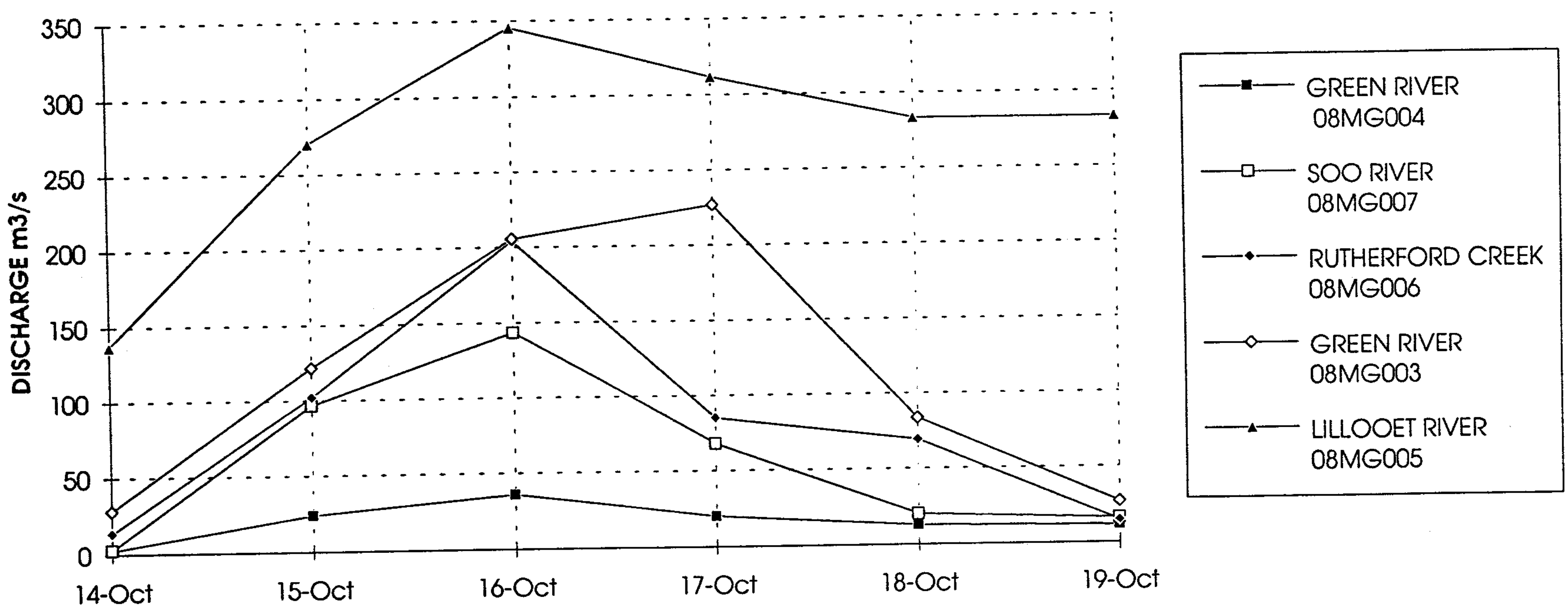
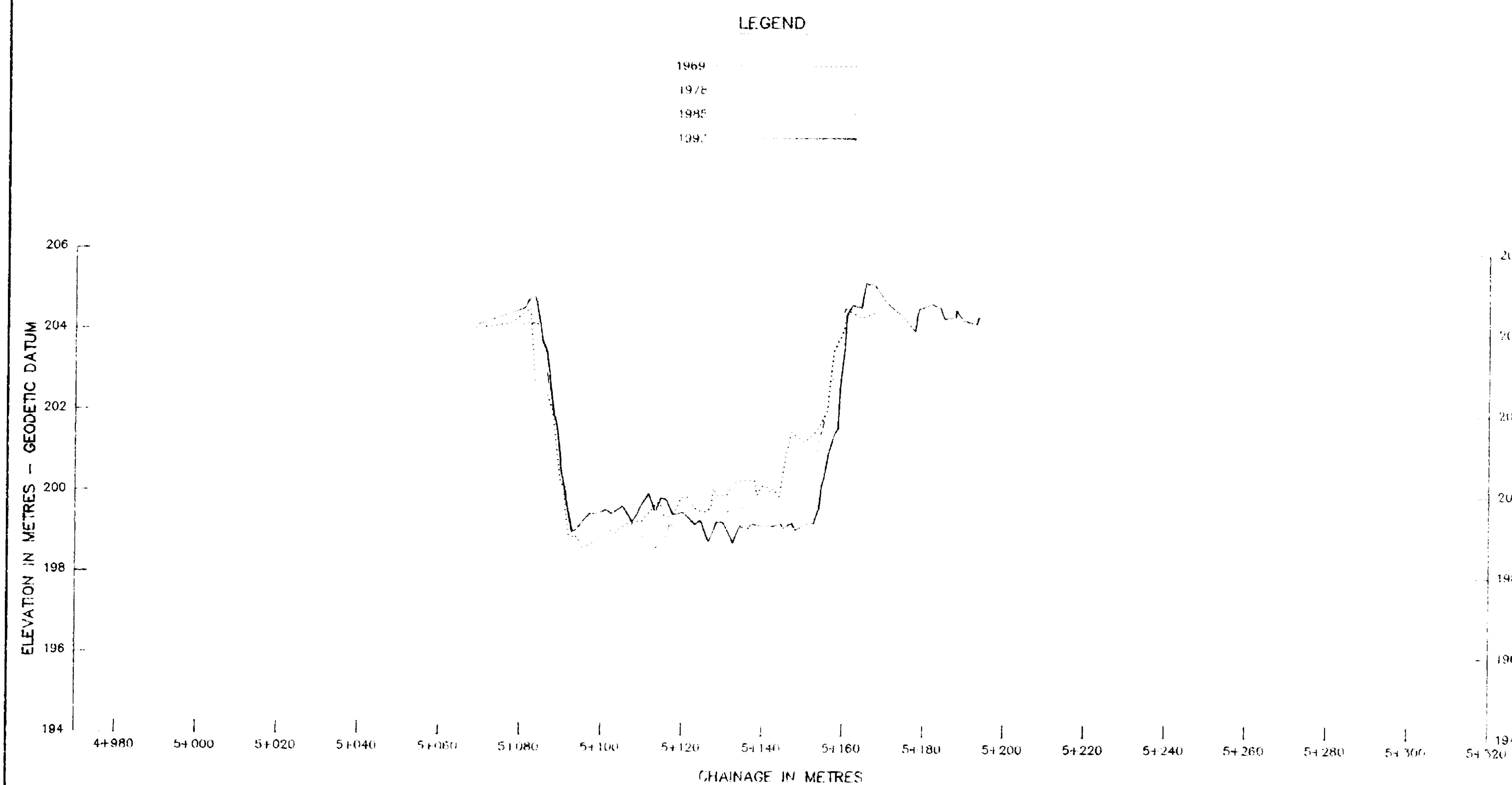


