Water Management Branch
Ministry of Environment

HYDROLOGIC IMPACT OF SALVAGE LOGGING IN THE TROUT CREEK WATERSHED NEAR PENTICTON, B.C.

J.D. Cheng
Forest Hydrologist
Hydrology Section

May 1981

ABSTRACT

This study was conducted to assess the hydrologic effects of salvage logging necessitated by a mountain pine beetle infestation within the Trout Creek Basin of the Okanagan Valley in south central B.C.

After making some necessary assumptions and using available regional streamflow data, the USFS water yield increase analysis procedure was applied to estimate streamflow changes in Camp Creek, a tributary to Trout Creek, after salvage logging in its watershed. The results indicate that increases of 3.5, 13.9, 14.8, 3.8 and 0.8 percent respectively can be expected for the mean annual, March, April, May and August flows in Camp Creek after the 1977-79 logging. These increases would become 6.6, 22.3, 24.9, 7.2 and 2.5 percent respectively after the completion of additional salvage logging in 1981. Although these results cannot be substantiated due to the lack of comparable streamflow data from a nearby unlogged control watershed, they probably represent the relative order of streamflow changes which are likely to take place. The estimated streamflow changes are small at this initial stage of salvage logging but as the extent of forest removal dictated by mountain pine beetle attacks increases in the future, the flow regime alteration may reach a scale significant to water management operations. The lack of quantitative channel stability survey data prevents a meaningful calculation of allowable annual timber removal for the Camp Creek watershed. On the other hand, field observations indicate that the degree and extent of ground disturbance associated with the salvage logging as presently

evident in the study watershed is not very likely to cause significant erosion and stream sedimentation problems.

This study suggests that the USFS water yield increase analysis procedure could be a useful operational tool in assessing the impact of logging on some aspects of streamflow for watersheds with adequate input data. Improvements to the analysis procedure, such as the capability of assessing changes in late summer low flow as well as daily and instantaneous peak flows should be attempted as part of its future development by specialists in soils, forestry and hydrology. The usefulness of the USFS water yield increase analysis procedure for application in B.C. can be assured and greatly enhanced only if a well-designed province-wide field data collection program is implemented to provide the required input data. With proper application of the analysis procedure, it should be possible to place the operational forestry-related water management problems and their solutions in a better perspective.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. INTRODUCTION

In the Trout Creek Basin of the Okanagan Valley and other areas in south central and southwestern British Columbia (B.C.,) the mountain pine beetle has recently become a major factor in determining the extent of logging operations in terms of the location and volume of annual cut (Figure 1). This is partly due to the present policy of the B.C. Ministry of Forests to salvage as much infested timber as possible.

Because of the importance of Trout Creek to the water supply needs of the City of Summerland, a major concern of the B.C. Water Management Branch and the water users is the hydrologic consequences of this salvage logging with respect to detrimental changes in water yield and flow regime. The purpose of this study is to evaluate the hydrologic effects of salvage logging on a mountain pine beetle-affected tributary watershed, Camp Creek watershed, within the Trout Creek Basin (Figures 1 and 2). This study was requested by the Water Management Branch of the B.C. Ministry of Environment in Victoria. The major efforts of this study are placed on the potential effects of salvage logging on water yield and flow regime. The impacts of this salvage logging on erosion and water quality are only briefly discussed based on observations made during one field trip in August, 1979. To estimate the potential changes in water yield and flow regime as a result of the watershed salvage logging, this study makes use of the U.S. Forest Service (USFS) water yield increase analysis procedure (Isacson, 1977; Russell, 1971; Hetherington, 1978). The selection of the Camp Creek watershed for this assessment is based on 1) its long record of streamflow (1965 to present) which is essential for the application of USFS water yield increase analysis procedure, and 2) its high percentage (13%) of watershed area already salvage-logged between 1977 and 1979, with additional logging over 8.6 % of the watershed by 1981.

The limitations of the methodology used in this report are discussed and suggestions for improvement are made. The water and forest management implications of the results presented in this study for the Trout Creek Basin in particular and the Okanagan Valley generally are briefly discussed.

2. WATERSHED AND STREAMFLOW CHARACTERISTICS

Camp Creek watershed, located in the headwater area of the Trout Creek Basin (Figures 1 and 2) has a drainage area of 13.1 mi^2, (above gauging station 08NM134) rising from 3260 to 6200 feet with a median elevation of 4770 feet (Table 1). The elevation distribution of the total watershed area is included in Table 2. The watershed slopes are mostly gentle to moderate gradient with an average of 122 feet per mile or 2.3% (Reksten 1974). The watershed is underlain almost equally by intrusive rocks of paleozic to tertiary and of middle to late jurassic. Coarse-textured soils such as sandy loams and gravelly sandy loams are characteristic of the watershed.

The major forest types at the lower elevations of the watershed are ponderosa pine, lodgepole pine, and Douglas-fir occurring in single or mixed types. According to information provided by the B.C. Ministry of Forests, the total area cleared by salvage logging and the B.C. Hydro powerline right-of-way from 1977 to July, 1979 is 1,087 acres, occurring at various elevations with the majority below 5,000 feet. In other words, approximately 13 percent of the total watershed is bared of forest cover as a result of timber harvesting. The elevation distribution of these 1977-79 logged areas relative to total watershed area is shown in Table 2. Additional logging planned for 1979 is scheduled for completion by 1981. The elevation distribution of the accumulated 1977-81 logged area is presented in Table 3. At the end of 1981, the total logged areas will be 1,813 acres or 21.6 percent of the total watershed area.

Based on available streamflow data collected at the hydrometric station near the watershed outlet, (08NM134, drainage area: 13.1 mi^2), the mean annual runoff for Camp Creek during the pre-logging period is 4,120 acre-feet or 5.9 inches. A major portion of the annual runoff is derived from snowmelt. Streamflow usually begins to rise in April, reaches its peak magnitude from mid-May to early June, and then begins to recede to low flow levels in August and September. Annual maximum peak flows mainly result from snowmelt, with or without rainfall. The estimated 25-year return period maximum daily and instantaneous peak flows, $(q_{pd})_{25}$ and $(q_{pi})_{25}$, are 8 and 10 cfs/mi^2 respectively. Although annual minimum low flows can occur in the winter and early spring, it is the low flows in the summer months of August and September that are most important to the downstream water users for irrigation and domestic purposes. The 25-year return period minimum 7-day average flow during the summer months is estimated to be 0.4 cfs or 0.03 cfs/mi^2. Other hydrometeorological characteristics of the Camp Creek watershed are summarized in the attached Hydrologic Inventory Form (Appendix I).

