

HYDROLOGY OF THE NOVEMBER 1989
CHILLIWACK RIVER FLOOD, AND
SOME OBSERVATIONS ON THE IMPACT
OF FOREST MANAGEMENT

by

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1. INTRODUCTION

On November 9-10, 1989, the Chilliwack River at Vedder Crossing experienced the second highest flood of record, in terms of both maximum instantaneous and mean daily discharge. Substantial damage was experienced due to high water and bank erosion near Vedder Crossing. Logging roads at many locations in the watershed were damaged by slides and washouts. (The highest instantaneous discharge was recorded on Dec. 26, 1980, and the highest daily discharge was recorded on Dec. 29, 1917. Other recent serious floods occurred in Dec. 1975 and Jan. 1984.)

In February, 1990, the writer was requested by the Chilliwack District of the Ministry of Forests (MoF) to investigate the hydrology of the flood, and to offer advice on whether logging in the watershed may have had an impact on the severity of the flood. The terms of reference for the study are appended to this report (Appendix 1).

It became apparent from an initial review of information on past flood events that flood problems on the Chilliwack-Vedder Rivers are largely a result of erosion and sedimentation during floods. Therefore, any investigation of the role of logging should focus on the effects of logging on sediment production. The report which follows is organized in three sections: hydrology of the 1989 flood; the extent of logging in the watershed and its effects; and sediment sources and transport in the river system.

The study was conducted during the period February 19-28, 1990. It was not feasible to do any field work because the river valley was heavily snow covered at this time. For this reason, and because of the short time spent on the study, only a very initial overview is made of erosion and sedimentation. Also, at the time of the study, only preliminary data were available for streamflow and precipitation. The data given in this report are unofficial and are subject to revision.



FIGURE 1
LOCATION MAP

Stream gauging stations ○
Climate stations □

0 10 20
Kilometres

2. METHODOLOGY AND SOURCES OF INFORMATION

Preliminary streamflow data for stations in the Chilliwack River basin for the period of the flood were obtained from the Water Survey of Canada (WSC). Rainfall data, and a report prepared on the storm, were obtained from the Atmospheric Environment Service (AES). Some additional information on snow and temperatures at high elevations was obtained from the Ministry of Highways and the Water Management Branch. Streamflow and rainfall data for adjacent areas in Washington state were obtained from the U.S. Forest Service and from the U.S. Geological Survey. These data enabled the history of the storm, and the patterns of rainfall and runoff, to be reconstructed. Streamflow and rainfall for this storm were compared to data for several previous storms, to help interpret the behavior of the river during floods.

Information on the logging history of the watershed was obtained from MoF forest cover maps provided by the Chilliwack district office. These maps were published in 1985, and had been updated to 1988 by district staff. High elevation (about 1:80,000 at river level) air photos taken in August 1988, and satellite images taken in 1988 and earlier dates, were used to check this forest cover information, and to map logging in the U.S. part of the watershed.

The main source of information on the sediment regime of the river was a study by D. McLean (1980), which examined sediment transport in the Vedder River and sediment sources in the Chilliwack watershed. An inventory of logging road damage made by MoF district staff following the flood helped to identify some of sediment sources that were active during the flood; it also helped to outline the area of high rainfall in the watershed and nearby areas. Air photos had been taken of the lower Chilliwack River shortly after the flood; however, it was not possible to obtain these during this study.

For the purpose of compiling land use and sediment information, the basin of the Sweltzer River (Cultus Lake) was excluded. Because this basin is lake-controlled, it contributes relatively little rapid streamflow and negligible sediment to the Chilliwack River. The location of climate and streamflow stations used in this study are mapped on Figure 1.

Streamflow measurements and flood frequency analysis

The following paragraphs give a brief review of how streamflow is measured and how some commonly used hydrologic statistics are derived. This may help in interpreting the data given in this report.

A continuous record of water level, or "stage", is taken at each streamflow gauging station, using a water level recorder. Older records (before 1968 on the Chilliwack River at Vedder Crossing) consisted of manual observations made daily (or hopefully several times daily during peak flows) on a staff gauge. A graph of stage versus discharge is derived for each station from discharge measurements taken with a current meter from a bridge or cableway; this enables the discharge at any time to be calculated from the stage record. Since discharge measurements are rarely taken at the highest flows, the peak discharge during floods may be only an estimate. Unfortunately, at some gauging stations (such as the Chilliwack River at Vedder Crossing), the stage-discharge relationship is unstable during floods because the river channel is subject to shifting and scour. In such cases, estimates of peak discharge during floods may not be very reliable. Total runoff for a day or any other period is calculated by dividing the mean discharge by watershed area. This gives an average depth over the watershed which is analogous to precipitation.

For floods, both the peak instantaneous flow and the mean daily flow (the average discharge from 00 to 24 hours) are recorded. For "flashy" or rapidly responding rivers like the lower Chilliwack, the daily flow may underestimate the true severity of a flood if the flow for a short flood happens to be divided between two days. (The same problem, of course, exists for rainfall data.) When only manual staff gauge readings were made, the estimate of the daily flow may be considerably in error if the observer missed the highest water level. Sometimes, during extreme floods, the gauging station is destroyed or damaged, so flows are missing for some days. (This happened on Slesse Creek during the 1989 storm.) In such cases, sometimes the peak water level is known from the water line on trees or from a special "crest gauge" at the station. For reference, the records of extreme flows for several stations are given in Appendix 4.

For flood hazard assessment and for engineering design, it is valuable to know the probability of occurrence for floods of a particular discharge. This information is usually expressed as return periods, e.g. the "100 year" or "200 year" flood, and is calculated from flood frequency analyses such as the one for the Chilliwack River shown in Fig. 2. A "100 year flood" means that a flood of that discharge or greater has a probability of 1/100 (or 1%) of occurring in any given year. The flood frequency curve can be drawn by eye (as in Fig. 2) or calculated using any of several mathematical methods. The calculation of long return period floods (100 years or longer) is very sensitive to the method used. The Water Survey of Canada has published flood frequency analyses for many rivers using data up to 1980; similar statistics have been published for American rivers by the U.S. Geological Survey. Many factors affect the reliability of this information, the most important of which is the length of record. Generally, flood estimates for return periods shorter than the period of record are very reliable, while those for longer return periods are much less reliable. For example, the 200 year flood (often used for floodplain zoning and dyke design), calculated from a 60 year record, is only an approximation, and one calculated from a 15 year record would be almost meaningless. For the Chilliwack River at Vedder Crossing, with a record of 49 years (to 1980), the WSC estimates of the 200 year flood vary from 775 to 1050 m³/s depending on the mathematical method used.

Flood frequency analysis can be done on the peak instantaneous flow or on the highest daily flow, or for any other desired flow statistic. For coastal rivers, which have separate rainstorm and snowmelt peaks in different seasons, it is useful to analyze snowmelt and rainstorm flows separately.

The period of record used for flood frequency analysis can bias the results. For example, the November 1989 flood on the Chilliwack River at Vedder Crossing had the second highest flow of record on both an instantaneous and daily basis. The instantaneous flow was estimated as having a return period of 15 years, because the period of record was only 19 years, and included the 1975-84 period of unusually frequent floods. The period of record for daily flows is 56 years, and includes the 1952-74 period when floods were rare; using this period, a much longer return period is calculated for the 1989 flood.

Similar frequency analysis can be done for rainfall data. Information on rainstorm return periods is available from the AES.

3. HYDROLOGY OF THE FLOOD OF NOVEMBER, 1989

The Chilliwack River, like other coastal rivers in B.C. draining mountainous watersheds, experiences two runoff peaks in most years, one in the spring/summer due to snowmelt, and one in the fall/winter due to rainstorms. Most precipitation falls in the fall and winter. Above about 1000 m, most of this falls as snow. However, rain frequently falls to high elevations, and in many years fall/winter rainstorms combined with snowmelt cause floods of one to three days duration. Floods due to summer rainfall are rare. The annual peak discharge occurs with about equal frequency in the spring/summer and in the fall/winter seasons. However, the highest discharge events, those which cause damaging floods, almost always occur in the fall and winter. These floods occur most frequently in the months of October to January.

