PROVINCE OF BRITISH COLUMBIA

MINISTRY OF ENVIRONMENT

WATER MANAGEMENT BRANCH

PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY

by

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File: P72-3

SYNOPSIS

This study, which was authorized following the record October 1984 flooding, examines the various levels of flood protection for the predominantly rural Pemberton Valley.

Sub-area unit costs for the recommended flood protection proposals, excluding the airport area, range from \$1355/ha to \$4455/ha for 1:50 protection and from \$1760/ha to \$6030/ha for 1:200 year protection.

1:200 year flood protection for the Village of Pemberton and the surrounding urbanized region, where there are very considerable benefits to be derived from increased flood protection, is expected to cost \$1.7 m.

The estimated overall cost for 1:50 year instantaneous flood protection works is \$10 m and for 1:200 year protection is \$13.7 m.

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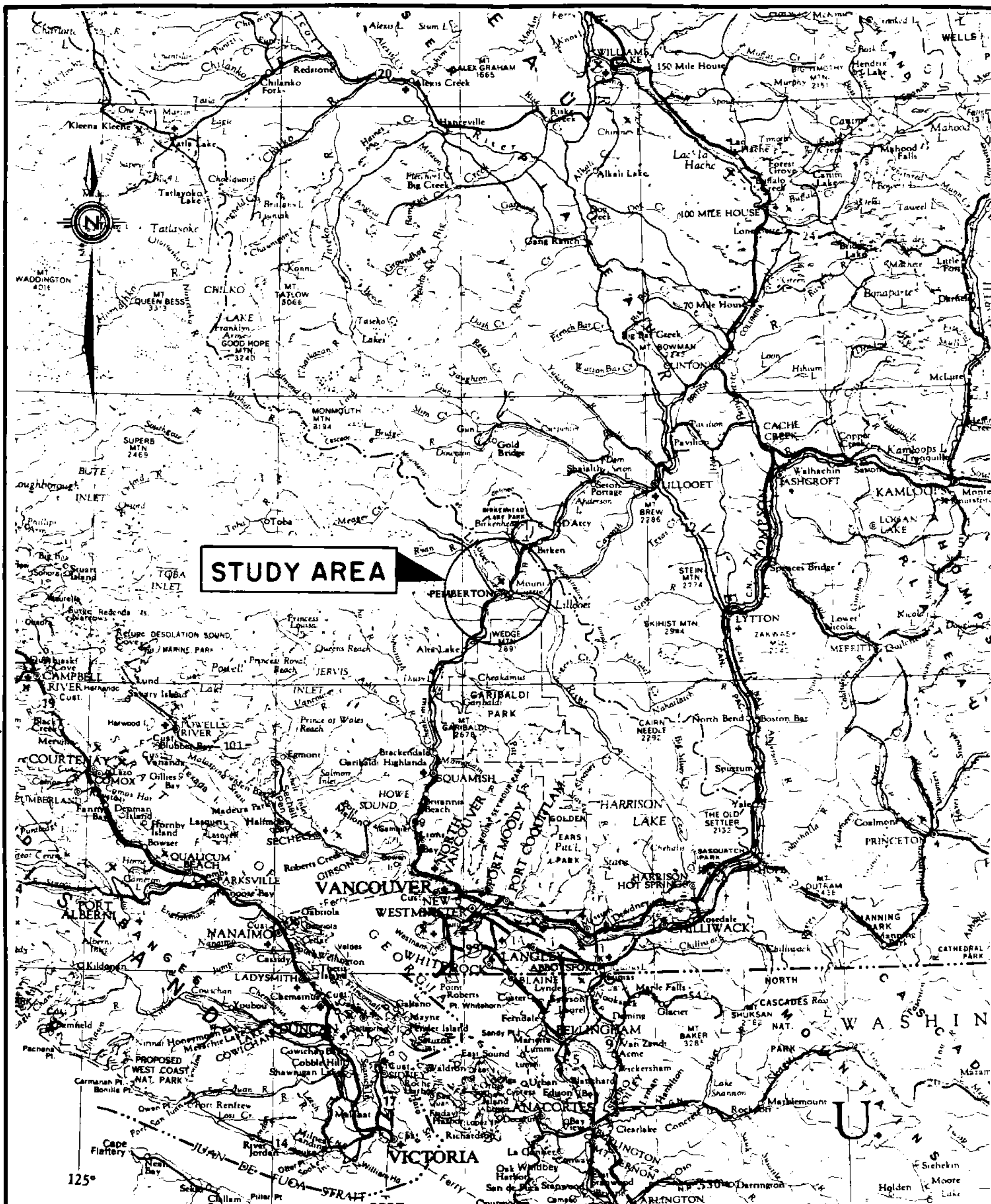

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON
PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
LOCATION PLAN

SCALE: 1:2 000 000	DATE	ENGINEER
MAP NO. 1J	JULY 1985	FILE No. P72-3 DWG No. 85-13-LOCATION PLAN

BCIL 7673-M E

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1.0 INTRODUCTION

Following the flooding of historic proportions which took place throughout the Pemberton (Lillooet River) Valley on October 8th and 9th, 1984, the area residents represented by the Squamish-Lillooet Regional District, the Village of Pemberton and the Pemberton Valley Dyking District requested this comprehensive study of flood alleviation measures.

Extensive reclamation[1] and erosion control work was undertaken throughout the valley by the Prairie Farm Rehabilitation Administration (P.F.R.A.) during the period from 1946 to 1953, followed by rehabilitation and further improvement work, mainly bank protection, carried out with A.R.D.S.A. funding over a five year period starting in 1979. The latter project included both extensive bank protection and limited dyking works on the Mt. Currie Indian Band lands. All of the Lillooet River Dyking Improvements were intended to protect to the 1:50 year instantaneous flood level although this was not defined precisely.

Coincident with the A.R.D.S.A. program was a series of flood events, starting with what was then a near record one on Dec. 26, 1980, followed by a higher one on Oct. 31, 1981, severe ice damage during January 1984 and culminating with the October 1984 flood. Federal-Provincial funding was provided through the Provincial Emergency Program to repair damages caused to the protective works by these events and to restore river channels blocked with gravel and debris. Most of the gravel removed under this program was utilized, in conjunction with the A.R.D.S.A. Program, to further improve the flood protection system, particularly in the Ryan River area.

The Pemberton Valley Dyking District is the local authority responsible for dyke construction and maintenance throughout most of the

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[1] Cut off channels shortened the channel length by 5.5 km (3.4 miles)

valley with the exception of the Indian Lands, which, although mostly within the Dyking District's boundaries, have not been subject to taxation. Responsibility for maintenance of the A.R.D.S.A. improvements on Indian Lands rests with the Federal Department of Indian and Northern Affairs.

Earlier reports pertaining to Pemberton Valley flooding include those prepared by Doughty-Davies[1], Wester[2] and Tempest[3], all of the Provincial Ministry of the Environment or its forerunners.

2.0 SCOPE OF REPORT

This report concerns protection for development within the Pemberton Valley extending from Lillooet Lake upstream past the Forest Service Bridge to and including Lot 813.

Embodied in the report are:

1. Water surface profiles for the updated, dyke confined 1:200 and 1:50 year instantaneous flood projections for all (6) significant watercourses within the study area.

2. Water surface profiles for the dyke confined (except in the case of Lillooet River), October 1984 flood, for the above watercourses.

3. Cost estimates, by areas, for dyking to protect against the 1:200 and 1:50 year floods; including appropriate alternatives.

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1 J.H. Doughty-Davies, Preliminary Report on Lillooet River Flood Control, B.C. Water Resources Service, Water Investigations Branch, (March 1972).

2 J. Wester, Preliminary Report on Pemberton Valley Dyking District Drainage Proposals, B.C. Water Resources Service, Water Investigations Branch, (Aug. 1967)

3 W. Tempest, Pemberton Valley Flood and Erosion Control, B.C. Ministry of Environment (Nov. 1977)

4. Examination of building elevation as an alternative to dyke construction.

5. Assessment of the potential flood relief achievable by the lowering of Lillooet Lake.

6. Consideration of the B.C. Railway embankment constriction.

7. Protection for the "McKenzie Cut" area.

8. Review of the options for drainage improvement in the Pemberton Village area.

9. Assessment of the extent and impact of timber harvesting in the area.

10. The relevance of seismic activity in relation to the October 1984 Meager Creek flood.

3. HYDROLOGY

3.1 October 1984 Storm

3.1.1 Observations

The Atmospheric Environmental Service[1], determined that heaviest precipitation from a broad frontal system which moved onto the B.C. Coast on October 7th, 1984, was concentrated in the Squamish area and in Central Vancouver Island.

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[1] John Thomas, Pacific Region Technical Notes, 84-014, Canada, Atmospheric Environmental Service.

The extreme runoff experienced in both the Squamish and Pemberton areas was attributed to the duration and north-south orientation of the frontal system, rather than to its intensity which, as may be seen from the following rainfall analysis summary, Table 1, was not exceptionally great in the Pemberton Village area.

TABLE 1

PEMBERTON VILLAGE RAINFALL[1] ANALYSIS

Duration	Precipitation	Return Period
1-day	68.4 mm	5 years
3-day	119.8 mm	20 years

Flow information from nearby gauged watersheds confirms the severity of this storm. The Squamish River peak instantaneous flow exceeded the previous record by some 15 percent, while the Elaho R. had its second highest peak flow and the Cheakamus River gauge near Brackendale recorded its third highest peak flow. In the small, glacier fed watersheds, Bridge River below the Bridge Glacier experienced a peak flow in the order of 200 m^3/s, more than double the previous record flow (5 year period), Place Creek near Birken registered a peak flow 70 percent geater than the previous 16 year record, and at Sentinel Creek, above Garibaldi Lake, the gauging station which had been in place for 19 years was washed away!

Within the Lillooet River Basin the only active hydrometric station is #08MG005, on the Lillooet River near Pemberton, a station for which 64

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[1] B.C. Forest Service Precipitation Gauge, Pemberton Village

years of records dating back to 1914 are available. Unfortunately, during the 1984 flood, dyke overtopping and subsequent failure in the Miller Creek area caused a considerable flow, estimated[1] to have averaged 184 m^3/s, to bypass this gauging station. Thus, the only reasonably accurate October 1984 flow data for the watershed are estimates for one location, derived from observed river flows adjusted to reflect bypassing overbank flow. The resulting provisional[2] estimated flows at this station, together with the previous recorded maximums, are:

Instantaneous Peak Flow	1310 m^3/s	Previous Record 993 m^3/s	Dec. 1980
Daily Peak Flow	1110 m^3/s	Previous Record 900 m^3/s	Oct. 1940

3.1.2 Analysis

The estimated maximum instantaneous and maximum daily flows at the Lillooet River gauging station, together with data from analysis[3] of flow records from previous major floods which had occurred while hydrometric stations were also in operation on the Green and Soo Rivers and on Rutherford Creek, were used to derive the probable flows at other locations throughout the drainage basin - see Table 3. Computer modelling techniques were then employed to reconcile these derived flows with flood profiles plotted from observed highwater marks[4]; appropriate adjustments were made where necessary.

3.2 Seismic Activity

The possibility that seismic activity might have triggered the sudden Meager Creek flood surge, which caused extensive damage on Oct. 9th,

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1 R.W. Nichols, B.C. Ministry of Environment, Water Management Branch
2 Beyond the range of the rating curve
3 Appendix A
4 Reference Water Management Branch Drawings No. 85-13-1 to 5 incl. not included in general distribution copies of report.

may be discounted since it has been established that the only recent preceding earth tremor of any significance, measuring 3.0 on the Richter Scale, occurred on September 22nd, and was centred in the Homathco Snowfield some 120 km to the northwest. A tremor of this magnitude would not be expected to cause ground or ice movement, even at its epicenter.

Examination of the Meager Creek watershed during the snow-free season would be necessary to determine the extent to which factors other than precipitation may have contributed to local problems in that area. The findings of such an investigation would, however, be inconsequential insofar as the study area is concerned since the steep Meager watershed constitutes only 13.5% of the Lillooet River drainage basin, as measured above the Ryan River confluence, and any sudden flow surges resulting from the collapse of channel blockages would have dissipated before reaching the study area.

3.3 Effects of Timber Harvesting

An assessment of the extent of timber harvesting activity and its effect on peak flows was undertaken by the Surface Water Section[1]. A synopsis of this assessment, details of which are to be found in Appendix C, is as follows.

During the period since 1958, when logging in the Pemberton Valley was first recorded, the average cutting rate has been 262 hectares (ha) per annum, for a total cut of 6800 ha or 3.1 percent of the total watershed area - see Table 2; of this area approximately fifty percent has been replanted since 1965 - see Figure 2.

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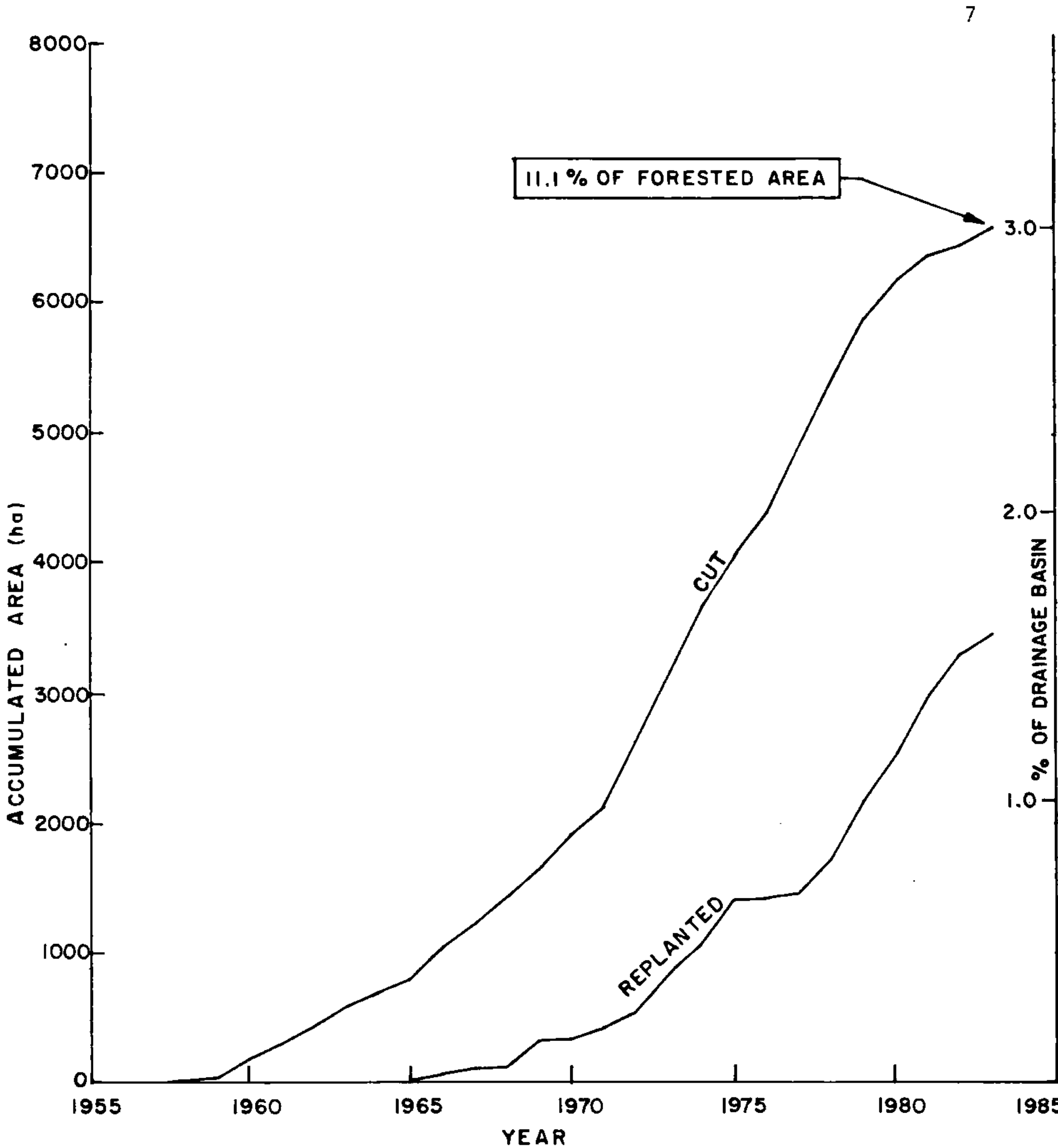
[1] D.E. Reksten, Technical Memorandum, Ministry of Environment, Planning and Resource Management Division, Water Management Branch, (Jan. 1985)



Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	TO ACCOMPANY REPORT ON PEMBERTON VALLEY FLOOD PROTECTION 1985 STUDY LILLOOET RIVER BASIN LOGGING HISTORY 1938-83
SCALE: AS SHOWN — DATE: JUNE 1985	D. E. REKSTEN / H.H.N - PORTER ENGINEER FILE No. P 72-3 DWG No. 85-13-18

BCIL 7873-M.E

FIGURE 2

In this watershed economically merchantable timber stands generally do not extend above the 1200 m elevation, consequently, to provide a more representative assessment of the stage to which harvesting has progressed the Timber Harvesting Summary provided in Table 2 includes "cut areas" as percentages of the "forested" watershed areas below the 1200 m elevation, for both the whole basin and for selected sub-basins.

TABLE 2

TIMBER HARVESTING SUMMARY

Basin	Basin Area (km^2)	Area Cut 1958-1983 (km^2)	Cut Area as % of Basin	Forested Area (km^2)	Cut Area as % of Forested Area
Lillooet River incl. tribs.	2160	68	3.1	610	11.1
<u>Sub-basins</u>					
Ryan River	419	17	4.1	82	20.8
Meager Creek	225	6	2.1	77	7.7
Pebble Creek	132	0.5	0.4	11	4.3
North Creek	82	2	2.4	14	14.0

From this tabulation, it is apparent that the extent of logging along the major watercourses has been comparatively small, ranging from 0.4 to 4.1 percent of watershed areas, and, consequently, will have had very little effect on the magnitudes of the recent flood events.

3.4 Flood Frequency - Discharge Estimates

3.4.1 Peak Daily Flows

An analysis of the records from the seven hydrometric stations which have operated whithin the Lillooet River drainage basin was carried out by the Modelling Section[1]. In cases where the period of record was short, the resulting frequency estimates were adjusted to correspond with those for the longer etablished Lillooet River Station 08MG005.

For other Lillooet River locations and for the smaller ungauged watersheds the return period estimates were derived, by the Surface Water Section[2], from those for appropriate gauged locations using the 'regional envelope curve' published by the Water Suvery of Canada[3].

For the larger Ryan River watershed, the return period flows were determined from a plot of the return period estimates derived for the Green and Soo Rivers and for Rutherford Creek.

3.4.2 Instantaneous Peak Flows

Return period estimates for instantaneous peaks for the Lillooet and Green River hydrometric stations (near Pemberton), and for the Lillooet Lake (stage) were determined, as for the daily peak flows,

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1 R. Wyman, Technical Memorandum, Ministry of Environment, Modelling Section, Feb. 22, 1985. - See Appendix B

2 D.E. Reksten, Technical Memorandum, Ministry of Environment, Surface Water Section, June 26, 1985. - See Appendix A.

3 Canada, Inland Waters Directorate - Pacific and Yukon Region, Magnitude of Floods - British Columbia - Yukon Territory, (Vancouver:1982), Vol. 3

from analysis of records for these stations. Elsewhere along the Lillooet River the return period instantaneous flows were calculated from the return period daily flows, using modifications of the ratio of instantaneous to daily peak flows (I/D) as determined for the Lillooet River gauging station (08MG005).

For the other watersheds appropriate I/D factors[1] were used to obtain the return period instantaneous peak flows, the confidence limits for which are considerably wider than for the mainstem Lillooet River locations.

Figures 3 to 8 show the flood frequency-discharge relationships which were developed for representative locations in each watershed. Figure 9 shows the stage-frequency curves for Lillooet Lake.

