CHAPTER 4

Water Quantity

Water quantity studies as defined under the Okanagan Basin Agreement were required: "to evaluate the existing hydrologic regime of the Basin, including studies of runoff, lake levels, flows, groundwater and geological structure, climatology and meteorology; to evaluate means of regulating flows through storage and diversion; and to evaluate means of augmenting water supplies within the Okanagan Basin."

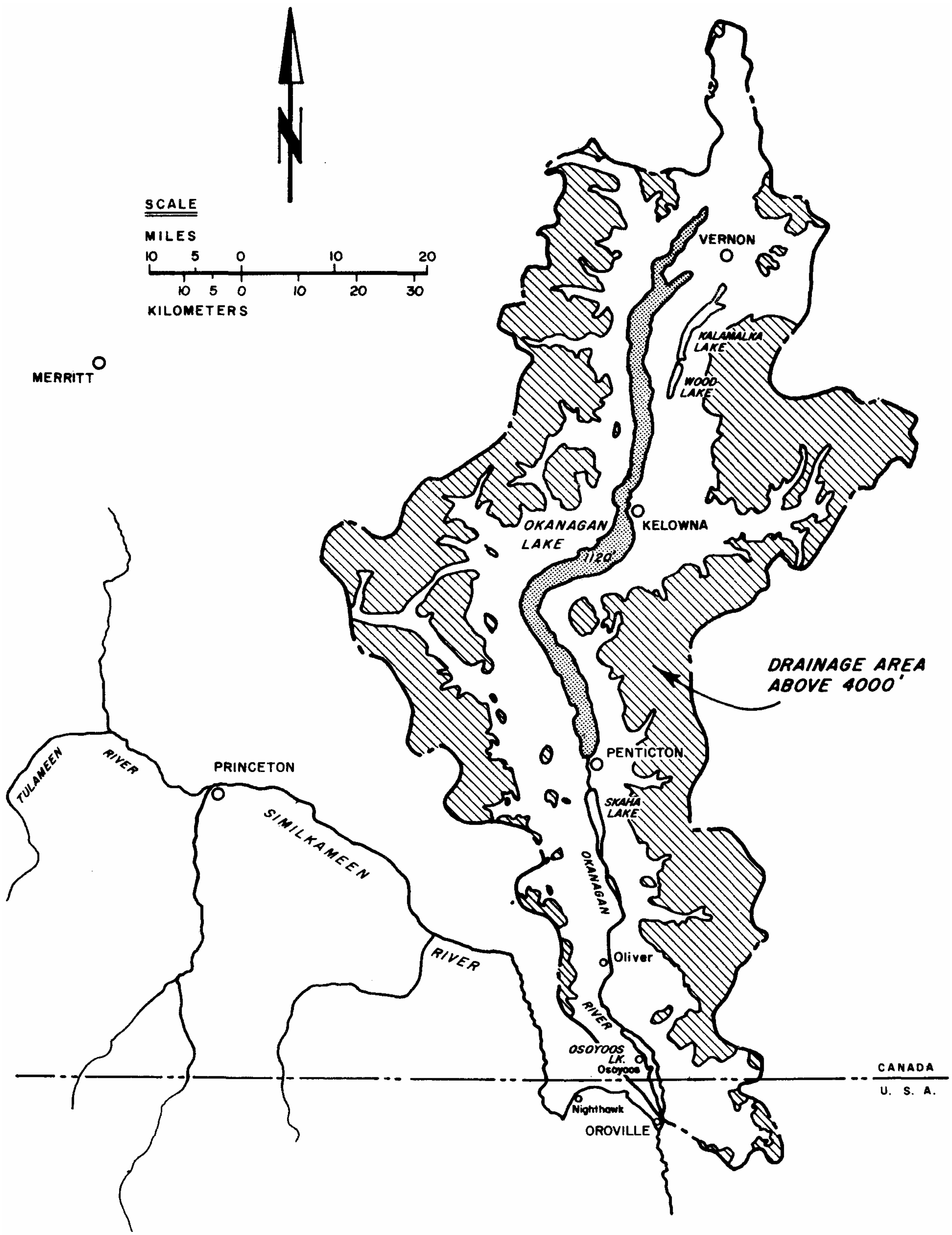
In order to appraise the hydrologic regime in the Canadian portion of Osoyoos Lake, it has been necessary to extend the Study downstream to the lake outlet at Oroville, Washington. Hence, the Okanagan Basin referred to in this portion of the report includes some 3,250 square miles of drainage area of which 3,165 are in British Columbia (Figure 4.1).

4.1 HYDROLOGY

4.1.1 Mainstem System

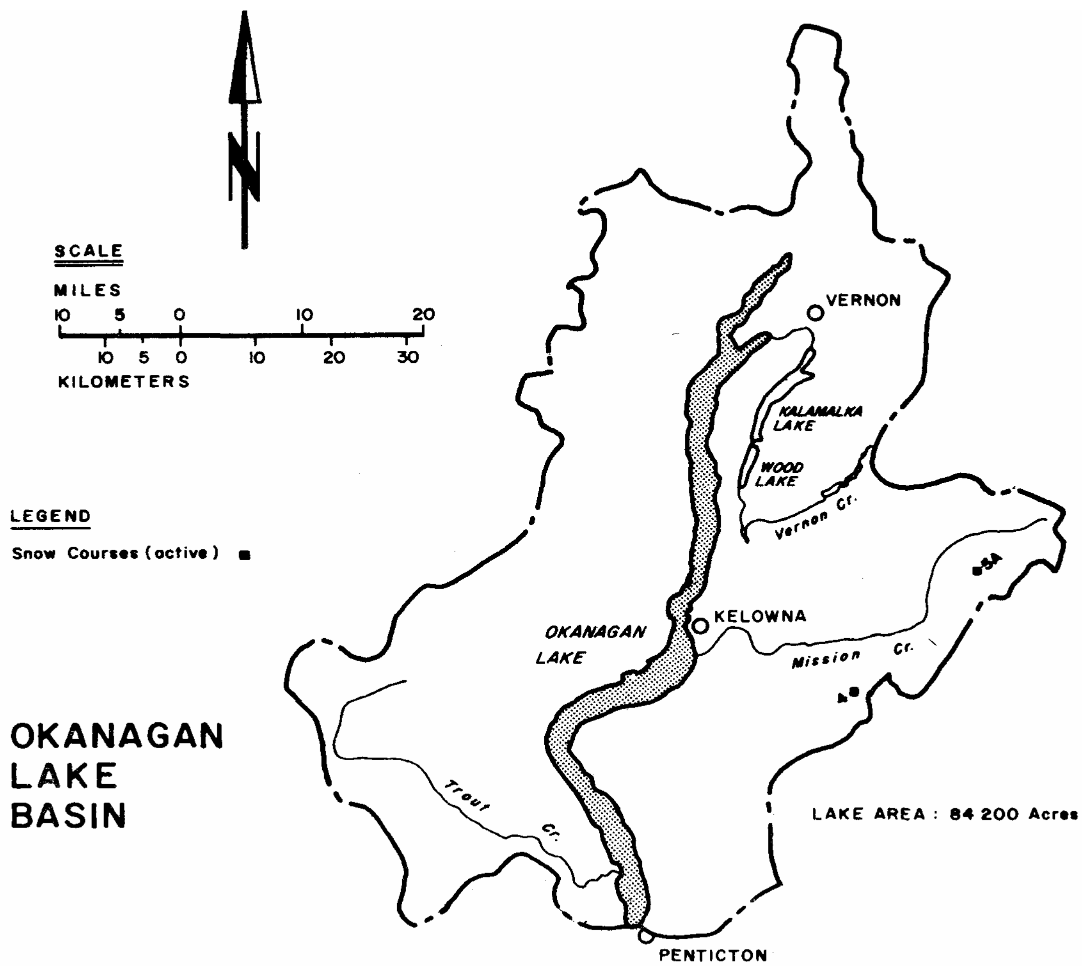
The Okanagan Basin hydrology is typical of the interior rivers of British Columbia, where the major portion of the annual runoff occurs during April to July inclusive, due primarily to snow melt in the higher portions of the Basin. Thus, in the Okanagan Lake Basin with an average elevation of 3,900 feet (Figures 4.1, and 4.2), snow accumulates during the winter months in the 4,000 to 7,000 foot band. Commencing in January, snow surveys are conducted at selected stations (Figure 4.3), from which forecasts of inflow to Okanagan Lake are estimated for the upcoming freshet period. Average snow water equivalents of two representative snow courses and accuracy of forecasts are illustrated in Figure 4.4.

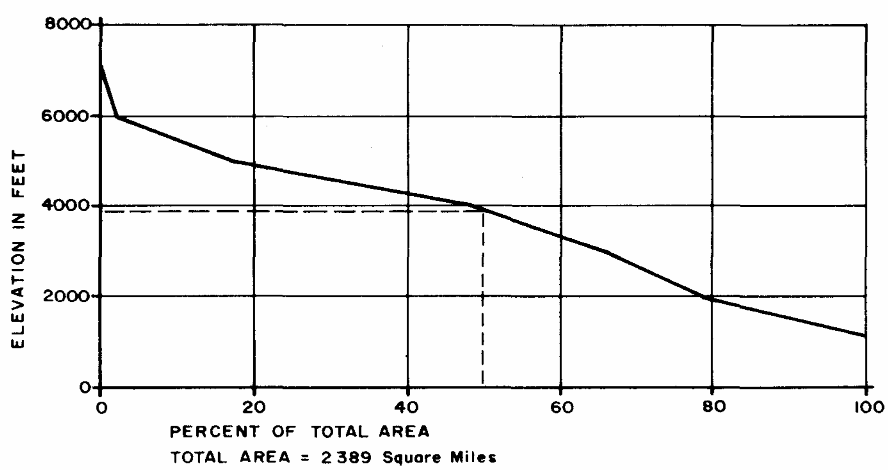
A portion of the gross inflow to Okanagan Lake Basin is retained in 50 headwater reservoirs which have a total active storage of 113,000 acre-feet (see Figure 4.5). The remaining inflow, in it's passage downstream to Okanagan Lake, is partially depleted by diversions from tributaries, primarily for irrigation purposes. The residual water entering Okanagan Lake, either as surface or groundwater flow, is further reduced through evaporation losses from the lake surface by 200,000 to 300,000 acre-feet per year. Thus, the net historic lake inflow, which is the actual water available in any particular year for use within Okanagan Lake or downstream, represents only a portion of the gross inflow to the Basin. Table 4.1 shows that of an average annual gross inflow to Okanagan Lake of 664,000 acre-feet, only about 332,000 are available in Okanagan Lake for use under present day development and operating practices.