Rainfall

On November 8-10, 1989, heavy rain occurred over southwestern B.C. and northwestern Washington State. A brief report on this storm was prepared by the Atmospheric Environment Service (Appendix 2). The heaviest rainfall in B.C. was recorded in the mountains just northeast of Vancouver, on western and northern Vancouver Island, and at Hope. In the U.S., heavy rain occurred in the Nooksack and Baker River drainages. The weather map for Nov. 9 (Appendix 3), and the satellite photo and upper air chart in the AES report, show a strong southwesterly flow of warm, moist, subtropical air, with southerly winds and warm temperatures (12-14 °C) at B.C. and Washington coastal stations. This pattern is quite typical for fall rainstorms. The only unusual feature of the storm is that several zones of extremely heavy rainfall occurred in a few small areas; this was recorded in the Coquitlam River, Pitt River, Stave Lake, and Nooksack River drainages, and at Hope. In the Nooksack River, the heavy rain persisted for four days.

The rainfall and other climate data for the Chilliwack River area are summarized in Table 1. By far the heaviest rainfall recorded was at Nooksack

Falls, where 572 mm fell in 3 days. Rainfall at other U.S. stations in the Baker-Skagit drainages show similar totals to Hope. Very heavy rain also fell further northwest in the Stave Lake area; one station on Stave Lake recorded 418 mm in three days. Rainfall at the one station in the Chilliwack River valley was not unusually heavy. Fairly heavy rain also fell in the preceding week; from Nov. 2-6, 140 mm was recorded at Hope, and 456 mm at Nooksack Falls. (It should be noted that all the data given here are preliminary; some stations, especially the U.S. ones, are unofficial and the data have not been checked.)

Hope Airport typically records the heaviest rainfall of any station in the Fraser Valley, probably due to the effect of orographic enhancement as rainstorms from the southwest are funnelled into the narrowing valley. It appears to be the station most representative of conditions in the Chilliwack watershed, although it probably receives more rain during storms than the average over the watershed; Hope consistently receives heavier rain than the stations in the Chilliwack valley. At Hope, the 3-day rainfall of 250.3 mm has a return period of 33 years (AES estimate), although the 1-day rainfall of 105.0 mm has a return period of only 8 years. Return period data were not obtained for U.S. stations, although a newspaper account reported a new one-day rainfall record for November at Bellingham.

Snowmelt during the storm may have contributed a substantial amount of runoff during the storm. Freezing levels at Quillayute, Washington (the nearest upwind upper air station) rose from 1220 m on Nov. 7 to 3230 m on Nov. 10, and dropped sharply after the storm. At Allison Pass, the temperature rose from 0.5 to 8 °C from Nov. 7 to 9.

Snow records at Allison Pass and Mt Baker ski area (Table 1) show considerable loss of snow during the storm. Assuming a snow density of 0.2 before the storm and 0.3 after, about 23 mm of snow water equivalent was lost from Nov. 8 to 10 at Allison Pass (elev. 1340 m), and 92 mm was lost from Nov. 8 to 12 at Mt Baker (elev. 1280 m). The snow pillow and weather station at Great Bear above the Coquihalla Highway were not operating during the storm. Various observations suggest that the lower limit of snow cover before the storm was about 1000 m. It is reasonable to assume that an average of about 50 to 60 mm of snow water equivalent was lost between 1000 and 2000 m elevation. About

TABLE 1. PRELIMINARY RAINFALL DATA, NOVEMBER 1989 STORM

		November:						3-day	return	
STATION	map	7	8	9	10	11	12	total	period	Notes
CANADA:										
Abbotsford A	1	0.4	39.0	70.8	45.4	14.4	0.0	155.2	22 y	A
Chilliwack	2	6.3	52.0	76.1	19.7	8.7	2.1	147.8	5 y	
Hope A	3	13.6	51.9	105.0	93.4	7.0	1.7	250.3	33 y	A
Agassiz Mtn	4	22.4	66.4	43.6	27.0	8.0	4.2	137.0		
Agassiz CDA	5	14.0	53.6	79.2	21.6	8.5	3.2	154.4		
Chilliwack R Hatch	6	3.0	85.8	68.1	21.0	9.0	3.6	174.9		
Laidlaw	7	14.6	53.6	96.0	30.4	11.0	3.6	180.0		
Wahleach Lake	8	10.5	64.3	113.4	77.6	12.6	n/a	255.3		BC Hydro
Sardis	9	3.4	58.6	60.2	13.3	9.6	2.0	132.1		
Allison Pass	10	3	40	39	9	n/a	n/a	88		MoH
U.S.:										
Nooksack Falls	11	13	262	180	130	114	10	572		USFS
Glacier RS	12	(56mm/2 days)		94	61	n/a	n/a	(approx 2057)		USFS
Marblemount RS	13	13	122	104	51	23	3	277		USFS
Upper Baker Dam	14	18	119	77	19	20	4	215		USFS
Lower Baker Concrete	15	8	119	61	24	17	1	204		USFS
Darrington RD	16	7	79	42	15	17	15	136		USFS

Notes: Canadian data are from AES, for period beginning at approx. 0800 on date shown, unless otherwise indicated.

All data are preliminary and are subject to revision.

A - Period beginning 2200 on previous day.

BC Hydro - Data from B.C. Hydro

MoH - Data from Ministry of Highways

USFS - Data supplied by U.S. Forest Service, from various sources.

Reporting periods begin at approx. 0700 to 0900 on date shown.

ALLISON PASS MoH : (elev. 1340 m) SUMMARY OF CLIMATE OBSERVATIONS										
	Nov.	3	4	5	6	7	8	9	10	11
Precip (mm)		22	5	7	17	3	40	39	9	
Snowfall (cm)		4	2	11	13	3	0	0	0	
Snow on ground (cm)		2	4	5	13	22	22	15	7	7
(at 0700)										
Present Temp. (°C)		0.5	0	0.5	0	-3	0	4.5	2	0
Max. Temp. (°C)		4	2	2	1	0.5	5.5	8	4	
Min. Temp. (°C)		0	0	0	0	-3	-3	0	4	-0.5

FREEZING LEVEL AT QUILLAYUTE, WA (m)													
Nov.:	6		7		8		9		10		11		12
hrs:	04	16	04	16	04	16	04	16	04	16	04	16	04
m:	1650	1740	1220	1460	2100	2960	2960	M	3230	2500	2230	1650	1070
													950

70% of the Chilliwack watershed lies in this range; thus, snowmelt might have contributed an equivalent of about 40 mm of runoff. If average rainfall over the watershed during the storm was about 200 mm, snowmelt might therefore have added about 20% to the storm runoff.

Streamflow

Streamflow records for the Chilliwack basin, the Coquihalla River, and several U.S. drainages for the storm are summarized in Table 2. These data are preliminary; for some stations, especially the Chilliwack River at Vedder Crossing, the rating curve shifted during the storm, and discharges are likely to be revised when a new rating curve is established.

The November, 1989, flood at Vedder Crossing was initially estimated to have a return period of about 15 years, based on peak instantaneous discharge (communication to MoF from H. Coulson, Water Management Branch). However, the record for instantaneous discharges is relatively short (since 1969) and includes a period of unusually frequent floods (1975, 1978, 1979, and 1980; 1984 is missing from the record). Although the 1989 instantaneous discharge was the second highest on record, in the context of this record it does not have a very high return period. The record for mean daily flows is much longer (1912-1930, and 1952-present). Based on the published WSC flood frequency analyses for daily flows (to 1980), the 1989 flood at Vedder Crossing has a return period of about 65 years. Figure 2 shows a plot of daily flood frequency data to 1988; based on a curve drawn by eye, the return period of the 1989 flood is about 50 years.

For the Chilliwack River above Slesse Creek, both the instantaneous and daily discharges are the highest on record; the return period for the daily discharge is about 100 years, based on the published WSC analysis. Slesse Creek also experienced the highest instantaneous discharge on record (return period of probably about 100 years). The gauging station was damaged in the flood, and daily discharge is not available. The return periods of the Chilliwack River at the outlet of Chilliwack Lake, and of the Coquihalla River, are not unusually high; most of these basins appear to have been outside the belt of heaviest rainfall.