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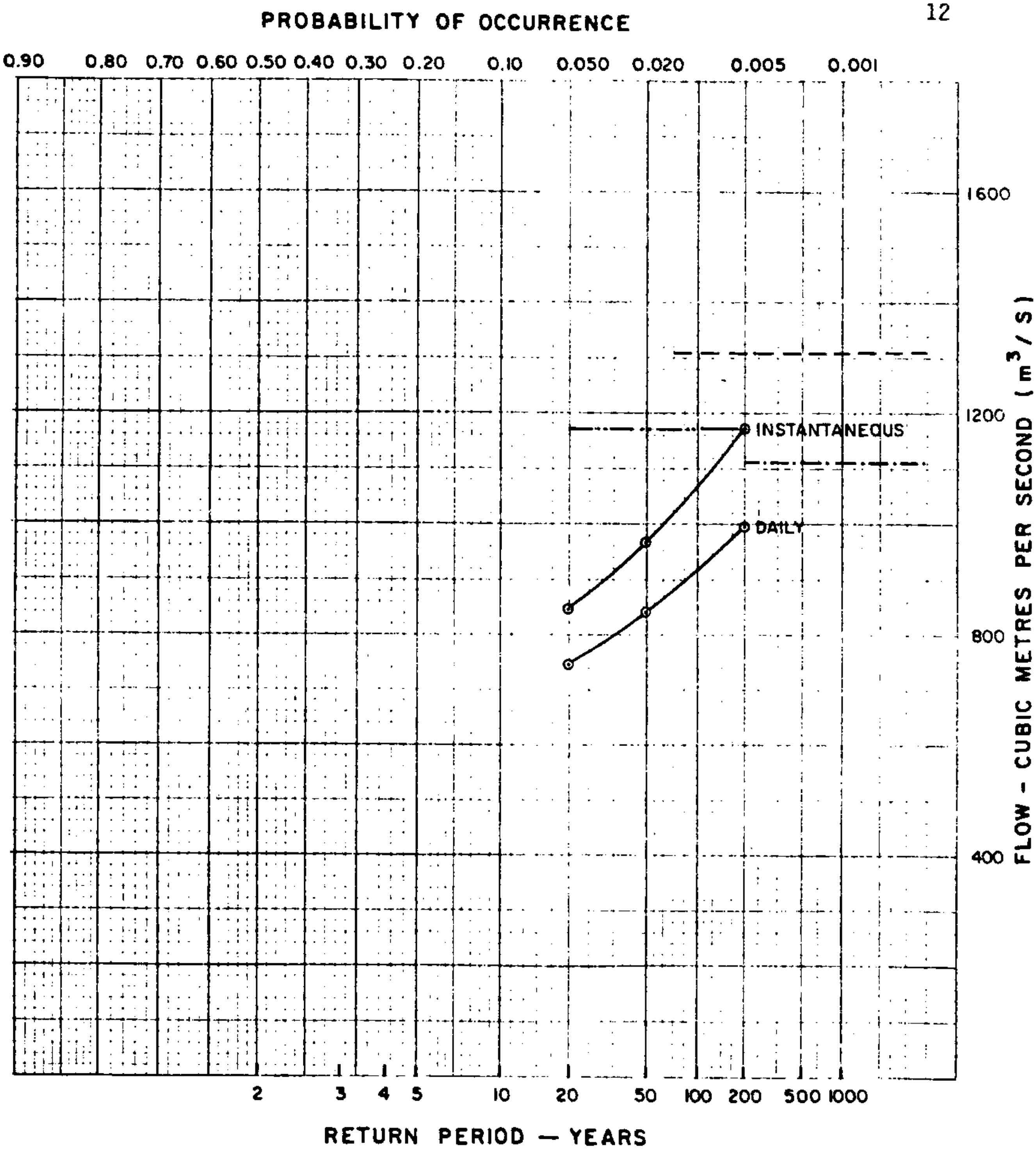
[1] See Appendix A, Table 2

TABLE 3

FLOOD MAGNITUDE AND RETURN PERIOD PREDICTION DATA

	LILLOOET RIVER					RYAN R.	MILLER CR.	PEMBERTON CR.	GREEN R.	BIRKENHEAD R.	
	Above Wolverine Creek	Above Ryan River	Nr. Pemberton Gauge #8MG005	Above Green River	Lillooet L. #8MG020	At Mouth	At Mouth	At Mouth	At Mouth	At Gauge # 8MG008	At Mouth
DRAINAGE AREA (km^2)	1560	1660	2160	2218	3200	419	78	51	868	597	638
EVENT											
October 1984 Flood											
- Daily flow	835	863	1110[1]	1139	1513	330[2]	124	25	350	149	160
- Instantaneous flow	1002	1049	1310[1]	1344	1755	430[2]	174	(37)	(392)	(194)	(208)
20 Year Return Period											
- Daily flow	593	622	746	765	990	256	100	46	382	267	278
- Instantaneous flow	670	703	843	864	1130	333	140	69	416	347	361
50 Year Return Period											
- Daily flow	655	690	840	860	1107	323	124	56	478	338	354
- Instantaneous flow	753	792	966	990	1290	420	174	84	525	439	460
200 year Return Period											
- Daily flow	796	830	992	1020	1312	432	170	79	660	536	565
- Instantaneous flow	939	979	1170	1200	1570	562	240	118	740	697	734

Footnotes:
1 Measured channel flow corrected for overbank loss
2 Derived from flood profile analysis
( ) May be grossly in error due to lack of data



—··—·· PRELIMINARY OCT. 1984 INSTANTANEOUS PEAK FLOW AS RECORDED AT GAUGE

— — — — PROBABLE OCT. 1984 INSTANTANEOUS PEAK FLOW

—·—·— PROBABLE OCT. 1984 DAILY PEAK FLOW

HYDROMETRIC STATION No. 08MG005

Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	PEMBERTON VALLEY FLOOD PROTECTION 1985 STUDY FREQUENCY - DISCHARGE CURVES LILLOOET RIVER NR. PEMBERTON
SCALE: VERT. ...... HOR ...... — DATE JUNE 1985	W. W. Nesbitt - Porter ENGINEER FILE No P 72 - 3 DWG No 85-13-28

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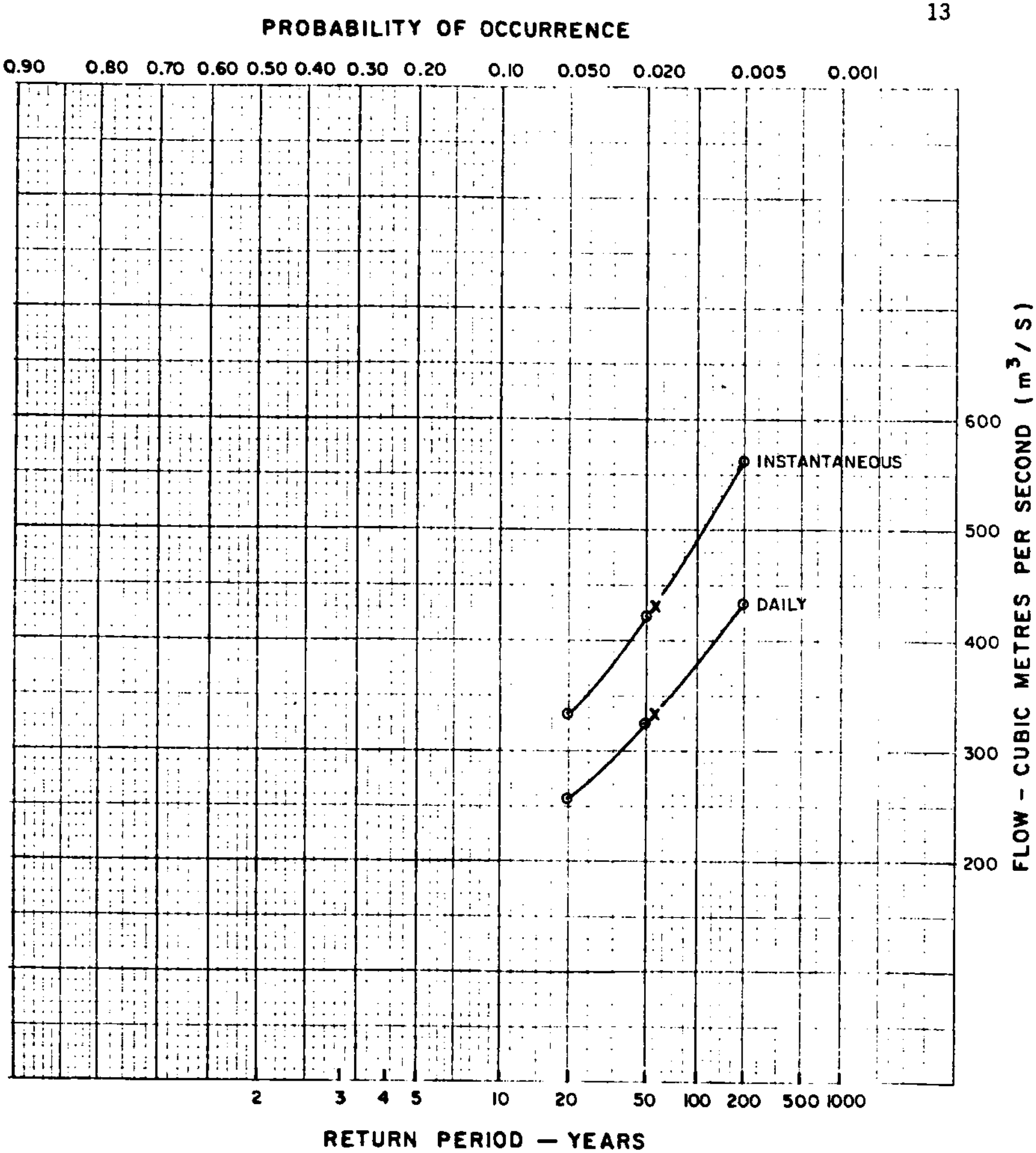
FIGURE 3



X PROBABLE OCT. 1984 FLOW

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
FREQUENCY - DISCHARGE CURVES
RYAN RIVER AT MOUTH

SCALE: VERT. ....
HOR ....

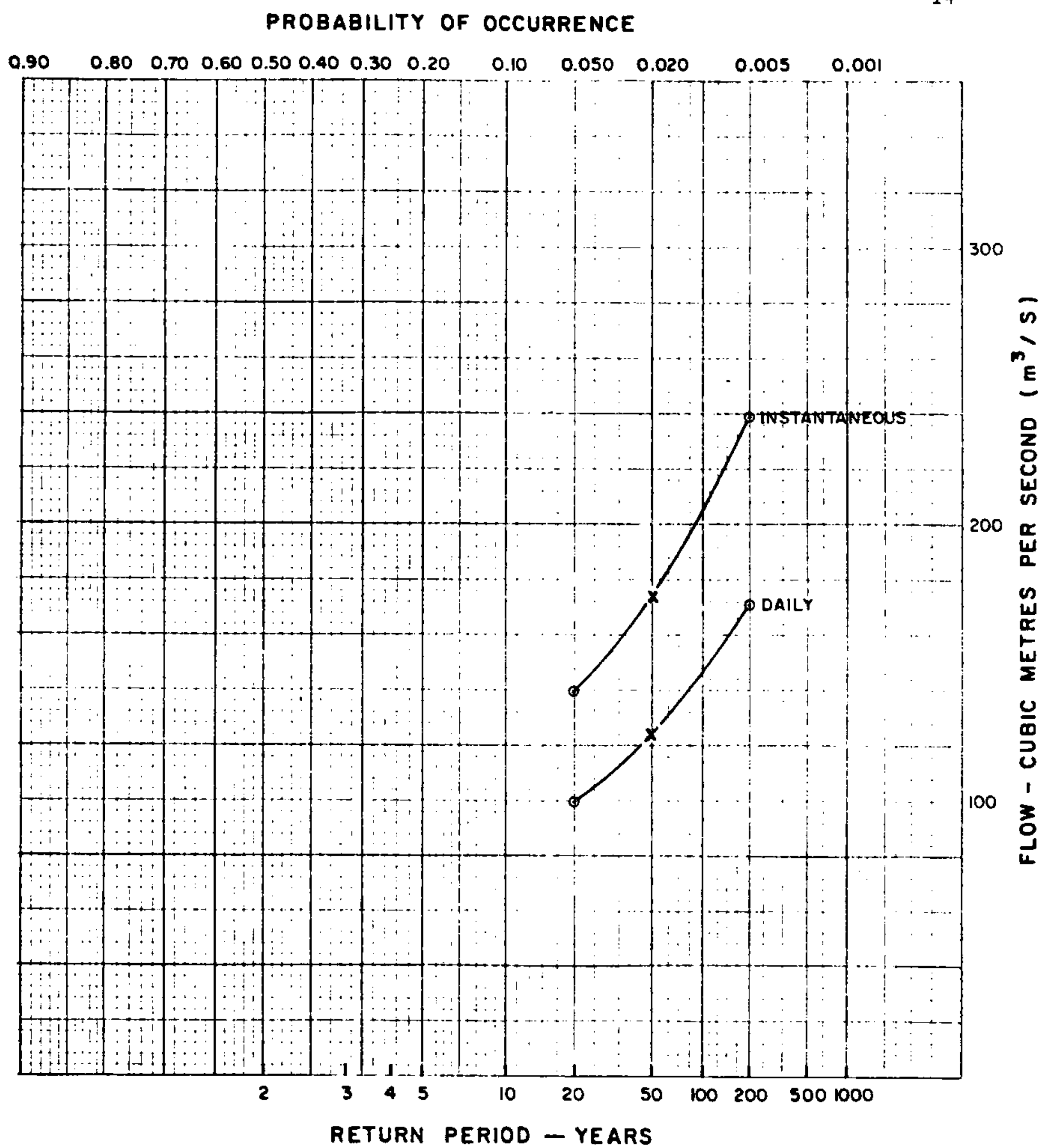
DATE
JUNE 1985

H. H. Nesbitt - Porter ENGINEER

FILE No. P 72 - 3 DWG No. 85 - 13 - 29

BCIL 7873-M E

FIGURE 4



X PROBABLE OCT. 1984 FLOW

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
FREQUENCY - DISCHARGE CURVES
MILLER CREEK AT MOUTH

SCALE: VERT. ....
HOR ....

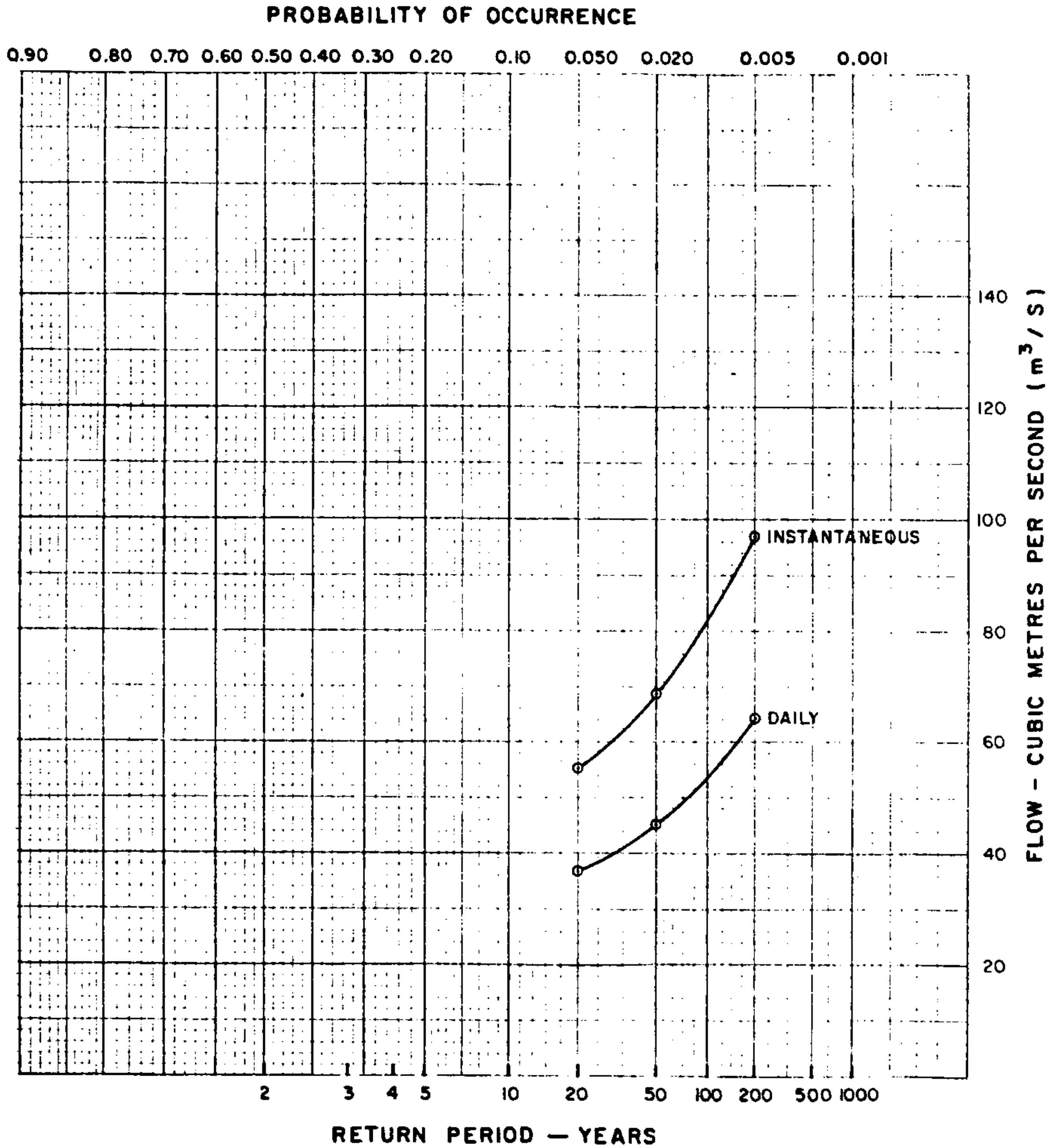
DATE
JUNE 1985

U. G. Nesbitt-Porter ENGINEER

FILE No P 72 - 3 DWG No 85-13-30

BCIL 7673-M E

FIGURE 5



Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
FREQUENCY - DISCHARGE CURVES
PEMBERTON (I MILE) CR. AT MOUTH

SCALE: VERT. ....
HOR ....

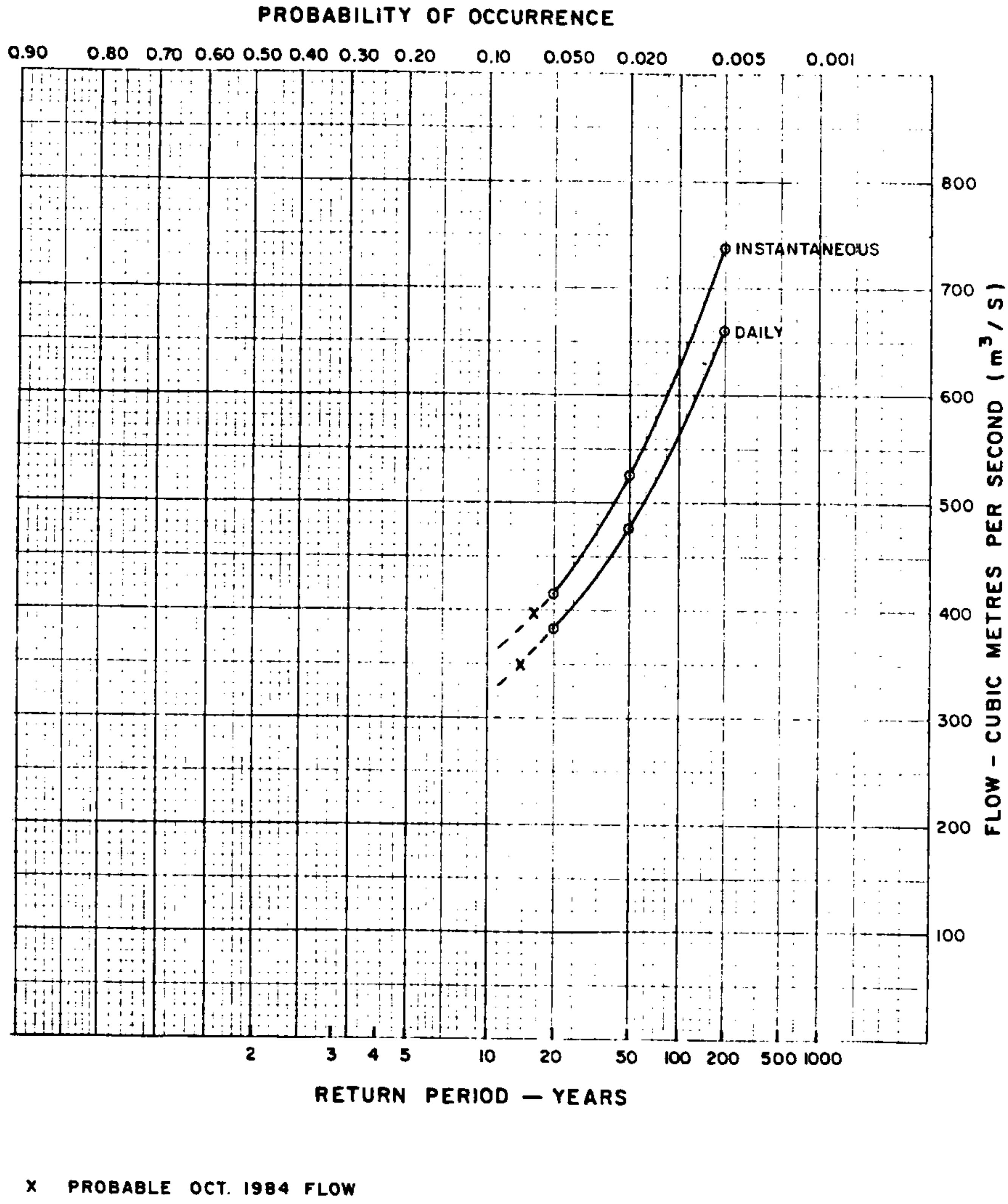
DATE
JUNE 1985

A. A. Nesbitt-Porter ENGINEER

FILE No P 72 - 3 DWG No 85-13-24

BCIL 7873-M E

FIGURE 6



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PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
FREQUENCY – DISCHARGE CURVES
GREEN RIVER AT MOUTH

SCALE: VERT ....
HOR ....