OKANAGAN BASIN NORTH OF OROVILLE
SHOWING UPPER DRAINAGE AREA
ABOVE 4000 FEET ELEVATION

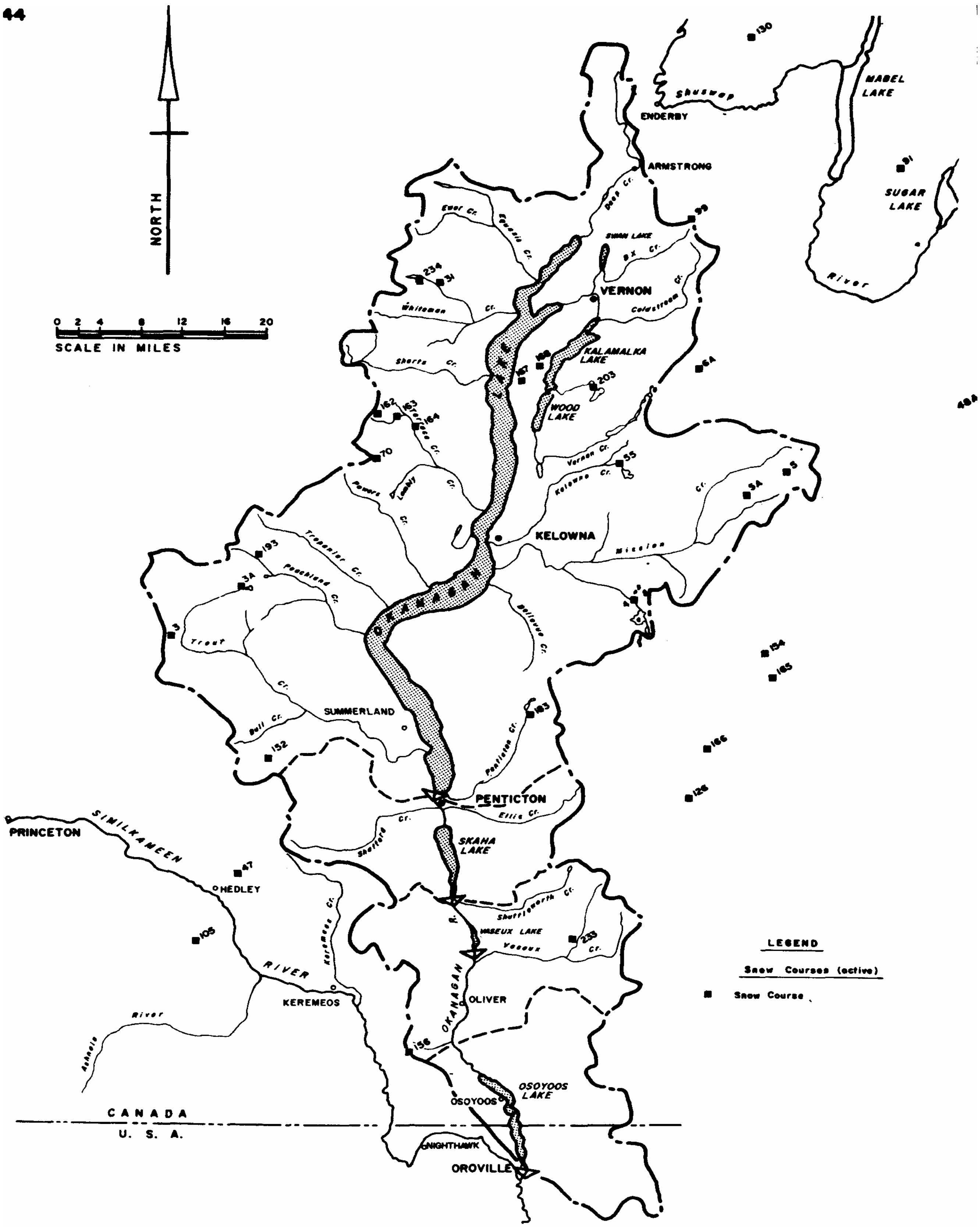
Figure 4.1





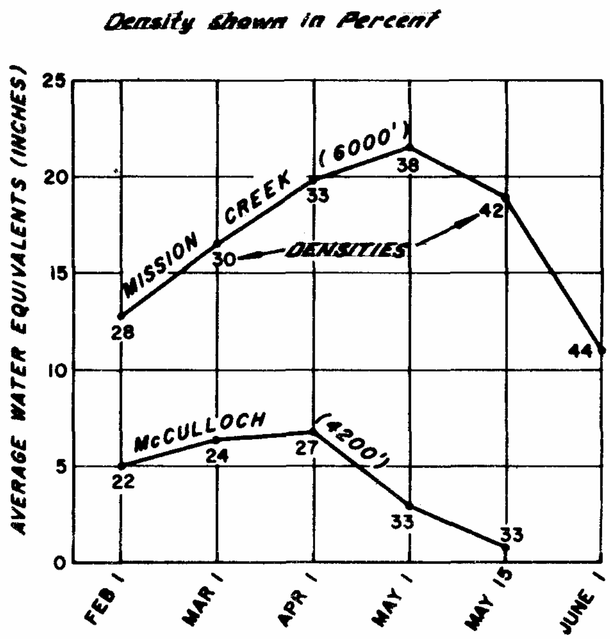
AREA-ELEVATION CURVE OKANAGAN LAKE BASIN

Figure 4.2



OKANAGAN BASIN
SNOW COURSES

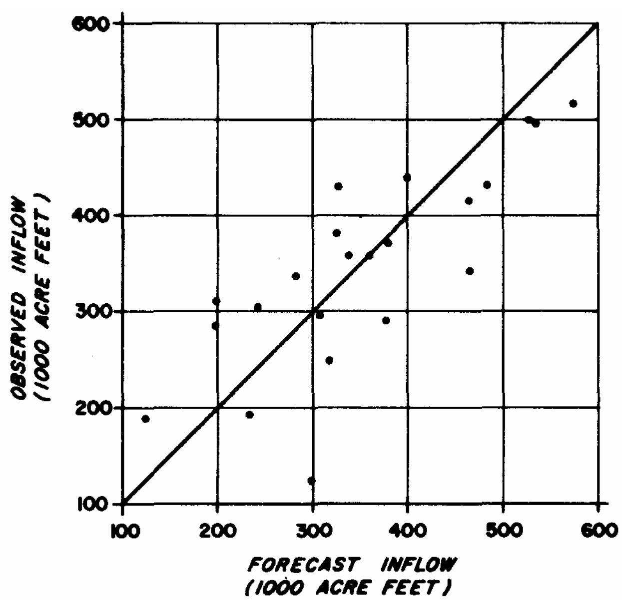
Figure 4.3



AVERAGE SNOW WATER EQUIVALENTS

MISSION CR. AND McCULLOCH SNOW COURSES

OKANAGAN LAKE BASIN



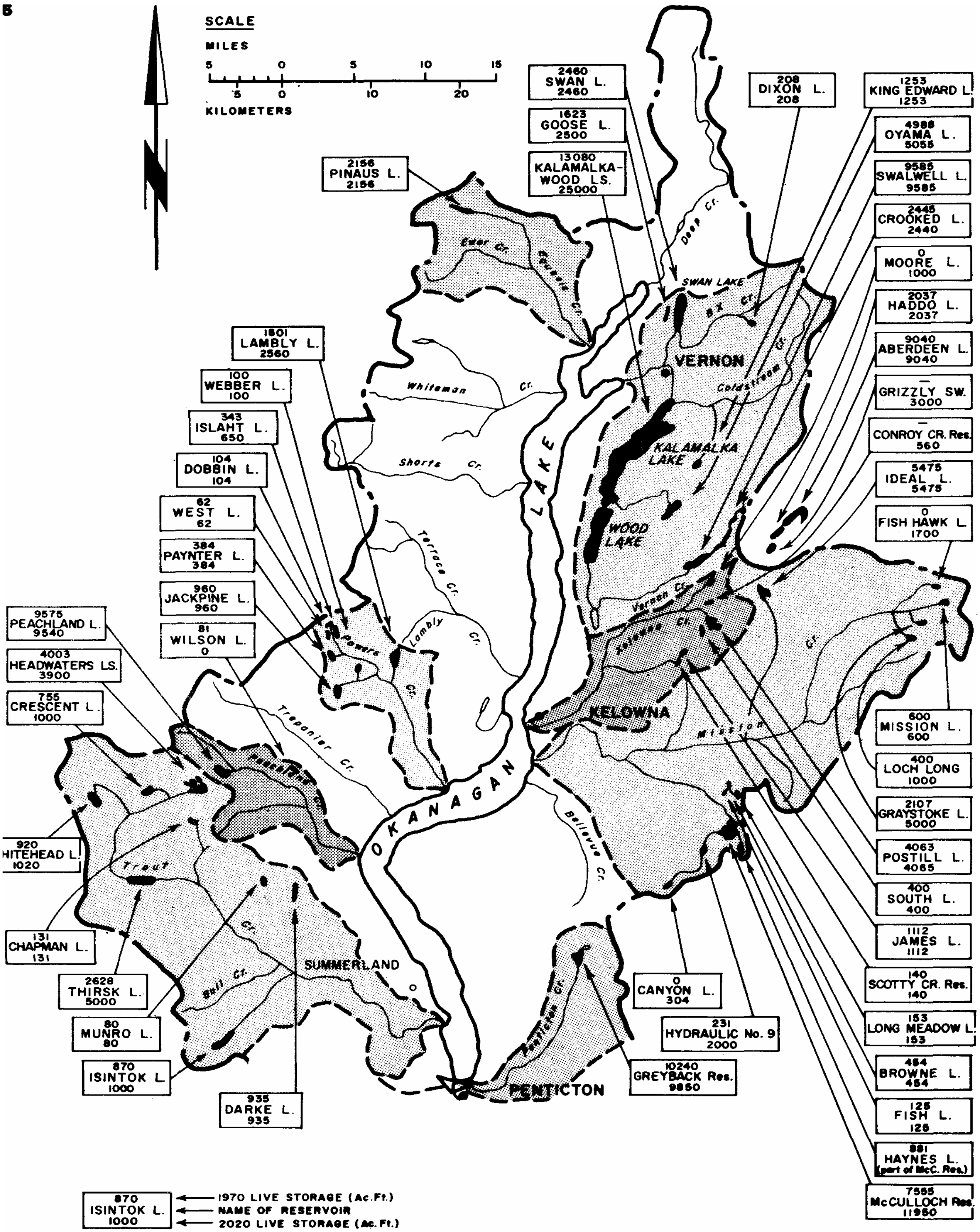
FORECAST ACCURACY

Without Hindsight Data

INFLOW TO OKANAGAN LAKE APRIL-JULY

YEARS 1950 - 1971

Figure 4.4



HEADWATER STORAGE RESERVOIRS
IN 8 SELECTED TRIBUTARIES Figure 4.5

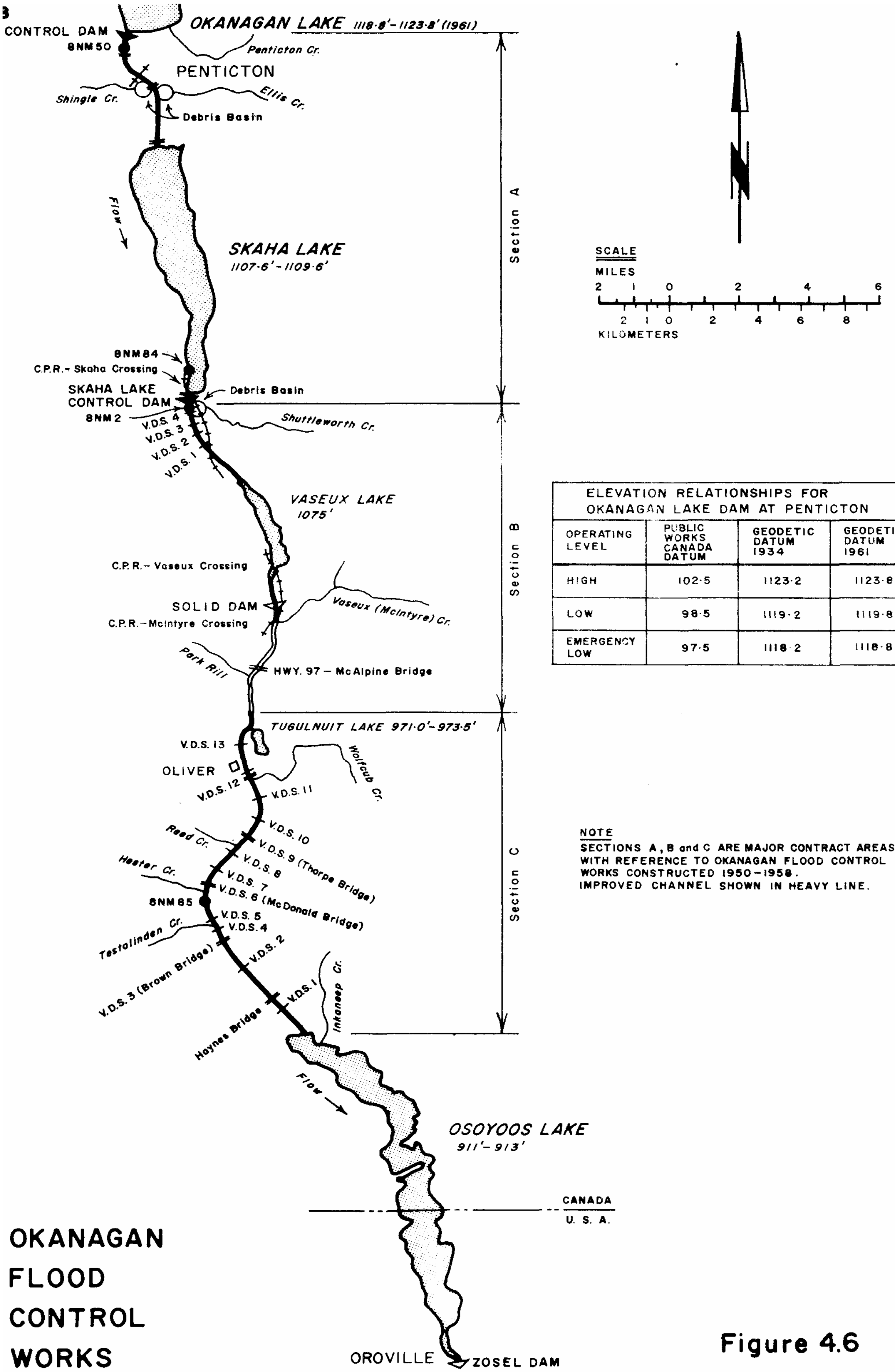
TABLE 4.1

AVERAGE ANNUAL WATER BUDGET-OKANAGAN LAKE BASIN

DESCRIPTION	INCHES ON OKANAGAN LAKE (131 SQUARE MILES)	INCHES OVER OKANAGAN LAKE BASIN (2,340 SQUARE MILES)	THOUSANDS OF ACRE FEET	REMARKS
Precipitation		21.80		Period 1931-1960
Evapotranspir-ation		16.48		Period 1921-1970
Gross Historic Basin Inflow		5.32	664.0	Period 1921-1970
Okanagan Lake Evaporation	38.0	2.14	266.7	Period 1921-1970
Net Historic Basin Inflow		3.18	397.3	Period 1921-1970
Consumptive Use under 1970 Development		0.52	65.0	Irrigation, Domes-tic, Municipal & Industrial
Net Modified Lake Inflow (1970 Develop-ment)		2.66	332.2	Period 1921-1970

The outflow from Okanagan Lake is controlled by a concrete dam at Penticton (Figure 4.6). The normal operating range for Okanagan Lake water levels is 1119.8 to 1123.8 feet (Geodetic Survey of Canada, 1961 Datum), which were established at the time of constructing these works, but lower levels maybe reached during prolonged drought periods, and higher levels reached during extreme floods. This four feet of storage on Okanagan Lake is equivalent to 340,000 acre-feet which is approximately the same as the average annual net runoff into Okanagan Lake under present day development. Since about 80% of the inflow to the Okanagan Lake Basin upstream of Oroville, Washington occurs above Penticton, the regulation of Okanagan Lake Dam is of prime importance to the Valley.

The Okanagan Lake Dam, along with other structures and improved river channel between Penticton and Osoyoos Lake, make up the Okanagan Flood Control Works. Ancillary works include the debris retaining basins at the mouths of Shattford (Shingle) Ellis and Shuttleworth Creeks. The operation of these works is under the direction of the B.C. Water Resources Service, Department of Lands. Forests and Water Resources, while maintenance costs are shared between this department and the Federal Department of Public Works. Discharges from Okanagan Lake Dam are limited by the channel capacity of the Okanagan River, which varies from 2,100 cfs. at Penticton to 3,400 cfs. at the inlet to Osoyoos Lake. Only minor regulation (9,400 acre-feet) can be obtained on Skaha Lake (surface area 4,710 acres) which is maintained between elevations 1107.6 and 1109.6 by a concrete dam at Okanagan Falls.



ELEVATION RELATIONSHIPS FOR OKANAGAN LAKE DAM AT PENTICTON			
OPERATING LEVEL	PUBLIC WORKS CANADA DATUM	GEODETIC DATUM 1934	GEODETIC DATUM 1961
HIGH	102·5	1123·2	1123·8
LOW	98·5	1119·2	1119·8
EMERGENCY LOW	97·5	1118·2	1118·8

NOTE
SECTIONS A, B and C ARE MAJOR CONTRACT AREAS WITH REFERENCE TO OKANAGAN FLOOD CONTROL WORKS CONSTRUCTED 1950–1958.
IMPROVED CHANNEL SHOWN IN HEAVY LINE.

OKANAGAN FLOOD CONTROL WORKS

Figure 4.6

In addition to the Okanagan Flood Control Works, a small concrete dam at the outlet of Vaseux Lake (surface area 690 acres), operated by the Southern Okanagan Land Improvement District (S.0.L.I.D.), maintains a water elevation on the lake of 975 feet and diverts a portion of the flow, up to 150 cfs through a canal to serve irrigation requirements in and around Oliver.

The maximum discharge at Oliver below the Vaseux Lake dam is currently held below 3,000 cubic feet per second (c.f.s.) because of channel capacity limitations, local inflow from tributaries which is not controllable, and high water levels on Osoyoos Lake when flows in the Simi1kameen River are high.

The level of Osoyoos Lake is normally maintained between 910.0 and 912.0 feet GSC (910.3 and 912.3 USCGS) although the upper level may be exceeded in any flood year due to lack of control of floodwater on the Similkameen River. The lower level is maintained by the Zosel dam which is located at the outlet of Osoyoos Lake in the State of Washington, U.S.A. The original purpose of this structure when built in 1927 by the Zosel Lumber Company, was for the creation of a mill pond for log storage. In 1948 the dam was modified in accordance with the International Joint Commission's order of September 12, 1946 to pass 2,500 c.f.s. at a pool elevation not exceeding 911.0 feet USCGS (910.7 GSC). Because of the age of this structure, there is considerable leakage during low flow periods which has to be compensated for by additional releases from Okanagan Lake to maintain Osoyoos Lake at it's normal summer water elevation of 910.7 GSC.

Map 1 (Map Section) shows the schematic profiles of the main valley Okanagan Lakes and Okanagan River, and Table 4.2 summarizes the operating criteria for the Okanagan Flood Control Works.

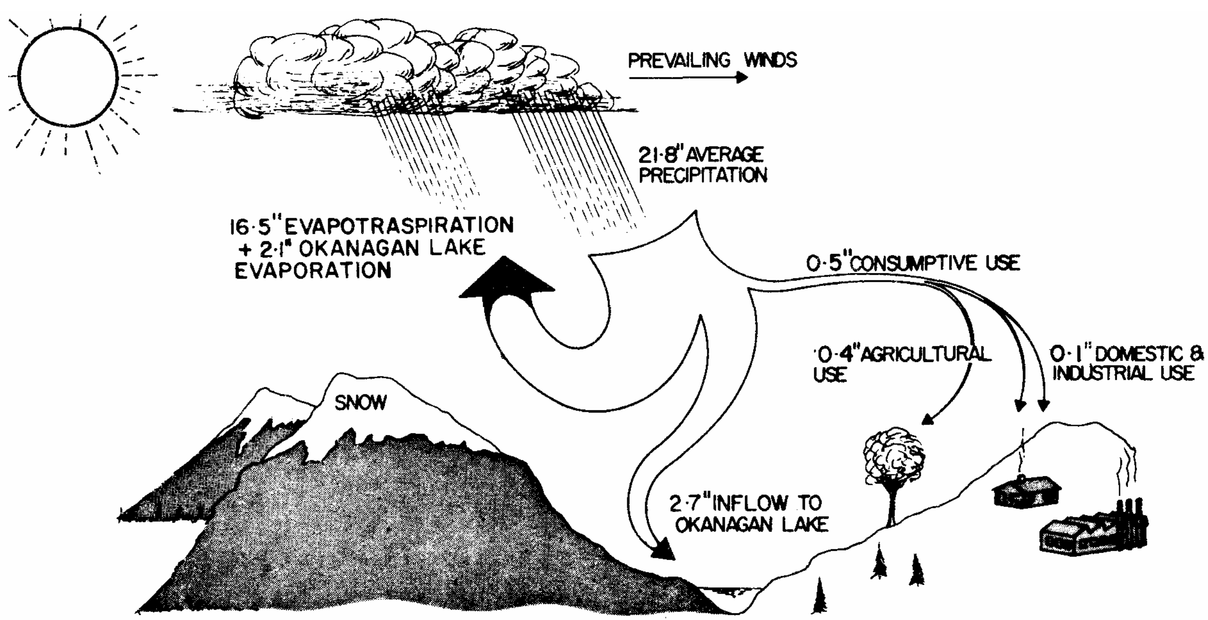
4.1.2 Okanagan Lake Basin Water Budget

The predominance of Okanagan Lake Basin as a main source of water supply for the area has led to a detailed examination of its hydrology. Through the use of a grid square model technique, it has been possible to develop an isohyetal map showing average precipitation distribution over the whole basin north of Oroville (Figure 1.4). Based on this study, the average precipitation on Okanagan Lake Basin has been estimated at 21.8 inches. A schematic presentation of what happens to this precipitation is presented in Figure 4.7.