TABLE 2. STREAMFLOW DATA, NOVEMBER 1989 STORM

STATION	Basin area (sq. km)	INSTANTANEOUS PEAK				1-DAY			5-DAY		
		day/time	discharge (cms)	(2) intensity (mm/day)	(3) return period	day	discharge (cms)	runoff (mm)	(4) return period	discharge (cms)	runoff (mm)
CANADA:											
Chilliwack R at Vedder Crossing 08MH001	1230	9/1045	816	57	15 y	10	684	48	50-65 y	337	118
Chilliwack R above Slesse Cr 08MH103	645	10/0345	464	62	30 y?	10	343	46	100 y	207	139
Chilliwack R at Outlet of Ch. L. 08MH016	329	11/0310	101	27	15 y	11	97.9	26	20 y	72.6	95
Slesse Cr 08MH056	162	9/0900	227	121	100 y						
Coquihalla R above Alexander Cr 08MF068 (1)	741	10/0315	497	58	7 y						
U.S.: (5)											
North Fork Nooksack R 12-2050-00	272	10/0430	317	101	80 y	10	212	67	>100 y	117	186
Nooksack R at Oeming 12-2105-00	1513	9/1100	1034	59	11 y	9	838	48	13 y	552	158
Wells Cr	56	9/0300	57	89							
Glacier Cr	35		250	620							
Swift Cr 12-1907-10	94	9/2300	138	127		9	98	90		50.1	230
Park Cr 12-1907-18	27	9/0430	55.2	177		9	38.2	122		17.1	274
Sauk R above Whitechuck R 12-1860-00	394	10/1230	240	53	< 5 y	10	208	46	< 5 y	137	150
Sauk R near Sauk 12-1895-00	1849	10/1800	1019	48	< 5 y	10	855	40	< 5 y	560	131

NOTES:

1. Data are combined with station 08MF003. Data provided by M. Miles.
2. Flow "intensity" for instantaneous flow is the runoff that would occur if that discharge were sustained for one day.
3. Instantaneous return periods estimated by Water Management Branch, except 08MH103, which is estimated by the writer.
4. 1-day return periods estimated from WSC flood frequency analysis, or from Fig. 2.
5. Return periods for U.S. stations estimated from USGS flood frequency analysis. Glacier Creek may have been affected by an outburst flood.

TABLE 3. STREAMFLOW DATA FOR FLOODS ON THE CHILLIWACK RIVER

Date	CHILLIWACK RIVER AT VEDDER CROSSING						CHILLIWACK R ABOVE SLESSE CR				RAINFALL AT HOPE	
	INSTANTANEOUS discharge (cms)	inst/daily ratio	1-DAY discharge (cms)	runoff (mm)	5-DAY discharge (cms)	runoff (mm)	INSTANT. discharge (cms)	1-DAY discharge (cms)	5-DAY discharge (cms)	runoff (mm)	1-DAY (mm)	3-DAY (mm)
Dec. 1917			765	54	est 447	157						
Dec. 1975	787	1.48	530	37	370	130	283	227	176	118	142.0	309.1
Nov. 1978	762	3.06	249	17	138	48	247	109	67	45	56.2	76.2
Dec. 1979	781	1.75	447	31	337	118	210	172	144	96	71.7	145.7
Dec. 1980	856	1.61	533	37	325	114	387	262	181	121	82.3	184.6
Jan. 1984	-	-	-	-	est 321	113	404	278	141	94	136.5	205.6
Nov. 1986	767	2.20	349	25	211	74	202	113	81	54	106.9	130.3
Nov. 1989	816	1.19	684	48	337	118	464	343	207	139	105.0	250.3

NOTES:

All flow data are in cubic metres per second (cms).

Floods since 1952 with peak instantaneous or daily flow at Vedder Crossing of at least 500 cms are listed, plus the 1917 flood.

Record for instantaneous flows began in 1969 for 08MH001 (Vedder Crossing), and in 1963 for 08MH103 (above Slesse Cr).

Data for Jan. 4, 1984, is missing for 08MH001. Daily flow is estimated at 523 cms, based on regression with 08MH103 flows.

In the U.S., the North Fork of the Nooksack River experienced the highest instantaneous and daily discharges on record, with return periods of 80 years, and at least 100 years, respectively. Several small basins on Mt Baker draining into the Nooksack and Baker Rivers also showed extremely high discharges on a unit area basis. The return periods for the larger Nooksack River, and for the Sauk River (the next drainage to the south with unregulated flow) are not unusually high.

In Table 2, daily discharge data are also given in terms of unit area runoff, for comparison with rainfall data. The 5-day runoff gives a very rough indicator of total storm runoff (a better estimate would require analysis of the continuous discharge hydrographs, which are not readily available). The highest runoff occurred in the North Fork Nooksack basin and in the small basins on Mt Baker, although based on the peak instantaneous discharge, the one-day runoff of Slesse Creek was probably extremely high as well. These runoff data are fairly consistent with the observed pattern of rainfall. The fact that the 5-day runoff totals for the Chilliwack and Nooksack watersheds are considerably lower than the 3-day rainfall observed at Hope and Nooksack Falls suggests that the zones of extremely heavy rainfall were confined to relatively small parts of the watersheds.

A problem in interpreting the discharge records of the Chilliwack River at Vedder Crossing is that the river bed, and hence the rating curve, at this location is very unstable. Discharges for this and earlier floods, therefore, may be subject to considerable uncertainty. The rating curve for the station above Slesse Creek, however, is quite stable. The return period of the daily discharge at Vedder Crossing, and the discharge figures themselves, are inconsistent with the high return periods and discharges for the Chilliwack above Slesse Creek and for Slesse Creek. On Nov. 9, the estimated daily discharge of $257 \text{ m}^3/\text{s}$ at Vedder Crossing is actually less than the $291 \text{ m}^3/\text{s}$ recorded above Slesse Creek; Slesse and Tamihi Creeks probably contributed at least $150 \text{ m}^3/\text{s}$ more. On Nov. 10, the estimated discharges are consistent. It is possible, therefore, that the discharge for Nov. 9 at Vedder Crossing has been substantially underestimated.

Comparison with other floods

Copies of the stage recorder charts for the 1989 and 1980 floods on the Chilliwack River, and for 1989 on the Nooksack River, are shown in Figure 3. Discharge and rainfall data for several floods on the Chilliwack River are given in Table 3. The main features of the 1989 flood appear to be the two separate peaks of about equal magnitude, and the relatively long duration of the flood. The 1980 flood, which had a higher peak instantaneous discharge but a lower daily discharge than the 1989 flood, is by comparison relatively short and more dominated by one peak. Some other floods on the river, for example those of 1978 and 1986, were very short with a single peak. The 1989 flood appears to be most comparable to the 1975 flood, which also had a high 5-day total runoff and a very high 3-day rainfall at Hope. It is possible that long-duration floods such as these are more damaging than short floods because they cause more erosion and transport more sediment.

Figure 4 shows a time series of the maximum daily fall/winter floods on the Chilliwack River at Vedder Crossing. It is remarkable that the frequency of floods higher than 500 m³/s in the last 15 years is greater than for any period since 1914-1921, when three floods occurred in an 8-year period. (500 m³/s is the approximate lower limit for floods listed by McLean [1980] as damaging.) This pattern is also apparent in the rainfall record. At Hope, 6 of the highest 7 one-day rainfall events in the last 51 years have occurred since 1974. (This statistic is somewhat misleading; the Hope station was moved in 1973, so its record is not homogeneous.) The longer record at Agassiz was examined by Church and Miles (1987). They found an above-average frequency of high annual maximum one-day precipitation during three periods, 1917-24, 1948-56, and 1971-84. It appears, therefore, that the high frequency of floods in the Chilliwack watershed in the last 15 years is due to a period of more frequent than average heavy rainstorms.