FIGURE 5

LILLOOET RIVER WATERSHED GAUGES
OCTOBER 1926 EVENT





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

LILLOOET RIVER
CROSS SECTION NO. 11

SCALE: HORIZ. 1:1000 VERT. 1:100	
PROJECT NO: 9318R038	DATE: JULY 1993

FIGURE 6

TABLE 1 LILLOOET R BASIN FLOOD

92-09-14																
FLOOD FLOW EVENT							08MG005								08MG008	
		LILLOOET R AB WOLVERINE	TRIB FLOW	LILLOOET R AB RYAN R	RYAN R AT MOUTH	MILLER CR AT MOUTH	LILLOOET R NR PEMBERTON	08MG025 PEMBERTON CR	PEMBERTON CR AT MOUTH	LILLOOET R AB GREEN R	GREEN R AT OUTLET GREEN LK	GREEN R AT MOUTH	TRIB FLOW	LILLOOET R AT LAKE	BIRKENHEAD R	BIRKENHEAD R AT MOUTH
Drainage area	km2	1558	71	1629	419	77.7	2160	31.9	51	2218	189.5	868	76	3162	597	638
DAILY PEAK FLOWS																
Aug. 30, 1991	m3/s	985	33.5	1,018	330	90.1	1260	16.6	24.0	1284	147	476	25.08	1673	149	160
	L/s/km2	632	471	625	788	1160	583	520	470	579	776	548	330	529	250	251
	% of 8MG005	78.1	2.7	80.8	26.2	7.2	100	1.3	1.9	101.9	11.7	37.8	2.0	133	11.8	12.7
Oct. 8, 1984	m3/s	835	28	863	330	124	1110		24.4	1139		350	22.8	1513	149	160
	L/s/km2	536	394	530	788	1596	514		478	514		403	300	478	250	251
	% of 8MG005	75.2	2.5	77.7	29.7	11.2	100.0		2.2	102.6		31.5	2.1	136	13.4	14.4
20 year return period	m3/s	625		648	256	100	817		17	827		382		1090	267	278
50 year return period	m3/s	753		779	323	124	963		22	980		478		1280	338	354
200 year return period	m3/s	963		995	432	171	1230		29	1250		660		1640	536	565
INSTANTANOUS PEAK FLOWS																
Aug. 30, 1991	m3/s	1132		1171	429	117	1410	21.9	31	1438	163	590		1840	194	208
	I/D	1.15		1.15	1.3	1.3	1.12	1.32	1.3	1.12		1.24		1.10	1.3	1.3
Oct. 8, 1984	m3/s	1002		1049	430	174	1310		36.6	1344		392		1755	194	208
	I/D	1.2		1.2	1.3	1.3	1.18		1.5	1.18		1.12		1.16	1.3	1.3
Return Period I/D		1.13		1.13	1.3	1.3	1.13		1.3	1.13		1.1		1.13	1.3	1.3
20 year return period	m3/s	706		732	333	130	922		22.1	935		416		1232	347	361
50 year return period	m3/s	851		880	420	161	1090		28.6	1107	163	525		1446	439	460
200 year return period	m3/s	1088		1124	562	222	1400		37.7	1413	220	739		1853	697	735