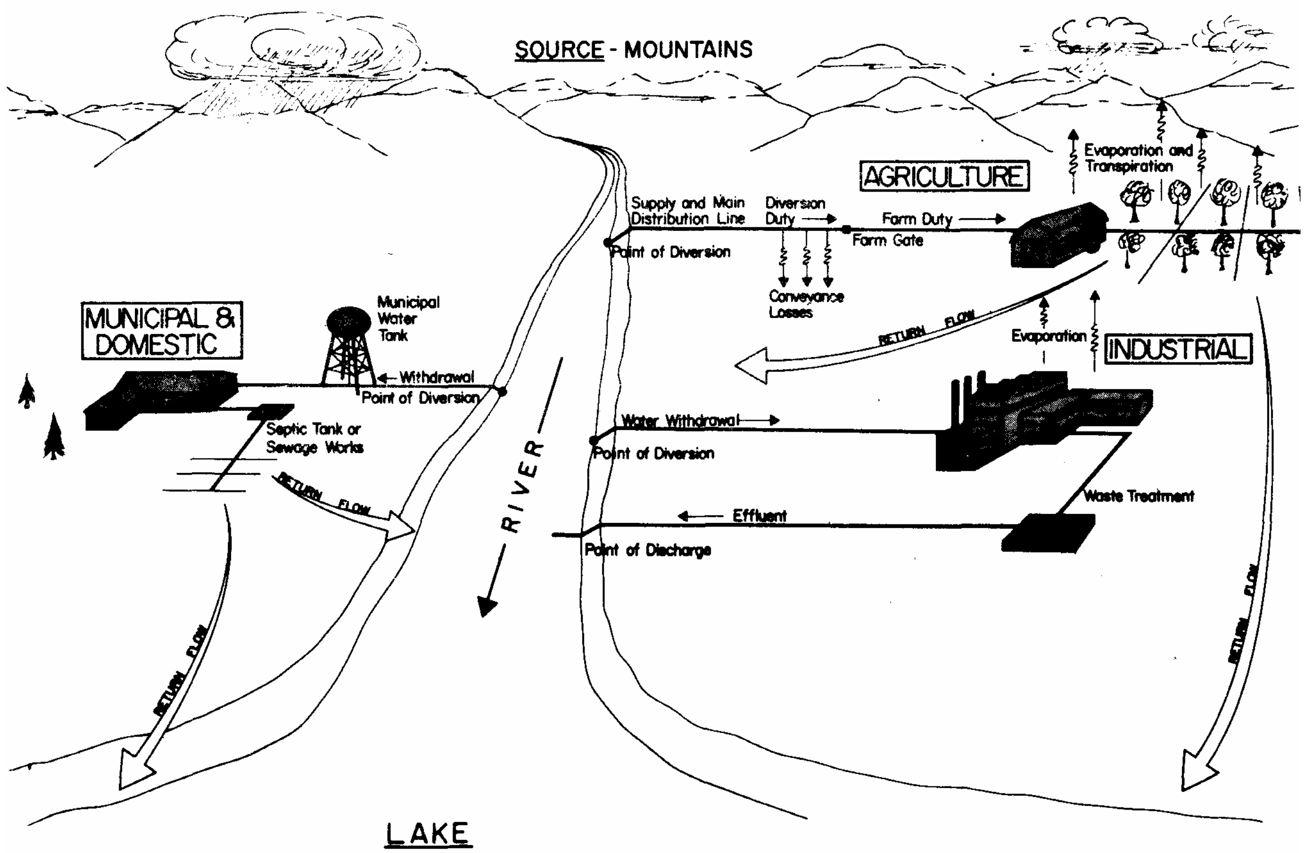
The water available in Okanagan Lake in an average inflow year is 332,000 acre-feet under present day (1970) development. This compares with the average net historic inflow of 355,000 acre-feet to Okanagan Lake. Thus, out of an average precipitation of 21.8 inches within the Okanagan Lake Basin, only 25% (5.32 inches) appears as runoff, and only about one half of this runoff is available for use in the mainstem Okanagan Lake and River system. Unfortunately, equivalent precipitation data over the whole basin for dry and wet years are not available, and therefore the more critical water budgets could not be developed.

TABLE 4.2 ELEVATIONS AND DESIGN DISCHARGES, OKANAGAN FLOOD CONTROL WORKS AND OTHER CONTROL STRUCTURES

Drainage Basin	Drainage Area in sq. mi.		Details of Okanagan Flood Control Works Note: Elevations based on Geodetic Survey of Canada 1961 datum						
	Local	Cumulative	Structure	Operating Level in ft.		Operating Range in ft.	Discharge Capacity in cfs	Lake Surface Area in ac.	Remarks
				High	Low				
Okanagan Lake Hydrometric Sta. No. 8NM-50 at Penticton	2388.7	2388.7	Okanagan Lake Dam at Penticton	1118.8	1123.8	5	2100 with 2 ft. gate opening and at lake elevation 1119.8	84200	5 sluice gates sill elevation: 1114.6 normal range: 1119.8 - 1123.8 emergency range: 1118.9-1123.8 extreme lake surface area at high water: 86080 ac.
Okanagan River between Hydrometric Sta. No. 8NM-50 at Penticton and Hydrometric Sta. No. 8NM-84 at Okanagan Falls	286.9	2675.6	Okanagan River between Ok.Lk. Dam and Shingle Cr. Shingle Cr. and Ellis Cr. Ellis Cr. and Skaha Lk.				2100 2400 2700		140 ft. base 2:1 side slope approx. 6 ft. fall
			Skaha Lake Dam at Okanagan Falls	1107.6	1109.6	2	2700 at lake elevation 1107.6 (6' above crest)	4710	4 radial gates and 6 stop log bays top gates elevation: 1110.1
Okanagan River between Hydrometric Sta. No. 8NM-84 at Okanagan Falls and Hydrometric Sta. NO. 8NM-85 near Oliver	117.8	2993.4	Okanagan River between Skaha Lake Dam and Vaseux Lake Dam SOLID Canal				2800 150		Includes 4 drop structures
			Vaseux Lake Dam (SOLID Diversion Dam)					690	Vaseux Lake normal elevation: 1074.6 flooding starts at lake elevation: 1076.0
			Okanagan River between Vaseux Lake Dam and Osoyoos Lake				3400		channel width varies from 74 ft. to 88 ft. includes 13 drop structures
Okanagan River between Hydrometric Sta. No. 8NM-85 near Oliver, B. C. and International Boundary	172.3	3165.7	Osoyoos Lake					3657	Osoyoos Lake Normal elevation: 912.1
Okanagan River between International Boundary and Hydrometric Sta. NO. 8NM-127 at Oroville, Wash.	89.0	3254.7						2003 Total: 5660	



WATER CYCLE IN THE OKANAGAN LAKE BASIN IN AN AVERAGE RUNOFF YEAR



WATER USE DIAGRAM

Figure 4.7

However, the budget for average conditions does point up the major difficulties in attempting to forecast the annual inflow to Okanagan Lake, particularly during extreme droughts when natural losses through evapotranspiration and lake evaporation make up even a larger portion of the total than those under average conditions.

4.1.3 Hydrometric, Meteorological and Water Use Data

The hydrometric and meteorological data available for the Okanagan Basin has been and still is very limited. Monthly historic inflows from the tributaries to Okanagan Lake for the 50 year study period of April 1921 to March 1971 inclusive have therefore been estimated and adjusted to allow for historic consumptive use, tributary storage changes and evaporation from Okanagan Lake. These calculated inflows provided the "gross" historic inflow to the Okanagan Lake Basin. Equivalent data were also developed for the portions of the Okanagan Basin between Penticton and Okanagan Falls and Okanagan Falls and Oliver. For the section south of Oliver through to Oroville, only the historic records for the period 1943 to 1970 were used.

Over the 50 year historic study period, agriculture has been the major user of water and the requirements for irrigation alone make up 80% of the total consumptive use within the Basin. Most of this development has taken place within the tributaries of Okanagan Lake where some 45,000 acres(out of a total of 60,000 acres for the whole basin) are served from these sources, supported by headwater storage reservoirs.

It has been assumed that 50% of the water diverted from tributary sources as well as that taken from the mainstem system appears as return flow either to Okanagan Lake or to the main river and lake system downstream. Similarly it was assumed that 65% of the water used for domestic and municipal purposes, and 90% of the water used for industrial purposes is returned to the system. These various types of use including diversion, consumptive use and return flow are demonstrated graphically in the water use diagram shown in Figure 4.7. The historic evaporation and precipitation on Okanagan, Skaha, Vaseux and Osoyoos Lakes have also been calculated in order to complete the water cycle budget. (For details, see Technical Supplements I and II).

4.2 PRESENT (1971) WATER REQUIREMENTS

Agricultural water requirements were based on the amount of land irrigated and water duties recommended by the B.C. Department of Agriculture, with all return flow credited to Okanagan Lake or the main river system. Municipal and domestic water requirements as well as industrial withdrawals were determined from municipal records.

In addition to the above consumptive use requirements, are the in-channel flows needed to maintain minimum residual discharges and flows to maintain fisheries. In the operation of the Okanagan Flood Control Works, these non-consumptive requirements have normally been met.

While fishery flow requirements in the tributaries have recently been developed, the management of water in these sub-basins has, to date, been primarily for consumptive use requirements only.

Hence, present water requirements based on historical practices, include all consumptive uses, both in the tributaries and the mainstem system with minimum and fishery flow requirements included only for the latter. Tables 4.3(a), 4.3(b) and 4.3(c) detail these requirements, while Table 4.4 summarizes this data.

From Table 4.4, it can be seen that the consumptive use along the Okanagan River from Penticton to Osoyoos Lake is only about one half that required in the Okanagan Lake Basin. However, residual or minimum flows needed to provide for take evaporation losses, adequate submergence of intakes during the irrigation season (April to September inclusive), and minimum salmon fishery flows downstream of Vaseux Lake, total about two thirds of the total water requirements for the whole basin.

4.3 WATER SUPPLY AND FLOOD CONTROL

The regulation of Okanagan Lake, the major storage reservoir in the Valley, is the key to water quantity management in the mainstem Okanagan. Its large storage capacity can be used in high runoff years to reduce the threat of flooding and in low runoff years to provide additional water supplies to and around the lake and south of its outlet at Penticton. Indeed, the lake supplies almost alt Okanagan River flows which serve consumptive and non-consumptive uses south of Penticton as well as areas adjacent to Okanagan Lake.

This study has been concerned not only with the adequacy of water supply sources to meet present and future needs, but also the management of these systems under extreme flood and drought conditions.

Present day water management practices are based on the "Okanagan Flood Control Report of 1946" prepared by the Joint Board of Engineers formed by the Federal and Provincial Governments. The level of Okanagan Lake is normally maintained within the four foot range - 1119.8 feet to 1123.8 feet GSC - as recommended by the Joint Board of Engineers. However, due to the large variability in annual inflows to Okanagan Lake and the difficulty of forecasting these inflows accurately, fluctuation above and below this four-foot range are possible. Because most shoreline development has adjusted to the normal range of lake levels,

TABLE 4.3 (a)

DIVERSION (WITHDRAWAL), CONSUMPTIVE USE & RETURN FLOW FOR OKANAGAN RIVER BASIN IN B.C. - 1970

Population 102,000 I.
OKANAGAN LAKE DRAINAGE (Region north of Okanagan Lake Dam at Penticton)
Ac. irrig. 46,000

MONTH	IRRIGATION					MUNICIPAL & DOMESTIC					INDUSTRIAL				TOTAL
	Diversion 113,160 ac-ft; Return Flow 56,580 ac-ft; Consumptive Use 56,580 ac-ft					Diversion 22,760 ac-ft; Return Flow 14,790 ac-ft; Consumptive Use 7,970 ac-ft					Diversion 26,500; Return Flow 22,320; Consumptive Use 4,180				CONS.
	DIVERSION		RETURN FLOW		CONS. USE	DIVERSION		RETURN FLOW		CONS. USE		DIVER-SION	RETURN FLOW	CONS. USE	USE
	%	ac-ft	%	ac-ft	ac-ft	%	ac-ft	%	ac-ft	ac-ft	%	ac-ft	ac-ft	ac-ft	ac-ft
Apr.	-	-	4	2260	-2260	6	1360	7	1030	330	7	1860	1570	290	-1640
May	15	16970	11	6230	10740	10	2280	9	1330	950	8	2120	1780	340	12030
June	25	28290	14	7920	20370	13	2960	10	1480	1480	9	2390	2010	380	22230
July	25	28290	15	8490	19800	16	3640	13	1920	1720	10	2650	2230	420	21940
Aug.	25	28290	14	7920	20370	16	3640	12	1770	1870	11	2920	2460	460	22700
Sep.	10	11320	12	6790	4530	8	1920	10	1480	340	12	3180	2680	500	5370
Oct.	-	-	9	5090	-5090	7	1590	8	1180	410	8	2120	1780	340	-4340
Nov.	-	-	5	2830	-2830	5	1140	7	1040	100	7	1860	1570	290	-2440
Dec.	-	-	5	2830	-2830	5	1140	6	890	250	7	1850	1560	290	-2290
Jan.	-	-	4	2260	-2260	5	1140	6	890	250	7	1850	1560	290	-1720
Feb.	-	-	4	2260	-2260	4	910	6	890	20	7	1850	1560	290	-1950
Mar.	-	-	3	1700	-1700	5	1140	6	890	250	7	1850	1560	290	-1160
TOTAL		113160		56580	56500		22760		14790	7970		26500	22320	4180	68730

NOTE 1. Irrigation volumes include a 10% allowance for conveyance losses.
NOTE 2. Consumptive Use is calculated from the amount diverted less the return flow, month by month
NOTE 3. No allowance has been made for minimum residual flows or fishery requirements in tributaries of Okanagan Lake

TABLE 4.3 (b)

DIVERSION (WITHDRAWAL), CONSUMPTIVE USE & RETURN FLOW FOR OKANAGAN RIVER BASIN IN B.C. - 1970

II. OKANAGAN RIVER REGION (From Okanagan Lake Dam at Penticton to International Boundary at Osoyoos Lake)
Population - 10,980; Land Irrigated - 14,000 acres.

MONTH	IRRIGATION					MUNICIPAL & DOMESTIC					INDUSTRIAL				TOTAL
	Diversion 62,860 ac-ft; Return Flow 31,430 ac-ft; Consumptive Use 31,430 ac-ft					Diversion 2,110 ac-ft; Return Flow 1,370 ac-ft; Consumptive Use 740 ac-ft					Diversion 1,500; Return Flow 1,270; Consumptive Use 230				CONS.
	DIVERSION		RETURN FLOW		CONS. USE	DIVERSION		RETURN FLOW		CONS. USE		DIVER-SION	RETURN FLOW	CONS. USE	USE
	%	ac-ft	%	ac-ft	ac-ft	%	ac-ft	%	ac-ft	ac-ft	%	ac-ft	ac-ft	ac-ft	ac-ft
Apr.	-	-	4	1260	-1260	7	150	7	100	50	7	110	100	10	-1200
May	15	9430	11	3460	5970	11	230	9	120	110	8	120	100	20	6100
June	25	15710	14	4400	11310	13	270	10	140	130	9	130	110	20	11460
July	25	15720	15	4710	11010	15	320	13	180	140	10	150	130	20	11170
Aug.	25	15710	14	4400	11310	13	270	12	160	110	11	160	130	30	11450
Sep.	10	6290	12	3770	2520	9	190	10	140	50	12	180	150	30	2600
Oct.	-	-	9	2830	-2830	6	130	8	110	20	8	120	100	20	-2790
Nov.	-	-	5	1570	-1570	5	110	7	100	10	7	110	90	20	-1540
Dec.	-	-	5	1570	-1570	5	110	6	80	30	7	110	90	20	-1520
Jan.	-	-	4	1260	-1260	5	100	6	80	20	7	110	90	10	-1220
Feb.	-	-	4	1260	-1260	5	100	6	80	20	7	100	90	10	-1230
Mar.	-	-	3	940	- 940	6	130	6	80	50	7	100	90	10	- 880
TOTAL		62860		31430	31430		2110		1370	740		1500	1270	230	32400

NOTE 1. Irrigation volumes include a 10% allowance for conveyance losses.
NOTE 2. Consumptive Use is calculated from the amount diverted less the retrn flow, month by month.

TABLE 4.3(c)

SUMMARY OF FISHERY AND MINIMUM FLOW REQUIREMENTS

FOR THE OKANAGAN RIVER IN BRITISH COLUMBIA

MONTH	FISHERY REQUIREMENTS				MINIMUM FLOW Okanagan River below Penticton Dam	
	Minimum Flow at Osoyoos Lake outlet	In Okanagan River Channel below S.O.L.I.D. Dam				
		Desirable Range	Maximum (Gravel Scour)	Minimum Fishery Flow	Present Con-ditions	With Improve-ments
	c.f.s.	c.f.s.	c.f.s.	c.f.s.	c.f.s.	c.f.s.
APRIL		175 - 1000		175	300	100
MAY					300	100
JUNE					300	100
JULY 1-15 16-31	100				300 300	100 100
AUGUST	100	300 - 450		300	300	100
SEP. 1-15 16-30	100	300 - 450 350 - 550		300 350	300 300	100 100
OCTOBER		350 - 550		350	100	100
NOVEMBER		175 - 1000	1000	175	100	100
DECEMBER		175 - 1000	1000	175	100	100
JANUARY		175 - 1000	1000	175	100	100
FEB. 1-15 16-28		175 - 1000 175 - 1000	1000	175 175	100 100	100 100
MARCH		175 - 1000		175	100	100

TABLE 4.4

PRESENT (1970) CONSUMPTIVE USE REQUIREMENTS

IN OKANAGAN LAKE BASIN AND TOTAL WATER

REQUIREMENTS OKANAGAN RIVER BASIN IN CANADA

	Acre Feet	Acre Feet	Percent of Total
1 OKANAGAN LAKE BASIN			
(a) CONSUMPTIVE USE from tributaries and directly from area adjacent to Okanagan Lake			
Irrigation	56,580		
Municipal & Domestic	7,970		
Industrial	4,180		
Total Okanagan Lake Basin Consumptive Use		68,730	22.0
2 MAINSTEM OKANAGAN RIVER			
(a) CONSUMPTIVE USE			
Irrigation	31,430		
Municipal & Domestic	740		
Industrial	230		
Total Okanagan River Consumptive use		32,400	10.4
(b) EVAPORATION LOSSES FROM SKAHA Vaseux and Osoyoos Lakes	49,120		
(c) MINIMUM FLOW REQUIREMENTS			
Intake submergence, flushing, aesthetics addtional water to	122,660		
meet salmon fishery flows	39,320	211,100	67.6
Okanagan Lake Basin consumptive use and main Okanagan River water requirements		312,230	100.0

such extreme fluctuations can cause inconvenience and even damage to shoreline users. In a succession of drought years, there may not be sufficient water to maintain Okanagan Lake within its normal range and at the same time supply all downstream requirements in Okanagan River. Thus, either Okanagan Lake must be drawn down below its normal low water elevation, or water releases to Okanagan River must be reduced.