Summary of the meteorology and hydrology of the 1989 flood

The rainstorm of November 8-10 contained a zone of unusually heavy rainfall, which moved into the Nooksack River drainage from the southwest. Very heavy rain occurred on the Nooksack-Chilliwack divide, the first major mountain barrier encountered by the storm centre, and also on the north and east sides

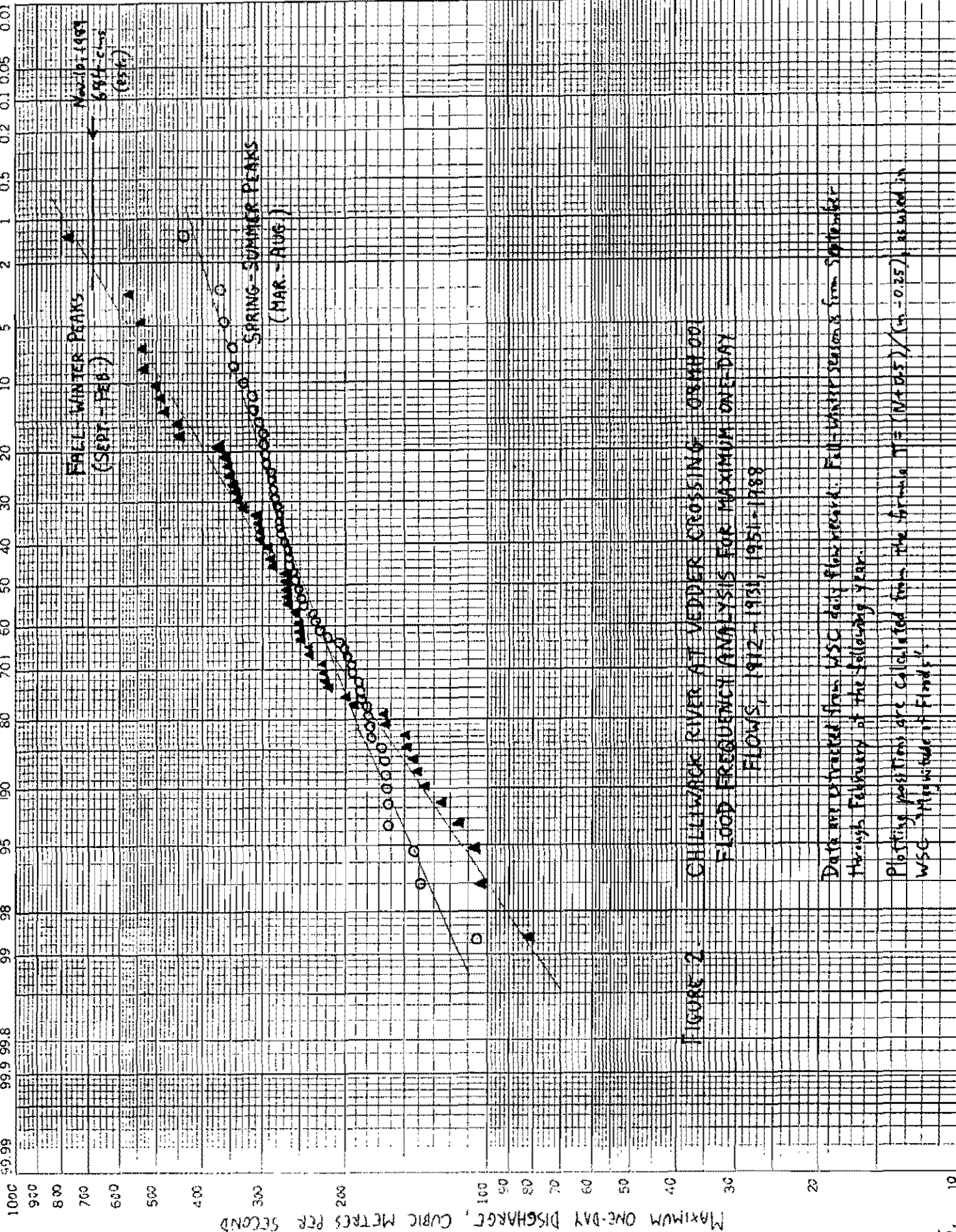


FIGURE 2 CHILLIWACK RIVER AT VEDDER CROSSING - ON-HOOL
FLOOD FREQUENCY ANALYSIS FOR MAXIMUM ONE-DAY
FLOWS, 1912-1981, 1961-1988

Data are extracted from WSC daily flow record. Fall-Winter season is from September through February of the following year.

Plotting positions are calculated from the formula $TF = (N+0.5)/(N+0.25)$, assumed in WSC "Magnitude of Floods".

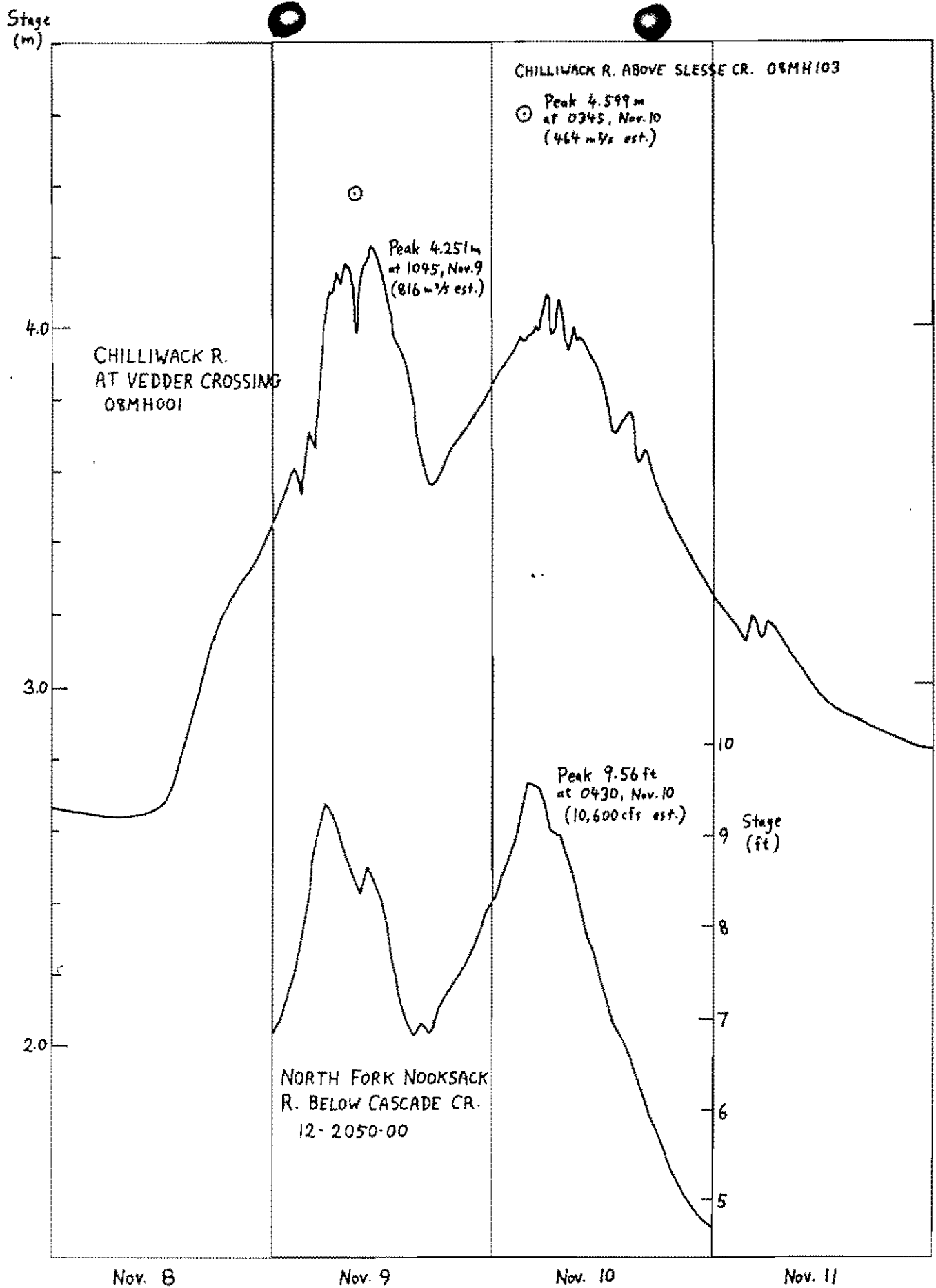


FIGURE 3A. HYDROGRAPH CHARTS FOR NOVEMBER 1989 FLOOD
CHILLIWACK AND NOOKSACK RIVERS

Stage
(m)