3. HYDROLOGIC EFFECTS OF LOGGING

As pointed out earlier, the total logged area from 1977 to July 1979 accounted for approximately 13 percent of the Camp Creek watershed. However, the salvage logging within the watershed is an on-going activity. According to the B.C. Forests Ministry, the logging company operating in this watershed (Gorman Brothers Ltd. of West Bank, B.C.), is short of timber and is planning to harvest all the areas that are affected by the mountain pine beetle. Therefore, it is very likely that the hydrologic effects of salvage logging in the watershed with respect to water quantity (water yield) and flow regime no matter how small in the initial stage may eventually build up over time to reach a significant magnitude as the scale and extent of logged areas increase. This could be particularly true when we consider the fact that the re-growth on most logged areas, especially in the high elevation zone, is very slow under the climatic constraints in the B.C. interior. The present B.C. Forests Ministry practice is first to rely on natural reproduction on all cut blocks, and then to check on the success of regeneration in the third year following logging. If a logged area is not satisfactorily stocked in terms of silvilcultural objectives, a decision to plant is then made. Since it normally takes two years to grow useable seedlings, planting can only take place at least five years after logging. This practice, plus the unfavourable climatic conditions in interior B.C. for rapid vegetation regrowth mentioned previously, leads to a very slow overall vegetation recovery rate, particularly in terms of achieving a satisfactorily favourable level of forest influence on snow accumulation and melt as well as streamflow regime.

3.1 Erosion And Water Quality

With the exception of a small portion of the B.C. Hydro power-line right-of-way clearcut, the logged areas within the Camp Creek watershed are generally confined to fairly gentle and moderate terrain and, according to present B.C. Forest Ministry practices, logged areas with more than one-third exposed mineral soil are or will be seeded with grasses. Based on field observations made in August, 1979, no significant erosion problems are evident on logged areas. This field check also indicated that the logging roads have been adequately designed and constructed with suitable drainage facilities as there are no signifacant failures in road cuts or fills. Another field trip made in September 1980 in general confirms the above observations. It appears reasonable to assume that the degree and extent of ground disturbance associated with the salvage logging as presently evident in the Camp Creek watershed is not very likely to cause significant erosion and thus adversely affect the streamflow water quality through increased stream sedimentation.

3.2 Water Quantity And Flow Regime

In this and the following sub-sections, attempts are made to assess, by using the USFS water yield increase analysis procedure, the potential changes in annual water yield and flow regime (monthly flow distribution) of Camp Creek as a result of (1) past watershed salvage logging from 1977 to July 1979, ie., 1977-79 logging, and (2) additional salvage logging proposed for 1979-81.

3.2.1 Annual Water Yield

Water yield increases after watershed forest removal occur mainly as a result of (1) a reduction in evapotranspiration (interception and transpiration) losses, (2) an increase in wind turbulence that results in the redistribution of snow and greater local snow accumulation, and (3) more efficient conversion of the snowpack to streamflow. The water yield increase analysis procedure used by the USFS in Idaho and Montana (Isaacson, 1977; Russell, 1971) essentially calculates the annual water yield increase (AWYI) for each equivalent clearcut area (ECA) for various elevation zones on a small sub-drainage basis as follows:

$$AWYI = ECA \times K \times R$$

The value of ECA, in acres, is based on information obtained for each cut block on what and when ground cover changes took place and the actual extent of subsequent vegetation recovery. The water yield increase factor K expressed as a percentage increase is determined as a function of elevation as well as the form of precipitation. The runoff factor R expressed as depth in feet can be determined from regional runoff-elevation or precipitation-elevation relationships.

In order to apply the USFS procedure originally developed for Idaho and Montana to the Camp Creek watershed, the following explanations and assumptions have to be made.

1. Because of its small size (13 mi^2), the layout of its drainage system and the distribution of logged areas (Figure 2), the Camp Creek watershed is not further divided into sub-drainages.

2. All the timber removal in the watershed is considered to be clearcut.

3. Due to the lack of detailed forest ecosystem maps required for developing suitable hydrologic recovery classes plus the fact that essentially reforestation for most logged areas has not yet started, all logged areas (1977-79, 1979-81) are assumed to be in the same hydrologic "condition" as in the first year following clearcutting, i.e., still at their maximum level of capability, 100% of ECA, for causing hydrological changes in terms of snow accumulation and melt. This assumption is expected to be one of the major sources of error in the results.

4. As there are no applicable data in the study region on water yield changes following watershed forest removal, the values of the on-site water yield increase factor K for various elevation zones in the Camp Creek watershed are simply adopted from Isaacson(1977) and Russell (1971) without any modification. This is expected to be the other source of error in the results.

A runoff-elevation relationship is required to provide runoff R values for various elevation zones in the Camp Creek watershed.

For this study, a regional runoff-elevation relationship is first developed using mean annual water yield and median elevation values for 13 watersheds located south of 50° latitude in the Okanagan Valley. The median watershed elevation values were either computed from topographic maps or obtained from Reksten (1974). The estimates of runoff values for various elevation zones obtained from this relationship were then adjusted to obtain a total annual water yield value that would most closely match the recorded value for Camp Creek (Appendix 2).

The calculations and estimates for potential mean annual water yield increase after the 1977-79 logging are presented in Table 2. This estimated mean annual water yield increase for Camp Creek is 152 acre-feet or a 3.5 percent increase over that under natural forest cover conditions. Similarly, the calculations and estimates for potential mean annual water yield increase after the completion of scheduled additional logging in 1981 are presented in Table 3. An increase of 284 acre-feet of 6.6 percent in mean annual water yield may be expected. An independent check on the validity of these results is not possible due to the lack of a nearby, unlogged control watershed that has concurrent streamflow data during the pre- and post-logging periods. Therefore, speculation on the probable magnitude of water yield increases as a result of future salvage logging has to be based on these results. If the rate and elevation distribution of future logging over the five years after 1981 is the same as the 1977-81 period, an increase of approximately 568 acre-feet, or 13.2 percent in annual water yield might be expected after 1986. However, the vegetation recovery on some of the 1977-81 logged areas at that time will reduce the magnitude of this estimated increase. In most cases, the amount of mean annual water yield increase in the future would depend heavily on the actual rate of logging, its elevation distribution and the degree of vegetation regrowth on the earlier logged areas.