At the other extreme, Okanagan Lake must be carefully regulated during high inflows. When large runoffs are forecast, the lake is normally drawn down in the early spring to accommodate the freshet. The degree of drawdown possible and the volume of water that can be released during the freshet is dependent on the channel capacity of Okanagan River and the complicated hydrology of Osoyoos Lake. High flows in the Similkameen River can restrict releases from Osoyoos Lake and this, coupled with the need to maintain high discharges down Okanagan River, can create flooding on Osoyoos Lake. In practice, a balance must be sought to minimize the flood damage around both lakes.

A drought year is defined as one in which the net inflow to Okanagan Lake is less than the water requirements (244,000 acre-feet), while a flood year is defined as one with an inflow of 550,000 acre-feet or greater. These volumes can be compared with the normal four foot storage in Okanagan Lake equivalent to 340,000 acre-feet. Thus, the regulation of Okanagan Lake varies from strict conservation to the other extreme of flood control.

The present methods of operating both the mainstem system and the tributaries, were simulated in computer models. The output from the models in the form of water levels and discharges, was used as the basis for comparison of alternative water management options.

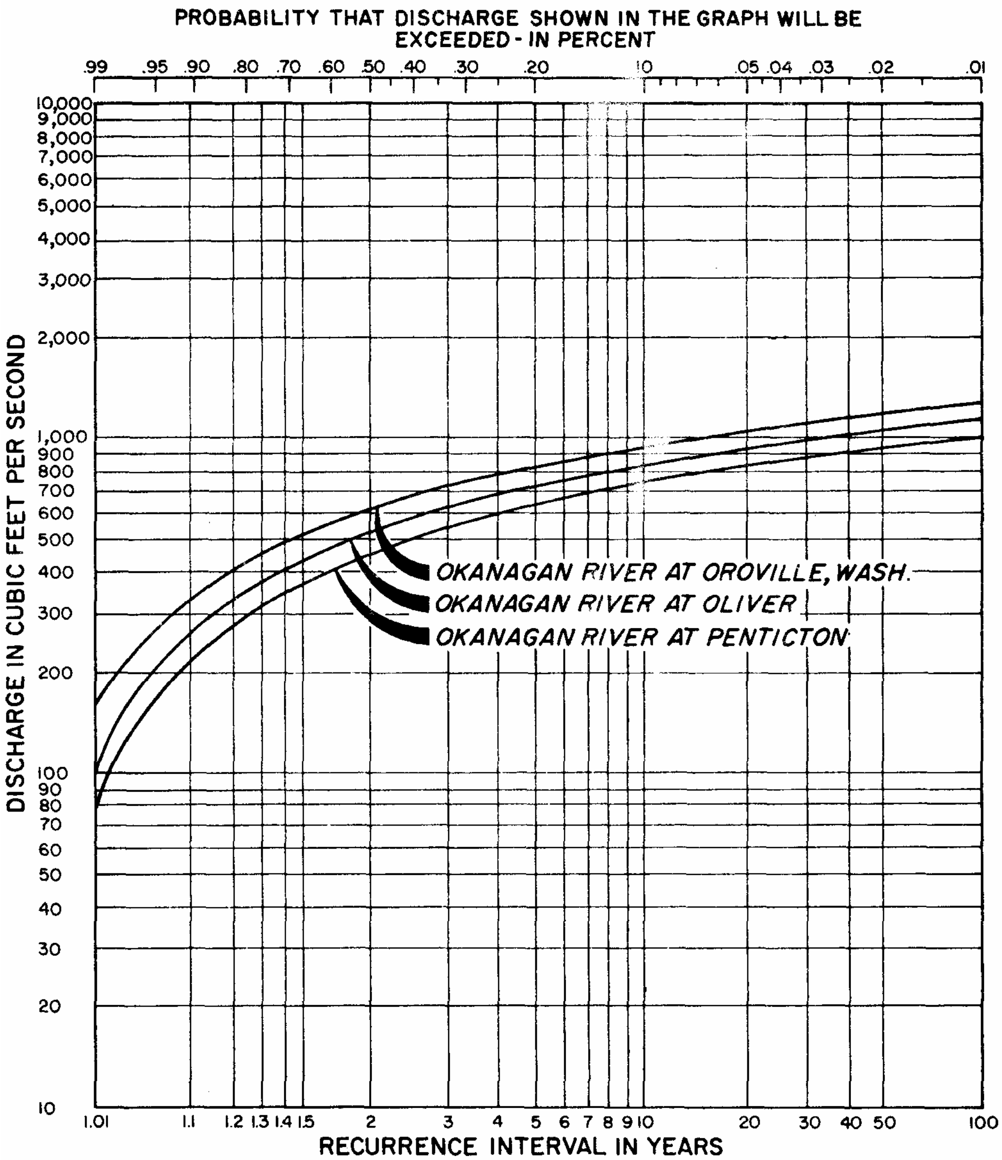
The annual discharges for Okanagan River at Penticton, Oliver and Oroville as similated by the mainstem computer model, are shown in Figure 4.8. These model discharges assume the Okanagan Flood Control Works in operation for the 50 year period of record (1921-1970), and are based on 1970 consumptive demands in the Okanagan Lake Basin.

The model terminates at the hydrometric station four miles south of Oliver and the equivalent discharges at Oroville, Washington have been prepared from the more limited historical data available for the period 1943 to 1970.

The discharges at Penticton are between 81 and 85 percent of the Oliver discharges. The gross local inflow for the Penticton-Oliver and the 0liver-Oroville reaches of the river compared with the gross inflow to Okanagan Lake Basin, for dry, average and wet years (selected from the limited common period of 1943 to 1970) are listed in Table 4.5 and illustrated for an average inflow year in Figure 4.9. This provides further evidence of the dominant role Okanagan Lake Basin

TABLE OF ANNUAL AVAILABLE FLOWS AT VARIOUS PROBABILITY LEVELS

FLOW UNIT	MEAN FLOW	FLOW EQUALLED OR EXCEEDED IN PERCENT OF TIME				LOCATION
		50	80 Median Flow	90	95	
C.F.S. K.A.F.	646 467.7	625 452.5	433 313.5	345 249.8	276 199.8	Okanagan River at Oroville, Wash.
C.F.S. K.A.F.	548.5 397.1	529.6 383.4	353.9 256.2	272.3 197.1	209.9 152.0	Okanagan River at Oliver
C.F.S. K.A.F.	466.0 337.4	449.0 325.4	296.0 214.3	224.8 162.4	170.3 123.3	Okanagan River at Penticton



FREQUENCY CURVE,COMPUTER MODEL SIMULATION OF ANNUAL DISCHARGE,OKANAGAN RIVER AT PENTICTON AND OLIVER AND ANNUAL HISTORIC DISCHARGE,OKANAGAN RIVER AT OROVILLE,WASH.

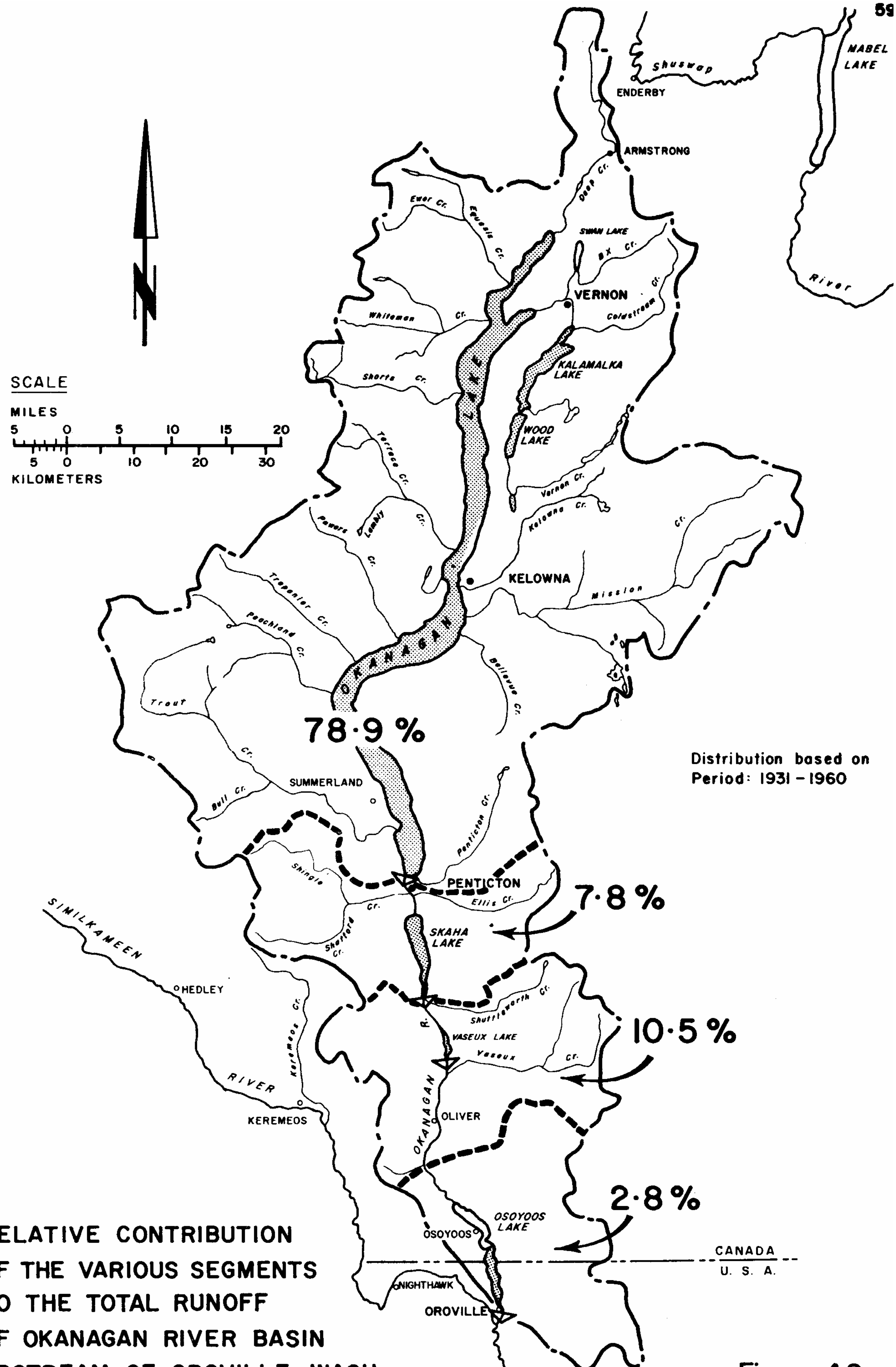
Figure 4.8

TABLE 4.5

COMPARISON OF ANNUAL GROSS HISTORIC INFLOWS TO VARIOUS SEGMENTS OF OKANAGAN RIVER BASIN _ UPSTREAM OF OROVILLE, WASHINGTON, WITH ANNUAL GROSS HISTORIC INFLOW TO OKANAGAN LAKE BASIN FOR SELECTED YEARS

DRAINAGE BASIN	DRAINAGE AREA		DRY YEAR (1970)			AVERAGE YEAR (1958)			WET YEAR (1959)		
	SQUARE MILE	PERCENT	KILO-SQUARE-FEET	PERCENT	INCHES	KILO-SQUARE-FEET	PERCENT	INCHES	KILO-SQUARE-FEET	PERCENT	INCHES
Okanagan Lake	2388.7	100.0	382.1	100.0	3.06	690.8	100.0	5.54	932.4	100.0	7.47
Okanagan River Between Penticton and near Oliver	604.7	25.3	74.1	19.4	2.30	114.3	16.5	3.54	146.5	15.7	4.54
Okanagan River Between near Oliver and Oroville, Wash.	261.3	10.9	54.3	14.2	3.90	99.5	14.4	7.14	114.0	12.2	8.18
Okanagan River Between Penticton and Oroville, Wash.	866.0	36.2	128.4	33.6	2.78	213.8	30.9	4.63	260.5	27.9	5.64

NOTE: The above table is based on the period 1943-1970



RELATIVE CONTRIBUTION
OF THE VARIOUS SEGMENTS
TO THE TOTAL RUNOFF
OF OKANAGAN RIVER BASIN
UPSTREAM OF OROVILLE, WASH.

Figure 4.9

inflow plays in meeting the water requirements of the tributaries and along the mainstem. While Osoyoos Lake was not included in the mainstem model, the minimum releases at its termination point at the Oliver hydrometric station have included what are considered to be adequate allowances for consumptive and natural losses as well as in-channel flows between Oliver and Osoyoos Lake.

4.3.1 Okanagan Mainstem Operation

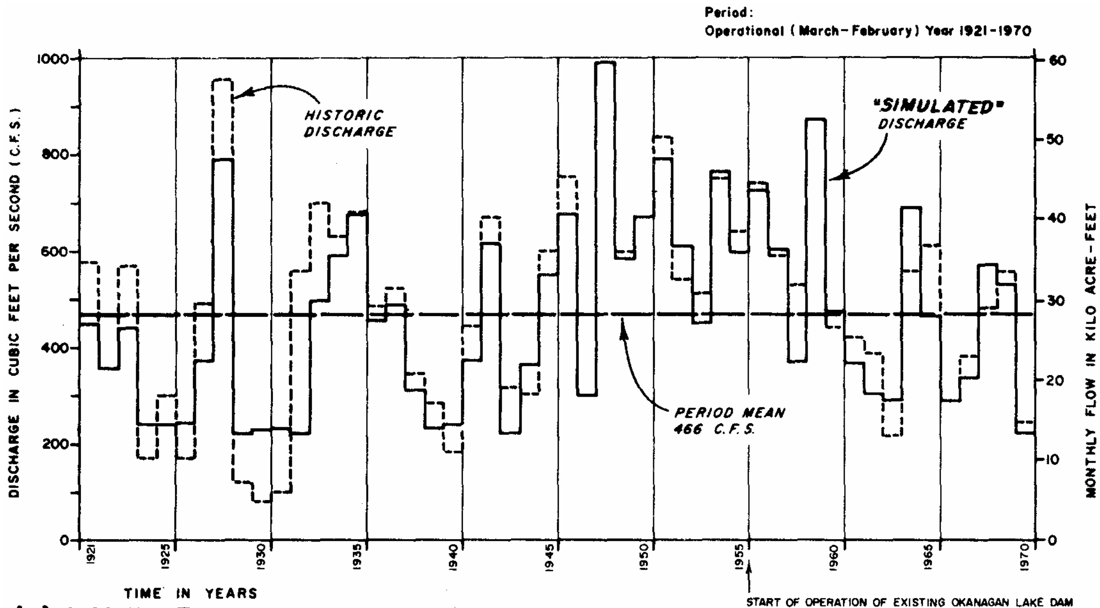
The mainstem computer model which simulated the operation of Okanagan Lake and Okanagan River from Penticton to Oliver required definition of the present water management objectives and policies. Using these and computed inflows, the model was used to simulate operation on a monthly basis over the 50 year period 1921 to 1970. In running the model it was assumed that the Okanagan Flood Control Works (Figure 4.6), which were actually constructed during the period 1950 to 1958, were in operation throughout the period. In each run it was assumed that either the present day water requirements or some projected future set of water demands were met for the 50 year period. The model generated inflow forecasts so that the simulation would have the degree of uncertainty that exists in practice due to the errors inherent in making forecasts.

Since the completion of the Okanagan Lake Dam in 1956, water releases have been based on meeting consumptive use and in-channel minimum flow requirements. In most years, any additional discharges to provide minimum fishery flows required for the successful migration of sockeye salmon through Osoyoos Lake and as far upstream as Vaseux Lake Dam, have also been released.