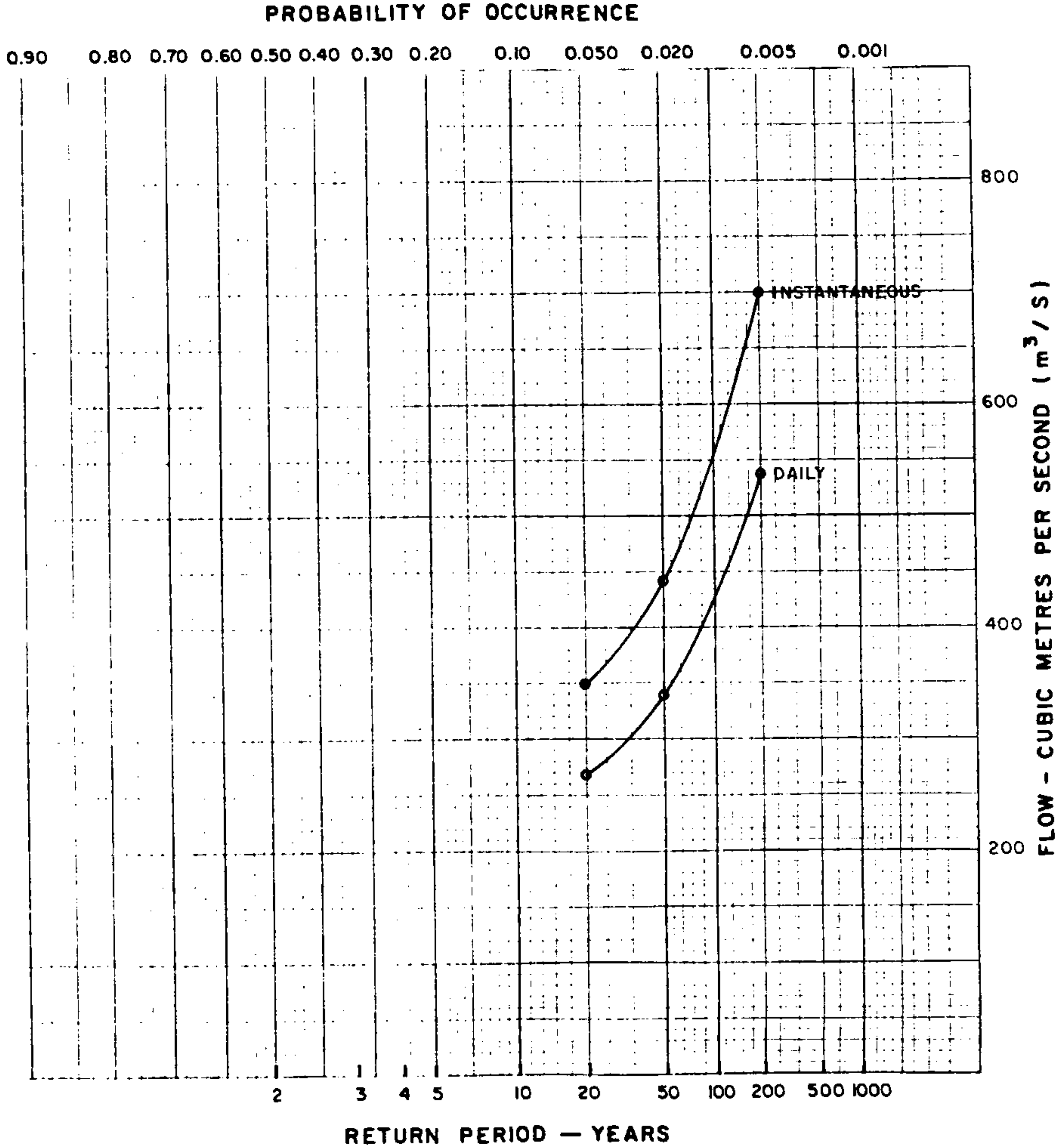
DATE
JUNE 1985

W.A. Nesbitt-Porter ENGINEER

FILE No P 72 – 3 DWG No 85 – 13 – 25

BCIL 7873-M E

FIGURE 7



Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
FREQUENCY – DISCHARGE CURVES
BIRKENHEAD RIVER AT GAUGING STN. 8MG008

SCALE: VERT. ...... HOR	DATE JUNE 1985	ENGINEER: [signature]
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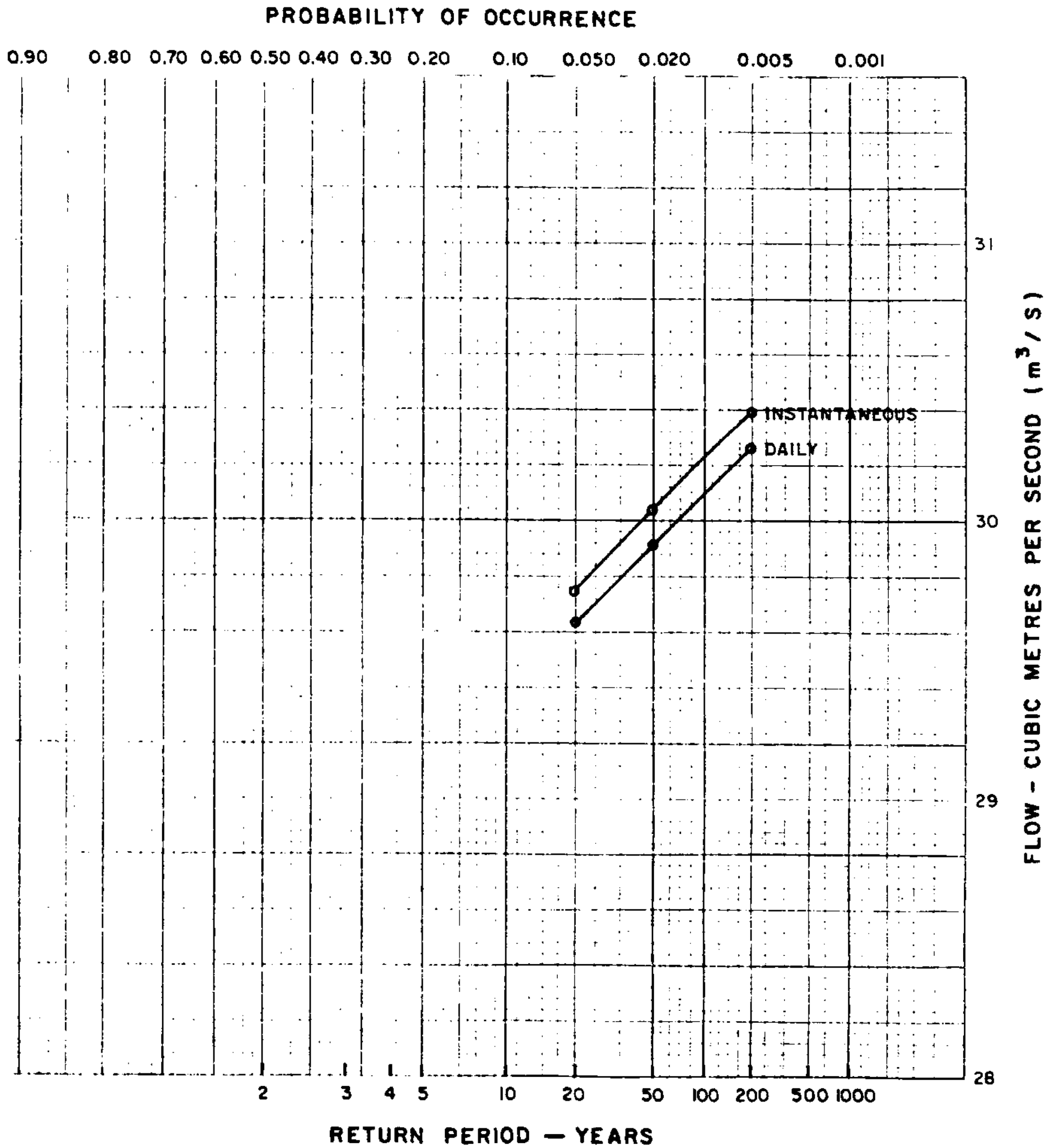
BCIL 7873-M E

FIGURE 8



HYDROMETRIC STATION No. 08MG020

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
STAGE - FREQUENCY CURVES
LILLOOET LAKE

SCALE: VERT. ....
HOR. ....

DATE
JUNE 1985

H. H. Nesbitt-Porter ENGINEER

FILE No. P 72 - 3 DWG No. 85-13-27

BCIL 7673-M E

FIGURE 9

4.0 LILLOOET LAKE

The water level in Lillooet Lake is controlled by narrows, some 24 km (15 miles) downstream from the head of the lake - see Figure. 10. During the period of P.F.R.A. activity in the valley, from 1946-53, extensive dredging of the narrows was carried out, resulting in a general lowering of the Lillooet Lake water levels and consequent changes along the downstream reach of the Lillooet River.

Following the 1984 flood, during which the lake reached a record level of 199.36 m (654.1 ft.), there was renewed local interest in the possibility that further excavation of the narrows would result in significant flood relief, at a reasonable cost.

To test the validity of this contention, 1:200 year instantaneous flow design flood profiles were calculated from Lillooet Lake upstream, assuming (a) that the lake level had been lowered by 1.3 m (4.0 feet) without any allowance for consequent bed scouring and (b) that the lake level had been lowered by 3.0 m (10.0 feet) and that 3.0 m of scour had resulted at cross section 0 (XS-0), reducing to zero scour at cross section 10 (XS-10). The flood profile elevation reductions which would result from these changes are shown in Table 4, from which it may be seen that the expected flood relief becomes insignificant (less than 0.3 m or 1.0 feet) by XS-4 and XS-11 (Green River confluence) respectively.

Extrapolation of updated cost estimates from the 1972 Doughty-Davies Report[1] indicates that a probable minimum expenditure in excess of $4 million, as determined in Section 8.2 would be required just to widen and deepen the narrows, undetermined further expenditures would be required for modifications to the Forestry Bridge crossing of the Little Lillooet (Tenasse) Lake Narrows, for excavation of those Narrows and for improvements to the outlet of Little Lillooet (Tenasse) Lake.

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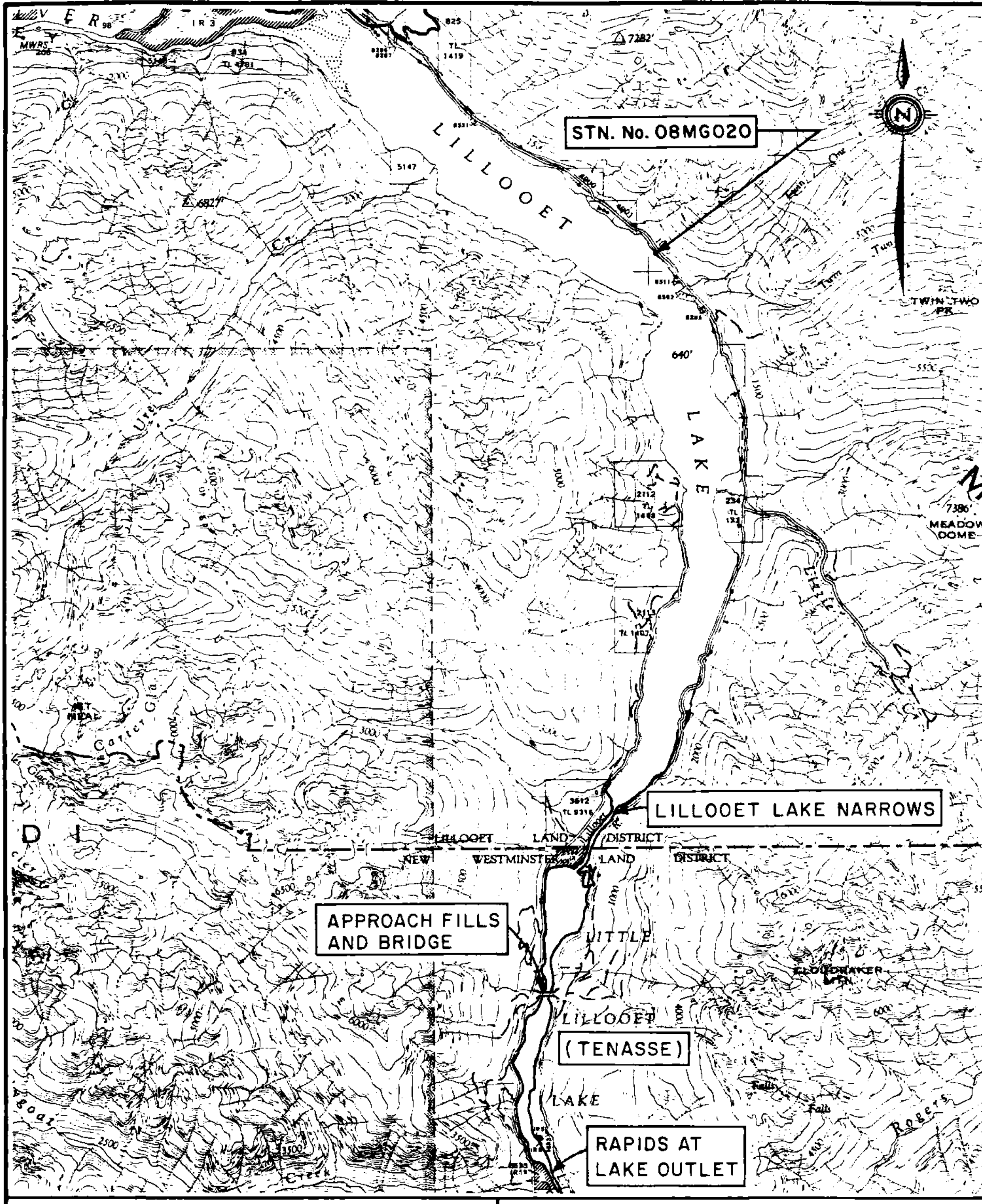
[1] J.H. Doughty-Davies, Preliminary Report on Lillooet River Flood Control, B.C. Water Resources Service, Water Investigations Branch, (March 1972, Design #1, p. 9



Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON
PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
LILLOOET LAKE DETAILS

SCALE: 1:125 000	DATE	H. H. Nesbitt-Porter	ENGINEER
MAP NO. 92 J/SE	JULY 1985	FILE No. P72-3	DWG No. 85-13-0

BCIL 7673-M.E.

FIGURE 10

In addition to the direct cost of such a project, which is prohibitively high in comparison to the meager benefits to be derived, a reduction in the level of Lillooet Lake would cause increased velocities in both the Lillooet and Birkenhead Rivers, resulting in further bank erosion, bed scour and consequent undercutting of the toe of existing riprap protection.

TABLE 4

LILLOOET LAKE LEVEL REDUCTION EFFECTS - 1:200 INSTANTANEOUS FLOW

XS#[1]	1.3 m Drop No Scour	3.0 m Drop		Distance from Lake (km)
	W.L. Reduction (m)	Assumed Scour (m)	W.L. Reduction (m)	
0	1.2	3.0	3.0	0
1	1.0	2.7	3.1	1.5
2	0.6	2.4	3.0	2.4
3	0.4	2.1	2.7	3.1
4	0.2	1.8	2.4	3.8
5	0.1	1.5	2.1	4.7
6		1.2	1.8	5.5
7		0.9	1.4	6.3
8		0.6	1.1	7.1
9		0.3	0.9	7.9
10			0.5	8.7
11			0.3	9.4
12			0.1	10.1

The hydraulic efficiency of the Little Lillooet (Tenasse) Narrows road crossing, a four-span bridge with extensive approach embankments, was

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1 Cross Section Number (XS#)

examined on October 10th, 1984 when the lake was almost at its recorded maximum peak instantaneous stage of 199.36 m[1]. At that time the head loss across the structure was observed to be 0.55 m (1.8 feet). The stage-frequency curve for Lillooet Lake - see Figure 9, being very flat throughout the 20-200 year return period range, indicates that this relatively small head loss probably remains fairly constant for all peak flows.

5.0 DESIGN FLOOD PROFILES

The peak instantaneous flood frequency-discharge predictions shown in Table 3 were utilized in conjunction with the HEC-11 computer program to simulate, dyke confined, flood flow conditions along all of the significant watercourses within the study area. The resulting flood profiles for the anticipated 1:50 year and 1:200 year floods are shown on the river profile Figures 16-20 inclusive, in addition to which confined Oct. 1984 flow[2] profiles are shown for all watercourses except the Lilloet River, for which the unconfined (1984 conditions) observed profile is shown, and for Miller Creek where it is assumed to be coincident with the 1:50 year profile.

The accuracy of these flood profiles is affected by the lack of up-to-date cross section survey data, none of which is more recent than 1978, this deficiency has, however, been partially overcome by manipulation of the Mannings "n" roughness coefficient during computer modelling[2].

The simultaneous occurrence of equal return period floods is assumed at each river or lake confluence for the purpose of determining the

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1 14 years of record only, 1971 to 1984.

2 Ref. Section 3.1.2.

downstream starting conditions for each flood profile. While this coincidence of events is quite improbable, the conservative errors so induced are insignificant since, in the case of low-gradient tributaries the height of any necessary dyking would otherwise be determined by design flood conditions in the mainstem channel, and where steeper gradient tributaries are concerned the induced error diminishes rapidly as one moves upstream. In the case of Lillooet Lake, the stage (surface elevation) is not frequency sensitive, as may be seen from Figure 9, and hence the consequences of minor errors in the basic assumption are unimportant.

It should be noted that in the derivation of the mainstem Lillooet River design flows[1] the simultaneous occurrence of equal-magnitude flow events is not assumed.

6.0 PROTECTIVE WORKS

6.1 General Considerations

For each significant floodplain area protective measures have been considered for both the 1:50 year (Q_{50}) and the 1:200 year (Q_{200}) instantaneous flows. In each case, to provide sufficient freeboard, the design dyke crest profile was set a minimum of 0.6 m (2.0 feet) above the theoretical flood profile. In areas where a paved roadway is relied upon for protection, the minimum freeboard allowance is reduced to 0.3 m (1.0 feet) because of the scour resistance of the pavement.

6.2 Dykes

It has been assumed that all new dyking would be of granular fill construction, however, impervious clays or other locally available

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1 Ref. Section 3.4

material would be incorporated where practical or necessary.

Typically, dykes would be built as detailed in Figure 11, having a 4.0 m (13 feet) minimum crest width and 2:1 side slopes, protected where necessary with broken rock riprap.

Where the integrity of an existing dyke is in anyway suspect its reconstruction or relocation has been assumed.

A minimum setback of 30 m (100 feet) from the top of the riverbank is generally maintained and an average clearing width of 25 m (80 feet) is assumed, to provide room for a separate truck return road.