3.2.2 Flow Regime

The USFS water yield increase analysis procedure (Isaacson, 1977) permits the assessment of only two aspects of the flow regime: monthly flow distribution and the timing and magnitude of the maximum monthly flow. For these two aspects of flow regime calculations, tables of monthly percentage distribution of the mean annual water yield increase as a function of the elevation and aspect of a given ECA unit prepared by Isaacson (1977) for northern Idaho are used (Appendix 3). These tables show that the estimated monthly distribution of the mean annual water yield increase varies from March to August in response to changes in snowmelt rates and reduction in evapotranspiration losses as a result of forest removal. There are no locally available data which can be used to judge the applicability of those estimated increases to the Camp Creek watershed. This must be kept in mind when assessing the reliability of the final results.

The monthly distribution for mean annual water yield increase is mainly determined on the basis of the natural diversity in snow accumulation and melt that exists by virtue of differences in elevation, slope-aspect and vegetation cover. An increase in elevation at a given latitude is associated with an increase in snow accumulation, a delay in snowmelt timing, and an increase in average melt rate over the snowmelt period. Slope-aspect influences snow accumulation and melt through its influence on radiation input and exposure to winds. The timing of initial and maximum snowmelt is earlier on the south aspect than on the north. Such differences are greatest at low elevation and decrease with increasing elevation. The results of experiments in the U.S.A. and Canada indicate that on all aspects and elevations, snowmelt in clearcut openings usually occurs earlier and at a rate higher than in the uncut forest. However, the higher melt rate for the opening is partially offset by the higher snow accumulation, and consequently the timing of snow disappearance from the opening could remain the same as for the original uncut forest. In British Columbia where the canopy openings created by harvesting are normally much larger (>40 acres) than those for experiments (<20 acres), rapid snowmelt due to exposure may result in much earlier snowpack disappearance than in the uncut forest.

The results of the monthly flow increase calculation (Appendix 4) for Camp Creek as a result of the 1977-79 salvage logging are presented in Table 4 and Figure 4. May, the month in which the highest monthly flow occurred before logging, has the highest flow increase in acre feet (62). April a low runoff month, has the highest percentage increase (14.8%) with March being the next highest (13.9%). The month of August has a mere 1.4 acre-feet or 0.8 percent increase in flow. This is partly due to the concentration of 1977-79 logging in the low elevation zones below 4,500 feet. For example , 24% of the area in the 3,500 - 4,500 foot elevation zone had been logged compared to only 7.8% of the area logged in the 4,500 - 5,000 foot zone during the 1977-79 salvage logging. As a result of increased logging above 4,000 feet from 1979 to 1981 (Table 3), most percentage monthly flow increases are shown to be more than double those resulting from 1977-79 logging (Table 5). The calculation of monthly flow increases as a result of 1977-81 logging is illustrated in Appendix 5 and Figure 5. If the majority of logging after 1981 is concentrated above 4,500 feet, the flow regime changes would respond accordingly with the possibility that the highest percentage flow increase would occur in May or June.

4. DISCUSSION

Because it was necessary to make certain assumptions and use curves and values developed by Isaacson (1977) and Russell (1971) without modification, the analysis as presented in this report is somewhat oversimplified. The factors and processes involved in determining the amount and timing of water yield changes following forest removal are very complex. The results of this study are intended to be used only as a first quantitative approximation.

An evaluation of the application of the USFS procedure to B.C. by Hetherington (1977) indicates that with adequate input data and proper interpretation of results, the water yield increase analysis procedure as proposed constitutes a valuable, practical tool for assessing the potential effects of forest harvesting on water yield. However, the available input data are far from adequate at the present time for most watersheds in B.C. The scarcity of locally available data on the impact of logging on water flows prevents a critical assessment of the analysis procedure as it applies to watersheds in B.C. This, in turn, makes the proper interpretation of the results a very difficult task at present.

Available streamflow data from hydrometric stations in the region of the Camp Creek watershed have made it possible to develop an adequate elevation-runoff relationship required for water yield increase calculations.

However, the lack of channel stability data as proposed by Pfankuch (1975) prevents a calculation of allowable annual cut for the study watershed. The assignment of hydrologic recovery curves to various cover types or ecosystem types, although not attempted in this study due to the lack of data, should definitely be included in future studies when more data and local research results become available.

Two other areas of concern which could be incorporated into the procedure with further research and development are the prediction of changes in maximum daily and instantaneous peak flows as well as changes in late summer low flows. The success of including these two aspects in the analysis procedure will of course depend on the availability of available input data and appropriate research results.

Because the potentially detrimental impact of forest harvesting on late summer low flows is of major concern to Trout Creek (and Okanagan Valley) water users, a brief discussion on this subject is appropriate.

Studies conducted in areas where precipitation is mainly in the form of rain indicate that forest removal, particularly from deep soil sites, reduces evapotranspiration, thereby increasing annual water yield and low summer flows. However, none of these studies involved serious ground disturbance to an extent that resulted in a significant reduction in soil infiltration capacity over the watershed. If the logging-induced infiltration reduction over the watershed is more than the saving in evapotranspiration losses associated with forest removal, there is a good chance that summer low flows may decrease despite an increase in annual water yield. This would not appear to be an important factor in causing summer low flow reduction in the Camp Creek watershed according to our field observations. However, in areas like the Camp Creek watershed where streams are primarily fed by snowmelt, there is another possibile cause of reduced summer low flows following logging. This arises when forest removal causes the snowpack in high elevation zones, considered to be the major source areas for summer low flows, to disappear completely at a much earlier date than under the original forest cover condition. In this case, although the soil moisture deficit under the forested condition may be greater due to high evaportranspiration losses, the reduced evapotranspiration losses following tree removal may be overidden by the lack of snowmelt contribution late in the summer. On the other hand (in the late summer months) if the accumulated soil moisture increase due to decreased evapotranspiration after forest removal is <u>greater</u> than the amount of reduction in snowmelt contribution due to earlier snowpack disappearance in the high elevation area, a certain increase in late summer low flows may be expected. Despite the great uncertainties involved in determining the direction (increase or decrease) and magnitude of logging-caused low summer flow changes for Camp Creek, it is hydrologically important for any forest harvesting operation to avoid significant ground disturbance and to minimize the detrimental impact of earlier snowpack disappearance in the high elevation areas of the watershed.

5. CONCLUSIONS

The application of the USFS water yield increase analysis procedure to assess streamflow changes after salvage logging in the Camp Creek watershed involves making reasonable assumptions and using available streamflow data to develop and adequate elevation-runoff relationship. The results of this analysis indicate that small percentage increases in mean annual water yield and monthly flows from March to August may be expected for Camp Creek as a result of the first three years (1977-79) of salvage logging. Following the completion of scheduled additional logging in 1981, the percentage increases in both mean annual water yield and monthly flows are expected to be more than double those resulting from the 1977-79 logging. The streamflow changes may eventually increases over time to reach a scale of significance to water management operations as the extent of salvage logging increases in response to the expansion of mountain pine beetle - attacked areas in the future. Field observations suggest that the present degree and extent of ground disturbance in the salvage-logged areas is not likely to cause significant erosion and stream sedimentation problems. When quantitative stream channel stability data for Camp Creek become available in the future, it would be possible to calculate the allowable annual cut for the watershed.