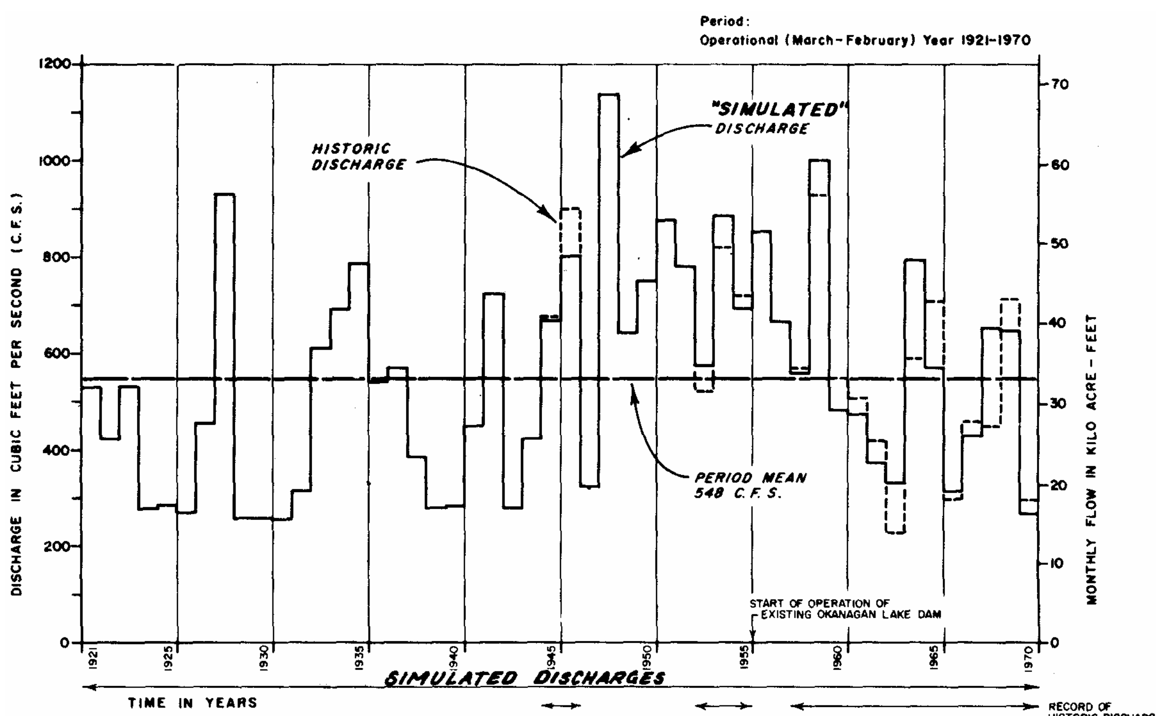
Details of this model can be found in Technical Supplement II "Water Quantity Computer Models".

The degree of success in the operation of the model can be judged by an examination of Figure 4.10 for the period 1956 to 1970 in which the model discharges at Penticton and Oliver compare very closely with the actual discharges which occurred. Similarly, while the model terminated at Oliver, the historic flows at Oroville from 1956 to 1970 (Figure 4.11) reflect the operation of the existing Okanagan Lake Dam. For an exact comparison at Oroville however, all historic discharges since 1956 would have to be reduced by the increase in water consumption between that particular year and 1970.

Figure 4.12 shows the modified inflows, elevations and discharges for Okanagan Lake, resulting from the model operation over the 50 year study period under present operating conditions. A recurrence of the extreme drought conditions of 1929-31 would result in Okanagan Lake being drawn down at least 3.2 feet below its normal low water operating level, assuming all water requirements are met. The lake would drop below its normal low water elevation in the middle of the second year of the drought and not refill to a level of 3.0 feet above the normal low level until three years later. Such a prolonged drought has occurred only

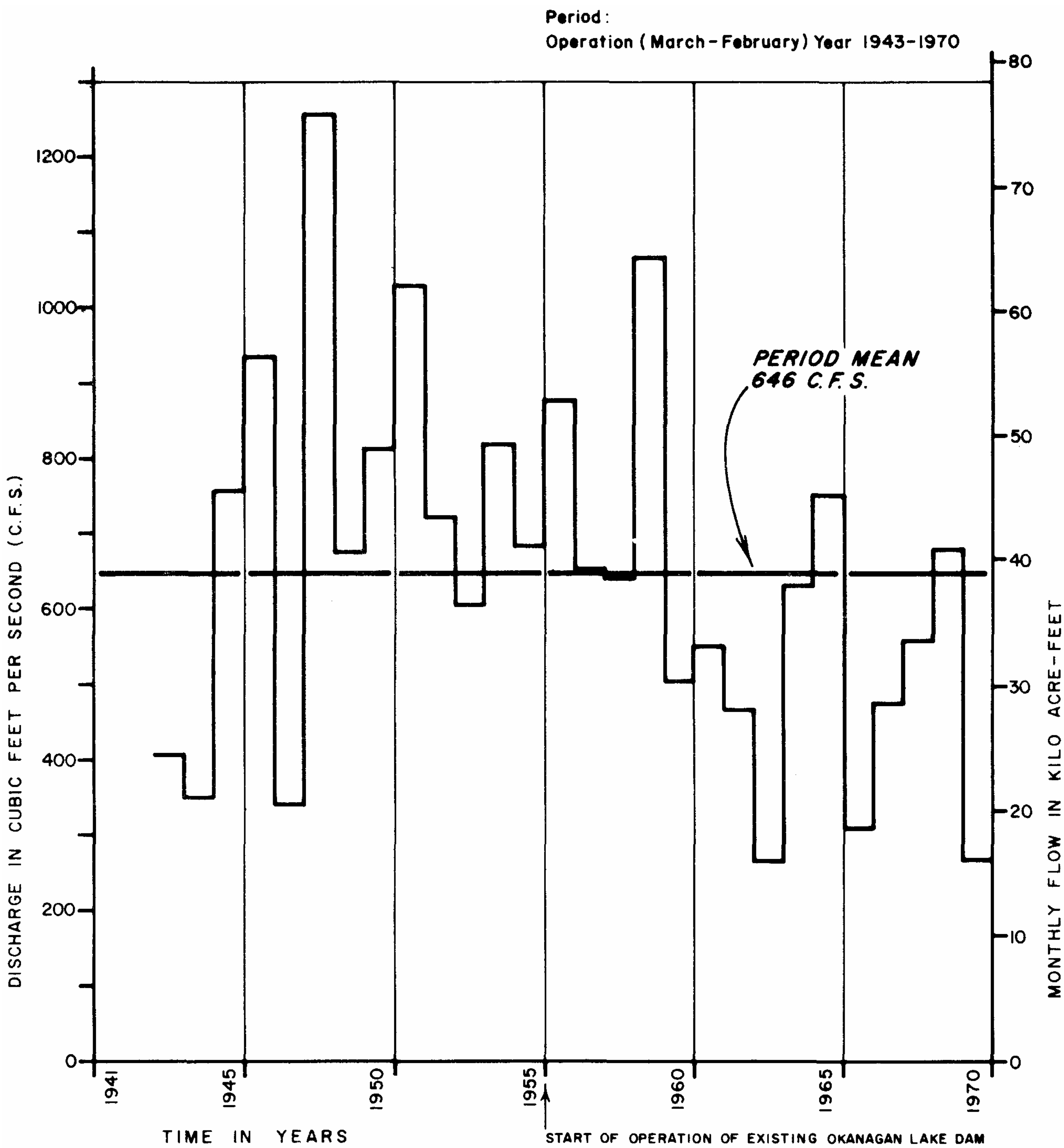


(a) SIMULATED MODEL DISCHARGES OKANAGAN RIVER AT PENTICTON COMPARED TO HISTORIC DISCHARGES.



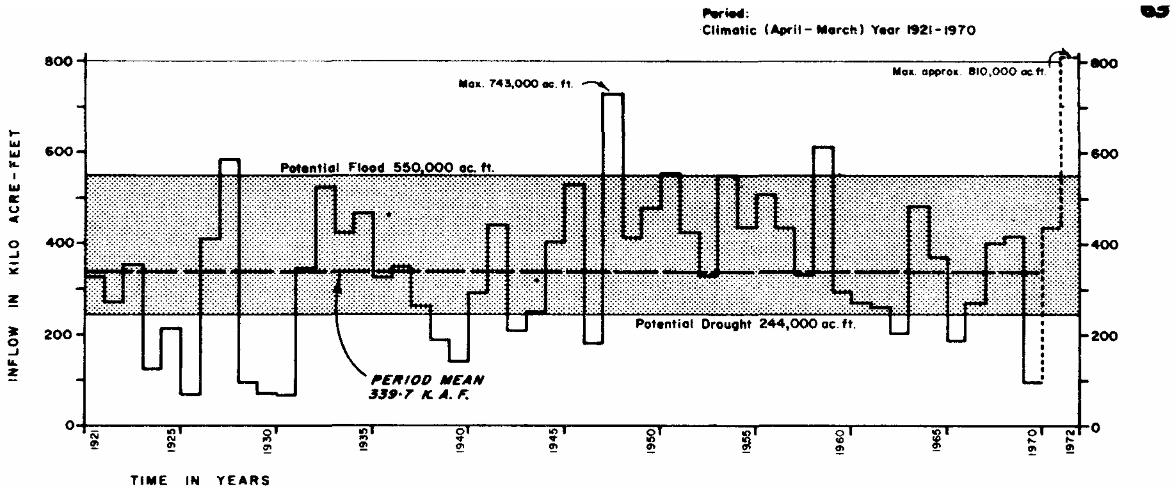
(b) SIMULATED MODEL DISCHARGES OKANAGAN RIVER NEAR OLIVER COMPARED TO HISTORIC DISCHARGES.

Figure 4.10

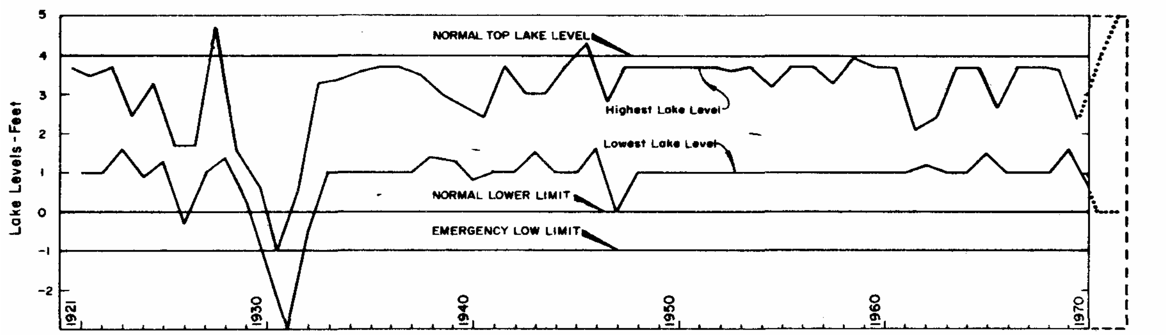


ANNUAL HISTORIC DISCHARGE,
OKANAGAN RIVER AT OROVILLE, WASH.

Figure 4.11

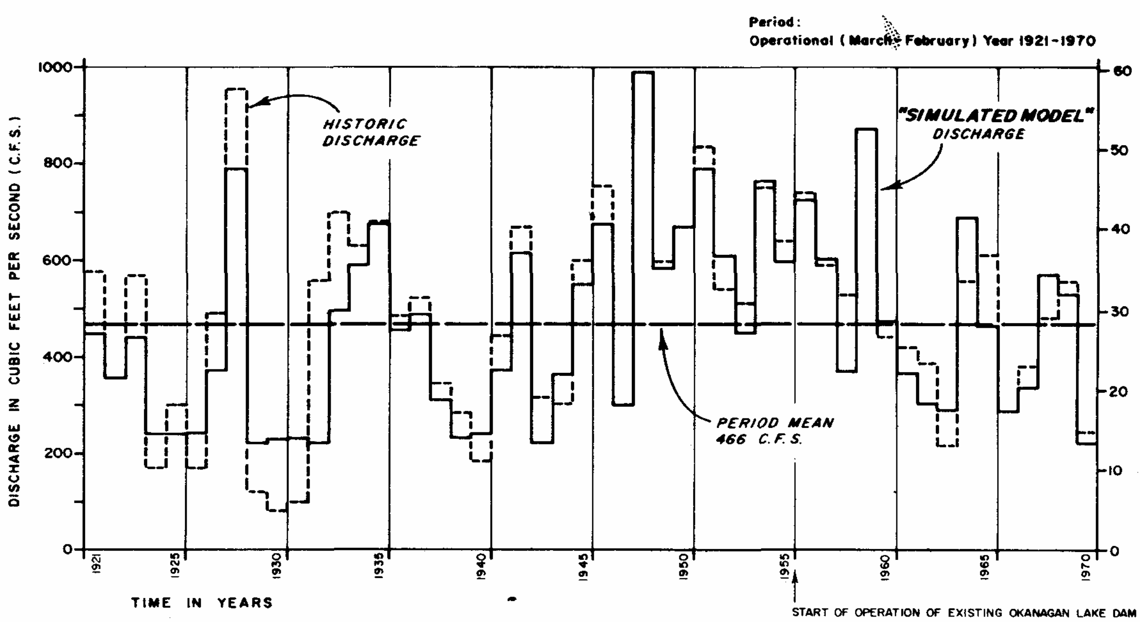


ANNUAL NET MODIFIED (1970 DEVELOPMENT) INFLOW, OKANAGAN LAKE



Computed Variations in Okanagan Lake Levels for the period 1921-1970 assuming Present (1970) Operating Conditions and that all Consumptive Demands and Fisheries Requirements are met, when possible.

——— Present Operating Conditions with Residual Flow of 300 cfs in Okanagan River



SIMULATED MODEL DISCHARGES, OKANAGAN RIVER AT PENTICTON COMPARED TO HISTORIC DISCHARGES.

MODIFIED INFLOWS, ELEVATIONS and DISCHARGES for OKANAGAN LAKE BASED on OPERATION of COMPUTER MODEL for PERIOD 1921-70. Figure 4.12

once in this century and was prevalent over much of North America.

The total volume of water required each year to satisfy all uses on Okanagan River, including minimum flows for the salmon fishery, are presently estimated at 244,000 acre-feet. Assuming that all this has to be supplied from Okanagan Lake, this inflow will be equalled or exceeded in all but about one year in four as shown in Figure 4.13. However, lesser inflows do not necessarily mean water shortages, providing Okanagan Lake enters the drought with carry-over storage. If forecasts made from snow surveys and other hydrologic parameters indicate low runoff, Okanagan Lake is operated to retain as much carry-over storage as possible which can amount to a foot or more.

While single-year droughts such as occurred in 1970 and again in 1973 can easily be handled, the possibility of a succesion of dry years cannot be overlooked. As mentioned above, if there were to be a major prolonged drought of three years (such as occurred in 1929 to 1931) Okanagan Lake would have had to be drawn down to 1116.6 feet, or some three feet below its normal low water elevation in order to meet present day requirements.

A frequency analysis of both two-year and three-year drought sequences (Figures 4.14 and 4.15), indicates that the 1929-31 drought was exceptionally severe and that it probably has a recurrence interval of about 200 years. A two-year drought of the severity of the 1929-30 inflow (the driest two-year sequence on record) is indicated as having a return period of about 100 years.

At the other end of the spectrum are those years in which excessive inflows or floods occur. In general, a forecast seasonal inflow of greater than 550,000 acre-feet is considered to indicate a potential flood. In years in which high inflows are forecast, Okanagan Lake is drawn down to its normal low water elevation prior to the freshet to provide maximum storage.

During the study period, extreme floods occurred in 1928 and 1948 and the computer simulation of these are compared with the recent 1972 flood in Table 4.6.