FIG. 1 AUG 30, 1991 DAILY PEAK FLOW

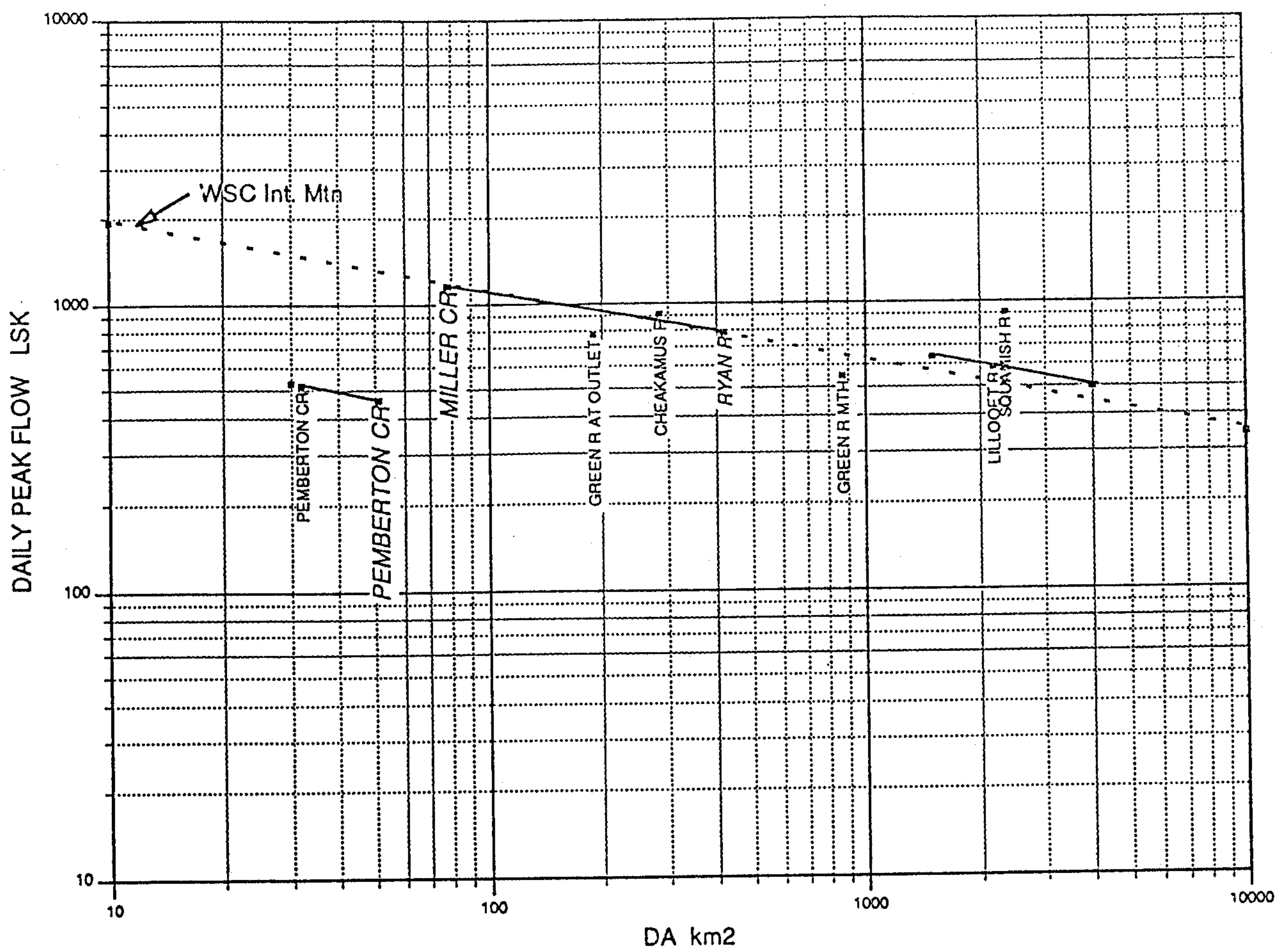


FIG. 2 OCT. 8, 1984 DAILY PEAK FLOW

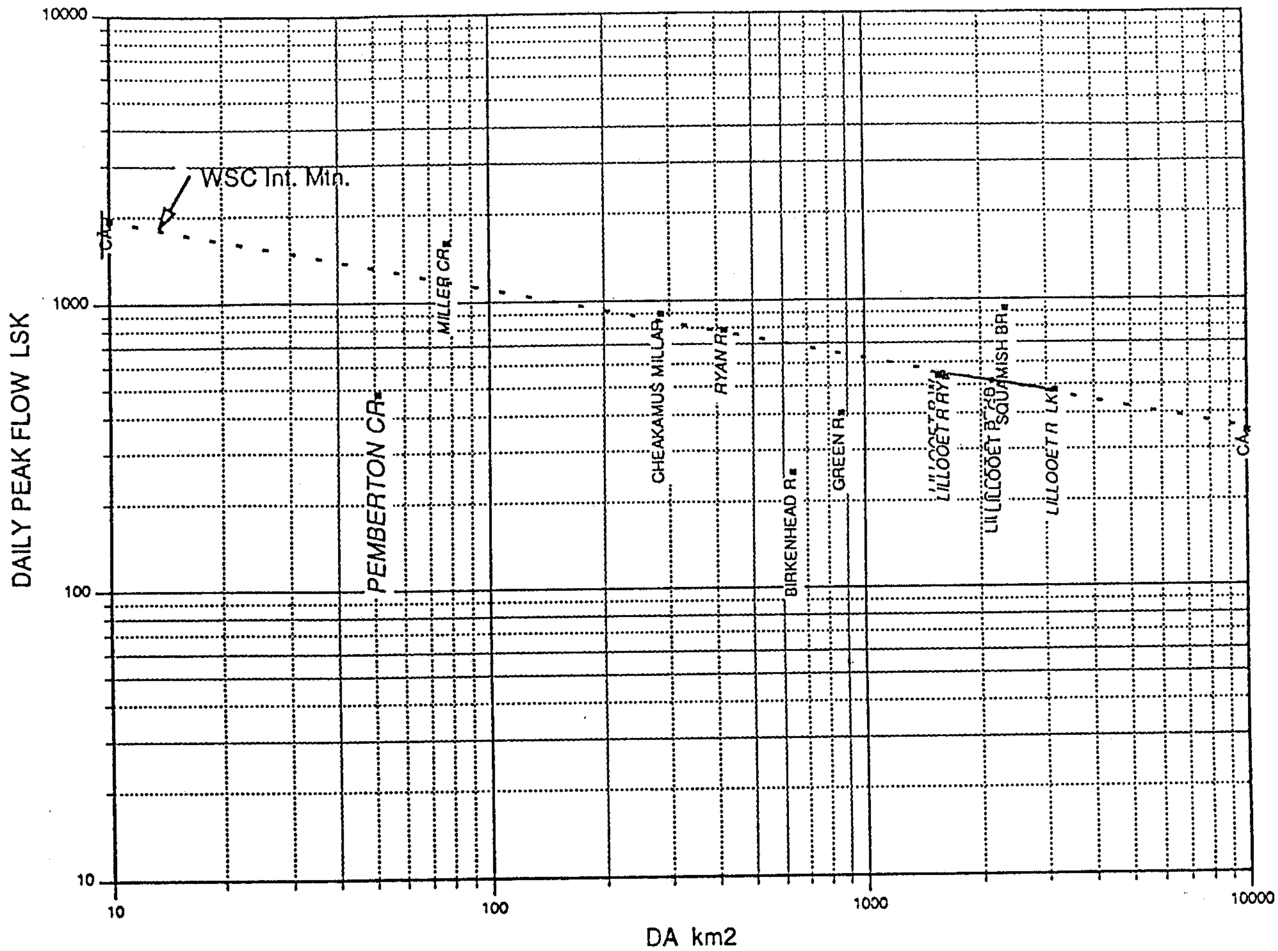


FIG. 3   20 YR RP DAILY PEAK FLOW

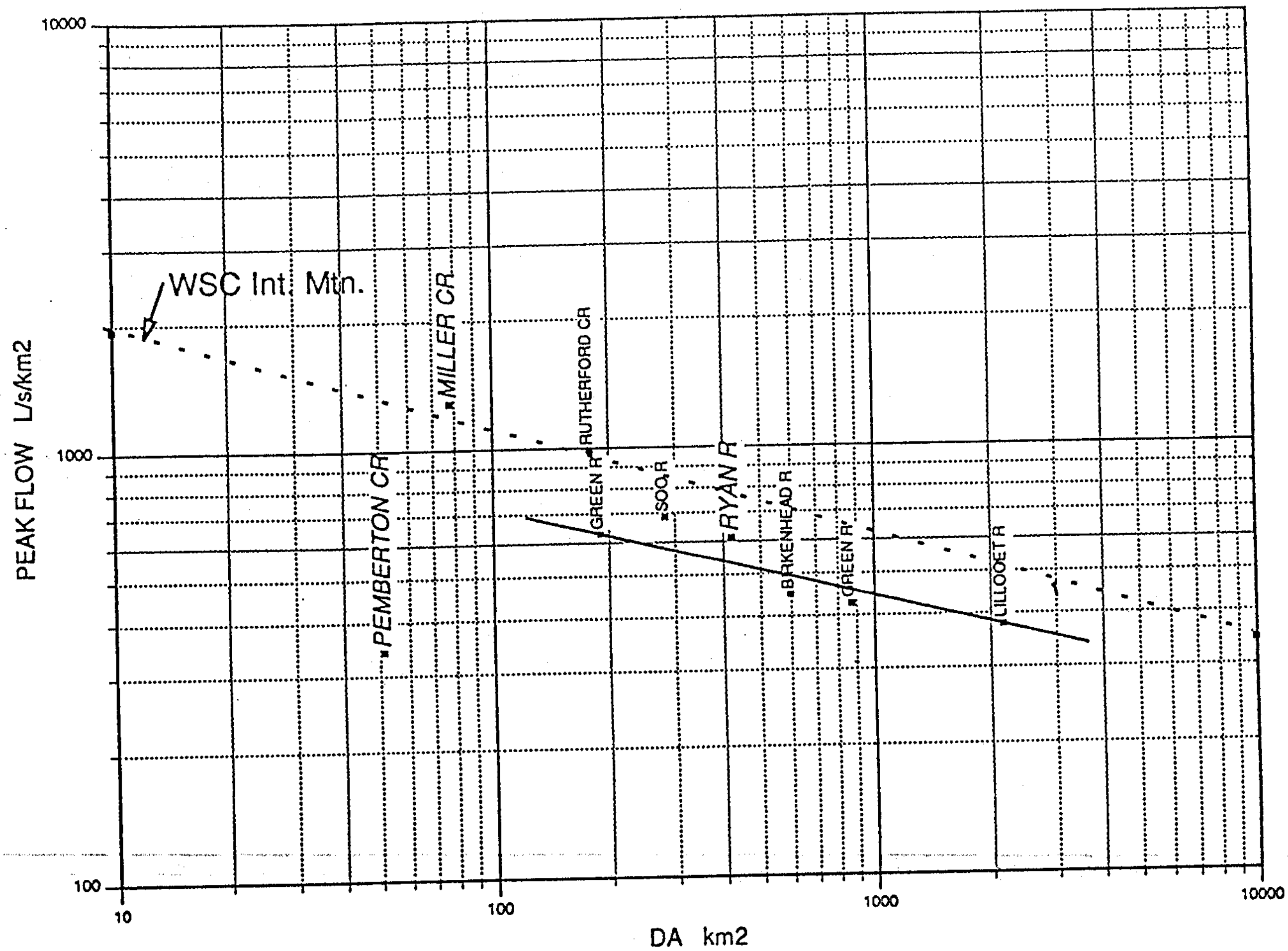


FIG. 4   50 YR DAILY PEAK FLOW

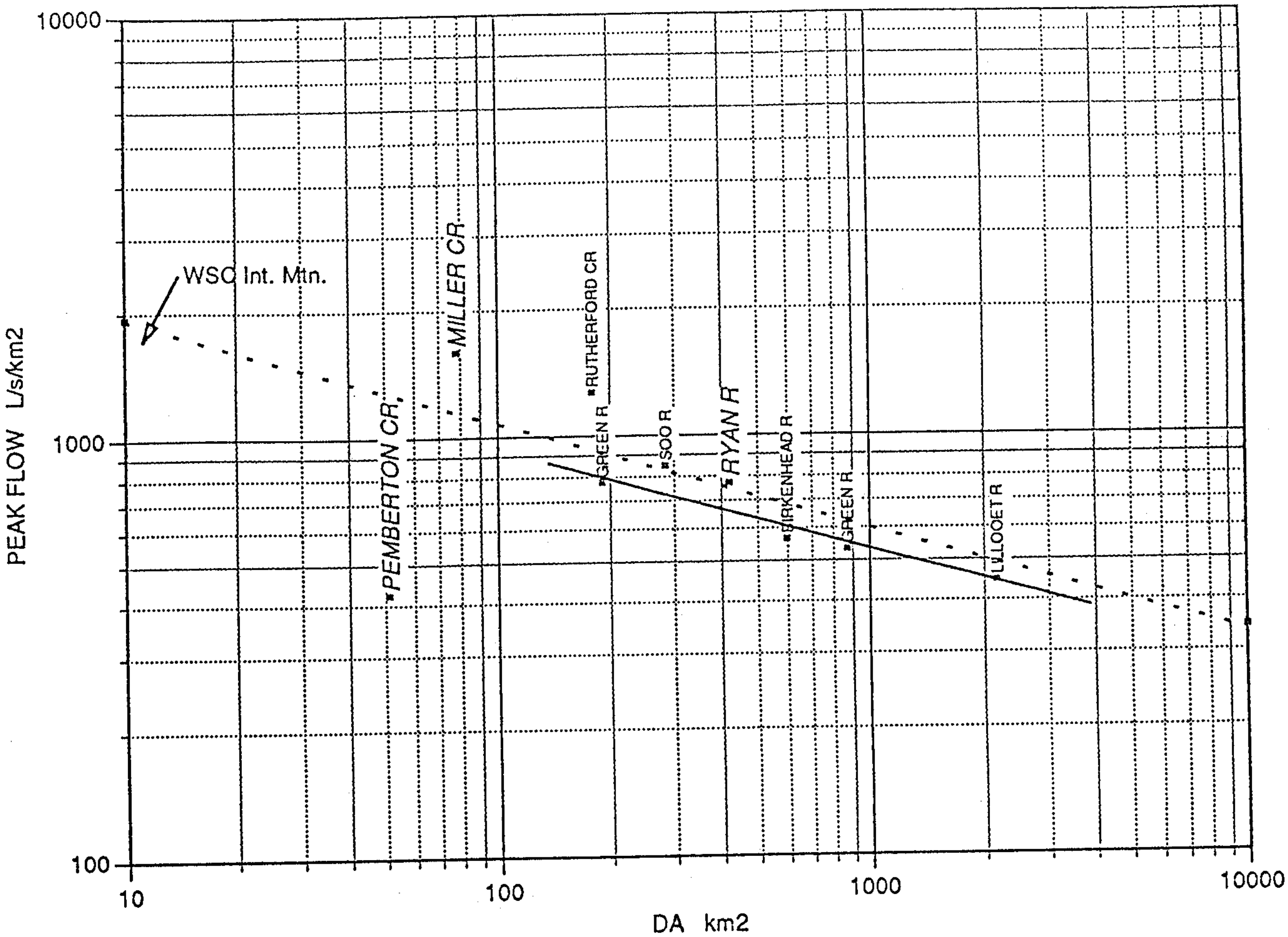


FIG.5 200 YR DAILY PEAK FLOW

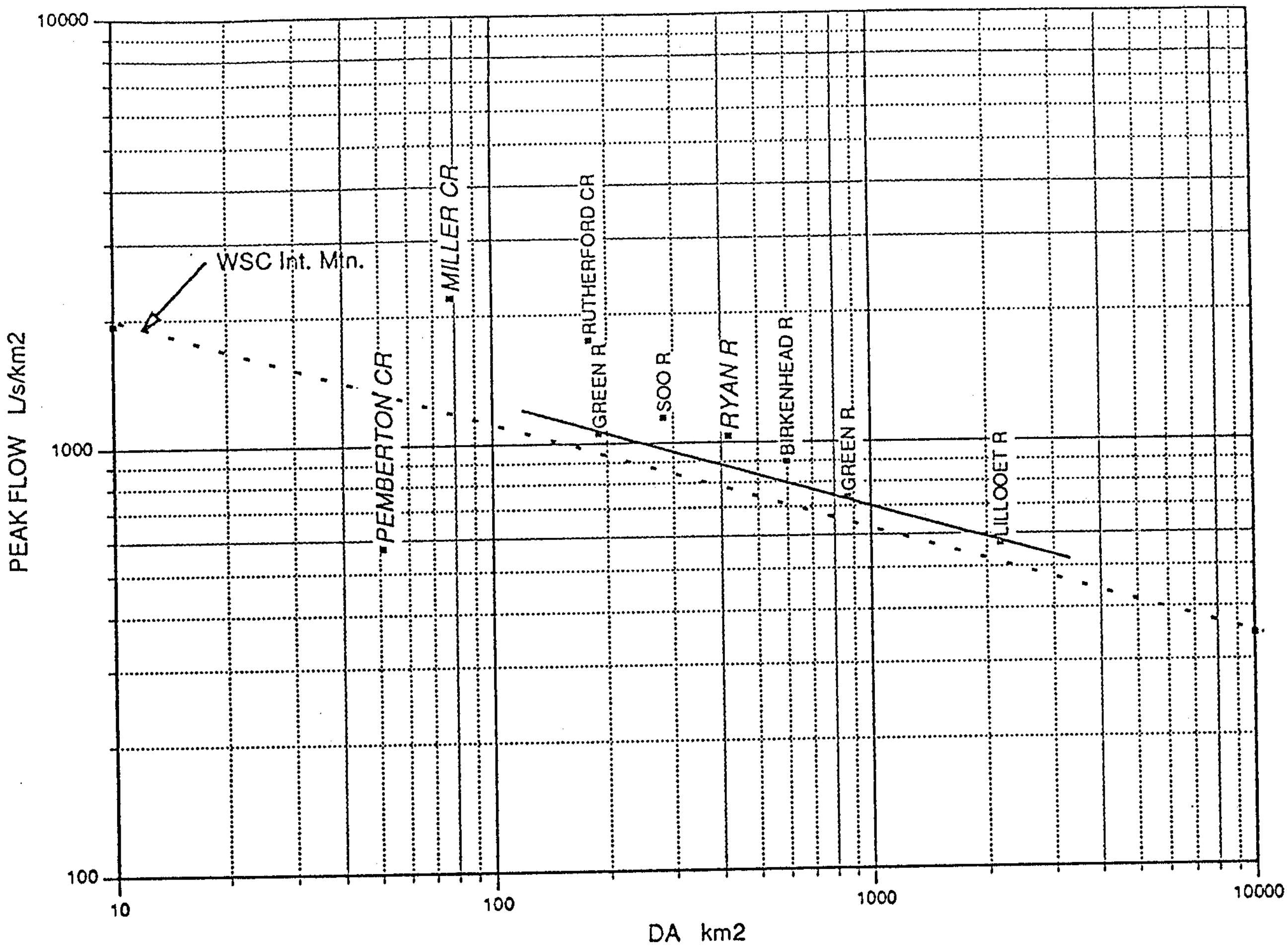


TABLE 1

LILLOOET RIVER BASIN FLOOD FLOWS*																
FLOOD FLOW EVENT		LILLOOET R AB WOLVERINE	TRIB FLOW	LILLOOET R AB RYAN R	RYAN R AT MOUTH	MILLER CR AT MOUTH	08MG005 LILLOOET R NR PEMBERTON	08MG025 PEMBERTON CR	PEMBERTON CR AT MOUTH	LILLOOET R AB GREEN R	GREEN R AT OUTLET GREEN LK	GREEN R AT MOUTH	TRIB FLOW	LILLOOET R AT LAKE	08MG008 BIRKENHEAD R	BIRKENHEAD R AT MOUTH