It appears that the USFS water yield increase analysis procedure in its present form may be utilized as a useful operational tool in assessing the impact of logging on some streamflow characteristics for watersheds with adequate input data. The usefulness of this analysis procedure for application in B.C. can be assured and greatly enhanced if (1) it is modified to allow the assessment of the impact of logging on late summer low flow and daily peak flow, and (2) a well-designed province-wide data collection program is implemented to provide the required input data.

6. REFERENCES

Hetherington, E.D. 1978
Assessment of U.S. Forest Service water yield increase analysis procedure. Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C.

Isaacson, J.A. 1977
A computer model for determining water yield from forest activities - IPNF* LIB. H2OY 1977 version. USDA Forest Service, Idaho Panhandle National Forest, Coeur D'Alene, Idaho.

Pfankuch, D.J. 1975
Stream reach inventory and channel stability evaluation USDA Forest Service, Northern Region. Missoula, Montana.

Reksten, D.E. 1974
Regionalization of Okanagan sub-basin runoff from basin characteristics. Canada-British Columbia Okanagan Basin Agreement. Preliminary Report No. 43.

Russell, W.L. 1971
Procedures for estimatating average water yields and increases in water yield due to vegetation manipulation with interim guidelines for Clearwater National Forest. USDA Forest Service. Clearwater National Forest, Orofina, Idaho.