TABLE 4.6
COMPARISON OF COMPUTER SIMULATION OF FLOODS OF 1928 and 1948 WITH 1972 FLOOD
- PRESENT METHOD OF OPERATION AND EXISTING STORAGE FACILITIES -

	OKANAGAN LAKE INFLOWS		
YEAR	INFLOW APRIL-JULY INCLUSIVE (Acre-Feet)	ANNUAL INFLOW APRIL-MARCH INCLUSIVE (Acre-Feet)	MAXIMUM ELEVATION IN FEET ABOVE NORMAL HIGH WATER OF 1123.8 (Feet)
1928	638,236	615,500	0.9
1948	606,240	742,600	0.5
1972	697,206	742,278	0.9

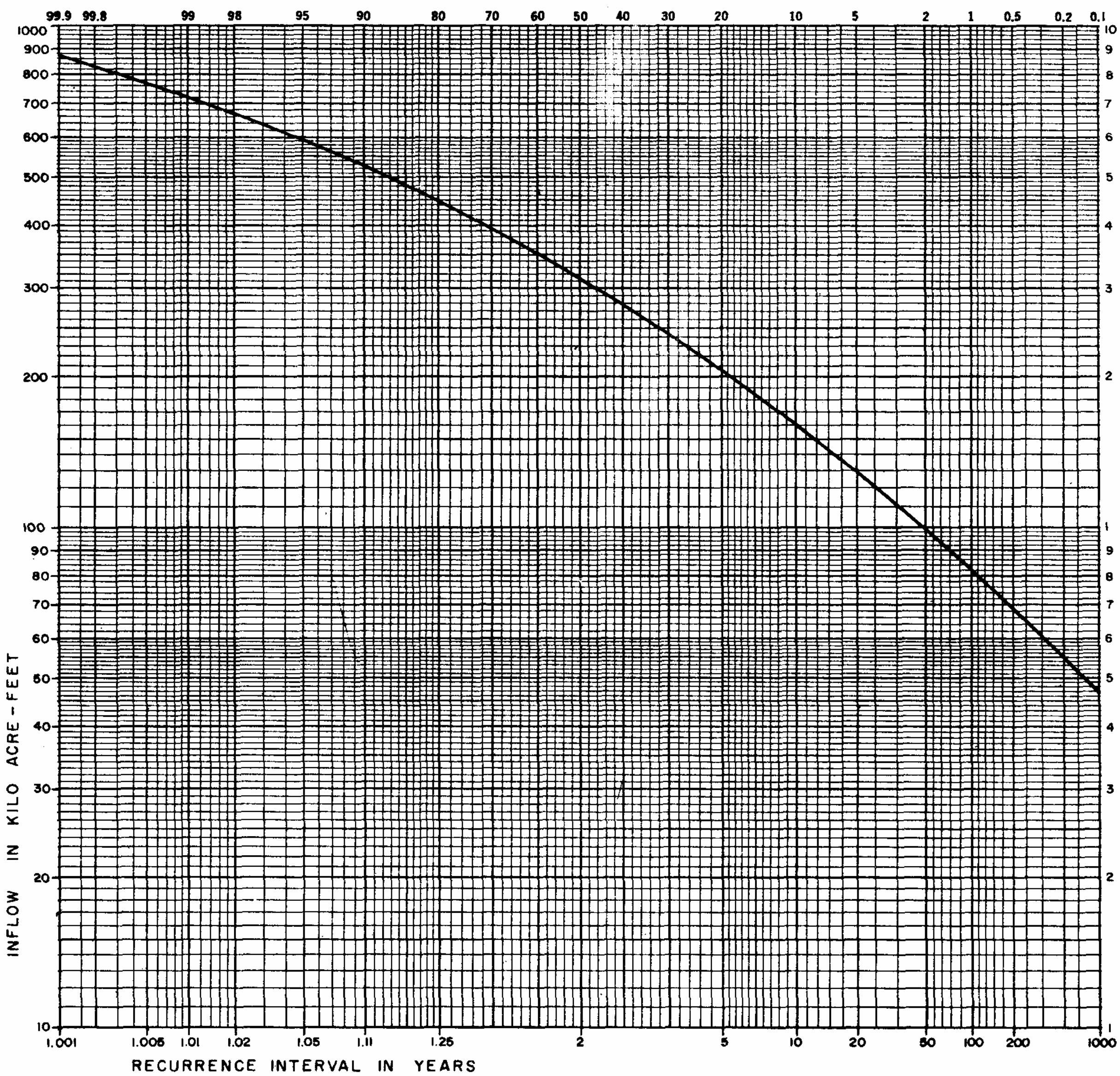
NOTE: Freshet inflow in 1928 greater than annual inflow due to heavy evaporation losses after July.

TABLE OF MOST CRITICAL YEARS

MAGNITUDE (K.A.F.)	YEAR
96.0	1929
116.2	1931
127.4	1970
127.9	1926
131.4	1930
137.2	1973
146.6	1924

TABLE OF CURVE VALUES

PROBABILITY IN PERCENT	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.1
RECURRENCE INTERVAL IN YEARS	2.0	5.0	10.0	20.0	50.0	100.0	200.0	1000.0
MAGNITUDE IN KILO ACRE-FEET	312.7	205.2	160.2	128.6	98.8	82.1	68.8	46.7



Period: 1921-1973

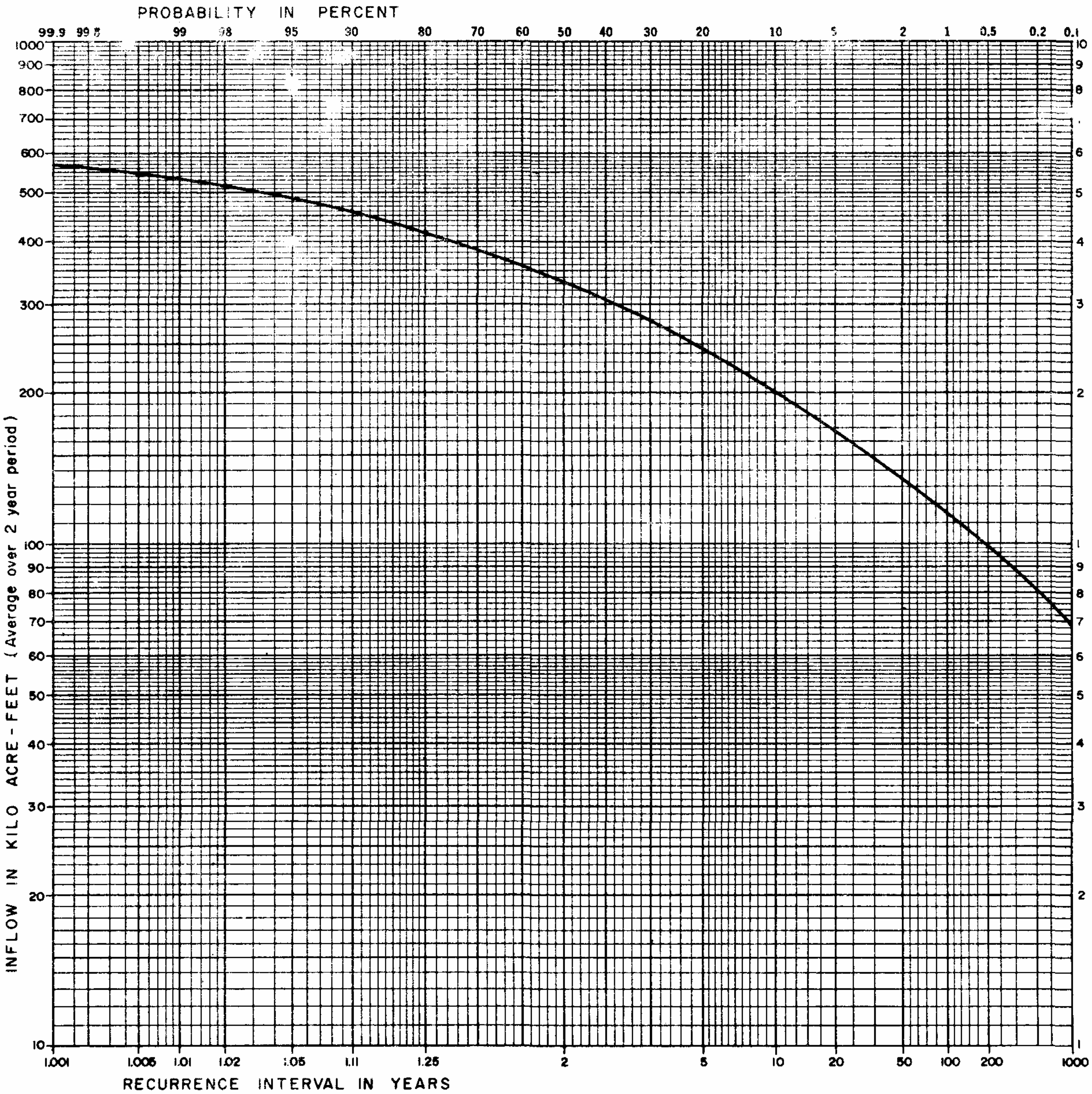
LOW-FLOW FREQUENCY CURVE, SEASONAL (APRIL-JULY) NET INFLOWS, OKANAGAN LAKE **Figure 4.13**

TABLE OF MOST CRITICAL YEARS

MAGNITUDE (K.A.F.)	YEARS
113.7	1929-1930
123.8	1930-1931
184.8	1926-1927
192.0	1940-1941
197.0	1939-1940
200.8	1925-1926

TABLE OF CURVE VALUES

PROBABILITY IN PERCENT	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.1
RECURRENCE INTERVAL IN YEARS	2.0	5.0	10.0	20.0	50.0	100.0	200.0	1000.0
MAGNITUDE IN KILO ACRE-FEET	332.4	244.6	201.5	168.5	135.0	115.0	98.5	69.6



Period: 1921-1973

LOW-FLOW FREQUENCY CURVE,
2 YEAR MOVING AVERAGE
SEASONAL (APRIL-JULY) NET INFLOWS, OKANAGAN LAKE

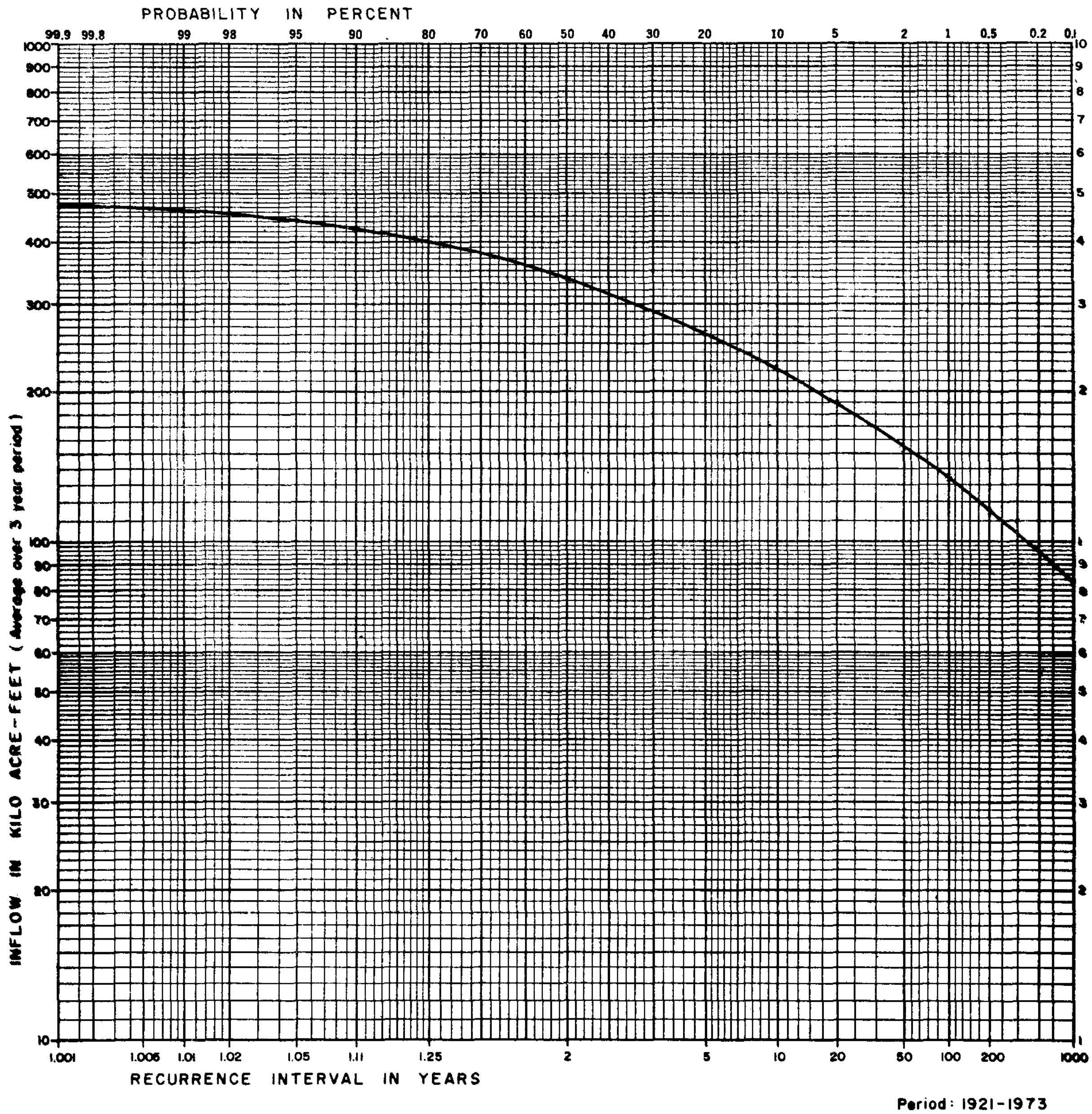
Figure 4.14

TABLE OF MOST CRITICAL YEARS

MAGNITUDE (K.A.F.)	YEARS
114.5	1929 - 1930 - 1931
182.7	1924 - 1925 - 1926
196.2	1930 - 1931 - 1932
200.4	1939 - 1940 - 1941
214.4	1925 - 1926 - 1927
227.9	1938 - 1939 - 1940

TABLE OF CURVE VALUES

PROBABILITY IN PERCENT	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.1
RECURRENCE INTERVAL IN YEARS	2.0	5.0	10.0	20.0	50.0	100.0	200.0	1000.0
MAGNITUDE IN KILO ACRE-FEET	337.2	262.3	221.8	189.3	154.9	133.7	115.7	83.4



LOW-FLOW FREQUENCY CURVE.
3 YEAR MOVING AVERAGE
SEASONAL (APRIL-JULY) NET INFLOWS, OKANAGAN LAKE

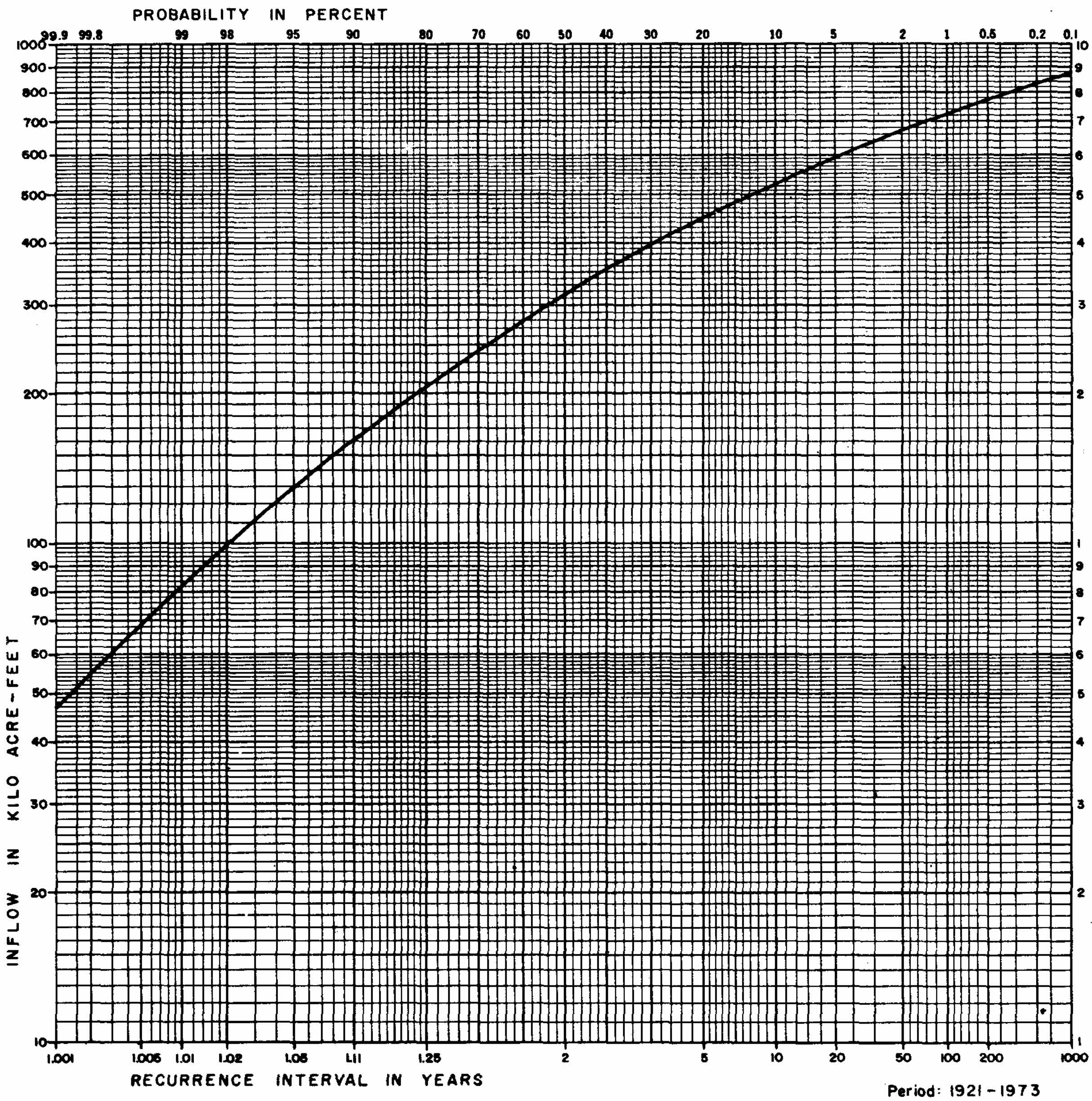
Figure 4.15

TABLE OF MOST CRITICAL YEARS

MAGNITUDE (K.A.F.)	YEAR
697.3	1972
638.2	1928
606.3	1948
547.2	1946
522.9	1951

TABLE OF CURVE VALUES

PROBABILITY IN PERCENT	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.1
RECURRENCE INTERVAL IN YEARS	2.0	5.0	10.0	20.0	50.0	100.0	200.0	1000.0
MAGNITUDE IN KILO ACRE-FEET	312.7	446.0	523.8	591.2	668.4	720.4	767.9	864.1



HIGH-FLOW FREQUENCY CURVE, SEASONAL (APRIL-JULY) NET INFLOWS, OKANAGAN LAKE

Figure 4.16

A frequency analysis (Figure 4.16) that floods with magnitudes greater than 550,000 acre-feet will probably occur on an average, every twelve years, but that the recurrence interval for the 1972 flood is in the region of 80 years. Sequences of successive flood years are not considered as the effects are not cumulative as in the case of successive droughts.