Drainage area	km2	1558	71	1629	419	77.7	2160	31.9	51	2218	189.5	868	76	3162	597	638
DAILY PEAK FLOWS																
Aug. 30, 1991	m3/s	985	33.5	1,018	330	90.1	1260	16.6	24.0	1284	147	476	25.08	1673	149	160
	L/s/km2	*632*	*471*	*625*	*788*	*1160*	*583*	*520*	*470*	*579*	*776*	*548*	*330*	*529*	*250*	*251*
	% of 8MG005	78.1	2.7	80.8	26.2	7.2	100	1.3	1.9	101.9	11.7	37.8	2.0	133	11.8	12.7
Oct. 8, 1984	m3/s	835	28	863	330	124	1110		24.4	1139		350	22.8	1513	149	160
	L/s/km2	*536*	*394*	*530*	*788*	*1596*	*514*		*478*	*514*		*403*	*300*	*478*	*250*	*251*
	% of 8MG005	75.2	2.5	77.7	29.7	11.2	100.0		2.2	102.6		31.5	2.1	136	13.4	14.4
20 year return period	m3/s	625		648	256	100	817		17	827		382		1090	267	278
50 year return period	m3/s	753		779	323	124	963		22	980		478		1280	338	354
200 year return period	m3/s	963		995	432	171	1230		29	1250		660		1640	536	565
INSTANTANEOUS PEAK FLOWS																
Aug. 30, 1991	m3/s	1132		1171	429	117	1410	21.9	31	1438	163	590		1840	194	208
	I/D	*1.15*		*1.15*	*1.3*	*1.3*	*1.12*	*1.32*	*1.3*	*1.12*		*1.24*		*1.10*	*1.3*	*1.3*
Oct. 8, 1984	m3/s	1002		1049	430	174	1310		36.6	1344		392		1755	194	208
	I/D	*1.2*		*1.2*	*1.3*	*1.3*	*1.18*		*1.5*	*1.18*		*1.12*		*1.16*	*1.3*	*1.3*
Return Period I/D		1.13		1.13	1.3	1.3	1.13		1.3	1.13		1.1		1.13	1.3	1.3
20 year return period	m3/s	706		732	333	130	922		22.1	935		416		1232	347	361
50 year return period	m3/s	851		880	420	161	1090		28.6	1107	163	525		1446	439	460
200 year return period	m3/s	1088		1124	562	222	1400		37.7	1413	220	739		1853	697	735
1989 Studies 200 year Instantaneous	m3/s	939		979	562	239	1170		118	1200		739		1570		734