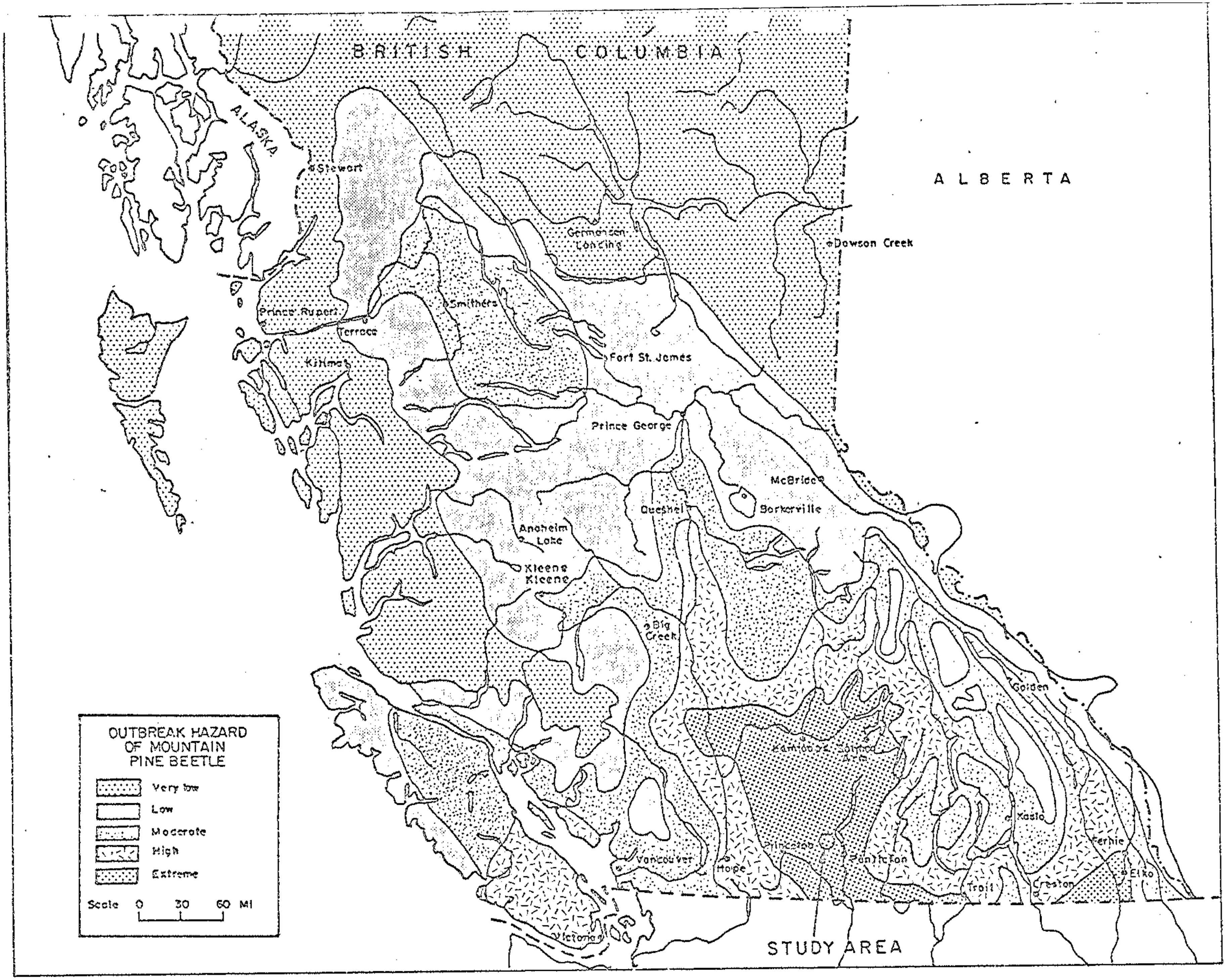


Figure 1. The Location of Study Area

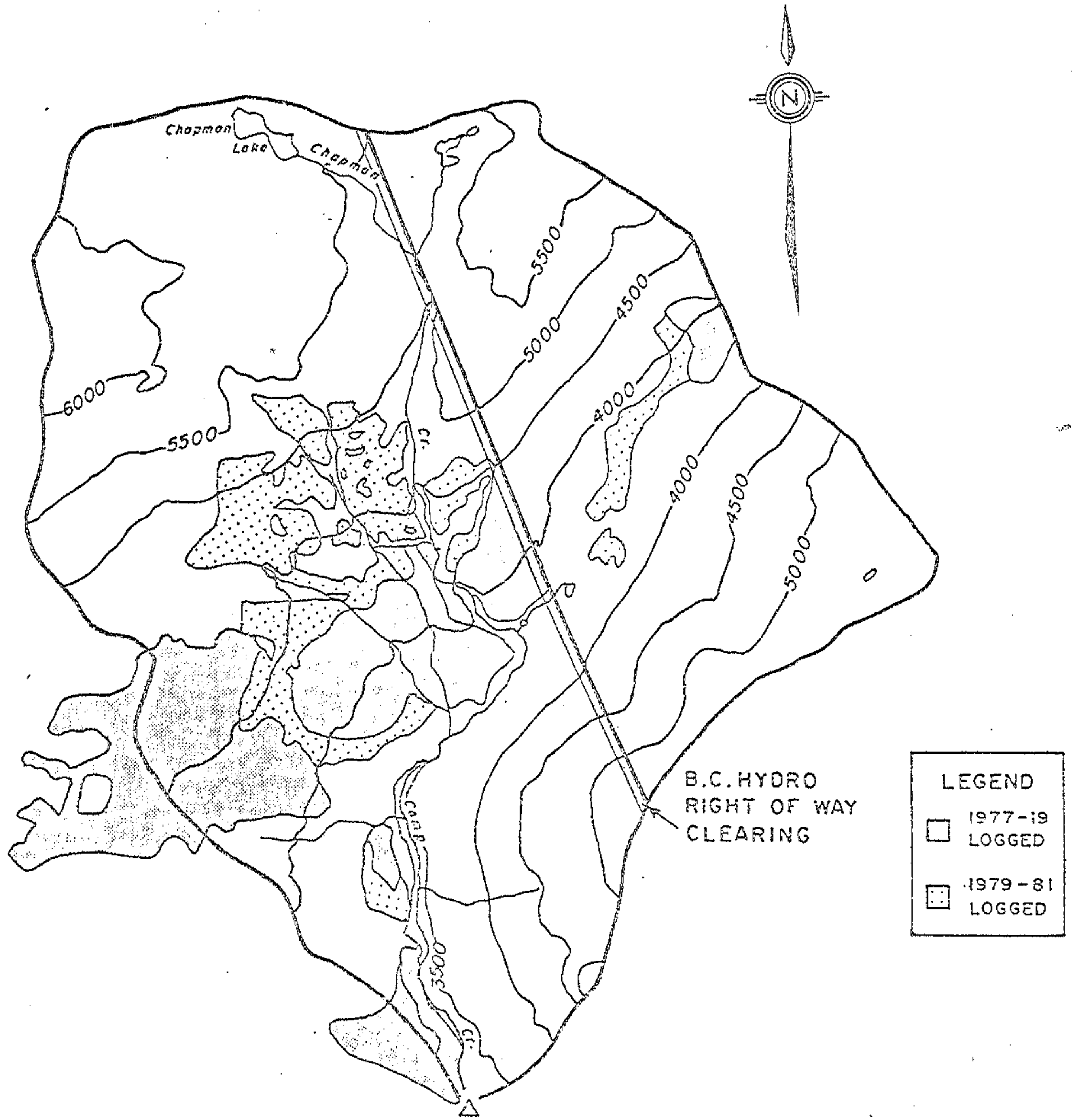


Figure 2. The Map Showing Logged Areas Within the Camp Creek Watershed

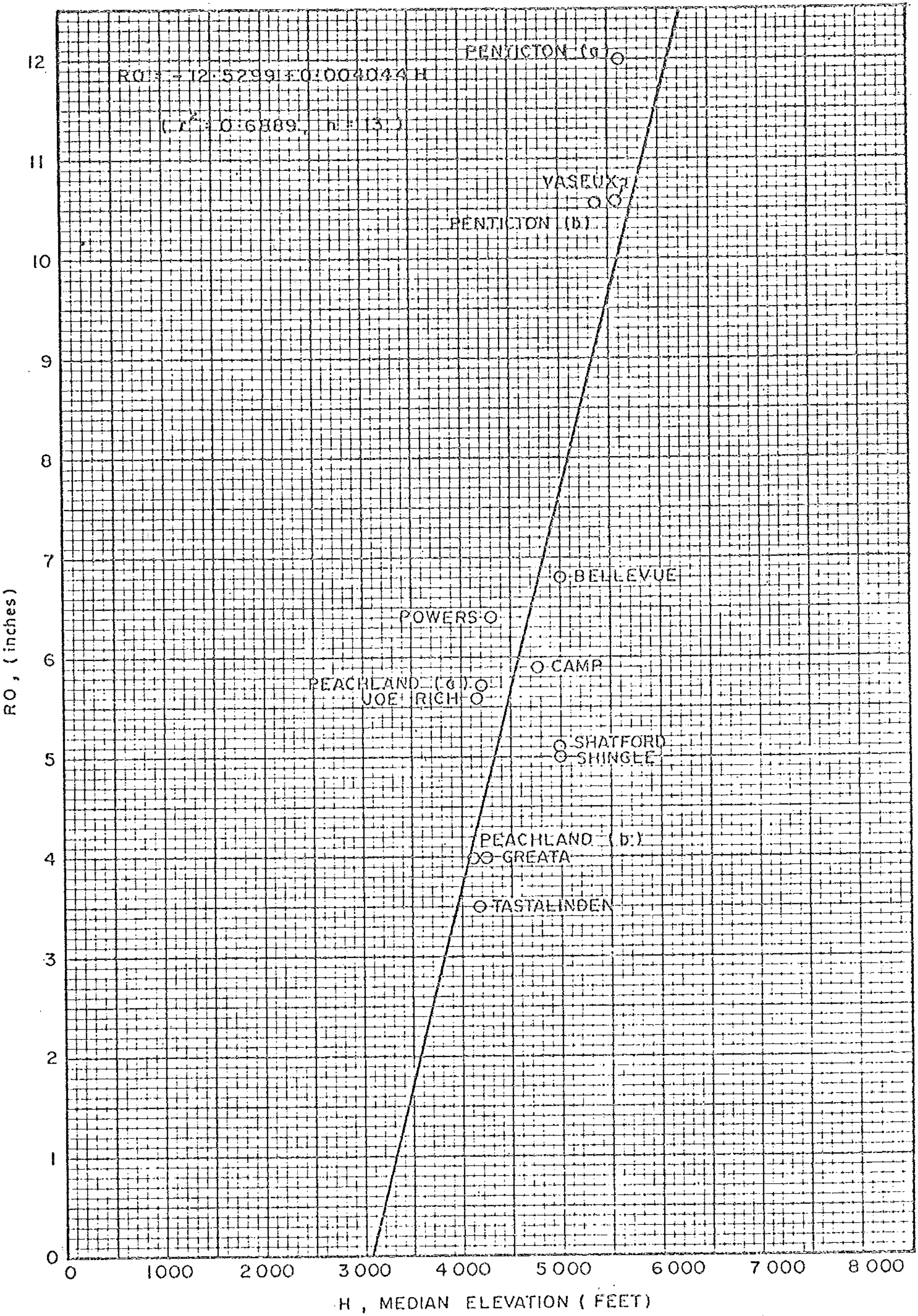


Figure 3. Runoff-Median Elevation Relationship for the Southern Okanagan Basin Area