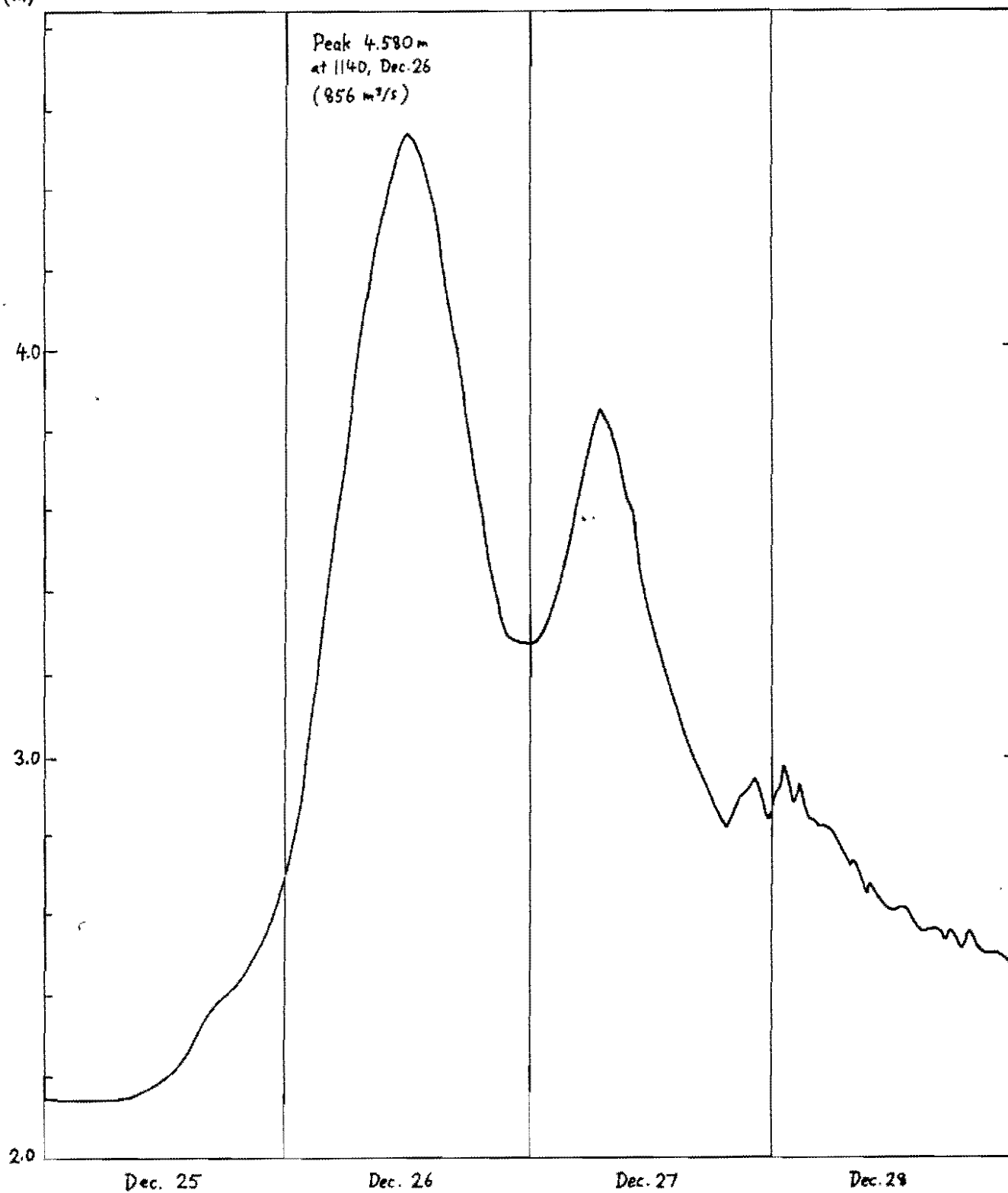
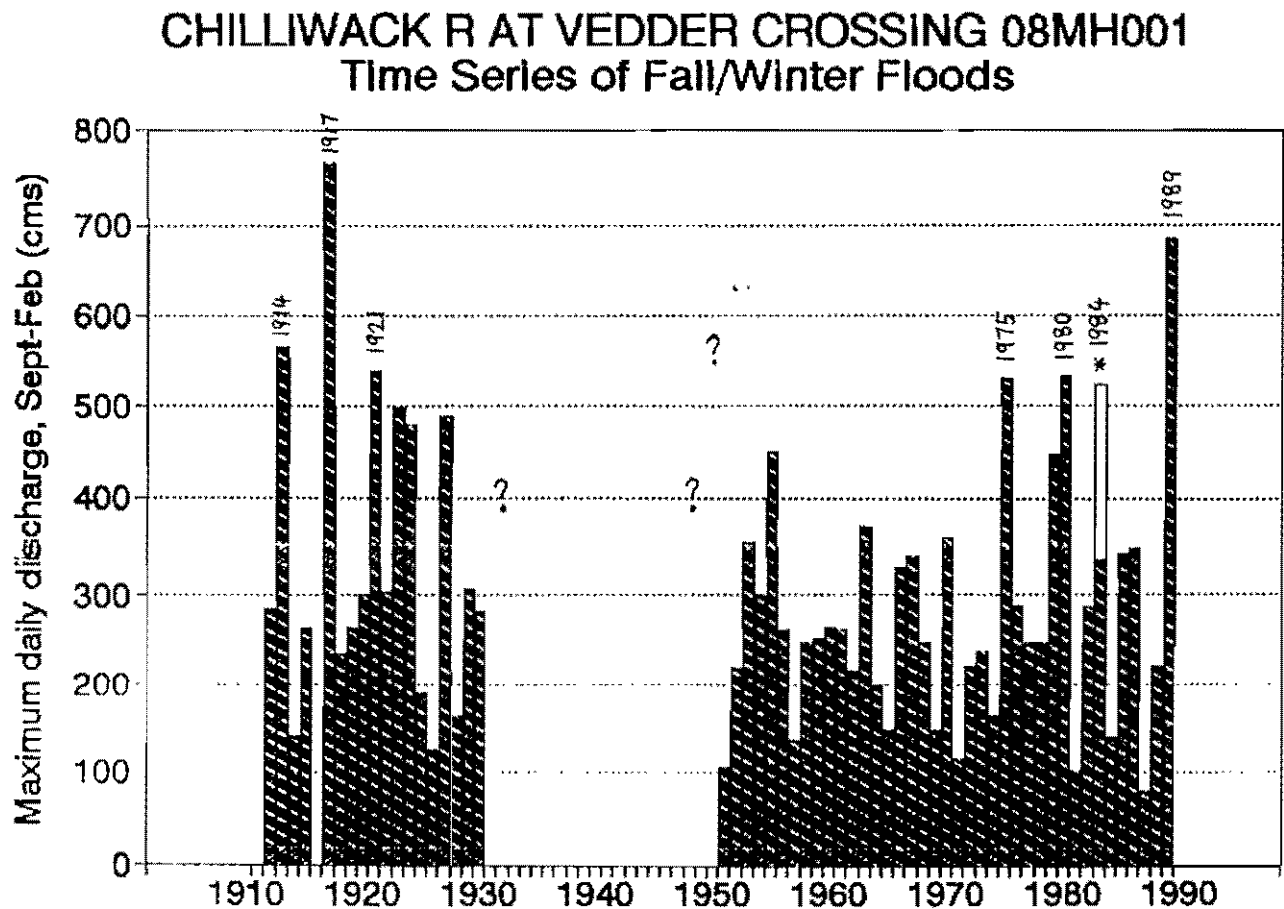


FIGURE 3B. HYDROGRAPH CHART FOR DECEMBER 1980 FLOOD.

CHILLIWACK RIVER AT VEDDER CROSSING OBMH001

FIGURE 4



* Jan. 1984 Flood : peak day (Jan. 4) is missing. Estimated discharge, based on regression with 08MH103, is shown.

? Floods also occurred in 1932, 1949, and 1951. Estimated discharges (from McLean, 1990; very approximate) are shown by question marks.

of Mt Baker. The zone of heavy rain moved northeast over the southern and central part of the Chilliwack River drainage, Wahleach Lake, Hope, and into the lower Coquihalla River drainage. The rainstorm had two peaks about 24 hours apart, causing two separate runoff peaks on November 9 and 10. Total storm rainfall on Nov. 8-10 in the Nooksack and southern Chilliwack drainages was probably about 200 to 500 mm or more. The highest flow in 52 years of record occurred on the North Fork Nooksack River, with a return period for daily flow in excess of 100 years. The Chilliwack River above Slesse Creek, and Slesse Creek, experienced peak instantaneous and one-day flows of about 100 years return period. The return period of the one-day discharge on the Chilliwack River at Vedder Crossing was about 50-65 years, but this flow may have been underestimated. Total storm runoff was unusually high because of the double peak and relatively long duration of the storm. The freezing level rose sharply during the ~~snow~~^{STORM}, melting much of the snow which had accumulated above 1000 m in the previous week; this snowmelt probably increased runoff in the Chilliwack watershed by about 20%.