*From Study No. 362 - Hydrology Section - File 42500-60/FL

TABLE 2

LILLOOET RIVER WATERSHED GAUGES					
OCTOBER 1940 EVENT - DAILY DISCHARGE (m3/s)					
DATE	GREEN RIVER 08MG004	SOO RIVER 08MG007	RUTHERFORD CREEK 08MG006	GREEN RIVER 08MG003	LILLOOET RIVER 08MG005
17-Oct	5.6	11.2	8.9	56.6	96.3
18-Oct	32.6	114.7	62	209.3	484.2
19-Oct	77.3	184.3	141.3	402.1	900.5
20-Oct	52.4	106.2	91.5	250	668.3
21-Oct	27.8	95.1	41.6	164.2	436.1
22-Oct	25.8	39.1	34	98.8	314.3
23-Oct	23.7	25.2	26.6	84.9	190
24-Oct	20.1	21.2	21.5	70.2	167.1
OCTOBER 1926 EVENT - DAILY DISCHARGE (m3/s)					
DATE	GREEN RIVER 08MG004	SOO RIVER 08MG007	RUTHERFORD CREEK 08MG006	GREEN RIVER 08MG003	LILLOOET RIVER 08MG005
14-Oct	2.4	2.7	13.5	28.3	137.1
15-Oct	23.8	96.3	101.9	121.5	270.7
16-Oct	35.7	143.6	203.9	205.3	345.5
17-Oct	19.8	68	85	226.5	311.5
18-Oct	12.7	20.1	68.9	83.2	283.2
19-Oct	11.3	16.2	14.4	26.9	283.2

TABLE 3

LILLOOET RIVER - COMPARISON OF AUG. 31, 1991 HIGH WATER MARKS TO DESIGNATED FLOOD LEVELS

REACH	# OF HWM's	AVG. (FL* - 1991 LEVELS)	COMMENTS
UPSTREAM OF RYAN RIVER	12	0.7	FLOWS ESTIMATED BY HYDROLOGY SECTION
CONFL.			
SHEETS 8 TO 11			
MILLER CR. CONFL. TO	8	0.4	FLOWS ESTIMATED BY HYDROLOGY SECTION
RYAN RIVER CONFL.			
SHEETS 6 TO 8			
PEMBERTON CR. CONFL. TO	7	0.4	FLOWS MEASURED BY WSC GAUGING STATION 08MG005
MILLER CR. CONFL.			
SHEETS 5 AND 6			
LILLOOET LAKE TO	7	-0.03	INFLUENCED BY GREEN RIVER FLOWS; 1991 FLOOD
MILLER CR. CONFL.			MAGNITUDE FOR GREEN RIVER NOT RECORDED
SHEETS 3 TO 5			
*FL -FLOOD LEVEL FROM FLOODPLAIN MAPPING SHEETS			
(INCLUDES ALLOWANCE FOR HYDRAULIC AND HYDROLOGIC UNCERTAINTIES)			

TABLE 4

LILLOOET RIVER

COMPARISON OF CHANNEL CROSS SECTIONS - 1969, 1978, 1985 AND 1993

XS	AREA 1969	AREA 1978	%DIFF TO 1969	AREA 1985	%DIFF TO 1969	AREA 1993	%DIFF TO 1969	AREA 1985	%DIFF TO 1978	AREA 1993	%DIFF TO 1978	%DIFF TO 1985
6	604.5	677.1	12.01	654.8	8.32	627.1	3.74	654.8	-3.29	627.1	-7.38	-4.23
7	513.3	583.9	13.75	557.8	8.67	550	7.15	557.8	-4.47	550	-5.81	-1.40
8	704.8	870.3	23.48	788.7	11.90	762.1	8.13	788.7	-9.38	762.1	-12.43	-3.37
9	488.9	502.3	2.74	582.9	19.23	548.3	12.15	582.9	16.05	548.3	9.16	-5.94
9.1				841.5		797.6		841.5		797.6		-5.22
9.2				516.3		530.2		516.3		530.2		2.69
10	397.6	521.9	31.26	513.8	29.23	489.4	23.09	513.8	-1.55	489.4	-6.23	-4.75
11	348.6	380.8	9.24	375.2	7.63	379.7	8.92	375.2	-1.47	379.7	-0.29	1.20
12	415.5	460.1	10.73	498.4	19.95	478.1	15.07	498.4	8.32	478.1	3.91	-4.07
13	362.3	442.4	22.11	441.5	21.86	441.5	21.86	441.5	-0.20	441.5	-0.20	0.00
14	359.6	402.1	11.82	395.5	9.98	421.5	17.21	395.5	-1.64	421.5	4.82	6.57
14.1				412.8		465.3		412.8		465.3		12.72
14.2				634.5		625.2		634.5		625.2		-1.47
15	441.7	475.7	7.70	468.6	6.09	433.7	-1.81	468.6	-1.49	433.7	-8.83	-7.45
15.1				449.2		421.8		449.2		421.8		-6.10
15.2				393.3		364.9		393.3		364.9		-7.22
15.3				379.2		353.6		379.2		353.6		-6.75
15.32						348.0				348.0		
15.33						379.5				379.5		
15.4				515.6		500.6		515.6		500.6		-2.91
15.5						523.4				523.4		
15.6						438.8				438.8		
16	455.4	495.6	8.83	544.1	19.48	524.2	15.11	544.1	9.79	524.2	5.77	-3.66
16.1						399.9				399.9		
		AVG	14.0	AVG	14.8	AVG	11.9	AVG	1.0	AVG	-1.6	-2.2

APPENDIX 2

Province of British Columbia

BC Environment
WATER MANAGEMENT DIVISION

MEMORANDUM

To: R. W. Nichols
Special Projects Section

Date: September 16, 1992

File: 42500-60/FL
42500-40/2
Study No: 362

Re: Lillooet River Floodplain Mapping

Further to our preliminary memo dated August 7, 1992, attached is a memo providing the August 30, 1991 flood flow estimates and updated return period peak flow estimates for selected locations in the Lillooet River basin as requested on December 10, 1991.