6.3 Roads as Flood Protection

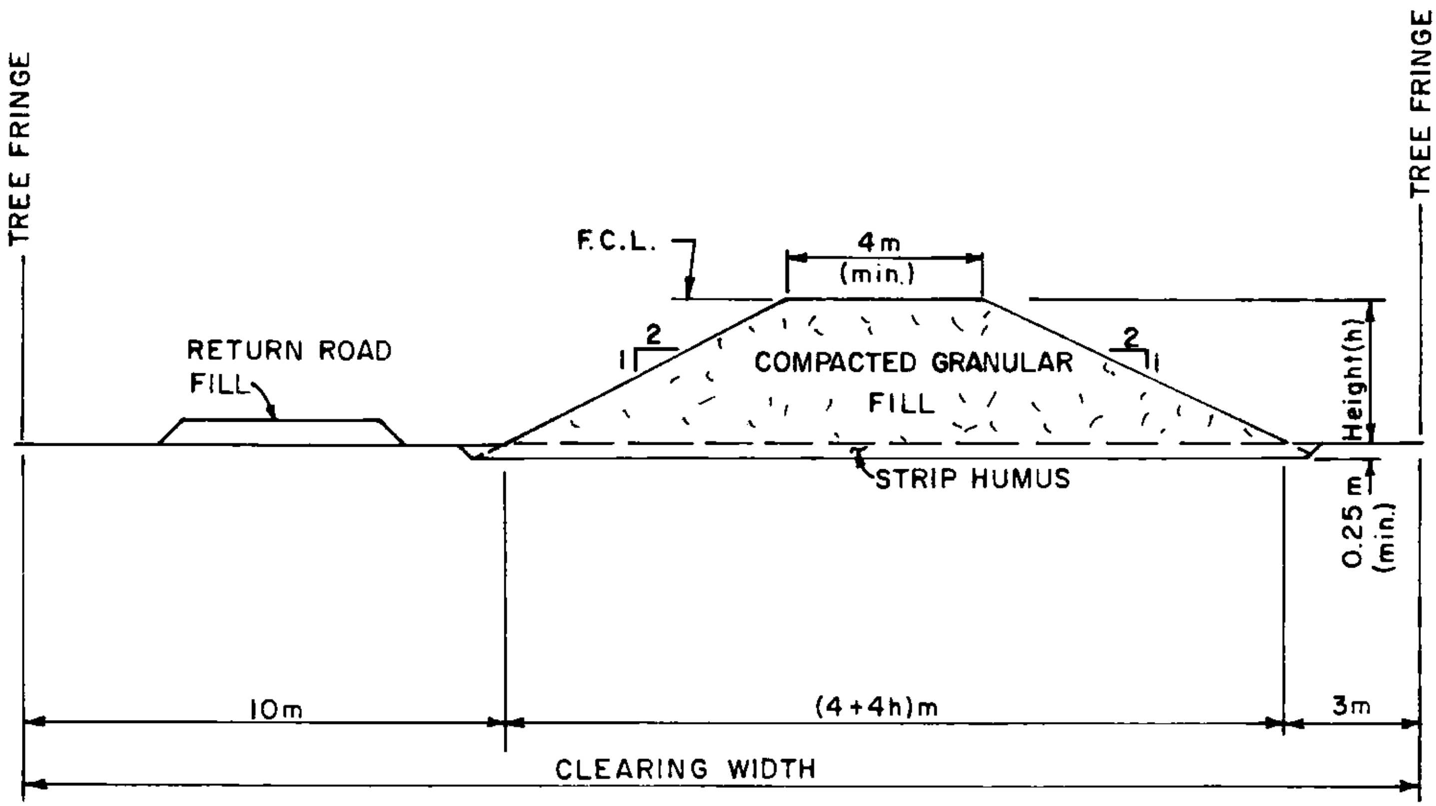
Where it is proposed to raise public roadways, to provide the required protection, cross section geometry as shown on Figure 12 has been assumed for costing purposes.

6.4 Erosion Protection

6.4.1 Natural Banks

Under the 1979-1984 A.R.D.S.A. Program, bank protection was provided for most of the serious erosion areas, with the exception of the Ryan River and the McKenzie cut between XS-26 and XS-31, along the Lillooet River. Some hitherto stable areas now require protection.

Where such erosion threatens existing or proposed dykes, through loss of the adjacent overbank area, broken rock riprap protection is proposed. Typical bank protection details are shown on Figure 13.



NOTE:

FLOOD CONSTRUCTION LEVEL (F.C.L.)
= DESIGN FLOOD ELEVATION + 0.6 m

Province of British Columbia
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WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON

PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
TYPICAL DYKE
CROSS SECTION DETAILS

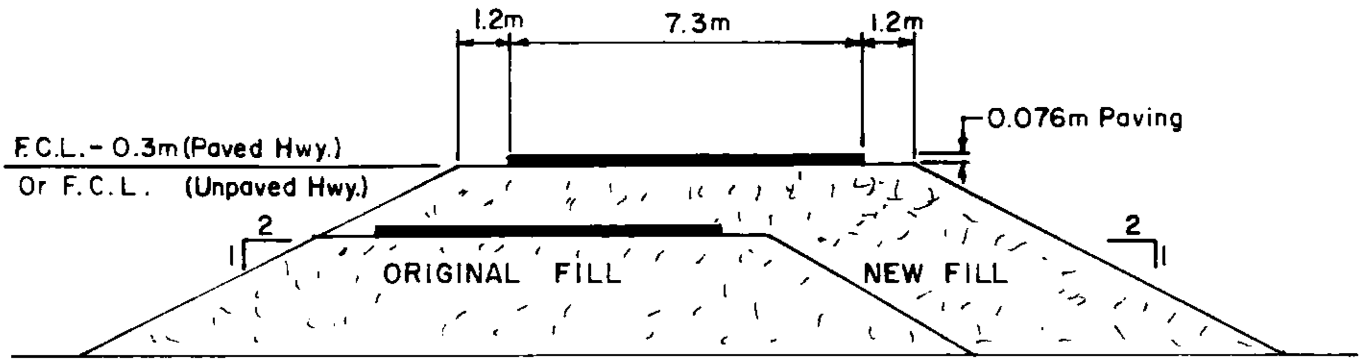
SCALE: NOT TO SCALE

DATE JUNE 1985

U.A. Nesbitt Porter ENGINEER

FILE No P 72-3 DWG No 85-13-15

FIGURE 11



SURFACING QUANTITIES

BLACK TOP ≈1400 tonnes/km

PRIMER ≈1100 litre/km

NOTE:

FLOOD CONSTRUCTION LEVEL (F.C.L.)
= DESIGN FLOOD ELEVATION + 0.6 m

Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH		TO ACCOMPANY REPORT ON PEMBERTON VALLEY FLOOD PROTECTION 1985 STUDY TYPICAL RAISED HIGHWAY FILL DETAIL	
SCALE: NOT TO SCALE	DATE JUNE 1985	ENGINEER FILE No P 72-3	DWG No. 85-13-17

BCIL 7873 M.E

FIGURE 12

6.4.2 Exposed dykes

Where dykes are considered to be vulnerable to erosion riprap protection is required, as shown on Figure 13.

6.5 Floodproofing as an Alternative to Area Dyking

Some of the means by which isolated existing buildings can be protected from flood damage include:

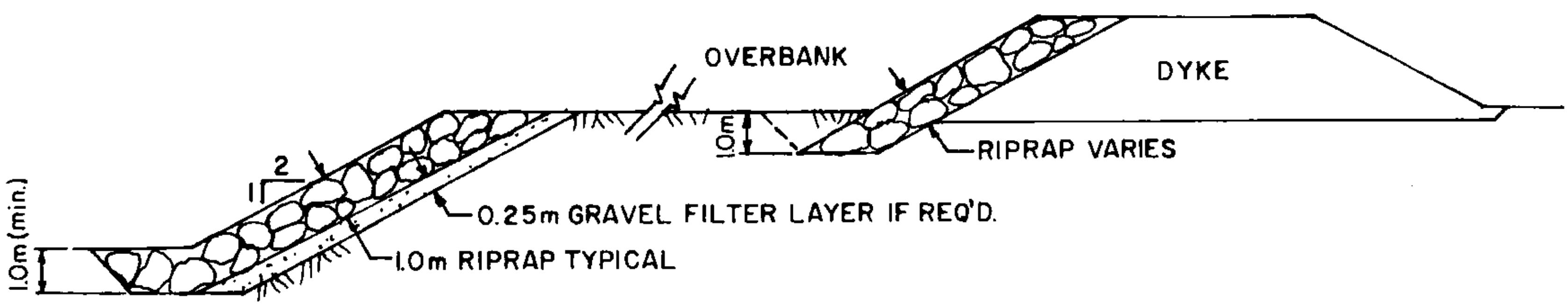
i construction of a surrounding ring-dyke,
ii raising them above the Flood Construction Level (F.C.L.) on gravel pads,
iii elevation of the building by the addition of concrete or masonry foundation walls

Mobile homes are readily suited to the raised gravel berm solution, which can be undertaken economically, whereas, for permanent homes having brick or stonework chimneys, patios, carports or other appurtenances, the cost can readily approach the total value, particularly in the case of older houses.

Some of the disadvantages of floodproofing, as compared to comprehensive dyking, are that ring-dykes are aesthetically unattractive and may necessitate the provision of pumping systems to control the internal water levels; contamination of water wells frequently results as a consequence of flooded septic disposal fields or broken sewer pipes and both access and egress along flooded roads may be hazardous or even impossible.

Based on experiences elsewhere, it is estimated that to raise an average 1200 ft^2 house would cost $45,000, while a mobile home would cost an estimated $15,000.

Because of the multiplicity of designs, sizes, ages and construction materials involved, estimates are not provided for barns or other farm buildings.



Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	TO ACCOMPANY REPORT ON PEMBERTON VALLEY FLOOD PROTECTION 1985 STUDY TYPICAL RIPRAP PROTECTION DETAILS	SCALE: NOT TO SCALE H. H. Nesbitt-Porter ENGINEER FILE No. P 72-3 DWG No 85-13-19	DATE JUNE 1985

VANCAL — 7189

FIGURE 13

7.0 PROTECTION PROPOSALS - BY AREAS

The natural drainage system divides the study area into six logically independent zones. For examination of the flood protection requirements, these areas have been treated individually. A further subdivision of the two downstream areas segregates the Indian Band lands and the airport area, to facilitate possible separate funding consideration from appropriate sources.

7.1 Outdoor School Farm Area

Background

This low area extending from XS-52 to XS-56, on the left bank of the Lillooet River, is partially dyked where a privately undertaken cutoff channel was constructed subsequent to the downstream P.F.R.A. Project. The area, which includes an ox-bow lake used for recreational and instructional purposes by the Outdoor Farm School, is also vulnerable to flooding from upstream overbank flow.

Surface runoff from the adjacent mountainside causes drainage problems.

Proposed Works

To provide 1:50 year flood protection for this area, dyking as shown on Figure 16 and averaging 2.0 m (6.5 feet) in height is required, together with drainage outlet culverts and additional bank protection. Improvements to the internal drainage interceptor ditching are also anticipated.

For 1:200 year protection similar works but with a dyke averaging 2.5 m (8.2 feet) in height are proposed.

The estimated costs of the protective works, details of which are provided in Section 8, Area 1, are:

1:50 year - $411,000
1:200 year - $529,000

7.2 Salmon Slough to Ryan River Confluence

7.2.1 Lillooet River Dyking

Background

During the October 1984 flood the upstream portion of this largely undyked area, which extends from XS-54 to XS-26, suffered considerable depositional damage as a result of silt and sand laden overbank flow emanating in the vicinity of XS-28, above the Forest Service Bridge.

This bridge, locally considered to have been the cause of the problem, is located at the upstream end of a long, naturally constricted, reach of the river. Pending completion of a current survey project it will not be possible to determine the extent to which this bridge is responsible for the considerable increase in the flood profile gradient which is evident in this vicinity.

Similar breakout and silt deposition problems were encountered downstream of XS-28, along the McKenzie Cut, where the continuing lateral development of this artificially created reach resulted in breaching of an old, privately constructed silt berm which had, until 1984, afforded a measure of protection for the downstream reach, locally known as Dr. Dill's farm.

Successive surveys and flood level observations show that this 4.36 km long reach of the river, which started in 1947 as a small pilot channel, has been degraded[1] and widened to the extent that it no longer constitutes the significant flow constriction noted in the Tempest report[2]. This being so, it is probable that its banks, which are mainly comprised of peat and consolidated muskeg with an overlying layer of silt, may now be considered to be relatively stable.

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1 See Figure 21

2 W. Tempest, Pemberton Valley Dyking District, Flood & Erosion Control, B.C. Ministry of Environment, 1977

Along the right bank of the Lillooet River, down to the Ryan River confluence, intermittent portions of low dyking, road fills and high ground provide varying degrees of protection for the area.

Proposed Works

For both the 1:50 and 1:200 year situations the most comprehensive protection would be provided by dyking across low areas, along an alignment close to the riverbank, as shown on Figures 16-18 inclusive. The proposed dyke would start at high ground upstream of XS-53, cross the upper reaches of Salmon Slough, where a floodbox is required for flow control and probably for fish passage, tie into the Forest Service Bridge approach fill, continue downstream enclosing most of the developed lands and incorporating existing dyking and road fills where practical. The average heights of dyking, where required, are respectively 0.85 m (2.8 feet) and 1.1 m (3.6 feet) for the 1:50 and 1:200 year events.

At the downstream end, from XS-27 to XS-32, the old partially eroded berm along the McKenzie Cut would be replaced by a new dyke set back from the top of the bank by a minimum distance of 10.0 m (33 feet) if the riverbank is adequately protected with riprap, or 30.0 m (100 feet) if the bank remains unprotected.

As a less permanent alternative to dyking and riprapping of the right bank, which averages between five and six metres (18 feet) in height, it could be shaped, as shown on Figure 14, to a three-to-one slope and the spoil material used to raise a twenty metre (65 feet) wide strip of the adjacent ground by some 1.8 m (6 feet), to the 1:200 design dyke height, thus eliminating the necessity for dyking. Erosion of the sloped bank, which could be retarded by planting with suitable vegetation such as willows, should be very gradual, although from time-to-time riprapping of localized areas would be required. A strip along the riverside of this raised berm would have to be sown to grass but could be used for hay production, or grazing if fenced to prevent animal disturbance of the sloped bank; the remainder could be cultivated.

Provision for riprapping of ~~4,000~~ 400 m of the left bank between XS-48 and XS-49 is included as Area 2L in the Overall Cost Summary - Table 5.

The estimated costs for the two levels of protection, details of which are provided in Section 8, Area 2.1, are:

1:50 year - $1,819,000

1:200 year - $2,332,000

Estimates could be reduced by the following amounts if the indicated alternative routes or options were adopted:

		1:50	1:200
Alternative route 2A - highway alignment	-	$285,000	$ 383,000
Alternative route 2B - setback alignment[1]	-	$ 95,000	$ 61,000
McKenzie Cut - berm option 2C	-	$838,000	$1,103,000

7.2.2 Ryan River Dyking - Left Bank

Background

Within the study area, starting at XS-R21 below the old logging bridge, this river which carries a considerable gravel bedload parallels the Lillooet River for about 14.2 km (8.8 miles). Immediately upstream from the bridge a very steep right bank tribuary gulley introduces sufficient large sized rock to maintain a steep control section. The consequent high localized velocities and downstream bedload deposition resulted in extensive overtopping of the dyke and flow diversion during the October 1984 flood. Throughout the remainder of the dyked reach, terminating at the Erickson Road/highway intersection

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[1] All excluded houses are believed to be above 1:200 year flood level.

(XS-R10), the crest elevation of the existing old dyke, which had been raised under the recent A.R.D.S.A. and P.E.P. programs, was marginally above the 1984 flood profile and would have required an estimated average additional height of 0.5 m (1.5 feet) to contain the total flow during that flood.

Between Erickson Road and the Ryan River bridge limited flood protection is provided by the highway, which, during the October 1984 flood, was overtopped and damaged. There is no further downstream flood protection.

Although the riverbanks did not sustain much damage during the 1984 flood the loss of undersized riprap was prevalent.

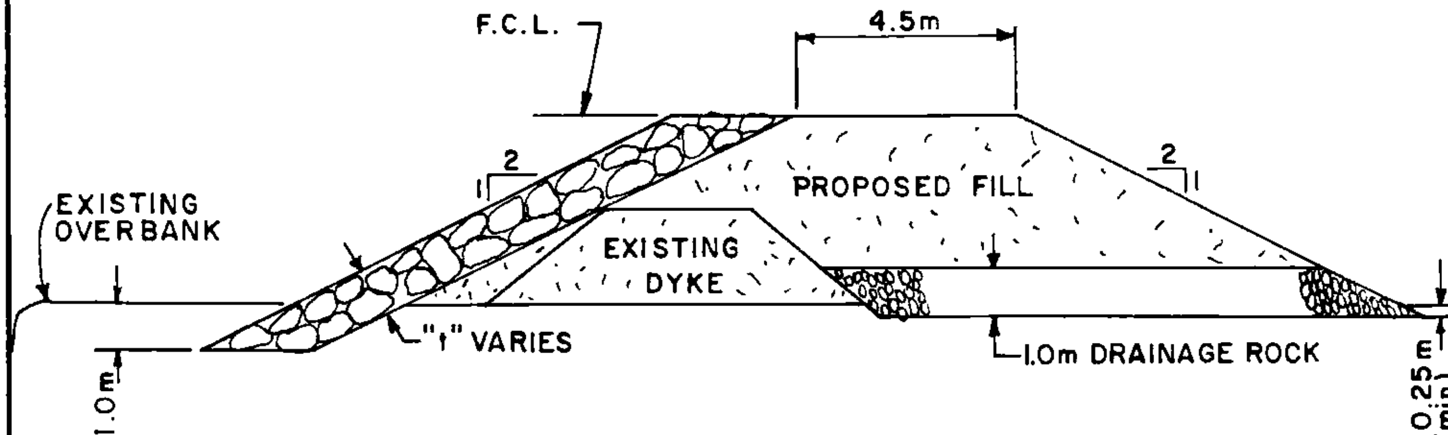
Proposed Works

Downstream from the 1984 dyke washout and subsequent reconstruction, the existing dyke must be raised by an average of 1.5 m (5.0 feet) for 1:50 year protection and by 2.1 m (6.9 feet) for 1:200 protection; in addition to which widening and reshaping of the fill is required, to reduce the present steep sideslopes to 2:1 on both faces. Details of a typical cross section including riprapping, if required, are shown on Figure 15.

Extensive riprapping of both the dyke and left bank of the river is required for 8.0 km (5.0 miles) down to the highway at Erickson Road.

For the next 3.3 km (2.0 miles) to the Ryan River bridge, the paved highway which currently serves as the left bank dyke must be raised by an average of 0.8 m (2.6 feet), or else a parallel dyke of similar height should be constructed, as Alternative A, to provide 1:50 year protection. For 1:200 year protection the highway should be raised by 1.4 m (4.6 feet).

From the highway bridge, which is expected to be replaced by a higher one having greater flow capacity, a setback dyke along the left bank would tie into the Lillooet River dyke or berm.



NOTE:
FLOOD CONSTRUCTION LEVEL (F.C.L.)
= DESIGN FLOOD ELEVATION + 0.6 m

Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	TO ACCOMPANY REPORT ON PEMBERTON VALLEY FLOOD PROTECTION 1985 STUDY TYPICAL RAISED HIGH DYKE DETAIL
SCALE: NOT TO SCALE — DATE JUNE 1985	U.K. Nesbitt-Porter ENGINEER FILE No P 72-3 DWG No 85-13-16

BCIL 7873-ME

FIGURE 15

The estimated costs for protective works[1] along the left bank of the Ryan River, details of which may be found in Section 8, Area 2.2, are:

1:50 year - \$2,332,000
1:200 year - \$3,109,000

The locations of the proposed work are shown on Figure 17 and 18.

Diversion Alternative

As an alternative to major upgrading of this dyke, the possibility of diverting a portion of the Q_{200} instantaneous flow was considered. Of the total 562 m^3/s flow some 200 m^3/s should remain in the present channel for fisheries considerations and because the channel has this demonstrated capacity. This leaves a diversion flow of 362 m^3/s which, if diverted directly to the Lillooet River along an alignment parallel to the Ryan River Road, would require a 1500 m (5000 feet) long riprap-lined channel having a 60 m (200 feet) wide base, 2 m (6 feet) depth of flow, 3 m (9 feet) high dykes, a flow division/ intake structure, a new highway bridge and the purchase of 15 ha (37 acres) of farm land.

The overall cost of such a diversion, exclusive of the additional improvements which would be required both downstream along the Ryan River and to contain the increased Lillooet river flow downstream to its present confluence, is estimated to be \$3,080,000, as detailed in Section 8, Area 2.2B.

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[1] Raised Highway alignment between Erickson Road and Ryan River Bridge.

7.3 Ryan River to Miller Creek

Background

The portion of this small area most susceptible to flooding lies east of the highway, and is bounded by the Lillooet River and its tributaries, the Ryan River and Miller Creek. Water levels in the downstream reaches of these two tributaries are controlled or directly influenced by levels in the Lillooet River and are also indirectly affected by the consequent bedload deposition. This deposition is generally greatest near the highway bridges, where the backwater effect becomes significant and the flood profile gradients diminish - see Figures 22 and 23.