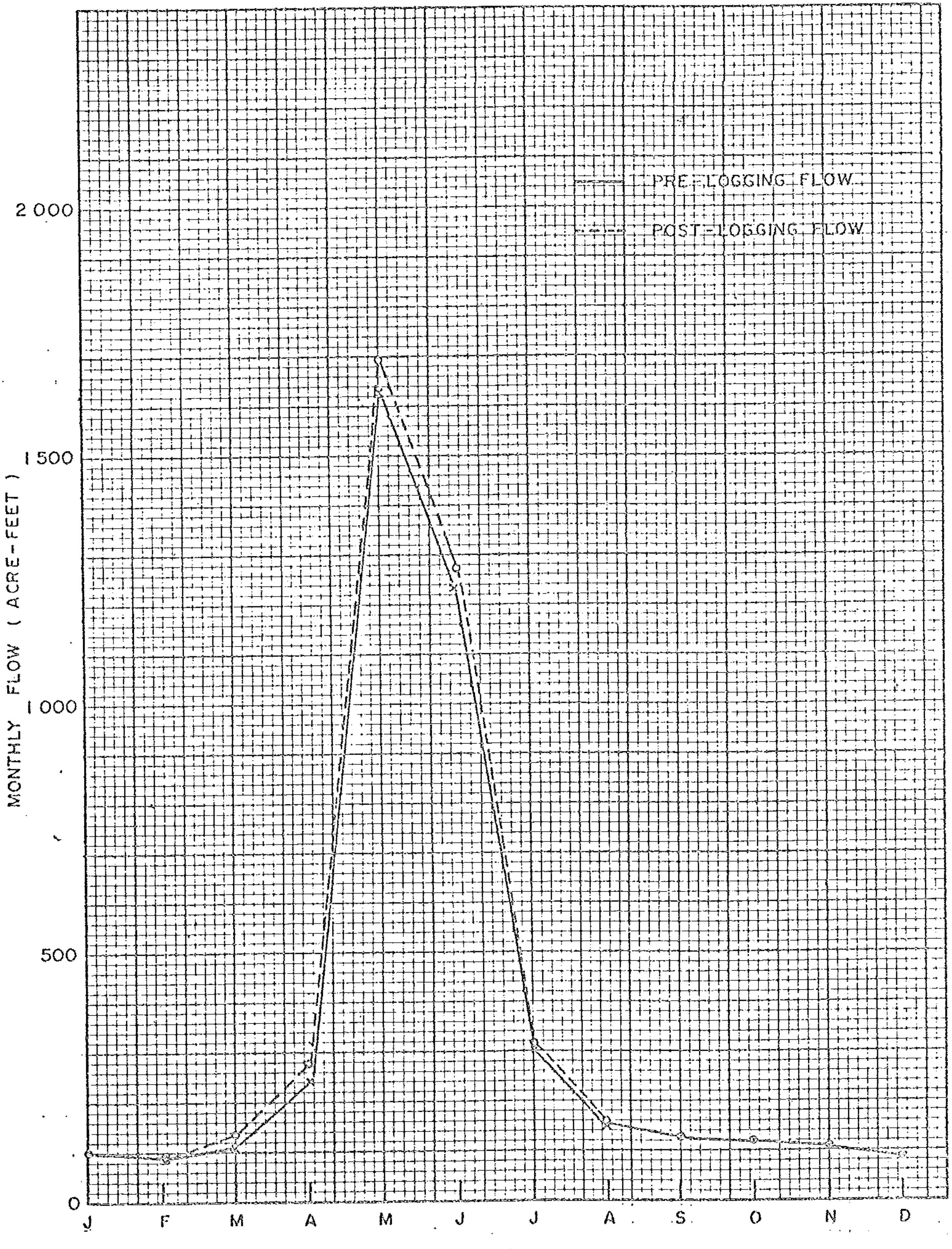


Figure 4. Estimated Monthly Flow Increases in Camp Creek After the 1977-1979 Logging