C. H. Coulson, P. Eng.
Head
Hydrology Section

DER:gg
HY8944

Attachment

cc: D. E. Reksten
H. Nesbitt-Porter

Province of British Columbia

BC Environment

WATER MANAGEMENT DIVISION

MEMORANDUM

To: C. H. Coulson
Head
Hydrology Section

Date: September 16, 1992

Study No. 362 ✓
File: 42500-60/FL

Re: Lillooet River near Pemberton
<u>August 30, 1991 Flood Flows and Design Flood Flows</u>

This memo is in response to a request dated December 10, 1991 from R. Nichols, Special Projects Section, to provide estimates of flows during the August 30, 1991 flood event and the 20, 50 and 200 year return period flows at mainstem and tributary locations. Similar information was provided in a memo dated June 26, 1985 after the October 8, 1984 flood event. The extreme flood flows which occurred on August 30, 1991, make it necessary to update the analysis done in June 1985.

Estimates are provided for the following locations:

Lillooet River above Wolverine Creek

Lillooet River above Ryan River
  Ryan River at the Mouth
  Miller Creek at the Mouth

Lillooet River above Pemberton Creek
(Lillooet River near Pemberton 08MG005)
  Pemberton Creek at the Mouth
  (Pemberton Creek near Pemberton 08MG025)

Lillooet River above Green River
  Green River at the Mouth
  (Green River near Pemberton 08MG003)

Lillooet River at Lillooet Lake

Birkenhead River at the Mouth
(Birkenhead River at Mount Currie 08MG008)

Some of the locations for which estimates are requested are at or near hydrometric stations. 08MG005 is assumed to be the same as Lillooet River above Pemberton Creek. Estimates made for Green River at the Mouth are estimates for 08MG003 adjusted for drainage area (868 km^2/841 km^2). The same approach was used for Birkenhead River at the Mouth (638km^2/597 km^2 for 08MG008).

The River Forecast Centre (RFC) provided updated return period estimates for 08MG005 as well as for Lillooet Lake (08MG020) as described in the attached memos dated July 24, 1992 and August 20, 1992.

1. DAILY PEAK FLOWS

1.1 AUGUST 30, 1991

The only active hydrometric stations in the Lillooet River basin are 08MG005 Lillooet River near Pemberton and 08MG025 Pemberton Creek near Pemberton.

Appendix 1 describes the method used to estimate flows at the ungauged locations. Table 1 lists the estimates including those given in the June 26, 1985 memo for the October 8, 1984 event, and Fig. 1 and 2 indicate the relationship between unit daily peak flow and drainage area for the 2 events.

The general approach used for the August 30, 1991 event is similar to that used for the October 8, 1984 event. Any difference is due to the amount and type of data available.

For August 1991, an estimate of Green Lake outflow was available as a result of studies done in the Whistler area. For Pemberton Creek 1991 data were available from the WSC hydrometric station whereas for the 1984 event it was estimated as a residual or difference between Lillooet River above Green River and above Pemberton Creek.

The August 30, 1991 daily peak flow at 08MG005 Lillooet River is 14% greater than the October 8, 1984 flow and is estimated to have a 200 year return period.

. . . 3

1.2 RETURN PERIOD FLOW ESTIMATES

Table 1 also lists return period estimates for each location requested. The available data are shown in Fig. 3 to 5. The estimates for Rutherford Creek, Soo River, Green River near Pemberton, and Birkenhead River in the June 1985 report were used again as no further data are available. Thus the estimates for Ryan River and Miller Creek are unchanged.

Recent analyses carried out for the Whistler area have resulted in new return period estimates for Green River at the outlet of Green Lake (08MG004 Green River near Rainbow).

The curves used to estimate the 20, 50 and 200 year return period flows are plotted in Fig. 3 to 5 as well as the Water Survey of Canada envelope curve for Interior Mountains. The curves were drawn through 08MG005 Lillooet River and fitted by eye through the Green River and Birkenhead River points.

In the June 1985 analysis it was assumed that Pemberton Creek would be best indexed by 08MG003 Green River. However the data for the August 30, 1991 event (Fig. 1) indicate that this may not be a good assumption as Pemberton Creek plots well below a curve through the other gauged watersheds. It is noted that for the 3 years for which peak flows are available, they are very similar to those for 08MG005 Lillooet River in terms of unit peak flows. Although not statistically significant, if correlated the R^2 is 0.97. This correlation is probably the best means of estimating Pemberton Creek flows at this time and is used to derive the values in Table 1.

3. INSTANTANEOUS PEAK FLOWS

3.1 AUGUST 30, 1991

The instantaneous peak flow for August 30, 1991, at 08MG005 is 1.12 times the daily peak flow. It is assumed for the instantaneous estimates in Table 1 that for the Lillooet River above Green River the same factor can be used due to the similarity in drainage area. A slight adjustment to 1.15 for the two mainstem locations above Pemberton was made, and for the location at Lillooet Lake 1.10 was used to account for the larger drainage area.

. . . 4

The I/D ratio for Pemberton Creek for August 30, 1991, is 1.32. The instantaneous flows given for other tributaries may be grossly in error as there are no data for this event. The figures shown are the rough daily estimates multiplied by an I/D ratio based on results from previous peak flow assessments.

3.2 RETURN PERIOD FLOW ESTIMATES

Table 1 also lists return period instantaneous peak flows for each location. Estimates for 08MG005 Lillooet River were supplied by the RFC (memo dated July 24, 1992) as were those for 08MG003 Green River (memo dated Feb. 22, 1985) and are based on frequency analysis of instantaneous peak flow data.