During the Oct. 1984 flood, overtopping of both the Ryan and Miller Creek dykes, which were constructed incrementally starting in 1950, resulted in flooding of the area. Damage to a private bridge across Miller Creek was caused by high water levels.

Proposed Works

To complete the 1:50 year flood protection for this area the existing dyking must be raised slightly, as must a portion of the highway and the access road to the Ryan River rock pit, all as shown on Figure 18. For 1:200 year protection the present dykes would be raised by an average of 1.1 m (3.6 feet) and extended upstream, as for the 1:50 year alternative.

The estimated costs of these proposals, details of which are provided in Section 8, Area 3, are:

1:50 year - $390,000
1:200 year - $559,000

7.4 Miller Creek to Pemberton (One Mile) Creek (Including Pemberton Village and B.C. Railway Embankment)

7.4.1 Miller Creek and Lillooet River Dykes

Background

Protection for this partially urbanized core area consists of dyking, originally built under the P.F.R.A. Project during 1950 and 1951 when some 170,000[1] m^3 (225,000 cu. yds.) of earth fill and 32,000[1] m^3 (42,000 cu. yds.) of riprap were placed.

During the intervening years minor improvements were made to these dykes and, under the A.R.D.S.A. Program (1979-84), the crest elevation was to have been raised, where necessary, to a crest elevation 0.9 m (3.0 feet) above the calculated level of the 1:50 year daily flood, as determined by Doughty-Davies[2] for hydrometric station #08MG005, upstream from the railway bridge. Instead, the dykes were raised to a crest elevation 0.6 m (2.0 feet) above the observed Dec. 27, 1980 peak flood[3] profile, which provided a much more dependable design basis. The consequence of this change was that the dykes were raised by an additional 0.15 m (0.5 feet) to a gauge reading, at the hydrometric station, of 6.25 m.

It has been estimated by the Water Survey of Canada that the October 1984 flood, which reached a stage of 6.2 m (provisional), would have been 0.28 m higher if the dykes had been high enough to prevent overtopping.

Almost all of the floodplain land between Miller and Pemberton (One Mile) Creeks was inundated when dyke overtopping at several places along the right bank of Miller Creek and at one nearby, downstream, Lillooet River location resulted in an estimated average inflow to the area of 184 m^3/s (6500 cfs). Further downstream, at the B.C. Railway bridge, emergency protection prevented additional overtopping of this dyke.

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1 Includes Pemberton (One Mile) Creek and Green River dykes

2 J.H. Doughty-Davies, Preliminary Report on Lillooet River Flood Control, B.C. ater Resources Service, Water Investigations Branch, (March 1972).

3 Analysis based on historical records to that time indicted that a flood of this magnitude had a probable return period of 165 years.

Downstream from the highway bridge, the airport access road/dyke was overtopped by impounded water escaping to the Lillooet River.

Proposed Works

The right bank dyke along Miller Creek and a short portion of highway must be raised by an average of 1.6 m (5.2 feet), excluding allowance for gravel deposition, for complete protection against the 1:50 year flood.

For protection against the 1:200 year event the Miller Creek dyke and the highway would have to be raised by an average of 2.1 m (6.9 feet) and the Lillooet River dyke raised by an average of 0.5 m (1.6 feet) throughout the reach downstream to the Pemberton Creek confluence.

The estimated costs of these proposals, details of which are provided in Section 8, Area 4.1, are:

1:50 year - $194,000
1:200 year - $464,000

7.4.2 Pemberton (One Mile) Creek - Left Bank Dyke

Background

The existing incomplete dyking along the left bank of Pemberton Creek was begun by the P.F.R.A. in 1951 and extended, along reaches upstream of the drainage canal outlet, at various times.

Flooding of this area has resulted from dyking and drainage inadequacy, augmented during October 1984 by inflows from dyke failure north of the B.C. Railway embankment[1].

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[1] see separate subsections 7.4.1, 7.4.3, and 7.4.4

Proposed Works

Until survey data which is currently being obtained has been assessed it will not be possible to make an accurate determination of the dyking requirements for this area, however, it is probable that dyke improvements and new dyking, as shown on Figure 19, will be required in addition to the drainage improvements detailed in subsection 7.4.4.

What are believed to be reasonable estimates of the costs of the required dyking, detailed in Section 8, Area 4.2, are:

1:50 year - $236,000
1:200 year - $349,000

7.4.3 B.C. Railway Embankment

Background

The B.C. Railway mainline crosses the Lillooet River floodplain on a high embankment fill, which, until 1972, had a trestle section some 58 m (190 feet) in overall length across the drainage canal. An additional 41 m (135 feet) long trestle section close to the Lillooet River spans the area which is now the Urdal Road underpass.

Replacing the main trestle section there are now two culverts of 2100 mm (7.0 feet) and 1500 mm (5.0 feet) diameter respectively. Initially these culverts were improperly placed but they were subsequently reset to provide improved upstream drainage, their intake inverts being some 1.7 m (5.6 feet) below the average adjacent ground elevation.

During the October 1984 flood this embankment restricted the passage of flood waters, which had overtopped the upstream dyke[1], and which caused very severe flooding and property damage both upstream and downstream from the railway.

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1 see Subsection 7.4.1

Initially flood water in excess of the capacity of the culverts, which were sized for internal drainage discharges only, ponded upstream of the railway; as the level of this water rose additional relief was obtained by flow through the Urdal Road underpass. The upstream level continued to rise until a peak elevation of approximately 210.2 m (689.6 feet) was reached around 0500 hrs. on October 9th, 1984, some 13.5 ~~25.5~~ hours after the initial dyke overtopping. At this level the water was up to the ballast between the rail ties and embankment failure was a possibility.

At the peak upstream water stage the head differential across the railway fill may have exceeded the 1.5 m (5.0 feet) difference between the upstream and downstream highwater marks.

A proposal[1] to breach the railway embankment, to relieve the upstream situation, would have exacerbated the flooding problems downstream, where the level[2] had not yet started to receed.

Flood alleviation Option

Once flood waters enter the area upstream from the railway the only possible gravity relief route is through the railway embankment. Since the extent of any possible future dyke failure is impossible to predict it is equally impossible to predict the discharge capacity which would be required. It should be noted that the incoming flow would be from a confined channel thus there would be a considerable hydraulic gradient and hence a large flow per unit of inlet cross-sectional area, whereas the outlet facility would have to operate at a very low gradient if upstream ponding were to be avoided. This means that even to convey the flow from a small breach in the dyke, a most unlikely situation where readily erodible fill is used, would require a relatively wide opening, either trestle or culverts.

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1 The subject of a public meeting held in Pemberton Village Hall during the afternoon of October 9, 1984.

2 Controlled by the Lillooet River level at Pemberton Creek confluence.

In order to provide some indication of the costs which could be involved if flood relief were to be considered, a bank of ten precast concrete culverts each 2400 mm (8.0 feet) square and 25 m (82 feet) in length is estimated[1] to cost $716,000 or $12,430/m^2 ($1120/ft^2), excluding foundation treatment. Precast concrete culverts were selected so as to minimize the period of railway closure, assuming that a construction area bypass is not practical.

7.4.4 Drainage Canal

A cursory review of the 1967 Wester drainage report[2] was carried out to confirm the current validity of the two proposals advanced in that report.

Proposal "A" to divert Pemberton (One Mile) Creek from XS-P1 into the Green River near XS-G7 - see Figure 19, does not appear to provide effective flood relief for the Pemberton Village area during the crucial extreme flood events. Based on currently available survey data, and assuming that the airport area will eventually be protected from flooding by the Green River, there would not be any hydraulic gradient advantage to be gained during peak flood stages by such a diversion. Assessment of its merits at lower river levels would require the up-to-date survey information which is currently being acquired for floodplain mapping purposes, but since even occasional flooding of the urbanized village area is considered to be unacceptable Proposal 'A' does not warrant further investigation.

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1 Based on updated costs for a similar structure at the B.C. Hydro & Power Authority rail crossing of the Vedder River - see Section 8, Area 4.3.

2 J. Wester, Pemberton Valley Dyking District - Drainage Proposal, B.C. Water Resources Service, Technical Report, 1967.

The alternative Proposal "B", to construct a combined gravity flow floodbox and pumpstation at the outlet of the canal, XS-P6 on Pemberton Creek, provides the only practical means of alleviating flooding throughout the 600 ha (1500 acre) valley bottom area drained by the canal.

The theoretical flood profiles shown on Figure 23 confirm the validity of the Pemberton Creek water levels as determined in the Wester report, and, because of the preliminary nature of this report, Wester's 1:25 design flow of 3.7 m^3/s (130 cfs) was also adopted.

Two or perhaps three submersible pumps would be preferable to the originally proposed two-unit vertical turbine system, however, since pumping is only expected to be necessary for short periods, used pumps of an suitable type could be considered.

The estimated capital cost of a floodbox/pumphouse facility, including an allowance of $100,000 for canal improvements is, as detailed in Section 8, Area 4.4, $853,000.

Average annual operating, maintenance and power costs should be in the order of $20,000.

7.5 Pemberton (One Mile) Creek to Green River - Excluding Airport

Background

This largely unprotected farm land area is vulnerable to flooding from the Lillooet River and from both tributaries, the Green River and Pemberton Creek. The only dyking consists of the airport access road along the Lillooet River, see Figure 19, and the remnants of a P.F.R.A. dyke along the left bank of the Green River, which was diverted to its present channel west of the airport to provide increased gradient.

Until up-to-date survey information is available the calculated flood profiles for the tributary watercourses, see Figure 23, and hence the dyke fill quantities, must be considered to be provisional and subject to considerable change.

Proposed Works

Protection for this area would necessitate dyking along the right bank of Pemberton Creek and along the left bank of the Green River. In both cases the dykes would start at high ground, see Figure 19, and extend downstream to tie into the existing airport access road, unless integrated with protection for the airport in which case the dyke across the north end of the airport would be omitted.

As detailed in Section 8, Area 5, the estimated costs of protection for this area, which would require average dyke heights of 2.2 m (7.2 feet) and 2.8 m (9.2 feet) respectively are:

1:50 year - $490,000
1:200 year - $663,000

7.6 Airport Area

Background

This area which is currently unprotected, save for the partially riprapped access road along the Lillooet River, is vulnerable to flooding from all three rivers, see Figure 19, and, during the October 1984 flood was completely inundated.

The necessity for protection of this area depends very much on the degree of flooproofing of the proposed permanent buildings and other facilities, and on the susceptibility of the soon-to-be paved runway to damage from occasional flooding.

Proposed Works

Dyking around the complete perimeter of the runway and apron area, possibly in conjunction with upstream dyking for the Pemberton Creek to Green River area, is proposed. Riprap will be required as detailed.

The estimated costs of dyking, detailed in Section 8, Area 6, and averaging 1.8 m (6.0 feet) and 2.3 m (7.5 feet) respectively are:

1:50 year - $1,060,000
1:200 year - $1,425,000

7.7 North Arm Plug to Mount Currie I.R. #1

Background

Situated on the left bank of the Lillooet River, see Figures 18 and 19, this area is traversed by an old flood channel, the upstream end of which, at XS-17, was closed off by a short dyke known as The North Arm Plug. Under the A.R.D.S.A. Program this plug was raised and extended downstream to the highway bridge. Between the bridge and Mt. Currie I.R. #1 the highway prevents eastward overbank flow, thus protecting most of the farm buildings and improved agricultural land from any overbank flow originating below the bridge.

During the October 1984 flood the upstream dyke was overtopped in the vicinity of "the plug", allowing a large flow to inundate the otherwise protected area. Overbank flow, downstream from the bridge, flooded most of the remainder of the area.

Proposed Works

Above the highway bridge limited additional riprap is required and, for 1:50 year protection, the dyke must be raised by an average of 0.2 m (0.6 feet) or, for 1:200 year protection, by 0.7 m (2.3 feet).

Below the bridge, where the highway effectively protects the easterly area, a setback dyke approximately as shown on Figure 19 would be necessary for protection of the remaining area, which includes Pemberton I.R. #2. For 1:50 year protection this dyke would average 1.8 m (6.0 feet) in height, and for 1:200 year protection an average height of 2.3 m (7.5 feet) would be required.

The estimated costs of these proposals, details of which are provided in Section 8, Area 7, are:

	Indian Lands	Other Lands	Total Cost
1:50 year -	$152,000	$502,000	$654,000
200 year -	$194,000	$651,000	$845,000

7.8 Mount Currie I.R. #1 to Lillooet Lake

7.8.1 Lillooet River

Background

Along the Lillooet River, from XS-11 to XS-1 flood protection is provided by a very low access road/dyke built under the recent A.R.D.S.A. Program. Upon completion of the imminent restoration of this dyke, damaged by overtopping at various locations during the October 1984 flood, protection to the 1:50 year level will have been restored, other than for the downstream area, including the rodeo ground, where flooding from Lillooet Lake results. Erosion endangers the dyke at two locations.

Proposed Works

Downstream from XS-2, the existing dyke should be raised slightly and extended for more complete 1:50 year protection. This area will, however, remain susceptible to flooding from the Birkenhead River unless the public road is raised, as proposed in subsection 7.8.2.2.

Additional bank protection is proposed at two locations.

The estimated costs of these proposals, details of which are provided in Section 8, Area 8.1, are:

1:50 year - $345,000
1:200 year - $442,000

7.8.2 Birkenhead River

Background

The Birkenhead and Lillooet Rivers, which flow in parallel for some 10.5 km (6.5 miles) before discharging into Lillooet Lake, share a joint floodplain as shown on Figures 19 & 20. At the upstream end of this area is the Indian Village of Mount Currie, situated partially on the alluvial outwash fan of the Birkenhead River and protected from it by a riprapped dyke constructed under the P.F.R.A. in 1950. Further downstream additional bank protection, together with a short dyke along Grandmother Slough, were constructed under the recently completed A.R.D.S.A. program.

At the mouth of the Birkenhead River, where delta formation is progressing rapidly, due mainly to bedload deposition from the Lillooet River, a road fill and bridge crossing constrict the floodplain and are expected to increase the upstream water levels by about 0.3 m (1.0 feet) during major floods. The upstream effect of this backwater is expected to diminish rapidly without resulting in significant damage.

Proposed Works

To improve the existing flood protection for the Village of Mount Currie, without interrupting the main railway line, or the spur line into a pole yard, and without crossing either the pole yard or the downstream fish habitat area in the vicinity of Grandmother Slough, expensive twin dykes would be required. The precise heights and extent of these dykes would depend on field survey information to be obtained later this year. As an alternate solution, the outer of these two dykes could be extended across the pole yard, as shown, to join the gravel surfaced highway shown on Figure 19. This would replace the second dyke.

Downstream, flood protection would be provided by raising the gravel highway which closely follows the right bank of the Birkenhead River throughout most of the proposed protection area. One house and one mobile home would be raised or else dyked around.

Culverts complete with flap gates would be required at all natural drainage outlets and where surface water could collect behind dykes.

The estimated costs of these proposals, details of which are provided in Section 8, Area 2, are:

1:50 year - $1,162,000
1:200 year - $2,042,000

8.0 COSTING

8.1 Basis

Equipment Rental Basis is assumed for all construction with the exception of the floodbox on Salmon Slough and the floodbox/ pumpstation at the drainage canal outlet on Pemberton Creek.

Dyke Fill material sources are generally river bars (subject to Fisheries approval) and gravel borrow pits. The use of limited quantities of other local materials has been assumed in some instances. All quantities shown are for compacted material.

Riprap costs are for talus slide material, or blasted rock, measured in place on the banks.

Clearing costs per hectare (1 ha $\approx$ 2.5 acres) are, where significant, shown separately.

Stripping costs are included with 'Clearing' or 'Fill' costs except where the excavation exceeds the nominal 0.25 m depth generally required.

Grading and other costs associated with the maintenance of haul roads are included in the 'Engineering and Contingency' allowance.

Culvert and Flapgate costs for the larger drainage outlets are detailed under the heading of 'Culverts'. Provision for additional outlets is made under the 'Engineering and Contingencies' allowance.

Paving costs incurred where a paved highway has to be raised are quoted in linear metres, for a running surface 7.3 m (24 feet) wide and 0.076 m (3 inches) thick. The unit cost is based on the assumption that a batch plant would have to be brought in to provide hot mix.

Land Acquisition costs are not included.

8.2 Quantities and Costs

The following pages detail the quantities, unit rates and cost estimates, by areas and component sub-areas. Quantities and costs have been rounded off for convenience.

LILLOOET LAKE NARROWS EXCAVATION

Updating of 1972 estimate for excavation to reduce lake level by 1.3 m (4.0 feet)

RATE COMPARISON

Source of data	YEAR		Increase
	1972	1985[1]	%
Engineering News Record Constructon Cost Index	1753	4172	238
Engineering News Record Building Cost Index	1048	2424	231
Equipment Rental Rates (B.C. Prov. Gov't.)	38.05[2]	103.70[2]	272
	Average increase %		247

Assume 1972 to 1985 (June) = 250%

COST COMPARISON

Item	Quantity	1972		1985	
		Rate	Cost $	Rate	Cost $
Rock	18,830 yd^3	$10.00/$yd^3$	188,300	$32.70/$m^3$	470,750
Soil	169,450 yd^3	$ 2.00/yd^3	338,900	$ 6.54/m^3	847,250

1985 Sub-total	$1,318,000
Add 25% Engineering & Congingencies	330,000
1985 Total	$1,648,000

As an indication of the minimum probable cost to reduce flood levels by 3.0 m (10 feet) instead of 1.3 m (4.0 feet) extrapolate as 10/4 (1,648,000) = $4,120,000

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1 January 1985

2 Average of hourly rental rates for: Clam (2.5 yd^3), Koehring 466/466D, Scraper 660B, Cat. D9H, F.E. Loader (3 yd^3)

SECTION 7

AREA 1 **OUTDOOR SCHOOL FARM AREA**

Lillooet River XS-52 to XS-56

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200				
	1:50				
Stripping	1:200				
	1:50				
Fill	1:200	85,000 m^3	4.50		382,000
	1:50	64,000 m^3	4.50	288,000	
Riprap	1:200	4,000 m^3	8.70		35,000
	1:50	4,000 m^3	8.70	35,000	
Culverts	1:200	2	3,000.00		6,000
	1:50	2	3,000.00	6,000	
Paving	1:200				
	1:50				
	Sub-total			329,000	423,000
	25% Engineering & Contingencies			82,000	106,000
	Total			411,000	529,000

AREA 2 **SALMON SLOUGH TO RYAN RIVER**

Sub-area 2.1 Lillooet River XS-26 to XS-54

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	24 ha	4,200.00		98,000
	1:50	14 ha	4,200.00	59,000	
Stripping	1:200				
	1:50				
Fill	1:200	162,000 m^3	5.90		956,000
	1:50	99,000 m^3	5.90	584,000	
Riprap	1:200	59,000 m^3	12.00		708,000
	1:50	59,000 m^3	12.00	708,000	
Culverts	1:200	18	3,000.00		54,000
	1:50	18	3,000.00	54,000	
Paving	1:200				
	1:50				
Flood Box	1:200	1	L.S.		50,000
	1:50	1	L.S.	50,000	
	Sub-total			1,455,000	1,866,000
	25% Engineering & Contingencies			364,000	466,000
	Total			1,819,000	2,332,000

AREA 2 **SALMON SLOUGH TO RYAN RIVER**

Sub-area 2.1 Lillooet River XS-26 to XS-54

Alternative A Raised Highway Option (XS-48 to XS-54)

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	20 ha	4,200,00		84,000
	1:50	12 ha	4,200.00	50,000	
Stripping	1:200				
	1:50				
Fill	1:200	128,000 m^3	5.90		755,000
	1:50	77,000 m^3	5.90	454,000	
Riprap	1:200	56,000 m^3	12.00		672,000
	1:50	56,000 m^3	12.00	672,000	
Culverts	1:200	17	3,000.00		51,000
	1:50	17	3,000.00	51,000	
Paving	1:200				
	1:50				
Gravel Crush	1:200	500 m^3	26.00		13,000
	1:50				
	Sub-total			1,227,000	1,575,000
	25% Engineering & Contingencies			307,000	394,000
	Total			1,534,000	1,969,000

AREA 2 **SALMON SLOUGH TO RYAN RIVER**

Sub-area 2.1 Lillooet River XS-26 to XS-54

Alternative B Setback Alignment (XS-35 to XS-38)