4. LOGGING IN THE CHILLIWACK RIVER WATERSHED

An inventory was made of logged areas, other clearings, and roads in the Chilliwack watershed, using the forest cover maps and air photos which are current to August, 1988. This inventory is intended to provide indexes which can be related to the hydrologic response of the watershed and its sub-basins during rainstorms; it may not be relevant to silvicultural applications. The following assumptions and methods were used:

- All map units ("polygons") on the forest cover maps which are marked as having been logged were counted and included in one category, regardless of date logged. (It would be feasible to compile an inventory of individual polygons and their logging dates only if the computerized data base were used.) The areas of logged polygons, in aggregate, were measured by hand with a polar planimeter, or with a dot planimeter for small irregular polygons. Areas are probably accurate to about $\pm 5\%$.
- Areas burned by wildfires were not inventoried. Most of these areas were burned in 1938 or 1958, and have grown back in new forest or brush.

- Logged areas were divided into two categories, "reforested" and "not reforested" as follows: If a polygon was planted before 1980, or if it had not been planted but had tree cover of any species with either age class or size class of 2 or greater, it was considered reforested; that is, it is assumed to be equivalent to unlogged forest in terms of hydrologic behavior and sediment yield. If it did not meet these criteria, or was mapped as NSR, it was included in the "not reforested" category. This distinction is arbitrary, but it corresponds fairly well with areas that appear, or do not appear, to be reasonably revegetated on the air photos and satellite images.

- Map sheet 92H.004 (Chilliwack Lake area) did not have any logging history symbols for most polygons. Air photos were used to classify the logged areas as reforested or not.

- The area of other clearings was determined from the forest cover maps in the same way. These clearings include residential, agricultural, industrial, prison, and military uses.

- The total forested area of the watershed is considered to be all area below treeline, including undisturbed forest, logged areas, burned areas, non-productive brush, avalanche slopes, etc. It was determined by measuring areas above treeline on 1:50,000 topographic maps. These areas were checked against the air photos, and adjusted if necessary. The forested area is then calculated as the total watershed area, minus the alpine area and the area covered by lakes and river channels. This area is somewhat greater than the area of productive forest that would be determined from the forest cover maps.

The total length of logging and other roads was estimated using the forest cover maps. The area covered by roads was estimated, very approximately, by assuming that the average disturbed width of all logging roads is 10 m, including ditches, cuts, fills, pullouts, landings, etc. The width of the main Chilliwack River road was estimated to be 15 m. Road area is double-counted in that it was not subtracted from the logged areas.

The data from this land use inventory is summarized in Table 4 and on Figure 5. In the entire Chilliwack watershed, about 15% of the forested area has been logged, and about 10% is classed as not reforested. Other clearings amount to about another 1% of forest land. The proportion of forest land

TABLE 4. LAND USE IN THE CHILLIWACK WATERSHED

All areas are in hectares. Basins are mapped in Fig. 6.

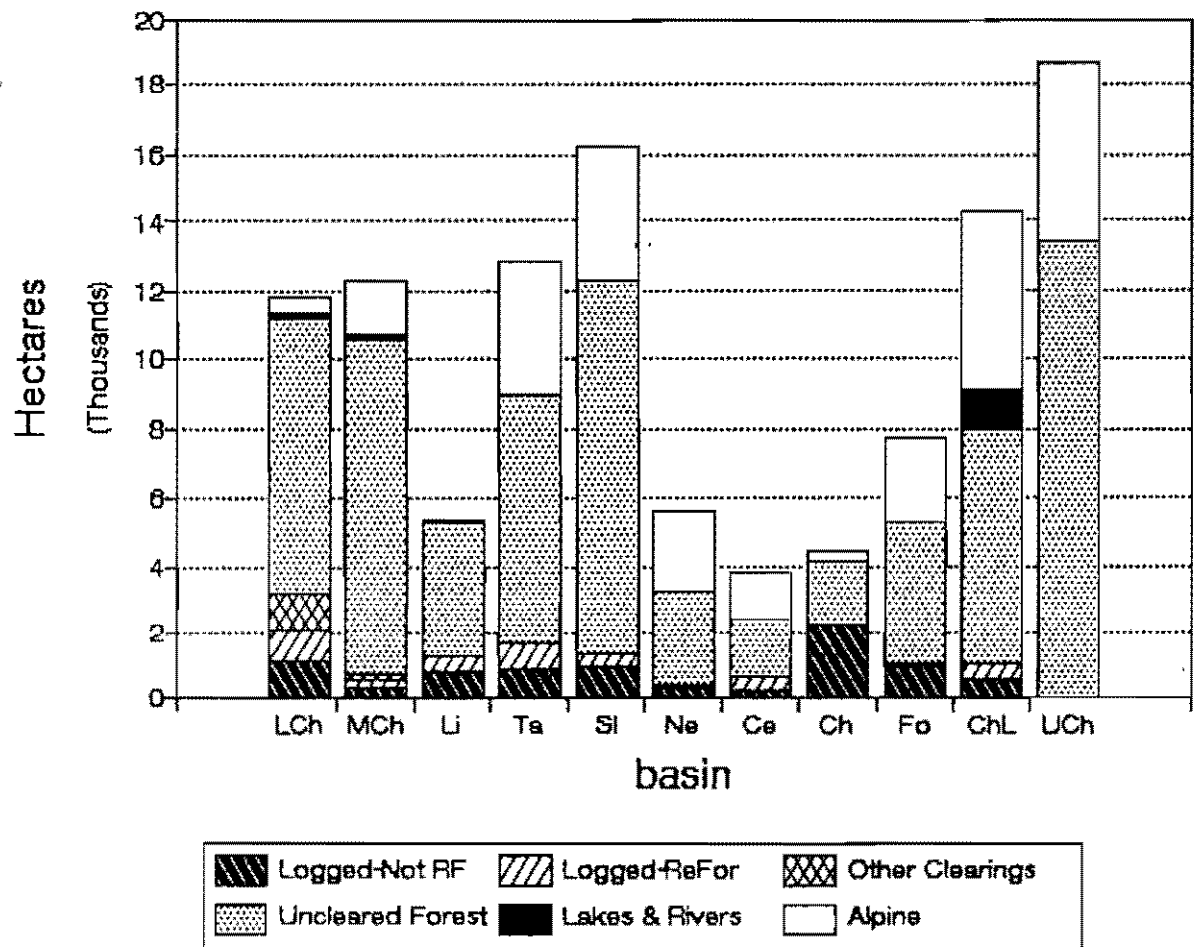
Basin	Logged- Reforested (1)	Logged- Not Refor. (2)	Total Logged (3)	Other Clearings (4)	Roads (5)	Lakes & Rivers (6)	Forest Area (7)	Total Area (8)	% Forest Logged (9)
Lower Chilliwack (below Slesse)	1044	1061	2105	1058	181	167	11200	11960	19%
Middle Chilliwack (above Slesse)	269	292	561	147	107	123	10600	12380	5%
Liumchen (6)	472	767	1239	8	39	3	3290	5390	23%
Tamihl	855	861	1716		63	26	9000	12910	19%
Slesse	422	933	1355	17	57		12300	16290	11%
Nesakwatch	75	296	371		24		3340	5640	11%
Centre	405	270	675		34		2460	3960	27%
Chipmunk	26	2174	2200		83		4200	4550	52%
Foley	98	942	1040		43	31	5300	7770	20%
Chilliwack Lake	487	397	1084	6	51	1160	8000	14360	14%
Upper Chilliwack (above lake)						40	13400	18710	0%
Total (7)	4153	8193	12346	1236	682	1550	85090	113920	15%

Notes:

1. Logged areas are considered reforested if planted before 1980, or if natural regrowth is of age or height class 2 or greater. (See section 4 of report.)
2. Includes residential, agricultural, industrial, military, etc.
3. This area is also included in logged and/or forested area.
4. Includes all naturally vegetated areas below treeline.
5. Total logged area divided by forested area.
6. Logged-Not Reforested area includes 470 ha in U.S.
7. Total watershed area does not include Sweltzer R - Cultus Lake basin.

FIGURE 5

CHILLIWACK WATERSHED Land Use



logged in the tributary basins ranges from zero in the upper Chilliwack (which is protected in a National Park) to 52% in Chipmunk Creek. With respect to possible impacts on the hydrology of the watershed, the relevant numbers are the area of roads, not-reforested logged areas, and other clearings; together, these amount to about 11.5% of the forest land, and about 8.5% of the total watershed area.