4.3.2 Effect of Droughts and Floods on Shoreline Development

Knowledge of possible damage to shoreline developments around Okanagan and Osoyoos Lakes as a result of extreme lake level fluctuations is essential information in the management of the mainstem system. This section discusses and evaluates the types of damage and inconvenience that can occur to a wide range of shoreline uses, both in economic terms and in social values in the case of recreation and aesthetic uses.

For Okanagan Lake, damage was assessed for 0.5 foot increments up to two feet above the present normal high water elevation of 1123.8 feet and for 0.5 foot increments down to three feet below the present normal low water elevation of 1119.8 feet. For Osoyoos Lake, the shoreline survey was restricted to assessing potential flood damage to 919.4 feet GSC (919.1 feet USCGS), 7 feet above the normal high water elevation of 912.1 feet GSC. No assessment of lake drawdowns was undertaken. These fluctuations are considered to include the maximum likely under extreme flood or drought conditions, assuming existing operating procedures are not drastically changed.

(a) Okanagan Lake

Impacts on shoreline landuse resulting from extreme fluctuations in Okanagan Lake are evaluated in both economic and social terms. Economic impacts include flood damage to properties and structures, adjustments to water intakes and to the Kelowna floating bridge, and loss of revenue at recreation sites. Social and environmental impacts involve loss of use of recreation facilities such as boat docks and boat launching ramps, exposure of unsightly lake bottom and inundation of public recreation sites. In addition, fluctuating lake levels can affect wildlife and fish spawning abilities and these are discussed in Chapters 8 and 9.

(i) Economic Damage

The major aspects of flood damage are shown on Table 4.7. If Okanagan Lake levels were to exceed the normal high water elevation by two feet, (1125.8 feet). approximately $476,000 damage would occur. Much of this damage is due to flooding of landscaped lawns and patios and from 58 private residences which have water in their main floors or basements. Flood damage potential increases rapidly above 1124.8 feet. However, most property owners have not improved their land below this elevation, as Okanagan Lake frequently rose to this level prior to the construction of the Okanagan Flood Control Works In 1956;. Since 1956, Okanagan Lake has only exceeded its normal high water elevation once (1972), and as a result new developments which extend down to the normal high water elevation suffered some flood damage in 1972.

TABLE 4.7

ECONOMIC COSTS OF EXTREME FLUCTUATIONS ON OKANAGAN LAKE

LAKE ELEVATION FEET (G.S.C.)	RELATIVE TO NORMAL MAXIMUM (FEET)	DIRECT DAMAGE (ANNUAL)	REVENUE LOSS (ANNUAL)	KELOWNA BRIDGE (ANNUAL)	TOTAL
1124.3	+0.5	$ 28,300	$ 400	$15,000 e/	$ 43,700
1124.8	+1.0	72,500	1,500	30,000	104,000
1125.3	+1.5	218,900	17,200	30,000 e/	266,100
1125.8	+2.0	420,000	26,000	30,000 e/	476,000

LAKE ELEVATION FEET (G.S.C.)	RELATIVE TO NORMAL MINIMUM (FEET)	KELOWNA* BRIDGE (ANNUAL COST)	LOWER INTAKES	DIRECT LOSS OF REVENUE
1118.8	-1.0	$ 900	0	$ 5,500
1117.8	-2.0	6,900	0	17,800
1116.8	-3.0	8,600	?	28,000
1116.0	-3.8	10,000 e/	10,000 e/	40,000

*NOTE: Costs are not additive because some represent amortized annual costs associated with structural changes, while loss of revenue costs only occur when lake is actually drawn down to elevations indicated.

e/ Estimated - very approximate

As most campsites and motels have been developed back from the lakeshore, only five establishments would suffer direct damage in a two-foot flood, relative to the normal maximum. While there would be little direct loss of revenue at motels and campsites, up to $26,000 of gas and rental sales could be lost at marinas and boat rental facilities due to high water levels.

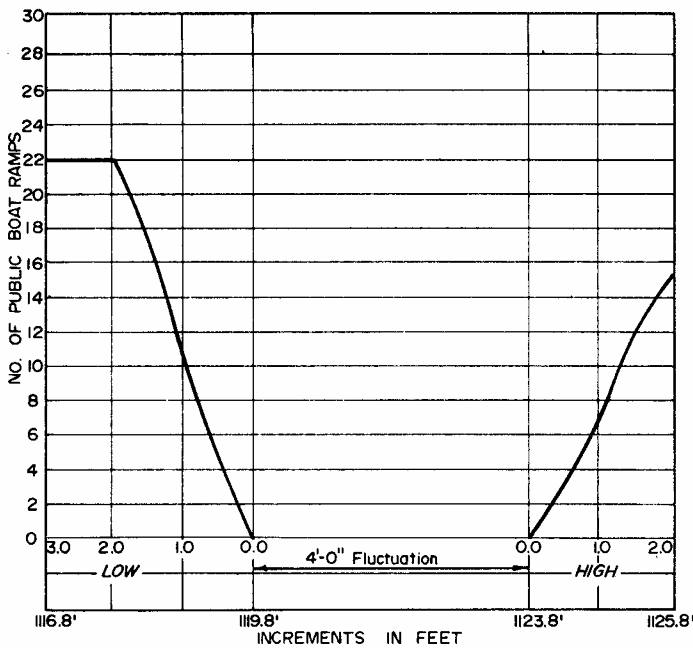
In 1972, when the lake rose to 1124.7 feet, approximately 0.9 feet above normal high water elevation, an estimated $56,500 damage occurred to shoreline development. About 45,500 of this total involved residential properties, the balance of $11,000 involving commercial establishments. This total does not include flood damage and seepage due to high water tables which affected residential properties at the mouths of Mission, Kelowna and Trout Creeks. In addition, there was seepage into basements and crawl-spaces at several lakeshore properties and flooding of septic tank drainage fields. Although little economic damage was reported from these problems during the 1972 flood, they were an incovenience and could result in more extensive damage during larger floods.

Adjustments to the Kelowna floating bridge are required if lake levels rise above 1123.8 feet. In 1972, approximately $30,000 was spent in ballasting pontoons to accommodate the high water. This cost is not expected to increase significantly at higher water elevations and would be somewhat lower for smaller floods.

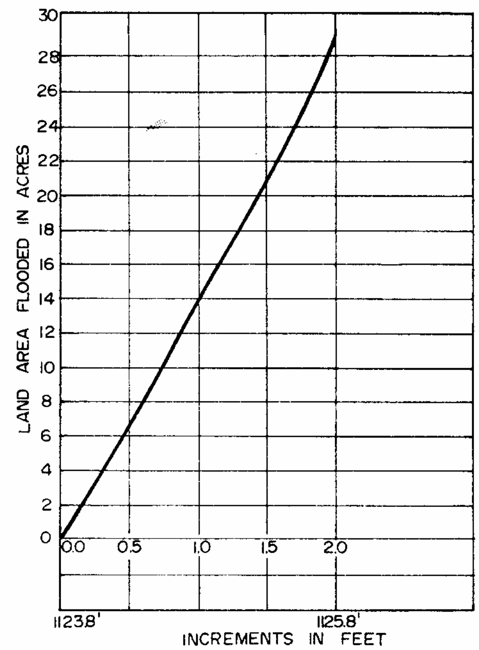
Direct economic costs associated with low water levels could total $200,000 If the lake was drawn down to 1116.0 feet. Indirect costs associated with loss of tourist trade due to low quality beach recreation could be substantial and will be discussed later in this chapter. It should be emphasized that direct and indirect cost estimates are very imprecise as lake levels below 1119.0 feet have not been experienced. This is due to the fact that prior to the construction of the new Okanagan Lake dam in 1956, the crest elevation of the previous dam and/or bar formations downstream did not allow the lake to be drawn down below elevation 1119.0 feet. During the 1929-31 drought, downstream requirements were not met and flows fell to zero at times. The main direct economic costs would involve structural adjustments to Kelowna bridge, estimated at $112,000 to allow the bridge to float at 1116.0 feet, and lowering irrigation and domestic water intakes which would cost about $100,000.

(ii) <u>Non-Economic Impacts</u>

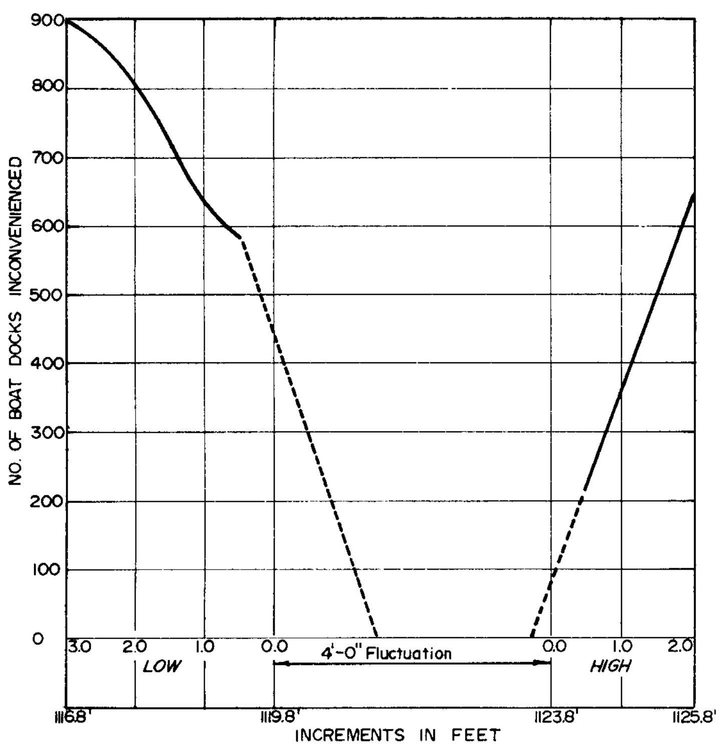
There appears to be a linear relationship between most categories of recreation and aesthetic uses of the shoreline, and lake level fluctuations (Figure 4.17). All 22 public boat launching facilities around Okanagan Lake would be Inoperable at lake elevations below 1117.8 feet, but as such low elevations would likely occur in winter and early spring, inconvenience could be relatively small. A large number of private boat docks are used only during the summer months and have been built to accommodate only the relatively small fluctuations in lake levels during this period (approximately 1121.5 to 1124 feet). Consequently, almost 600 boat docks would be inoperable at the normal minimum operating level of 1119.8 feet and almost 900 at an extreme low elevation of 1116.8 feet. Similarly, many boat docks are inundated at levels exceeding the normal Maximum of 1123.8 feet, but in most cases this is an inconvenience rather than a loss of use.



OKANAGAN LAKE
a) Public Boat Ramps Inconvenienced
-Cumulative



OKANAGAN LAKE
b) Area of Public Recreation Sites Flooded
-Cumulative



OKANAGAN LAKE
c) Boat Docks Inconvenienced
— Cumulative

EFFECT of LAKE LEVEL FLUCTUATIONS on SHORELINE RECREATIONAL FACILITIES, OKANAGAN LAKE.

Figure 4.17

There appears to be a significant loss of public recreation beach at higher water elevations, totalling almost 30 acres at an elevation of 1125.8 feet. During the 1972 flood, when almost 14 acres of public beach were under water, a survey of beach users indicated that the vast majority did not consider such a loss an inconvenience - many viewing it as a benefit as the shallow swimming area was extended. At some motels and private resorts where beaches almost disappeared, there was a greater loss of opportunity.

Lake drawdowns could potentially produce greater aesthetic and recreational losses. Soundings down to 1116.0 feet were taken during the shoreline survey and, in many developed area of shoreline, between 500 to 1000 feet of lake bottom would be exposed at such elevations (Map 2: Map Supplement). In most instances, low lake elevations are expected in winter and early spring, so such exposure, although aesthetically displeasing, would have little impact on the tourist industry. In a prolonged drought however, low lake levels could persist through the summer and significantly reduce the quality of beach recreation. In the absence of actual experience of such low lake levels, attempts were made to assess their impact on tourism during the beach user questionnaire survey. Although only a few respondents stated that they would not stay in the Okanagan under such conditions, it is believed that lake levels below 1120 feet throughout the summer could have a significant impact on the tourist industry.

(iii) Annual Damage

Fluctuations of Okanagan Lake beyond the normal four foot range occur very infrequently. The mathematical models which simulated operation of Okanagan Lake over the past 50 years indicated that flooding would only have occurred on three occasions (1928, 1948 and 1972) as shown in Figure 4.6 and lake drawdowns below 1119.8 feet on five occasions. Thus, although total damage in any one year could be relatively large, because such extreme events occur relatively infrequently, annual damage is considerably reduced in size and impact.

Estimates of average annual impacts on shoreline landuses are shown in Table 4.8. Non-economic impacts on value, in unit-days, represent the total opportunity lost during a period of extreme high or low water levels. For example, if 10 public boat ramps were unusable for a period of 60 days due to high water, a total of 600 boat launching days would be lost. This figure represents a maximum loss because the ramps may not be used every day, though seasonal useage of these and other recreational facilities was taken into account through the use of monthly weighting factors (see Technical Supplement III).

Annual economic costs due to flooding and lost revenue total some $2,000 though additional costs associated with possible structural adjustments to Kelowna bridge and water intakes could increase this to over $22,000. Likewise, other annual costs are relatively small with the exception of impacts on the use of private boat docks. In this case, many short-term adjustments are available and such costs should be considered an inconvenience rather than a real loss of use. There is little doubt that a recurrence of the 1929-31 drought would have significant impacts on recreation and general aesthetics and these would have to be balanced against the consequences of reducing releases into Okanagan River and the subsequent affects on fisheries and aesthetics in that region.

TABLE 4.8

TOTAL AND ANNUAL DAMAGES FOR SELECTED LANDUSE CATEGORIES AROUND OKANAGAN LAKE FOR SIMULATED OPERATION UNDER EXISTING CONDITIONS, 1921-1970

(a) ECONOMIC

ECONOMIC COSTS	TOTAL DAMAGE	ANNUAL DAMAGE
Property Damage	$ 67,000	$ 1,350
Loss of Revenue	38,750	780
Adjustments to Intakes	100,000 e/	10,000 e/
Adjustments to Kelowna Bridge	112,000 e/	10,000 e/
TOTAL COSTS	$317,750	$22,130

(b) NON-ECONOMIC

NON-ECONOMIC IMPACTS	TOTAL DAMAGE	ANNUAL DAMAGE
Public Boat Ramps (Ramp days)	3,920	78.4
Private Boat Docks (Boat Dock Days)	253,430	5,068.6
Public Recreation Sites (Acre-Days)	345	6.9
Private Property Flooded (Acre-Days)	2,642	52.8

e/ Estimated - very approximate

(b) Osoyoos Lake

In light of the significant flood potential on Osoyoos Lake and the recurrence of a major flood in June 1972, most emphasis in the shoreline survey was placed on damage assessment at high water levels.

Osoyoos Lake usually fluctuates within a two-foot range (910 to 912 feet GSC), the flood stage normally being considered to be 912.1 feet. In early June of 1972, Osoyoos Lake peaked at 917.11 feet USCGS (916.85 feet GSC), the highest level this century and the second highest on record. This event enables a detailed assessment of the economic and social costs of flooding on residential, commercial and recreational landuses.

(i) Economic Damage

As in the case of Okanagan Lake, direct economic damage to property, structures and utilities such as septic tanks is relatively small for the small more frequent floods, but increases rapidly to over $300,000 for a flood of 919.4 feet (Table 4.9). In the 1972 flood, actual damage including costs of flood prevention amounted to $121,000 - approximately $88,000 to residential properties and $33,000 to commercial establishments.