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	24 ha	4,200,00		98,000
	1:50	14 ha	4,200.00	59,000	
Stripping	1:200				
	1:50				
Fill	1:200	157,000 m^3	5.77		907,000
	1:50	87,000 m^3	5.84	508,000	
Riprap	1:200	59,000 m^3	12.00		708,000
	1:50	59,000 m^3	12.00	708,000	
Culverts	1:200	18	3,000.00		54,000
	1:50	18	3,000.00	54,000	
Paving	1:200				
	1:50				
Floodbox	1:200	1	L.S.		50,000
	1:50	1	L.S.	50,000	
	Sub-total			1,379,000	1,817,000
	25% Engineering & Contingencies			345,000	454,000
	Total			1,724,000	2,271,000

AREA 2 **SALMON SLOUGH TO RYAN RIVER**

Sub-area 2.1 Lillooet River XS-26 to XS-54

Alternative C Raised Berm McKenzie Cut Area (XS-26 to XS-31)

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	22 ha	4,200.00		92,000
	1:50	13 ha	4,200.00	55,000	
Stripping	1:200				
	1:50				
Fill	1:200	109,000 m^3	5.90		545,000
	1:50	65,000 m^3	5.90	384,000	
Riprap	1:200	8,000 m^3	12.00		96,000
	1:50	8,000 m^3	12.00	96,000	
Culverts	1:200	18	3,000.00		54,000
	1:50	18	3,000.00	54,000	
Paving	1:200				
	1:50				
Slope Bank	1:200	130,000 m^3	1.00		130,000
	1:50	130,000 m^3	1.00	130,000	
Relocate Utility Poles	1:200	44,000 m^3	1.50		66,000
	1:50	44,000 m^3	1.50	66,000	
	Sub-total			785,000	983,000
	25% Engineering & Contingencies			196,000	246,000
	Total			981,000	1,229,000

AREA 2 **SALMON SLOUGH TO RYAN RIVER**

Sub-area 2.2 Ryan River XS-R21 to Lillooet River Confluence

Raised Highway Option (XS-R5 to XS-R10)

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	8 ha	4,200.00		34,000
	1:50	8 ha	4,200.00	34,000	
Stripping	1:200				
	1:50				
Fill	1:200	348,000 m^3	4.90		1,705,000
	1:50	227,000 m^3	4.90	1,112,000	
Riprap	1:200	35,000 m^3	11.00		385,000
	1:50	35,000 m^3	11.00	385,000	
Culverts	1:200	2	3,000.00		6,000
	1:50	2	3,000.00	6,000	
Paving	1:200	3,500 m	70.00		245,000
	1:50	3,500 m	70.00	245,000	
Dyke Around Buildings	1:200	16,000 m^3	5.50		88,000
	1:50	11,000 m^3	5.50	60,000	
Relocate Utility Poles	1:200	40	600.00		24,000
	1:50	40	600.00	24,000	
	Sub-total			1,866,000	2,487,000
	25% Engineering & Contingencies			466,000	622,000
	Total			2,332,000	3,109,000

AREA 2 **SALMON SLOUGH TO RYAN RIVER**

Sub-area 2.2 Ryan River XS-R21 to Lillooet River Confluence

Alternative A Dyke Alongside Highway

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	11 ha	4,200.00		46,000
	1:50	11 ha	4,200.00	46,000	
Stripping	1:200				
	1:50				
Fill	1:200	368,000 m^3	4.90		1,803,000
	1:50	243,000 m^3	4.90	1,191,000	
Riprap	1:200	35,000 m^3	11.00		385,000
	1:50	35,000 m^3	11.00	385,000	
Culverts	1:200	2	3,000.00		6,000
	1:50	2	3,000.00	6,000	
Paving	1:200	1,920 m	70.00		135,000
	1:50	1,920 m	70.00	135,000	
Dyke Around Buildings	1:200	7,000 m^3	5.00		35,000
	1:50	5,000 m^3	5.00	25,000	
Relocate Utility Poles	1:200	25	600.00		15,000
	1:50	25	600.00	15,000	
	Sub-total			1,803,000	2,425,000
	25% Engineering & Contingencies			450,000	606,000
	Total			2,253,000	3,031,000

AREA 2 **SALMON SLOUGH TO RYAN RIVER**

Sub-area 2.2 Ryan River XS-R21 to Lillooet River Confluence

Alternative B Diversion Costs Only

Item	Freq.	Quantity	Unit Cost	1:50 Cost $	1:200 Cost $
Clearing	1:200	4 ha	5,000.00		20,000
	1:50				
Stripping	1:200	122,000 m^3	2.00		244,000
	1:50				
Fill Placing	1:200	77,000 m^3	1.50		116,000
	1:50				
Riprap	1:200	78,000 m^3	15.00		1,170,000
	1:50				
Culverts/ Bridge	1:200				360,000
	1:50				
Paving	1:200				
	1:50				
Filter Gravel					304,000
Diversion/ Intake					250,000
		Sub-total			2,464,000
		25% Engineering & Contingencies			616,000
		Total			3,080,000

AREA 3 RYAN RIVER TO MILLER CREEK

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	3 ha	4,700.00		14,000
	1:50	3 ha	4,700.00	14,000	
Stripping	1:200				
	1:50				
Fill	1:200	82,000 m^3	4.00		328,000
	1:50	50,000 m^3	4.00	200,000	
Riprap	1:200				
	1:50				
Culverts	1:200	2	3,000.00		6,000
	1:50	2	3,000.00	6,000	
Paving	1:200	1,200 m	70.00		84,000
	1:50	1,100 m	70.00	77,000	
Raise 1 Mobile Home	1:200	1	15,000.00		15,000
	1:50	1	15,000.00	15,000	
	Sub-total			312,000	447,000
	25% Engineering & Contingencies			78,000	112,000
	Total			390,000	559,000

AREA 4 MILLER CREEK TO PEMBERTON CREEK

(Summary Sheet)

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	2 ha	7,200.00		14,000
	1:50	2 ha	7,200.00	14,000	
Stripping	1:200				
	1:50				
Fill	1:200	129,000 m^3	4.65		600,000
	1:50	64,000 m^3	4.60	294,000	
Riprap	1:200	3,000 m^3	12.00		36,000
	1:50	3,000 m^3	12.00	36,000	
Culverts	1:200				
	1:50				
Paving	1:200				
	1:50				
Floodbox/ Pumpstation	1:200		L.S.		603,000
	1:50		L.S.	603,000	
Canal Improvements	1:200		L.S.		80,000
	1:50		L.S.	80,000	
	Sub-total			1,027,000	1,333,000
	25% Engineering & Contingencies			256,000	333,000
	Total			1,283,000	1,666,000

AREA 4 **MILLER CREEK TO PEMBERTON CREEK**

Sub-area 4.1 Miller Creek and Lillooet River Dykes

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200				
	1:50				
Stripping	1:200				
	1:50				
Fill	1:200	70,000 m^3	4.80		335,000
	1:50	25,000 m^3	4.80	119,000	
Riprap	1:200	3,000 m^3	12.00		36,000
	1:50	3,000 m^3	12.00	36,000	
Culverts	1:200				
	1:50				
Paving	1:200				
	1:50				
	Sub-total			155,000	371,000
	25% Engineering & Contingencies			39,000	93,000
	Total			194,000	464,000

AREA 4 MILLER CREEK TO PEMBERTON CREEK

Sub-area 4.2 Pemberton Creek - Left Bank Dyke Excluding Drainage Works

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	2 ha	7,200.00		14,000
	1:50	2 ha	7,200.00	14,000	
Stripping	1:200				
	1:50				
Fill	1:200	59,000 m^3	4.50		265,000
	1:50	39,000 m^3	4.50	175,000	
Riprap	1:200				
	1:50				
Culverts	1:200				
	1:50				
Paving	1:200				
	1:50				
	Sub-total			189,000	279,000
	25% Engineering & Contingencies			47,000	70,000
	Total			236,000	349,000

AREA 4 **MILLER CREEK TO PEMBERTON CREEK**

Sub-area 4.3 B.C. Railway Embankment

Cost estimate for hypothetical 10-bay culvert battery.

Culvert size 2400 mm (8.0 feet) square by 25 m (82 feet) long.

Lift track and surface		\$ 26,000
Supply and deliver ballast		20,000
Supply and deliver precast concrete culvert segments	250 m @ \$1030/m	258,000
Install culverts	250 m @ \$1000/m	250,000
Riprap scour protection	1000 m^3 @ \$16/m	16,000
Correct for initial track settlement		3,000
	Sub-total	573,000
	Add Engineering & Contingencies @ \$25%	143,000
	Total	\$716,000

AREA 4 MILLER CREEK TO PEMBERTON CREEK

Sub-area 4.4 Drainage Canal

Capital Cost		1:50/1:200
Timber pile foundation:		
1000 m @ $46.00		$ 46,000
Sheetpiling		40,000
Structure, including diversions		300,000
Submersible pumps and electrical		
1 x 75 kw (100 h.p.) and 1 x 37.5 kw (50 h.p.)		200,000
Warranty testing		17,000
		603,000
Allowance for improvements to canal		80,000
		683,000
Add 25% Engineering & Contingencies		$170,000
TOTAL		$853,000
Annual Costs		
Operation and maintenance		
0.02 x 753,000	$15,060	
Power: Demand and energy charges	4,540	
	$19,600	
SAY	$20,000	

AREA 5 PEMBERTON CREEK TO GREEN RIVER (Excluding Airport)

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	6 ha	6,000.00		36,000
	1:50	5 ha	6,000.00	30,000	
Stripping	1:200	17,000 m^3	0.75		13,000
	1:50	15,000 m^3	0.75	11,000	
Fill	1:200	105,000 m^3	4.50		473,000
	1:50	76,000 m^3	4.50	342,000	
Riprap	1:200				
	1:50				
Culverts	1:200	3	3,000.00		9,000
	1:50	3	3,000.00	9,000	
Paving	1:200				
	1:50				
	Sub-total			392,000	531,000
	25% Engineering & Contingencies			98,000	132,000
	Total			490,000	663,000

AREA 6 **AIRPORT AREA**

(Excluding Upstream Cutoff/Dyke Road)

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	12 ha	6,000.00		72,000
	1:50	10 ha	6,000.00	60,000	
Stripping	1:200	49,000 m^3	0.75		37,000
	1:50	42,000 m^3	0.75	32,000	
Fill	1:200	142,000 m^3	5.60		795,000
	1:50	93,000 m^3	5.60	521,000	
Riprap	1:200	23,000 m^3	10.00		230,000
	1:50	23,000 m^3	10.00	230,000	
Culverts	1:200	2	3,000.00		6,000
	1:50	2	3,000.00	6,000	
Paving	1:200				
	1:50				
	Sub-total			849,000	1,140,000
	25% Engineering & Contingencies			211,000	285,000
	Total			1,060,000	1,425,000

AREA 7 **NORTH ARM PLUG TO MT. CURRIE**

Lillooet River XS-18 to XS-11

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200	4 ha	6,000.00		24,000
	1:50	4 ha	6,000.00	24,000	
Stripping	1:200	18,000 m^3	0.75		14,000
	1:50	15,000 m^3	0.75	11,000	
Fill	1:200	88,000 m^3	5.00		440,000
	1:50	58,000 m^3	5.00	290,000	
Riprap	1:200	16,000 m^3	12.00		192,000
	1:50	16,000 m^3	12.00	192,000	
Culverts	1:200	2	3,000.00		6,000
	1:50	2	3,000.00	6,000	
Paving	1:200				
	1:50				
	Sub-total			523,000	676,000
	25% Engineering & Contingencies			131,000	169,000
	Total including Pemberton I.R.#2			654,000	845,000
	Pemberton I.R.#2			152,000	194,000
	Total excluding Pemberton I.R.#2			502,000	651,000

AREA 8 **MOUNT CURRIE I.R. #1 TO LILLOOET LAKE**

Sub-area 8.1 Lillooet River XS-11 to XS-1

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200				
	1:50				
Stripping	1:200				
	1:50				
Fill	1:200	18,000 m^3	6.00		108,000
	1:50	5,000 m^3	6.00	30,000	
Riprap	1:200	16,000 m^3	15.00		240,000
	1:50	16,000 m^3	15.00	240,000	
Culverts	1:200	2	3,000.00		6,000
	1:50	2	3,000.00	6,000	
Paving	1:200				
	1:50				
	Sub-total			276,000	354,000
	25% Engineering & Contingencies			69,000	88,000
	Total			345,000	442,000

AREA 8 **MOUNT CURRIE I.R. #1 TO LILLOOET LAKE**

Sub-area 8.2 Birkenhead River - Village to Lillooet Lake

Item	Freq.	Quantity	Unit Cost $	1:50 Cost $	1:200 Cost $
Clearing	1:200				
	1:50				
Stripping	1:200				
	1:50				
Fill	1:200	288,000 m^3	5.50		1,584,000
	1:50	160,000 m^3	5.50	880,000	
Riprap	1:200				
	1:50				
Culverts	1:200	3	5,000.00		15,000
	1:50	3	5,000.00	15,000	
Paving	1:200				
	1:50				
Raise 1 House and Mobile Home	1:200		L.S.		35,000
	1:50		L.S.	35,000	
	Sub-total			930,000	1,634,000
	25% Engineering & Contingencies			232,000	408,000
	Total			1,162,000	2,042,000

9.0 SUMMARY

9.1 Conclusions by Areas

Area 1

Dyking following higher ground along the Lillooet River would be required for protection of this agricultural area which includes an educational facility, most of the buildings for which are situated above the floodplain.

Area 2

Area 2 is a very extensive and generally unprotected agricultural area which is vulnerable to flooding from both the Lillooet and Ryan Rivers. Throughout this area the Lillooet River bed continues to degrade as a predictable long-term consequence of shortening the river's thalweg length.

For protection from flooding by the Lillooet River a dyke, generally parallelling the river bank and extending from XS-53 downstream to XS-27 is the recommended solution. The cost of this system could be greatly reduced by opting for less permanent protection along the McKenzie Cut - Alternative 2.1C.

The most practical means of providing Ryan River flood protection is to raise and improve the makeshift left bank dyke extending downstream to the highway, raise this highway and construct a new dyke from the highway bridge to join the Lillooet River system.

The feasibility of diverting Ryan River flood water directly into the Lillooet River, from XS-R21, was examined but found to be uneconomic.

Area 3

Improvement and extension of the existing dyking system, including raising of a portion of highway, are required.

Area 4

Flood protection for this relatively urbanized area, which includes the Village of Pemberton and two schools, requires modest improvements to the existing dyking system, preferably supplemented by pumping facilities at the main drainage canal, to prevent short term ponding of internal drainage during high water periods in Pemberton Creek.

Once the dykes have been raised to the 1:200 year design level, and provided that excessive gravel accumulation in Miller or Pemberton Creek is not permitted, the area should be secure from recurrence of the October 1984 flooding situation.

Although the railway embankment across the floodplain increased the severity of the 1984 upstream flooding, any expenditure in this area should be directed towards preventative upstream dyking rather than on aleviation works, such as additional culverts through the embankment.

Area 5

Flood protection for this uninhabited agricultural area would necessitate enclosure by a dyking system which should incorportate part of the airport access road/dyke and the Forest Service road to the new Green River Bridge.

Area 6

The circumferential dyking system proposed for protection of this small airport, which is undergoing rapid development to serve the

Whistler Resort Community, requires completion of a portion of the upstream Area 5 protection. Extensive Lillooet River bank protection forms an integral part of the flood protection proposed but is also required in the absence of additional dyking.

Area 7

Upstream from the highway bridge the existing dyke, which provides substantial protection for both Area 7 and for Area 8, should be raised slightly to provide 1:200 year flood freeboard.

Below the bridge the highway affords marginal 1:200 year flood protection for properties to the north. Protection for land between the highway and the Lillooet River, including I.R.#2, requires set-back dyking.

Area 8

Along the Lillooet River 1:200 flood protection for the sparsely inhabited Indian Lands would necessitate raising the existing 1:50 year dyke/access road.

For 1:50 year or 1:200 year flood protection of the Village of Mount Currie, improvement and extension of the short Birkenhead River dyke is required. To complete protection for the remaining rural area, and maintain uninterrupted access, the unpaved public road should be raised.

Floodproofing of individual homes, as an alternative to dyking would require detailed investigation.

Lowering of Lillooet Lake would significantly reduce flood levels on the downstream portion of this area but is uneconomic and would induce increased erosion.

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TABLE 5

OVERALL COST SUMMARY

(All Totals x $1,000)

Area	Sub-area	1:50		1:200	
		Sub-area $	Area Total $	Sub-area $	Area Total $
1 Outdoor Farm Area			411		529
2 Salmon Slough to Ryan River	2L Lillooet R.[1]	75*	4226	75*	5516
	2.1 Lillooet R.	1819*		2332*	
	2.1A Lillooet R.	1534		1969	
	2.1B Lillooet R.	1724		2271	
	2.1C Lillooet R.	981		1229	
	2.2 Ryan R.	2332*		3109*	
	2.2A Ryan R.	2253		3031	
	2.2B Ryan R.	-		3080**	
3 Ryan River to Miller Creek			390		559
4 Miller Creek to Pemberton Creek	4.1 Miller Cr. & Lillooet R.	194*	1283	464*	1666
	4.2 Pemberton Cr.	236*		349*	
	4.3 Railway Culverts	716		716	
	4.4 Drainage Canal	853*		853*	
5 Pemberton Creek to Green River (excl. airport)			490		663
6 Airport			1060		1425
7 North Arm Plug to Mt. Currie I.R.#1	Non-Indian Lands	502*	502	651*	651
		TOTAL NON-INDIAN LANDS	8362	TOTAL NON-INDIAN LANDS	11,009
	Indian Lands	152*	152	194*	194
8 Mt. Currie to Lillooet Lake	Indian Lands:				
	8.1 Lillooet R.	345*		442*	
	8.2 Birkenhead R.	1162*	1507	2042*	2484
		TOTAL INDIAN LAND:	1659		2678
		TOTAL:	10,021	TOTAL:	13,687

Notes: * Denotes item or alternative is included in area total

** Costs for the diversion system only, excludes all other works

A, B & C Denote alternatives to the recommended routes

1 Left bank riprap, XS-48 to XS-49

TABLE 6

UNIT AREA PROTECTION COSTS[1]

Area	Sub-area	Area Protected		1:50 Unit Cost		1:200 Unit Cost	
		ha	acres	$/ha	$/acre	$/ha	$/acre
1		96	236	4280	1740	5510	2240
2	2L	19	47	N/A	N/A	N/A	N/A
	2.1	1226	3030	1485	600	1905	770
	2.1A	1033	2553	1485	600	1905	770
	2.1B	1183	2924	1455	590	1920	775
	2.1C	1226	3030	800	325	1000	405
	2.2	1002	2476	2330	940	3100	1255
	2.2A	1002	2476	2250	910	3025	1225
	2.2B	N/A	N/A	-	-	-	-
	2.1 + 2.2[2]	1226	3030	3385	1370	4440	1795
3		128	317	3050	1230	4370	1760
4		946	2336	1355	550	1760	715
5		110	272	4455	1800	6030	2435
6		109	268	9725	3955	13070	5315
7		315	779	2075	840	2680	1085
8		848	2095	1780	720	2930	1185

[1] Floodplain areas are assumed to be as per current Floodplain Mapping, and identical for both 1:50 and 1:200 year floods.

[2] This combination should be used for preliminary comparisons of area unit costs.

9.2 General

Dyking generally provides the most practical flood protection throughout the study area. Most houses, with the exception of those in areas 4 and 8 are relatively secure from flooding and it is the farm land and other buildings which are vulnerable. In the relatively urbanized Area 4, the cost of floodproofing individual houses would far outweigh the cost of the proposed works.

Lowering of Lillooet Lake, which would benefit Area 8 only, is not feasible.

Drainage works, other than for basic improvements to the drainage canal in Area 4, have not been considered.

As may be seen in the Overall Cost Summary, Table 5, which provides details of both the preferred and alternative dyking alignments for each of the significant floodplain components of the study area, the estimated cost of complete 1:50 flood protection for the area is \$10 m, and for 1:200 year protection the cost is \$13.7 m.

Table 6 shows the estimated unit area protection costs for the selected dyke alignments detailed in Table 5.

Province of British Columbia

Ministry of Environment

WATER MANAGEMENT BRANCH

APPENDIX A

MEMORANDUM

To: C.H. Coulson, Head
Surface Water Section
Water Management Branch

Date: June 26, 1985

Our File: S2105

Re: Lillooet River near Pemberton
October 8, 1984 Flood Flow and Design Flood Flows

In response to a request from R.W. Nichols, Floodplain Planning and Surveys Section, we have estimated,* in conjunction with the Modelling Section, flows during the October 8 ,1984 event and the 20, 50 and 200 year return period flows at the following mainstem and tributary locations:

Lillooet River above Wolverine Creek

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

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

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 (638 km^2/597 km^2 for 08MG008).