Studies in other parts of North America have indicated that logging can result in an increase in runoff from rainfall, for several reasons including reduction of transpiration, reduction of interception, increase in overland flow over disturbed and compacted ground, and concentration of runoff by roads and ditches. The first two of these effects are not applicable to the humid, winter rainfall dominated, climate of the B.C. coast. Potential evapotranspiration in November is only about 1 mm per day. Forest cover might have an interception capacity of perhaps 10 mm in any one rainstorm, but the loss of this would have a negligible effect in storms with total rainfall amounts of 200 mm or more. Interception of snow by the forest canopy may actually enhance runoff, since snow retained in the branches is subject to rapid melting because of its relatively high exposure to warm winds during a rainstorm, as compared to snow on the ground. Overland flow is generally not an important runoff generation mechanism on forest soils on the B.C. coast, except in saturated areas near water bodies and in depressions; most rapid runoff during storms comes from subsurface flow through large pores and openings in the soil. There is little evidence that logging significantly increases the amount of overland flow or the rate of runoff concentration from forest soils, except on roads and skid trails.

Roads and ditches, however, do have a significant effect in concentrating runoff. Roads produce overland flow in an environment where it is naturally a rare phenomenon, and ditches and road cuts intercept subsurface drainage paths. In the Chilliwack watershed as a whole, slightly less than 1% of the total forested area is covered by roads. The effect of roads would be to slightly advance and perhaps increase the discharge peak; total runoff would not be affected. In a watershed of this size, the overall effect is probably negligible. In the mountainous tributaries on the south and east sides of the watershed, there are extensive areas of bare rock, and some areas of ice, which produce overland flow during rainstorms. The additional effect of roads

in these watersheds would be negligible. However, in Chipmunk Creek, which is of relatively low relief and was almost completely forest covered, the logging road network may have a locally important impact on runoff by increasing the amount of overland flow.

The main effect of logging in the Chilliwack and other coastal B.C. watersheds is to increase sediment production. This increase comes from soil erosion, from debris slides that can occur in steep clearcuts and on road cuts and fills, from debris torrents caused by ditches diverting runoff to gullies, from erosion along ditches, and from road washouts along streams or at stream crossings. In this study, no inventory was made of logging-related sediment sources, but numerous such sources were noted on the air photos.

In the 1989 flood, most of the extreme runoff appears to have come from the southern tributaries. In four of these basins (Centre, Nesakwatch, Slesse, and Tamihi), there are numerous natural debris torrent gullies visible on the air photos, and Slesse Creek in particular appears, from its wide unstable channel, to carry a very high coarse sediment load derived from natural sources. The importance of logging-related sediment sources relative to natural sources is entirely unknown. On Liumchen and Chipmunk Creeks, the importance of logging in increasing the sediment load may be great. On Foley Creek, much of the sediment released by logging-related failures would be trapped by Foley Lake.

The road washouts and road-related failures that occurred during the 1989 rainstorm were inventoried by the MoF district engineering staff. From their records, these features were marked on the maps and air photos (see Figure 6). The amount of sediment involved in these washouts and failures is very roughly estimated at possibly 50,000 to 100,000 m³, mostly from debris torrents or road washouts. This probably represents an upper limit on the amount of sediment that could have been delivered to the river system. Of this, perhaps 1/2 to 3/4 would be bedload-sized material which could affect the river channel. This can be compared to the estimated volume of coarse sediment deposited in the Vedder River during the 1975 flood of 200,000 m³, and the 500,000 m³ which was eroded from the floodplain above Vedder Crossing (McLean, 1980; see next section). If these rough estimates bear any relation to

reality, logging-related sediment sources could have resulted in a significant increase in the sediment supply of the river.

5. SEDIMENT IN THE CHILLIWACK RIVER

The Chilliwack River carries a substantial sediment load through the narrow gap at Vedder Crossing and into the Fraser Valley. Before the river was restricted to its present course in the Vedder River following the 1894 flood, it had built a large fan occupying most of the valley between Yarrow and Chilliwack, and frequently shifted its channels on this fan. Since then, deposition of sediment in the Vedder River channel, and erosion along its banks, have been major problems during floods. The complex sediment regime of the river, and the flood control measures that have been applied, are described in a study by McLean (1980).

The sediment load consists of suspended load and bedload. Most suspended load, once entrained by the river, is washed through the river system to its mouth. Bedload, consisting of medium-to-coarse sand and larger material, moves intermittently along the bed of the river, and typically moves only short distances during each flood event. McLean gives data suggesting that the average annual yields of bedload and suspended load are roughly equal, in the order of 80,000 m³ per year. However, almost all the bedload movement takes place in a few short-duration floods. The amount of bedload deposited in the Vedder River channel during the 1975 flood was estimated to be about 200,000 m³, and the volume mobilized from bank erosion in the floodplain above Vedder Crossing was about 500,000 m³.

According to McLean, the main sediment sources for the river are bank erosion of floodplain deposits in the reach of the river between Liumchen Creek and Vedder Crossing, landslides and bank erosion in the thick terraces of glacially deposited gravel, sand, and silt, mainly between Chipmunk and Slesse Creeks, and tributary creeks carrying sediment from upland areas, most notably Slesse Creek. The wide floodplain reach below Liumchen Creek, and other wide reaches below Slesse Creek, do not produce "new" sediment, but are storage sites for sediment delivered from upstream. McLean found, from air photo interpretation, that the lower floodplain reach narrowed and became

revegetated and less braided between 1940 and 1971, a period of few floods. Between 1971 and 1976, it widened, losing about 19 hectares to erosion, almost all of it in the 1975 flood. This erosion was the main source of sediment which was deposited in the Vedder River channel during the flood.

The sediment regime of the Chilliwack River can be summarized, in very simple terms, as follows: Coarse sediment from tributary streams and from erosion of the terraces bordering the river is carried through the steep, narrow reaches of the river during frequent, small floods, and stored in gravel bars in the wide floodplains below Slesse and Liumchen Creeks. During extreme floods, the river widens by bank erosion in these reaches, mobilizing the stored sediment which is carried through the gap at Vedder Crossing and into the Vedder River.

The 1975 flood was the first in a series of four major floods and several smaller ones, culminating in the 1989 flood. During the 1989 flood, large areas of floodplain were eroded and major channel shifts occurred. Several observers noticed that large trees with roots still attached, apparently derived from bank erosion a short distance upstream, were being carried and were snagging on gravel bars. This suggests that bank erosion in the floodplain reaches was again the major source of sediment. (Air photos were taken after the flood; however, these were not available during the study. Interpretation of these photos would identify sediment sources along the lower reaches of the river.) It is possible that sediment mobilized during the previous floods of 1975, 1980, and 1984 in tributary and upstream areas and stored in the floodplains of the Chilliwack River and tributary creeks, might have contributed in a cumulative manner to the sediment supply during the 1989 flood.

It is difficult to relate this complex pattern of sediment movement to possible increases in the upstream sediment yield due to logging. Any such increases would not affect the behavior of the river at Vedder Crossing directly. Rather, they would contribute to deposition in the floodplain storage reaches upstream from Vedder Crossing, and the sediment would be made available for erosion during floods perhaps decades later. Presumably, a greater amount of aggradation in a floodplain reach between major floods would lead to higher sediment transport volumes and a greater tendency for lateral erosion in the next large flood.

Studies of bedload transport, and of the routing of sediment through complex river systems such as the Chilliwack-Vedder, are notoriously difficult. It would be impossible to resolve the question of the role of sediment contributions from logging in any single study. However, an inventory of channel changes along the lower Chilliwack River during the 1989 and some earlier floods would lead to better understanding of sediment transport in the river system; some measurements toward this end are being made now by the Water Management Branch. Understanding of the role of logging and road construction is probably best achieved through studies of sediment sources and contributions from tributary streams.

6. CONCLUSIONS AND RECOMMENDATIONS

The November, 1989, flood of the Chilliwack River was the second highest on record at Vedder Crossing, and had a return period of 50 to 100 years on the basis of daily flows. The flood had two peaks and was relatively long in duration compared to other recent floods. This may have resulted in unusually large amounts of bank erosion and sediment transport. The flood was caused by heavy rainfall over a three-day period, and was enhanced by snowmelt. The rainfall was apparently heaviest along the divide with the Nooksack River, which experienced even more severe flooding.