For the mainstem Lillooet River ungauged locations it was assumed that the same I/D ratio as calculated from 08MG005 data should be used. For the tributary locations rough estimates based on results from previous regional peak flow assessments are used.

4. LILLOOET LAKE LEVELS

The attached memo from R. Wyman dated August 20, 1992 provides return period lake level estimates using data up to and including the August 30, 1991 event.

D E Reksten

D. E. Reksten, P. Eng.
Senior Hydrological Engineer
Hydrology Section

DER:gg
HY8942

Attachment

Province of British Columbia

BC Environment

WATER MANAGEMENT DIVISION

MEMORANDUM

To:

Date: July 24, 1992

File 42500-40

D.E. Reksten
Senior Hydrological Engineer
Hydrology Section
Water Management Division

Re: Lillooet River near Pemberton

Including the August 30, 1991 flood in the frequency analysis indicates that the flood statistics at this location require yet another change.

For the record, the following has transpired:

February, 1985:
200 year instantaneous flood estimated at 1170 m^3/sec. This was based on an estimated flood of 1050 m^3/sec on October 8, 1984.

November, 1988
200 year instantaneous flood changed to 1275 m^3/sec., using the revised estimate of 1310 m^3/sec for the 1984 flood.

July, 1991
Current analysis runs indicate the 200 year instantaneous flood should now be revised to 1400 m^3/sec..

The 1984 and 1991 floods are the largest experienced since recording began in 1914. There is no means available to determine whether or not these recent floods are caused by some sort of climate change and more such events will occur in the near future, or whether they simply represent random occurrences of low probability events in the long-term statistics. The latter is assumed in the current analysis and the following figures are now recommended:

Return Period	Daily Flows Lower 95%	Daily Flows Estimate	Daily Flows Upper 95%	Instantaneous Flows
2	470	495	522	549
5	570	620	675	693
10	640	720	802	804
20	712	817	942	922
50	809	963	1150	1090
100	888	1080	1330	1240
200	971	1230	1535	1400

No confidence limits are available for instantaneous flows, but the confidence range would be somewhat greater than for daily flows.

R. R. Wyman
Research Officer

R R Wyman

Province of British Columbia

BC Environment

WATER MANAGEMENT DIVISION

MEMORANDUM

To: D. E. Reksten
Senior Hydrological Engineer
Hydrology Section

Date: August 20, 1992
File: 42500-40

Re: Lillooet Lake

Several frequency analyses have been done for this lake in the last dozen years, the last one being in 1985, which included the 1984 flood of record (at that time). Only 14 years of record were available for daily levels, and 12 years for instantaneous levels. Consequently, it is not surprising that the new flood of record in 1991 would significantly change the statistics. The following figures are now recommended:

Return Period	Daily Levels			Instantaneous Levels		
	Lower 95%	Estimate	Upper 95%	Lower 95%	Estimate	Upper 95%
2	28.16	28.49	28.86	28.19	28.55	28.96
5	28.65	29.17	29.80	28.70	29.27	29.96
10	28.90	29.56	30.40	28.97	29.68	30.59
20	30.11	29.91	30.96	29.19	30.04	31.17
50	30.34	30.29	31.60	29.44	30.46	31.83
100	30.49	30.57	32.05	29.62	30.75	32.30
200	30.63	30.82	32.48	29.78	31.01	32.74

All levels are referred to local datum in metres. Add 169.335 for G.S.C. datum.

According to this analysis, the 1991 flood has a return period of about 40 years.

As with the Lillooet River near Pemberton, it is assumed that the two recent floods (1984 and 1991) consist of random occurrences of low probability events in the long-term statistics.

The flood estimates have progressed as follows:

	200 year flood estimate	
	Daily	Instantaneous
April, 1979	29.34	-
February, 1985	29.08	29.28
March, 1985	30.06	30.39
August, 1992	30.82	31.01

R. R. Wyman
Research Officer

RW/mjz/HY7188/Lillooet Lk.

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Recycled Paper

August 7, 1992

APPENDIX 1

Lillooet River Basin
Aug 30, 1991 Daily Peak Flow
Estimating Method

1. Lillooet R ab Wolverine
   Unit flow from curve through 8MG005 Lillooet R nr Pemberton with same slope as WSC envelope curve ($A^{-0.25}$)

2. Tributary inflow
   Flow (m3/s) is difference between Lillooet R nr Pemberton (1) and above Ryan (3)

3. Lillooet R ab Ryan
   Same as in (1).

4. Ryan R
   Based on info from R. Nichols the flow was similar to that estimated for Oct. 8, 1984 event (330 m3/s)

5. Miller Cr
   Unit flow from curve through Ryan R with same slope as WSC envelope curve. This results in a flow less than for Oct. 8, 1984 which agrees with observations (R. Nichols).

6. 8MG005 Lillooet R nr Pemberton
   Flow provided by WSC

7. Pemberton Cr
   Unit flow from curve through 8MG025 Pemberton Cr with same slope as WSC envelope curve.

8. Lillooet R ab Green R
   Flow is the sum of (6) and (7). The unit flow is the same as that obtained from the curve method as in (1).

9. Green R
   The flow at the mouth is estimated from a correlation between 8MG003 Green R nr Pemberton and 8GA024 Cheakamus R nr Mons. 8GA024 is inactive but is replaced by 8GA072 Cheakamus R ab Millar Cr which provides Aug 1991 data. Using this in the correlation yields the estimate for Green R

(476 m3/s). This is greater than the flow estimated for the Oct 1984 event (350 m3/s) which agrees with observed conditions (R. Nichols).

This must agree with an "observed" Aug 30, 1991 outflow from Green Lk of 147 m3/s.

The DA between the lake outlet and the mouth is 678 km2 and a flow of 329 m3/s (476 - 147) yields a unit flow of 485 L/s/km2. This area includes Rutherford Cr and Soo R (totalling 453 km2) for which some data are available in the 1920-1947 period. A unit flow of this magnitude is comparable to the mean peak flow values for these two streams which seems too low. However we are assuming that the peak flows for all the streams are occurring simultaneously which is not realistic.

10. Tributary inflow
    This was estimated at 10% greater than for the Oct. 1984 event.

11. Lillooet R at Lillooet Lake
    The unit flow is obtained from the curve method as in (1).