Also estimated** by the Modelling Section are the 20, 50 and 200 year return period levels for Lillooet Lake (08MG020).

1. October 8, 1984 Flows

The only active hydrometric station in the Lillooet River basin is 08MG005 Lillooet River near Pemberton. During the October 7-9, 1984

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* See accompanying Appendix B.
** See accompanying Appendix B1.

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flood this recorder station was operational, but the water levels were affected by a break in the Miller Creek dyke which allowed flow to bypass the gauge. R.W. Nichols provided an estimate of this flow and the time frame involved, and this data was forwarded to Water Survey of Canada. Taking into account the shape of the recorded water level graph and the data provided by R.W. Nichols, a "natural" water level graph was estimated and used to determine flows. The following WSC estimates have been provided as preliminary and subject to revision:

Instantaneous			Daily	
1310^E m^3/s	1600^E PST	Oct. 8/84	1110^E m^3/s	Oct. 8/84

[These flows are higher than those estimated previously which were 1050 m^3/s (instantaneous at 1200 PST) and 920 m^3/s (daily). The change is partially due to a revised stage-discharge rating curve.]

The instantaneous peak flow past the gauge (excluding bypass flow) as indicated by the water level recorder trace is 1170 m^3/s and occurred at 1300 PST. Based on the revised stage-discharge curve provided by WSC, if the flow had been contained within the dyked channel, the instantaneous peak stage would have been 0.28 m higher at the gauging station than that recorded.

No recorded peak flows are available for the other locations requested, nor were sufficient high water marks available (except for Ryan River and Miller Creek) to allow a rough estimation of the October 8, 1984 peak flow. However, during the 1924-47 period, gauging stations were in operation on the Lillooet River, the Green River, and two Green River tributaries. The approach used to estimate October 8, 1984 flows in the Lillooet River system is to analyse three peak flow events similar to October 1984 for which more flow data are available and assume that the contribution of various sub-basins during these historical floods represents that which occurred during the 1984 event. Also considered in this approach is the relationship between unit peak flows and drainage area for each event. The three events reviewed are October 19, 1940, October 16, 1929 and October 28, 1937. The 08MG005 flows on these dates are the 2nd, 6th and 9th highest flows in the 64 year period of record. For each event, flow data is available for:

08MG005 Lillooet River near Pemberton

08MG003 Green River near Pemberton
08MG006 Rutherford Creek near Pemberton
08MG007 Soo River near Pemberton
08MG004 Green River near Rainbow

08GA024 Cheakamus River near Mons

Beginning with the flows at 08MG005 and 08MG003, flows at the other ungauged locations requested were estimated by trial and error based on adding flows where appropriate and using the relationship between unit peak flows and drainage area for the stations listed above. Thus the estimates for each location had to make sense in terms of m^3/s as well as unit flow ($L/s/km^2$). For each event, the flows were expressed as a percentage of the flow at 08MG005 to illustrate the spatial variation in flow. This also highlighted the difference in storm runoff regimes between Lillooet River and Green River. In the October 16, 1929 event, Green River flow was 20% of Lillooet River (08MG005) and for October 28, 1937 74% of 08MG005.

October 8, 1984 flow data are not available for the Green River, the major tributary to the Lillooet River. Its flow estimate is based on its historical data and flow data for the nearby Cheakamus River. Concurrent "rainfall" peak flows for 08MG003 Green River and 08GA024 Cheakamus River near Mons (1924-47) were found to correlate fairly well. Although 08GA024 was not operating in 1984, the station 08GA072 Cheakamus River above Millar Creek (which is in almost the same location as 08GA024) has an estimated peak daily flow for October 9, 1984 of 175 m^3/s. The corresponding Green River flow would be 350 m^3/s. This is 32% of the flow at 08MG005 which is within the range recorded for the 1940, 1937 and 1929 events analysed. 350 m^3/s appears to be the best estimate of the Green River October 8, 1984 peak flow available at this time.

The estimate for the Birkenhead River is based on reports that its peak flow during the October 8, 1984 event was not unusually high and somewhere in the range of the normal "snowmelt" annual maximum. (This

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watershed rarely experiences "rainfall" annual maximums). Also considered was the flow on dates when the rainfall peak was occurring on the Lillooet River (1947-71). The estimate shown is comparable to a 5-10 year return period snowmelt peak flow.

Table 1 lists the estimated daily flows for selected locations on October 8, 1984. The estimates of least reliability are those for the small tributaries. Even on a daily flow basis (as compared to analysing instantaneous flows) their contribution on the date when 08MG005 Lillooet River is experiencing an extreme flow could be almost any amount due to storm characteristics and differing response times (i.e., time of concentration).

For instance, flood profile studies carried out by R.W. Nichols indicate that the instantaneous peak flow for Ryan River should be in the order of 326 m^3/s. Based on high water marks observed by H. Nesbitt-Porter in May 1985 a rough estimate of 430 m^3/s was made. This means that the daily flow estimate in Table 1 should be much higher. If a factor of 1.3 is used for instantaneous/daily (see Section 3) the daily peak flow would be 330 m^3/s. Flood profile studies on Miller Creek indicate that an instantaneous flow of 174 m^3/s would be reasonable resulting in an estimated daily peak flow of 124 m^3/s assuming the ratio of instantaneous to daily peak flows is 1.4.

The estimates for mainstem Lillooet River locations and Green River at the mouth are considered fairly reliable; however the estimates for tributaries may be significantly in error.

2. 20, 50 and 100 Year Return Period Flood Flow Estimates

Table 1 also lists return period estimates for each location requested. Frequency analysis was carried out for a number of hydrometric stations in the area as described in the attached February 22, 1985 memo from the Modelling Section. The results were plotted on graphs of unit peak flow vs. drainage area, and these relationships used to estimate return period peak flows for the requested locations which are ungauged.

Figures 1 to 3 show the return period estimates provided by the Modelling Section plotted against drainage area for stations in the region. It was assumed for the Lillooet River mainstem locations that a curve through 08MG005 and roughly parallel to the WSC regional envelope curve but with some weight given to the Green River stations (08MG003 and 08MG004) would be appropriate. Due to similarities in watershed characteristics, it was assumed that 08MG006 Rutherford Creek would be the best index for Ryan River and Miller Creek, so a parallel line was plotted through Rutherford Creek. Similarly, it was assumed that Pemberton Creek peak flow would be best indexed by 08MG003 Green River.

Another approach for which an argument could be made is to ignore the slope of the WSC "envelope" curve and plot the best fit line through the return period estimates for the gauged tributaries in the area which best index peak flows for Ryan River (08MG003 Green River, 08MG007 Soo River and 08MG006 Rutherford Creek). Based on this approach (Figure 4) the 200 year estimate for Ryan River is 432 m^3/s (15,200 cfs, 1030 $L/s/km^2$). The use of this relationship would result in virtually no change in the Miller Creek estimate, and although an increase in estimated peak flow might be indicated for Pemberton Creek, its low elevation and location indicate that the estimates from Figure 1 to 3 should be used.

Thus the return period peak flows in Table 1 are estimated from the "Figure 1 to 3" approach except for Ryan River for which the Figure 4 curve was used.

3. Instantaneous Peak Flows

The estimated instantaneous flow for October 8, 1984 at 08MG005 is 1.18 times the daily peak flow. It is assumed for the instantaneous estimates in Table 2 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 1.20 for the two mainstem locations above Pemberton was made, and for the location at Lillooet Lake 1.16 was used to account for the larger drainage area.

The use of 1.12 for Green River is based on the ratio obtained from the frequency analysis results in the February 22, 1985 memo by R. Wyman.

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The instantaneous flows given for other tributaries (shown in brackets) may be grossly in error as there are no data for the October 8, 1984 event which provide an indication of their magnitude. The figures shown are the rough daily estimates in Table 1 multiplied by an instantaneous to daily ratio based on results from previous regional peak flow assessments except for Ryan River and Miller Creek. Based on flood profile studies an instantaneous peak flow for Ryan River was estimated as 326 m^3/s, but this flow did not account for the problem of flow escaping or returning due to the dyke breach. Based on high water marks observed in May 1985 in a reach upstream of the breached dyke, an estimate of 430 m^3/s was obtained. This estimate is considered the best at this time. The estimate given for Miller Creek is based on flood profile analysis results as provided by R.W. Nichols (memo dated June 18, 1985).

Table 2 also lists return period instantaneous peak flows for each location. Estimates for the gauged locations 08MG005 Lillooet River and 08MG003 Green River were supplied by the Modelling Section (memo dated February 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 ratio of instantaneous to daily 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.

Although the 08MG005 Lillooet River and 08MG003 Green River frequency analysis results indicated a variation in I/D ratio with return period, this refinement was not felt justified for the tributary locations due to the low reliability of the estimated flows.

4. Summary

The only flow data available for the October 8, 1984 event in the Lillooet River basin are the daily and instantaneous flows provided by Water Survey of Canada for 08MG005 Lillooet River near Pemberton, and even these flows are the result of much judgement and estimates of flow bypassing the gauging station.

The extrapolation of flows at this single location to other sites on the Lillooet River and to its tributaries is fraught with unknowns, thus the flow estimates given in Table 1 and 2 should be treated accordingly. At the same time, with the combination of data from WSC, flood profile analysis and flood flow frequency analysis results for regional stations, the estimates provided can be considered the best available at this time and adequate for preliminary floodplain delineation.

More information on high water marks is being obtained this summer and when this is available it is intended to review this analysis. It is not likely that the estimates for the Lillooet R. mainstem locations will be revised, but it is quite possible that those for other locations could be.

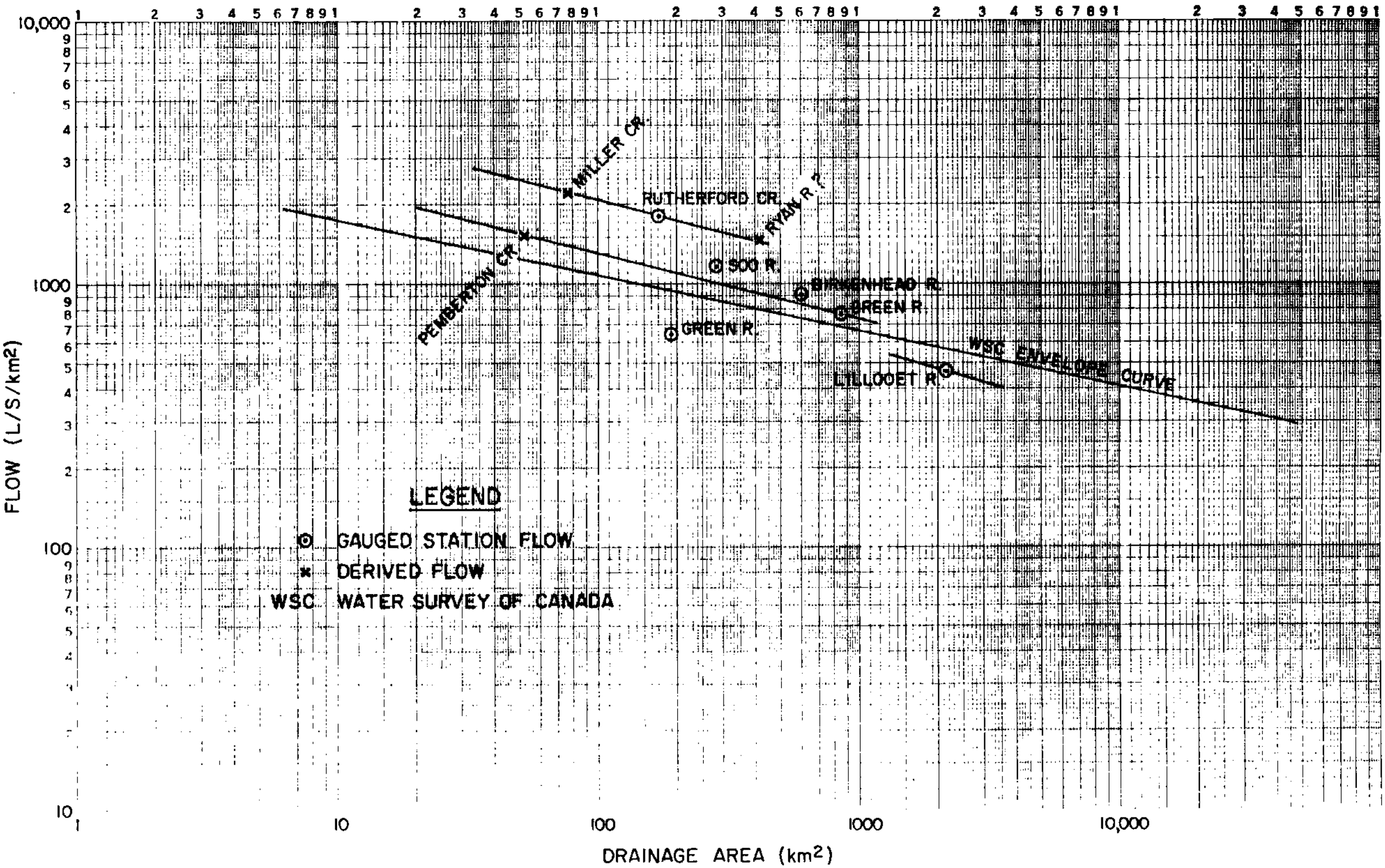
D.E. Reksten

D.E. Reksten
Senior Hydrological Engineer
Hydrology Section
Water Management Branch
387-1111

c.c. J.D.C. Fuller
R.W. Nichols
R.Y. McNeil
H. Nesbitt-Porter
J. McCracken

85·02·22

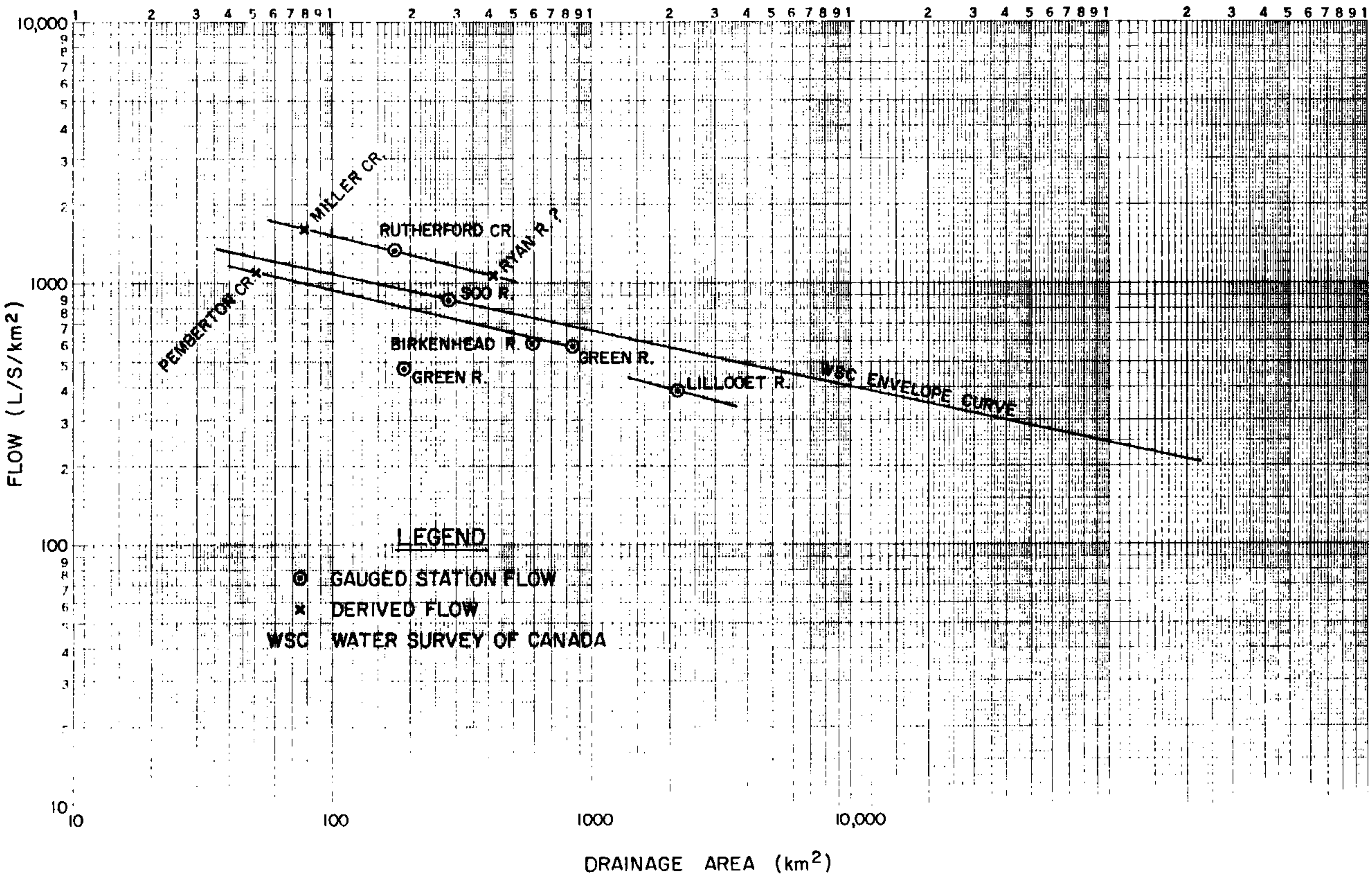
200 YR. DAILY PEAK FLOW



APPENDIX FIGURE I

DWG. NO. 85-13-20

50 YR. DAILY PEAK FLOW



APPENDIX FIGURE 2
DWG. NO. 85-13-21

20 YR. DAILY PEAK FLOW

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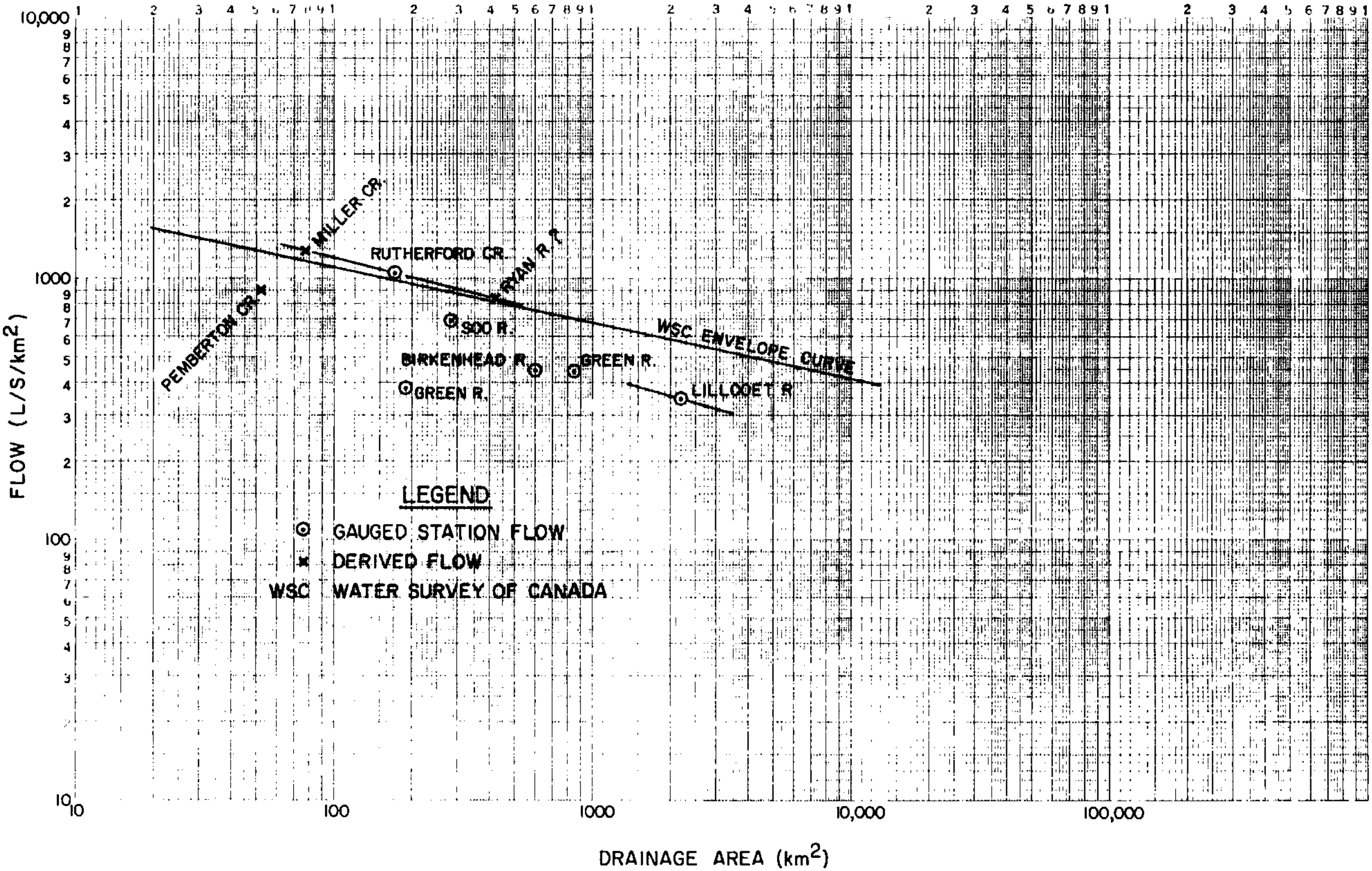