Logging in the Chilliwack watershed had no effect on total runoff during the storm, and probably had a negligible effect on the timing and peak flow of the flood. However, logging-related road washouts and slope failures have increased the sediment supply to the river. The amount and significance of this increase cannot be determined without considerable field work.

Flood hazard along the lower Chilliwack and Vedder Rivers is largely a function of the sediment regime of the river. In order to better understand the sediment regime and the effects of logging on it, further studies involving field work are necessary. These should include an examination of channel changes along the lower Chilliwack River, an inventory of sediment sources in the watershed, and monitoring of the effects of logging and road construction on sediment production.

7. REFERENCES AND SOURCES OF INFORMATION

McLean, D.G. 1980. Flood Control and Sediment Transport Study of the Vedder River. M.A.Sc. Thesis, Dept. of Civil Engineering, University of B.C.

Water Survey of Canada (undated). Magnitude of Floods - British Columbia and Yukon Territory. (To 1980.) Environment Canada, Water Resources Branch, Vancouver.

The following people and agencies were contacted and provided information used in this study:

Earl Coatta, Atmospheric Environment Service, Vancouver.

Monty Evin, Water Survey of Canada, New Westminster.

Martin Madelung, Ministry of Highways, Victoria.

Neil Matson, Chilliwack District, Ministry of Forests, Rosedale.

David McLean, Northwest Hydraulic Consultants, North Vancouver.

Mike Miles, M. Miles & Associates Ltd., Victoria.

Oliver Nagy, Water Survey of Canada, Vancouver.

Neil Peters, Water Management Branch, Ministry of Environment, Surrey.

David Thompson, Water Management Branch, Ministry of Environment, Victoria.

Bill Wiggins, U.S. Geological Survey, Tacoma, Washington.

Al Zander, Mt Baker Ranger District, U.S. Forest Service, Sedro Wooley, Washington.



Province of
British Columbia

Ministry of
Forests



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VOX 1X0

February 12, 1990

File: 985-5 Chilliwack River

Mr. Peter Jordan
3046 - West 7th Avenue
Vancouver, B.C.
V6K 1Z8

Dear Sir:

We require factual information in report form with respect to the November 8 to 11, 1989 floods in the Chilliwack River Valley.

Some of the information may have to come from the American side of the border because the river drainage extends south of the border.

The information we consider pertinent is as follows:

1. Climate information
 - (a) Rainfall intensities November 8, 9, 10, 11, 1989
 - 24 hour periods
 - daily return period
 - combination return periods
 - use AES or similar data from surrounding recording stations.
 - (b) Snowfall
 - what was there before the storm
 - what was left after the storm
 - what was the effect of rain on snow.
 - (c) Discharge rates as available from Water Management Branch or Water Survey of Canada.

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February 12, 1990

2. Area of deforestation in the drainage
 - (a) How many hectares does the drainage encompass
 - (b) How many hectares are deforested
 - % in cut over
 - % in roads
 - % in farms, etc.
 - How much is cut over but in a state of equivalency.
3. Professional advice as to whether logging can be implicated in the November 1990 flood and to what degree.
4. Any recommendations:
 - Emphasis on areas where logging has an impact with recommendations for reducing the affect.
5. Be prepared to make a presentation at public meeting with the information. (Optional and open for discussion.)
6. Suggested sources of information:
 - AES
 - Landstat photos
 - 1:70 000 air photos
 - High level photos

We will provide:

 - 1:70 000 air photos 1987-88 photography , ¹⁹⁸⁵⁻⁸⁶
 - 1:20 000 air photo maps based on the 1:70 000 photography
 - 1:20 000 inventory maps with disturbance history
 - Satellite image 1986

- We have some 1:10 000 coloured air photos 1985, which can be made available if required.

Information provided by Mike Miles:

- (a) Frequency analysis of multi-day precipitation at Abbotsford, Chilliwack and Hope airports.
- (b) Maximum Stream Discharge Values observed in the vicinity of Hope and their return periods.
- (c) Daily precipitation values observed in the vicinity of Hope.

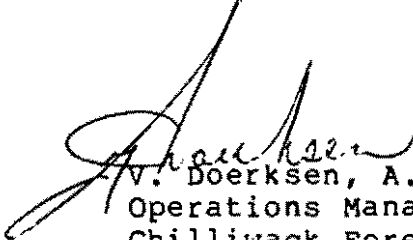
P. Jordan

- 3 -

February 12, 1990

- Information provided by Bert Argent, Forest
Service Bridge Engineer.

Yours truly,



V. Doerksen, A.Sc.T.
Operations Manager (Harvesting)
Chilliwack Forest District

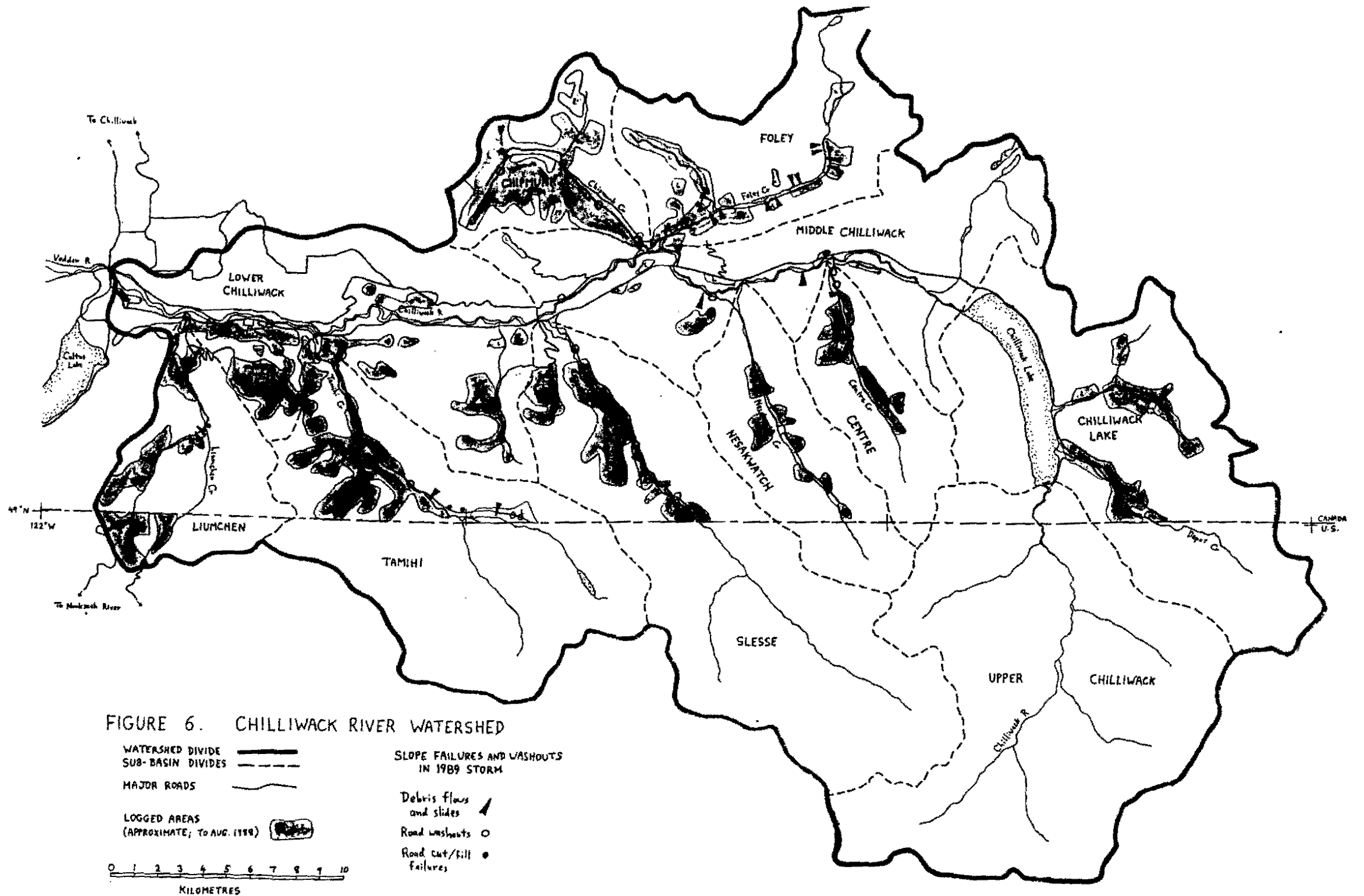


FIGURE 6. CHILLIWACK RIVER WATERSHED