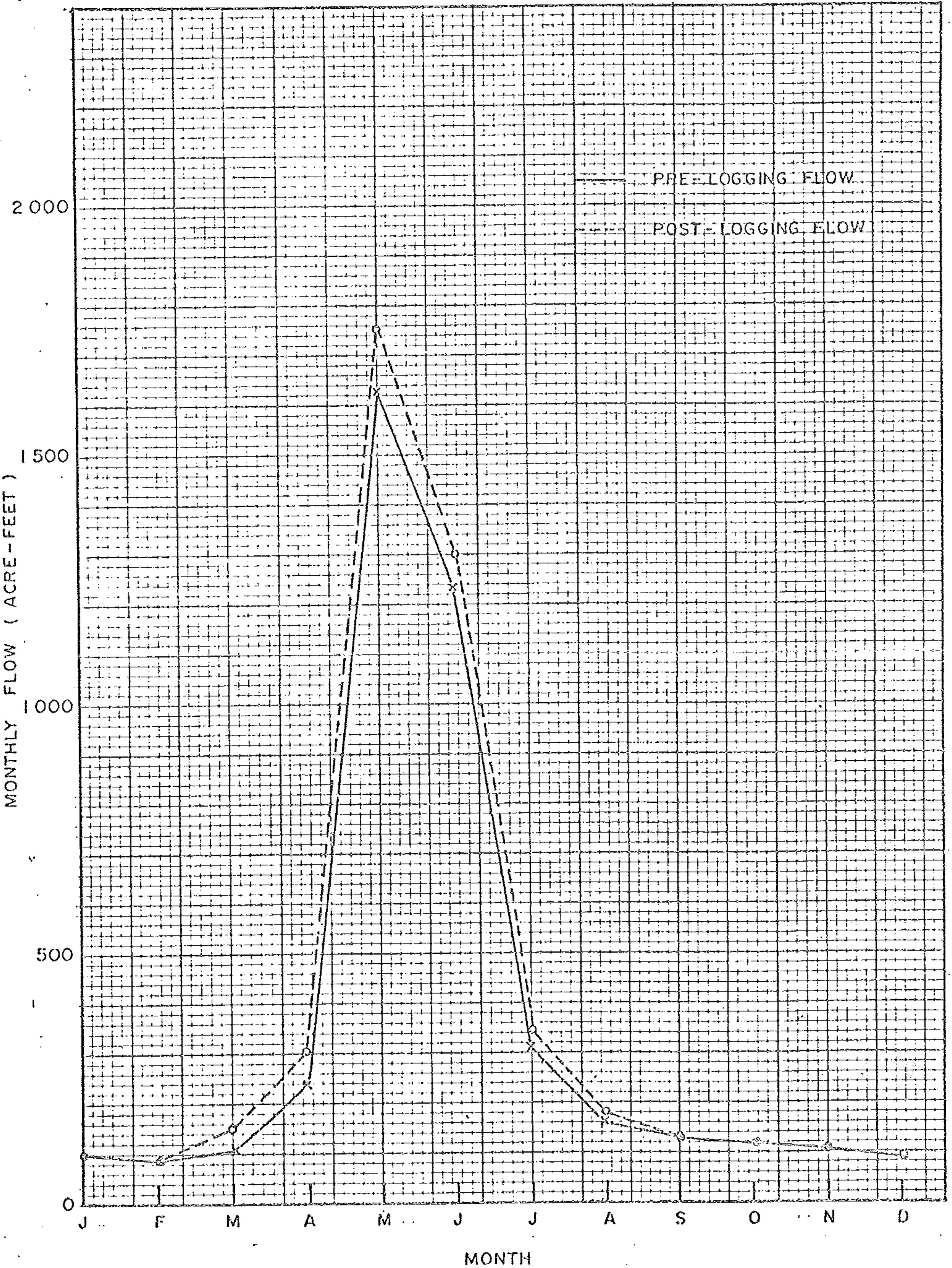


Figure 5. Estimated Monthly Flow Increases in Camp Creek After the 1977-1981 Logging

TABLE 1

WATERSHED CHARACTERISTICS OF CAMP CREEK

Drainage Area	13.1 sq. mi.
Elevation Median Range	4770 ft. 3260-6200 ft.
Forest Cover, (natural pre-logging)	99%
Lake Area	0.5%
Area above 5,000'	39%
Basin Slope	122 ft./mile

TABLE 3

ESTIMATED MEAN ANNUAL WATER YIELD INCREASES, 1977-1981

(1)	(2)	(3)		(4)	(5)		(6)	(7)
		Water Yield		Logged	Water Yield Increase			
Elev. Zone Feet	Total Area Acres	Feet	Acre-Feet	Areas Acres	%	Acre-Feet	(4)/(2) %	(5)/(3) %
3000-3500	168	0.1	17	46	60	3	27.4	17.6
3500-4000	1509	0.2	302	380	50	38	25.2	12.6
4000-4500	1677	0.3	503	634	45	86	37.8	17.1
4500-5000	1928	0.5	964	604	40	121	31.3	12.6
5000-5500	1593	0.7	1115	149	34	36	9.4	3.2
5500-6000	1258	0.9	1132	0		0	0	0
6000-6500	252	1.1	277	0		0	0	0
Total	8383		4310	1813		284	21.6	6.6

TABLE 4

MONTHLY FLOW INCREASES CAUSED BY
1977-79 SALVAGE LOGGING FOR CAMP CREEK WATERSHED

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
		Pre-logging flow												
Acre-Feet	(1)	95	91	108	237	1625	1237	306	159	129	121	108	95	4310
%	(2)	2.2	2.1	2.5	5.5	37.7	28.7	7.1	3.7	3.0	2.8	2.5	2.2	100
		Post-logging flow increase												
Acre-Feet	(3)	0	0	15	35.1	62.1	31.9	6.5	1.4	0	0	0	0	153.4
%	(4)	0	0	9.7	23.8	40.5	20.8	4.2	0.9	0	0	0	0	100
(3)/(1) %	(5)	0	0	13.9	14.8	3.8	2.5	2.1	0.8	0	0	0	0	3.56

TABLE 5

MONTHLY FLOW INCREASES CAUSED BY
1977-81 SALVAGE LOGGING FOR CAMP CREEK WATERSHED

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Pre logging flow														
Acre-Feet	(1)	95	91	108	237	1625	1237	306	159	129	121	108	95	4310
%	(2)	2.2	2.1	2.5	5.5	37.7	28.7	7.1	3.7	3.0	2.8	2.5	2.2	100
Post-logging flow increases														
Acre-Feet	(3)	0	0	24.1	59.1	117.8	65.3	14.9	3.9	0	0	0	0	285.1
%	(4)	0	0	8.5	20.7	41.3	22.9	5.2	1.4	0	0	0	0	100
(3)/(1) %	(5)	0	0	22.3	24.9	7.2	5.3	4.9	2.5	0	0	0	0	6.6

Appendix 1. Pre-logging Streamflow characteristics of Camp Creek

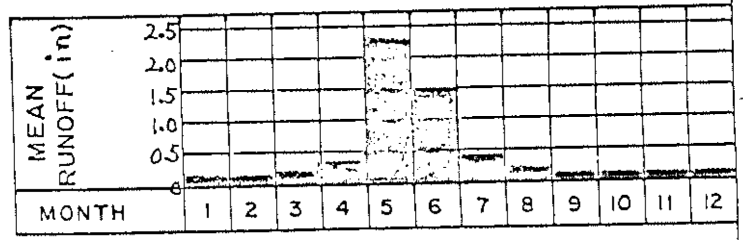
STREAMFLOW

STATION: CAMP CREEK NUMBER: 08NM134 DRAINAGE AREA: 13.1 Sq. Mi.

MEAN RUNOFF

PERIOD: 1965-1976

MONTH	1	2	3	4	5	6	7	8	9	10	11	12	ANNUAL
$ft.^3 s^{-1}$	1.5	1.4	1.7	3.7	25.4	19.3	4.8	2.5	2.0	1.9	1.7	1.5	5.7
$ft.^3 s^{-1} \cdot Mi^{-2}$	0.11	0.11	0.13	0.28	1.94	1.47	0.37	0.19	0.15	0.15	0.13	0.11	0.43
INCHES	0.13	0.11	0.15	0.32	2.24	1.64	0.42	0.22	0.17	0.17	0.14	0.13	5.84