APPENDIX FIGURE 3
DWG. NO. 85-13-22

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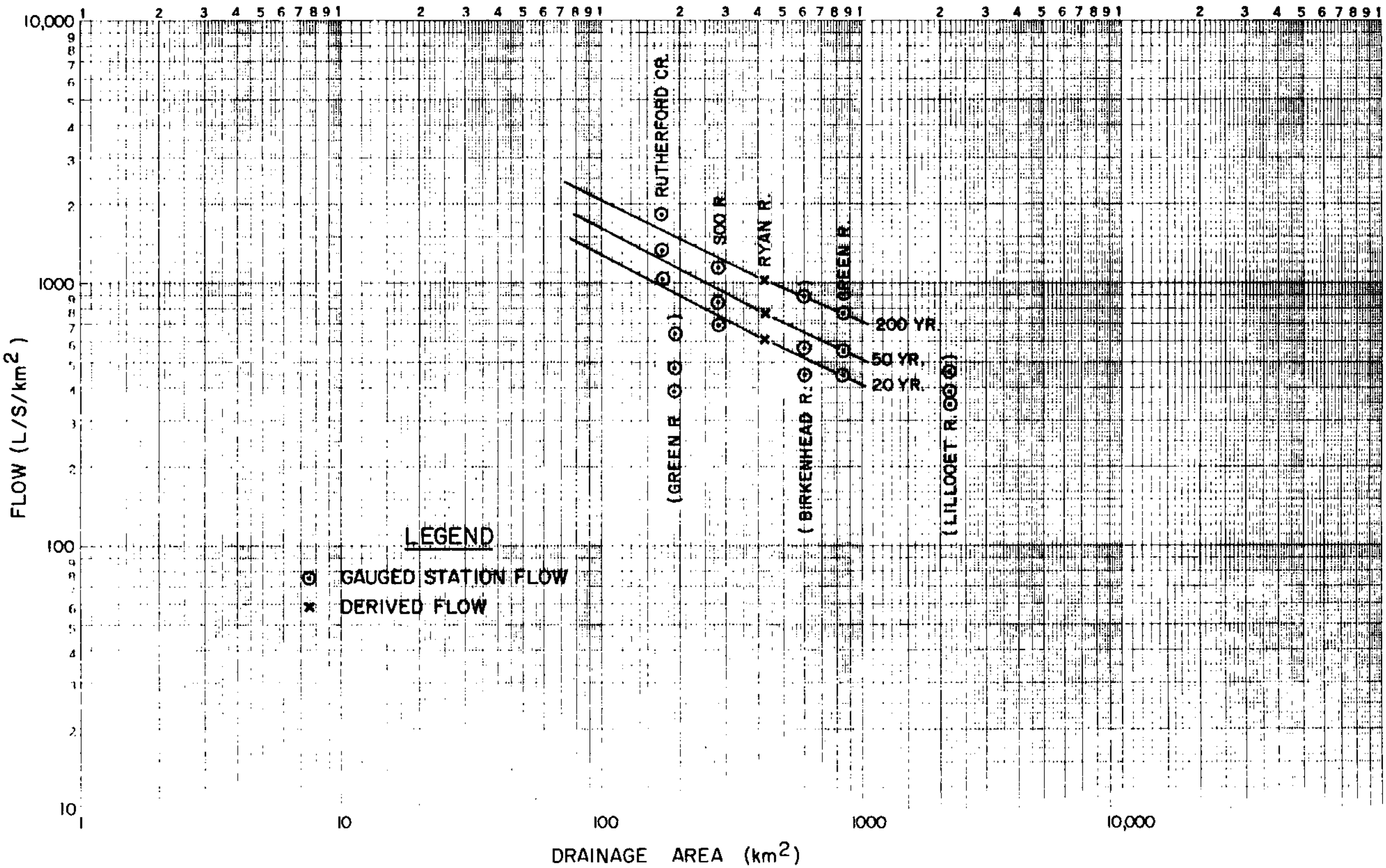
RETURN PERIOD DAILY PEAK FLOW



APPENDIX FIGURE 4
DWG. NO. 85-13-23

TABLE 1
DAILY FLOOD FLOWS

FLOOD FLOW EVENT		LILLOOET RIVER AB. WOLVERINE	TRIBUTARY FLOW	LILLOOET RIVER AB. RYAN RIVER	RYAN RIVER AT MOUTH	MILLER CREEK AT MOUTH	08MG005 LILLOOET RIVER NR. PEMBERTON	PEMBERTON CREEK	LILLOOET RIVER AB. GREEN R.	GREEN R. AT MOUTH	TRIBUTARY FLOW	LILLOOET RIVER AT LAKE	08MG008 BIRKENHEAD RIVER	BIRKENHEAD RIVER AT MOUTH
Drainage Area (km^2)		1 558	71.0	1 629	419	77.7	2 160	51.0 ++	2 218	868	76	3 162	597	638
October 8, 1984	m^3/s	835	28	863	330*	124*	1 110E	24.4	1 139	350	22.8	1 513	149	160
	$L/s/km^2$	536	408	530	788	1600	514	478	514	403	300	478	250	250
	% of 08MG005	75.2	2.5	77.7	18.0	4.2	100.0	2.2	102.6	31.5	2.1	136.3	13.4	14.4
*Flood profile analysis estimate														
20 Year Return Period	m^3/s	593	-	622	256+	99.5	746	45.9	765	382	-	990	267	278
50 Year Return Period	m^3/s	655	-	689	323+	124	840	56.1	861	478	-	1 107	338	354
200 Year Return Period	m^3/s	796	-	830	432+	171	992	78.5	1 020	660	-	1 312	536	565
+Estimated from Figure 4														

++ Includes drainage canal contribution

TABLE 2
INSTANTANEOUS FLOOD FLOWS

FLOOD FLOW EVENT		LILLOOET RIVER AB. WOLVERINE	LILLOOET RIVER AB. RYAN RIVER	RYAN RIVER AT MOUTH	MILLER CREEK AT MOUTH	08MG005 LILLOOET RIVER NR. PEMBERTON	PEMBERTON CREEK	LILLOOET RIVER AB. GREEN R.	GREEN R. AT MOUTH	LILLOOET RIVER AT LAKE	08MG008 BIRKENHEAD RIVER	BIRKENHEAD RIVER AT MOUTH
Drainage Area (km^2)		1 558	1 629	419	77.7	2 160	51.0 ++	2 218	868	3 162	597	638
October 8, 1984	m^3/s	1 002	1 049	430*	174*	1 310	(36.6)	1 344	(392)	1 755	(194)	(208)
	Inst./Daily	1.20	1.20	(1.3)	(1.4)	1.18	(1.5)	1.18	(1.12)	1.16	(1.3)	(1.3)
*Flood profile analysis estimate												
()May be grossly in error due to lack of data for October 8, 1984 event												
20 Year Return Period	m^3/s	670	703	333	139	843	68.8	864	416	1 130	347	361
	I/D	1.13	1.13	1.3	1.4	1.13	1.5	1.13	1.09	1.13	1.3	1.3
50 Year Return Period	m^3/s	753	792	420	174	966	84.2	990	525	1 290	439	460
	I/D	1.15	1.15	1.3	1.4	1.15	1.5	1.15	1.10	1.15	1.3	1.3
200 Year Return Period	m^3/s	939	979	562	239	1 170	118	1 200	739	1 570	697	734
	I/D	1.18	1.15	1.3	1.4	1.18	1.5	1.18	1.12	1.18	1.3	1.3

++ Includes drainage canal contribution

APPENDIX B

Province of British Columbia

Ministry of Environment

WATER MANAGEMENT BRANCH

MEMORANDUM

To: D.E. Reksten
Surface Section
Water Management Branch

Date: February 22, 1985
File: 0323545

Re: Lillooet River near Pemberton
Floodplain Mapping and Dyking Assessment

In response to your verbal request, the following return period estimates have been made for the WSC gauging station indicated:

	Year of Record	20 year		50 year		200 year		
		Daily	Inst.	Daily	Inst.	Daily	Inst.	
Rutherford Creek near Pemberton		177	-	227	-	311	-	
Soo River near Pemberton		194	-	240	-	324	-	
Green River near Rainbow		72	-	89	-	121	-	
Green River near Pemberton		370	403	463	509	639	716	
Birkenhead R. at Mount Currie		267	-	338	-	536	-	
Lillooet Lake near Pemberton*		29.01	29.17	29.05	29.23	29.08	29.28	*
Lillooet River near Pemberton		746	843	840	966	992	1170	

Discharges are in m^3/sec. and lake levels are in meters. Add 169.335 meters for GSC datum on Lillooet Lake.

Other than the Lillooet River near Pemberton, these rivers have relatively short periods of record. The frequency estimates have been adjusted to be consistent with the larger record of the Lillooet River. It was not possible to estimate instantaneous flows at some stations due to lack of data, but a very approximate estimate might be possible using unit discharge vs basin area data.

Because of the general interest in flooding of the Lillooet area arising from the October 8, 1984 flood, a very detailed analysis was done, and the results differ significantly from previous estimates (see memo: McNeil to Reksten, November 7, 1984, File 0323545). All available data was used, including the original 1984 daily and instantaneous flow estimates of 920 and 1050 m^3/sec., respectively. (These have since been re-estimated at 1088 and 1254 m^3/sec. - see Memo to File, D.E. Reksten, Feb. 1985). Careful analysis of snowmelt and rainfall peaks led to the realization that using the "accepted" method of combining probability curves for separate events yields unreasonably high floods for low probability events. See memo, McNeil to Fuller, Feb. 1985, File 0323545.

Two methods were used to analyze daily flows for the Lillooet River:

1. Calendar year annual maxima;

* All Lillooet Lake stage estimates revised--see accompanying memo dated March 6, 1985 (Appendix B1).

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DER 85-02-22

2. Partial duration series on fall events, adjustment for the period of record, and combination with probability of snow-melt events.

The two methods yielded very similar results.

For instantaneous peak flows, separate analyses were made for all available data, both instantaneous and daily flows for the same day. The ratio of instantaneous to daily thus obtained was used to adjust the instantaneous flow estimates to correspond to the longer period of record available for the daily flows.

Inclusion of the latest (increased) estimates of the 1984 flood made very little difference to the frequency estimates for the daily flows. However, the frequency estimate of the instaneous peaks was changed substantially by the inclusion of this one flow. The resulting 200-year instantaneous flow estimate would have been 30% higher than the corresponding daily flow estimate and had very wide confidence limits. This seems unreasonable because historically the ratio of instantaneous to daily has averaged only 1.10 with a range of 1.01 to 1.26. It was therefore decided to use the previously calculated frequency curve adjusted to the longer period of record of daily flows.

It is recommended that the above estimates replace all previous estimates given. It should be noted that there is much more confidence in the frequency curve for maximum daily flows than for the instantaneous flows. It would appear that the October 8, 1984 event was an event with an extremely low probability, having a return period considerably greater than 200 years.

R.J. Wyman

Robin Wyman
Modelling Section
Water Management Branch

APPENDIX B1

Province of British Columbia

Ministry of Environment

WATER MANAGEMENT BRANCH

MEMORANDUM

To: Mr. D.E. Reksten

Date: March 6, 1985

File: 0323545

Re: Lillooet Lake Flood Frequency

Further study of Lillooet Lake levels indicates that the preliminary figures quoted in my memo of February 22, 1985, should be changed. With only a total of 14 years of data available, the inclusion of the 1984 flood in the analysis results in marked changes in the statistical properties of the sample, producing return period estimates which are inconsistent with discharge estimates in the area. The results below appear to be unreasonably high and should perhaps be considered as upper limits, and the previous estimates as lower limits, the "true" values lying somewhere in-between.

	Daily	Instantaneous
20 years	29.63m	29.75m
50 years	29.91	30.04
200 years	30.26	30.39

R.R. Wyman

R.R. Wyman
Modelling Section
Water Management Branch

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APPENDIX C

Province of British Columbia | Ministry of Environment | WATER MANAGEMENT BRANCH

MEMORANDUM

To: C.H. Coulson, Head
Surface Water Section
Water Management Branch

Date: January 3, 1985

Our File: S2304

Re: Lillooet River Basin Logging Activities

As requested by Mr. Fuller, we have investigated the history of logging activities in the Lillooet River basin. The main source of the information was 1:20,000 scale MOF Forest Cover maps updated to 1983. Another source was 1981 1:40,000 air photos. The area investigated was the drainage area above the hydrometric station 08MG005 Lillooet River near Pemberton.

Recorded logging activities started in 1958. Since then the average rate of cut has been 262 hectares/year, or 0.12% per year of the 2160 km^2 basin. By 1983, 3.1% of the basin had been cut (67.8 km^2). The highest rate of cut (Figure 1) occurred during 1972-79 when it amounted to 469 hectares/year (0.22% per year). If only the "forested area" or the area below 1200 m is considered, the 67.8 km^2 cut to 1983 amounts to 11.1%, or 0.46% per year.

Logging activities have taken place mainly in the main valley bottom and near the mouth of tributary streams, generally below 800 m elevation. The distribution of clearcut areas amongst major tributaries was partially assessed by selecting six of them for analysis. The annual cut area was not determined, but the portion of the sub-basin area cut in total to 1983 was determined as:

Stream	Drainage Area (km^2)	Cut Area (ha)	Portion of Sub-Basin (%)
Miller Creek	77.7	158	2.0
Ryan River	419	1701	4.1
Meager Creek	225	589	2.1
Pebble Creek	132	49	0.37
North Creek	81.9	201	2.4
Wolverine Creek	3.63	6	1.6

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TABLE 1

LOGGING HISTORY

LILLOOET RIVER BASIN (AB. 8MG005 nr. Pemberton)

YEAR	AREA (ha.)		
	CUT	BURNED	PLANTED
(1930	-	1617	0)
1950	-	5.4	0
1958	2.7	0	0
1959	40.4	0	0
1960	138	69.4	0
1961	119	52.3	0
1962	119	89.0	15
1963	150	149	0
1964	116	33.4	0
1965	120	17.7	0
1966	243	144	68.7
1967	193	143	26.2
1968	199	147	0
1969	240	0	222
1970	217	317	0
1971	238	98.5	78.9
1972	536	98.2	122
1973	537	43.0	174
1974	420	676	347
1975	413	252	371
1976	342	196	0
1977	549	324	50.3
1978	488	543	241
1979	465	545	428
1980	294	396	361
1981	195	346	479
1982	96	115	310
1983	125	145	172
TOTAL	6595	4945	3466
+ cuts & burns with no date.	181	302	0
TOTAL 1950-1983	6776	5247	3466

Thus 40% of the area clearcut has occurred within these six sub-basins which comprise 43% of the total basin above 8MG005. The balance of the clearcutting has taken place in the mainstem valley bottom and small, low-elevation tributary sub-basins. The Ryan River has had the greatest portion clearcut of the above sub-basins with 4.1% since logging began in 1959.

77% of the area cut has been slash burned by "spot" and broadcast treatment. (It was noted on the maps that a large uncontrolled burn took place in 1930, mainly in the Ryan River - South Creek headwater divide area.)

About half the area cut over has been replanted (Fig. 1). It is assumed that the rest has been left to regenerate naturally. A detailed study of revegetation has not been carried out, but 1981 air photos indicate that it could be described as moderately successful based on canopy density and taking into account the length of time involved.

A brief overview of air photos indicates many sites of naturally unstable terrain resulting in debris torrents, landslides, etc. There do not appear to be major problems which could be attributed to logging activities.

In summary, the extent and rate of clearcutting in the Lillooet River basin above Pemberton has been minimal, even in tributary watersheds. Although the on-site effects of clearcutting might cause local changes in the hydrologic regime (soil moisture, snowpack distribution, etc.), it is not considered that present harvesting activities could have any impact on extreme flows in the Lillooet River in Pemberton.

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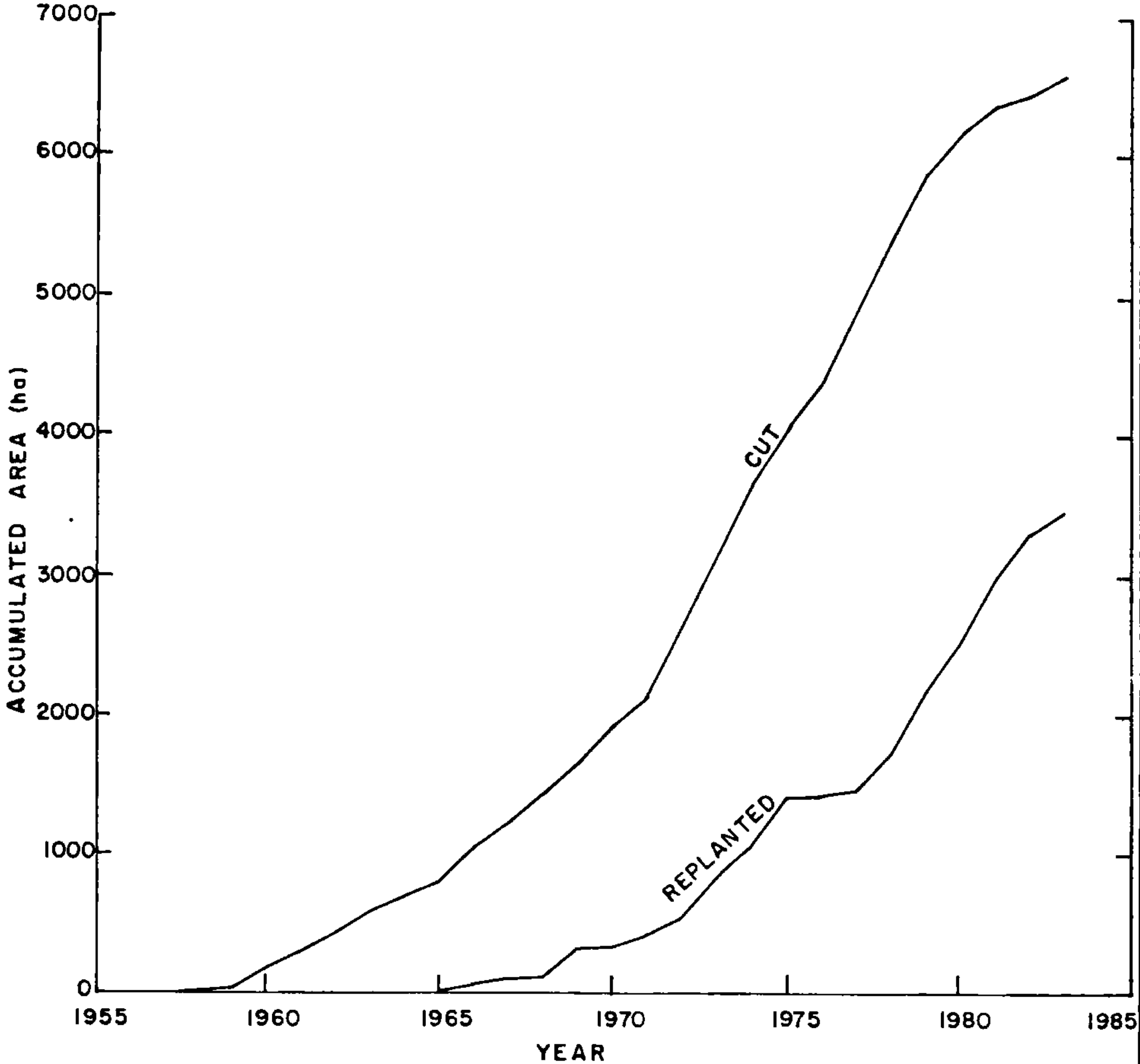

APPENDIX FIGURE 1

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON
PEMBERTON VALLEY FLOOD PROTECTION
1985 STUDY
LILLOOET RIVER BASIN
LOGGING HISTORY 1938-83

SCALE: AS SHOWN

DATE JUNE 1985

D. E. REKSTEN ENGINEER

FILE No. DWG. No.

BCIL 7673-M.E.