RECORDED ANNUAL MAXIMUM AND MINIMUM FLOW

FLOW			RANK 1	2	3	4	5	6	7	8	9	10
MAX.	DAILY	$ft.^3 s^{-1}$	121	64.0	60.8	58.8	49.2	48.2	47.0	46.7	28.9	24.4
		$ft.^3 s^{-1} \cdot Mi^{-2}$	9.2	4.9	4.6	4.5	3.8	3.7	3.6	3.6	2.2	1.9
		DATE	30/5/72	12/6/74	13/5/71	2/6/75	3/6/76	10/5/76	12/5/69	20/5/75	7/5/66	25/5/70
	INST.	$ft.^3 s^{-1}$	140	73.1	72.3	63.2	57.2	52.7	51.8	48.5	32.5	27.4
		$ft.^3 s^{-1} \cdot Mi^{-2}$	10.7	5.6	5.5	4.8	4.4	4.0	4.0	3.7	2.5	2.1
		DATE	29/5/72	12/6/74	13/5/71	1/6/75	3/6/67	9/5/76	20/5/68	12/5/69	7/5/66	16/5/73
MIN.	DAILY	$ft.^3 s^{-1}$	0.40	0.68	0.74	0.80	0.84	1.0	1.0	1.0	1.3	1.4
		$ft.^3 s^{-1} \cdot Mi^{-2}$	0.03	0.05	0.06	0.06	0.06	0.08	0.08	0.08	0.10	0.11
		DATE	17/3/66	8/8/73	27/8/70	2/3/76	5/1/74	1/1/67	5/2/71	15/12/75	2/3/72	1/1/69

FLOOD FLOW FREQUENCY (ANNUAL MAX. DAILY FLOW)

FLOW	MEAN ANNUAL	RETURN PERIOD (YEARS) 5	10	25	50	100	200
$ft.^3 s^{-1}$	48.8	66.9	81.7	100	(114)	(126)	(142)
$ft.^3 s^{-1} \cdot Mi^{-2}$	3.73	5.11	6.24	7.63	(8.70)	(9.77)	(10.8)

LOW FLOW FREQUENCY (ANNUAL MIN. 7 DAY FLOWS)

FLOW	MEAN ANNUAL	RETURN PERIOD (YEARS) 5	10	25	50	100	200
$ft.^3 s^{-1}$				0.4			
$ft.^3 s^{-1} \cdot Mi^{-2}$				0.03			

Appendix 2 WATER YIELD CALCULATION SHEET

Drainage No.: Trout Creek Data File: 0328555 District: Okanagan

Drainage Name: Camp Creek Date: Sept. 10/1980 Prepared By: Jack Cheng

Elev. Zone (Feet)	Elev. Ave. (Feet)	Total Acres	Wt. Mean Elev.	%	Precip. (in.)	Runoff (in.)	Runoff (ft.)	Acre Ft.
1000-1500	1250							
1500-2000	1750							
2000-2500	2250							
2500-3000	2750							
3000-3500	3250	168		2	20	1.2	0.1	17
3500-4000	3750	1509		18	22	2.4	0.2	302
4000-4500	4250	1677		20	24	3.6	0.3	503
4500-5000	4750	1928		23	26	6.0	0.5	964
5000-5500	5250	1593		19	28	8.4	0.7	1115
5500-6000	5750	1258		15	31	10.8	0.9	1132
6000-6500	6250	252		3	33	3.2	1.1	277
6500-7000	6750							
7000-7500	7250							
7500-8000	7750							
TOTAL	A	B	C		D	E	F	G

Base Hydrograph (compared to: Camp Creek at mouth (8NM134) Yrs. Record: 11)

Month	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
%	2.2	2.1	2.5	5.5	37.7	28.7	7.1	3.7	.3	2.8	2.5	2.2
Acre Ft.	95	91	108	237	1625	1237	306	159	129	121	108	95

Total Acres 8384

Annual Runoff 4310

Wt. Mean Elev. 5077

Monthly Distribution of the Water Yield Increase Expressed as a Percentage of the Total Yield Increase Volume, by Elev. Zones and General Aspect.

Elev. Zone	South Mar.	South Apr.	South May	South June	South July	South Aug.	North Mar.	North Apr.	North May	North June	North July	North Aug.
2-3500	30	40	25	5	0	0	10	30	40	20	0	0
3500-4500	20	30	40	10	0	0	5	20	40	30	5	0
4500-6000	10	20	45	20	5	0	0	5	35	45	10	5
6000-7000	0	10	50	25	10	5	0	5	25	50	15	5
Elev. Zone	**West**						**East**					
2-3500	25	35	35	5	0	0	10	35	45	10	0	0
3500-4500	15	25	40	15	5	0	5	25	40	25	5	0
4500-6000	5	15	45	25	5	5	0	10	40	35	10	5
6000-7000	0	5	45	40	5	5	0	5	35	45	10	5
Elev. Zone	**Southwest**						**Northwest**					
2-3500	27.5	37.5	30	5	0	0	17.5	32.5	37.5	12.5	0	0
3500-4500	17.5	27.5	40	12.5	2.5	0	10	22.5	40	22.5	5	0
4500-6000	7.5	17.5	45	22.5	5	2.5	2.5	10	40	35	7.5	5
6000-7000	0	7.5	47.5	32.5	7.5	5	0	5	35	45	10	5
Elev. Zone	**Southeast**						**Northeast**					
2-3500	20	37.5	35	7.5	0	0	10	32.5	42.5	15	0	0
3500-4500	12.5	27.5	40	17.5	2.5	0	5	22.5	40	27.5	5	0
4500-6000	5	15	42.5	27.5	7.5	2.5	0	7.5	37.5	40	10	5
6000-7000	0	7.5	42.5	35	10	5	0	5	30	47.5	12.5	5

* From Isaacson (1977)

APPENDIX 4

CAMP CREEK MONTHLY FLOW INCREASES (ACRE-FEET) AS A RESULT OF 1977-79 LOGGING

	MONTH					
Elevation Zones (feet)	Mar.	April	May	June	July	Aug.
<3500	0.6	1.1	1.1	0.2		
3500-4500	11.6	25.6	37.2	16.3	2.3	
4500-5500	2.8	8.4	23.8	15.4	4.2	1.4
Total Acre Feet	15.0	35.1	62.1	31.9	6.5	1.4
%	13.9	14.8	3.8	2.5	2.1	0.8

APPENDIX 5

CAMP CREEK MONTHLY FLOW INCREASES (ACRE FEET) AS A RESULT OF 1977-81 LOGGING

Elevation Zones (feet)		MONTH Mar.	April	May	June	July	Aug.
<3500		0.6	1.1	1.1	0.2	0	0
3500-4500		15.6	34.4	50.0	21.9	3.1	0
4500-5500		7.9	23.6	66.7	43.2	11.8	3.9
Total	Acre-Feet	24.1	59.1	117.8	65.3	14.9	3.9
	%	22.3	24.9	7.2	5.3	4.9	2.5