TABLE 4.9

STAGE-DAMAGE FUNCTION FOR 1972 LEVEL OF DEVELOPMENT AROUND OSOYOOS LAKE (DOLLARS)

STAGE (FEET) G.S.C.	RESIDENTIAL	COMMERCIAL	INDUSTRIAL	AGRICULTURAL	RECREATIONAL	LOSS OF REVENUE	TOTAL
912.9	4	4	-	20	-	-	28
913.4	3,538	41	-	43	-	2,000	5,622
913.9	9,006	5,266	59	117	-	4,900	19,348
914.4	19,899	6,135	59	131	-	11,800	38,024
914.9	31,585	12,829	59	1,081	-	18,300	63,854
915.4	49,904	20,000	178	1,838	514	27,000	99,434
915.9	57,138	22,297	1,013	3,946	680	89,500	174,574
916.4	76,005	27,068	1,013	6,049	905	55,600	166,640
916.9	97,971	36,649	1,013	10,342	905	80,000	226,880
917.4	116,033	53,957	1,013	13,283	1,308	106,000	291,594
917.9	133,247	68,503	1,679	16,071	4,004	130,000	353,504
918.4	152,239	71,350	1,679	18,858	4,315	146,000	394,441
918.9	163,290	100,636	1,679	23,307	,389	155,800	450,101
919.4	168,961	105,737	1,679	25,822	5,752	160,000	467,951

In addition to direct damage, there can be a significant loss of revenue to motels and campsites both during the period of flooding and cleanup. In 1972, for example, it is estimated that the Osoyoos region lost over $86,000 gross revenue due to loss of tourist business at shoreline resort facilities. Very little of this business appeared to move to other motels in the region, most affected tourists avoiding the Okanagan completely. Again, revenue losses are small up to the two-foot flood level ($130,000), and then level off to reach $160,000 at the seven-foot level. This stage-damage relationship should be interpreted with care, as revenue loss also depends on flood durations, but as it was based on the three-month flood of 1972, it probably does not underestimate losses.

(ii) Non-Economic Impacts

There are two public boat ramps on Osoyoos Lake and both are inundated at the 2.5 foot flood level (914.6 feet GSC). Recreation beaches are not seriously affected by high lake levels until the 4.5 foot flood level (916.6 feet GSC), when the causeway to the Provincial Park at Haynes Point would be submerged and most of the usable public beach area flooded. These conditions existed for a short time in 1972, forcing the closure of the Provincial campsite, but although lake levels remained high throughout July, most beach recreationists interviewed did not consider these conditions a major obstacle in their recreational enjoyment (Table 4.10).

In addition to direct economic costs, flooding can result in significant social costs such as loss of opportunity to enjoy one's property, volunteer labor costs and disruption of utilities (Table 4.11). In 1972, 130 private residences were directly affected by high water and over 60 acres (2.1 million square feet) of improved property was submerged. In addition, an estimated 21,000 man-hours of labor was required in flood prevention, evacuation, clean-up and repairs.

High lake levels create high groundwater tables at the shoreline. As the groundwater table rises, it can flood septic tank fields and even domestic water systems. It is estimated that in 1972, 70% of shoreline properties served by septic tanks were affected by seepage, some for as long as two months. In addition, people served by groundwater wells had to obtain alternative domestic water supplies until the wells were cleaned out, after the flood waters had receded.

(iii) Annual Flood Damage

Although flooding on Osoyoos Lake occurs more frequently than on Okanagan Lake, major floods are still a relatively rare occurrence. Figure 4.18 presents a stage-frequency curve for Osoyoos Lake and indicates that minor flooding may be expected every other year, but flood levels of the size occurring in 1972 are only expected once every 50 years. As the small flood produces very little economic damage, annual flood damage around Osoyoos Lake is small, totalling approximately $21,000 for the existing (1972) level of shoreline development.

4.3.3 Tributary Discharges

About 70% of the water consumed in the Okanagan Basin occurs within the tributaries of Okanagan Lake (Figure 4.9). Historically, tributary water has been relatively inexpensive as it provides a gravity water supply to agricultural lands. In order to make full use of these sources, headwater reservoirs have been constructed to regulate the flows during the irrigation season of April to September, inclusive.

TABLE 4.10

AREA OF PUBLIC RECREATION SITES FLOODED

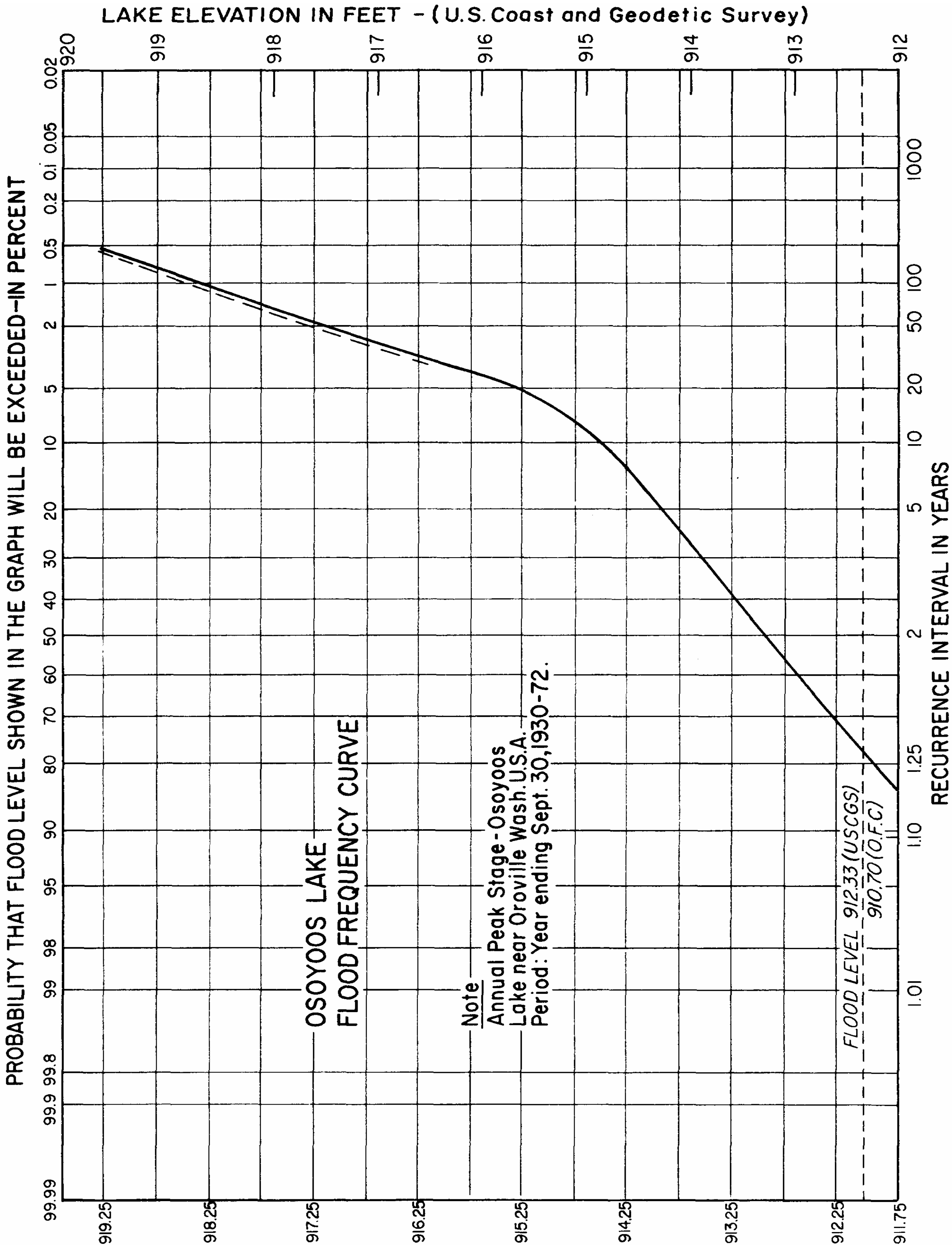
OSOYOOS LAKE

INCREMENT		INCREMENTAL		CUMULATIVE	
Feet GSC	Feet	Sq. Ft.	Acres	Sq. Ft.	Acres
912.1		Commencement of Flood Stage			
912.9	.8	19,265	.442	19,265	.442
913.4	1.3	26,290	.603	45,555	1.045
913.9	1.8	25,530	.586	71,085	1.631
914.4	2.3	17,530	.402	88,615	2.034
914.9	2.8	17,530	.402	106,145	2.436
915.4	3.3	19,195	.440	125,340	2.877
915.9	3.8	33,585	.771	158,925	3.648
916.4	4.3	33,585	.771	192,510	4.419
916.85	4.75		1972 Flood Level		
916.9	4.8	530,571	12.18	723,081	16.599
917.4	5.3	10,530	.241	733,611	16.841
917.9	5.8	7,155	.164	740,766	17.005
918.4	6.3	9,045	.207	749,811	17.213
918.9	6.8	12,015	.275	761,826	17.489
919.4	7.3	11,850	.275	773,676	17.761

TABLE 4.11

AREA OF PRIVATE PROPERTY FLOODED

INCREMENT		INCREMENTAL		CUMULATIVE	
Feet GSC	Feet	Sq. Ft.	Acres	Sq. Ft.	Acres
912.9	.8	83,926	1.93	83,926	1.93
913.4	1.3	158,721	3.64	242,647	5.57
913.9	1.8	162,149	3.72	404,796	9.29
914.4	2.3	102,918	2.36	507,714	11.66
914.9	2.8	321,230	7.37	828,944	19.03
915.4	3.3	250,801	5.76	1,079,745	24.79
915.9	3.8	336,836	7.73	1,416,581	32.52
916.4	4.3	759,401	17.43	2,164,182	49.08
916.9	4.8	527,694	12.11	2,691,876	61.79
917.4	5.3	281,734	6.47	2,987,810	68.59
917.9	5.8	277,025	6.36	3,263,835	74.93
918.4	6.3	293,670	6.74	3,558,505	81.69
918.9	6.8	344,935	7.92	3,903,440	89.61
919.4	7.3	371,515	8.53	4,274,955	98.14



LAKE ELEVATION IN FEET-(Okanagan Flood Control) **Figure 4.18**

GEODETIC SURVEY OF CANADA

For the most part, hydrometric and meteorological stations have only been operated in the lower reaches of the tributaries or within the main valley. The irrigation districts and municipalities who own and regulate most of the headwater reservoirs and diversions, provide the British Columbia Water Resources Service with monthly reservoir water elevations during the freshet, and in a few instances, measure the water diverted. Additional information is also made available each year with respect to the anticipated inflow to Okanagan Lake through regular snow surveys at the higher elevations carried out by the British Columbia Water Resources Service.

The lack of hydrometeorological data has become increasingly significant in the allocation of further water licences by the Water Rights Branch, British Columbia Water Resources Service. Some tributaries are now designated as "fully licenced" pending the attainment of further hydrological records.

It is evident that in order to develop and manage the tributary supplies efficiently for present and future demands, it is necessary to estimate as closely as possible the natural flows occurring in the various reaches of each stream under varying climatic conditions and to compare them with present and future water requirements.

Thus, the objectives of the tributary water quantity study were:

1) The estimation of natural flows under varying climatic conditions (dry year, average inflow year and wet year).
2) Regulation of the natural flows in accordance with present day (1970) procedures for the three types of years in 1), to meet present and future water requirements.
3) Regulation of the natural flows in accordance with improved methods of operation to meet present and future water requirements.

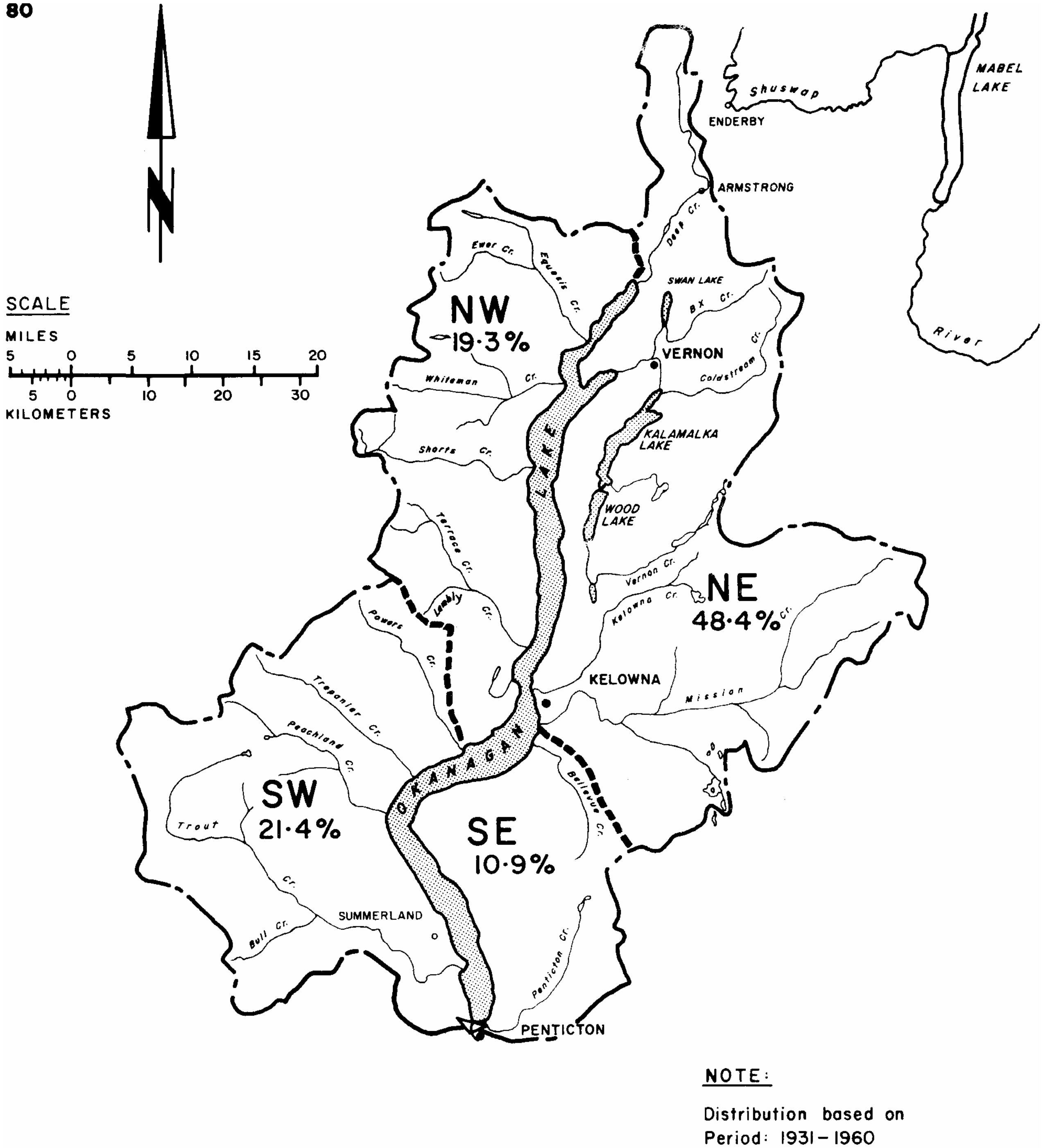
Objectives 1) and first part of 2) are dealt with in this Chapter, while the second part of 2) and objective 3) are covered in Chapter 14.

4.3.4 Distribution of Flows within Okanagan Lake Basin

In Chapter 1, the average precipitation pattern within the Okanagan Basin was illustrated using an isohyetal map which shows lines of equal precipitation. A contrast was also drawn between the precipitation shadow occurring in the western portion of Okanagan Lake Basin and the considerably heavier precipitation occurring to the northeast within the headwaters of Mission Creek.

These conditions, with respect to inflow to Okanagan Lake, are reflected in the average runoff map shown in Figure 4.19, in which Okanagan Lake Basin has been divided roughly into quadrants.

In spite of the unequal area distribution, it is evident that the northeast



RELATIVE CONTRIBUTION OF THE
4 QUADRANTS TO THE TOTAL RUNOFF
OF OKANAGAN LAKE BASIN

Figure 4.19

quadrant provides almost 50% of the total inflow, while there is little difference between the northwest and southwest sections.

These figures have been obtained from estimates of the natural monthly inflows to Okanagan Basin for the 50 year study period, broken down within 35 tributaries in accordance with drainage areas and location.

4.3.5 Method of Estimating Natural Flows in Selected Tributaries

Ideally, in order to parallel the computer modelling along the mainstem, it would be necessary to determine the natural flows of tributaries, not only at the mouth, but also at specific points upstream for the same 50 year study period.

Time did not permit the study of all of the 35 tributaries within the Okanagan Basin, and in an effort to concentrate the analysis in areas where it was most needed, the eight tributaries shown in Table 4.12 and Figure 4.20 were selected for detailed modelling. The selection was based primarily on the fact that they are the most heavily used streams within the Basin.

TABLE 4.12 TRIBUTARIES SELECTED FOR DETAILED MODELLING WITHIN OKANAGAN LAKE BASIN*

WEST SIDE	EAST SIDE
1. Trout Creek	5. Vernon Creek
2. Peachland Creek	6. Kelowna Creek
3. Powers Creek	7. Mission Creek
4. Equesis Creek	8. Penticton Creek

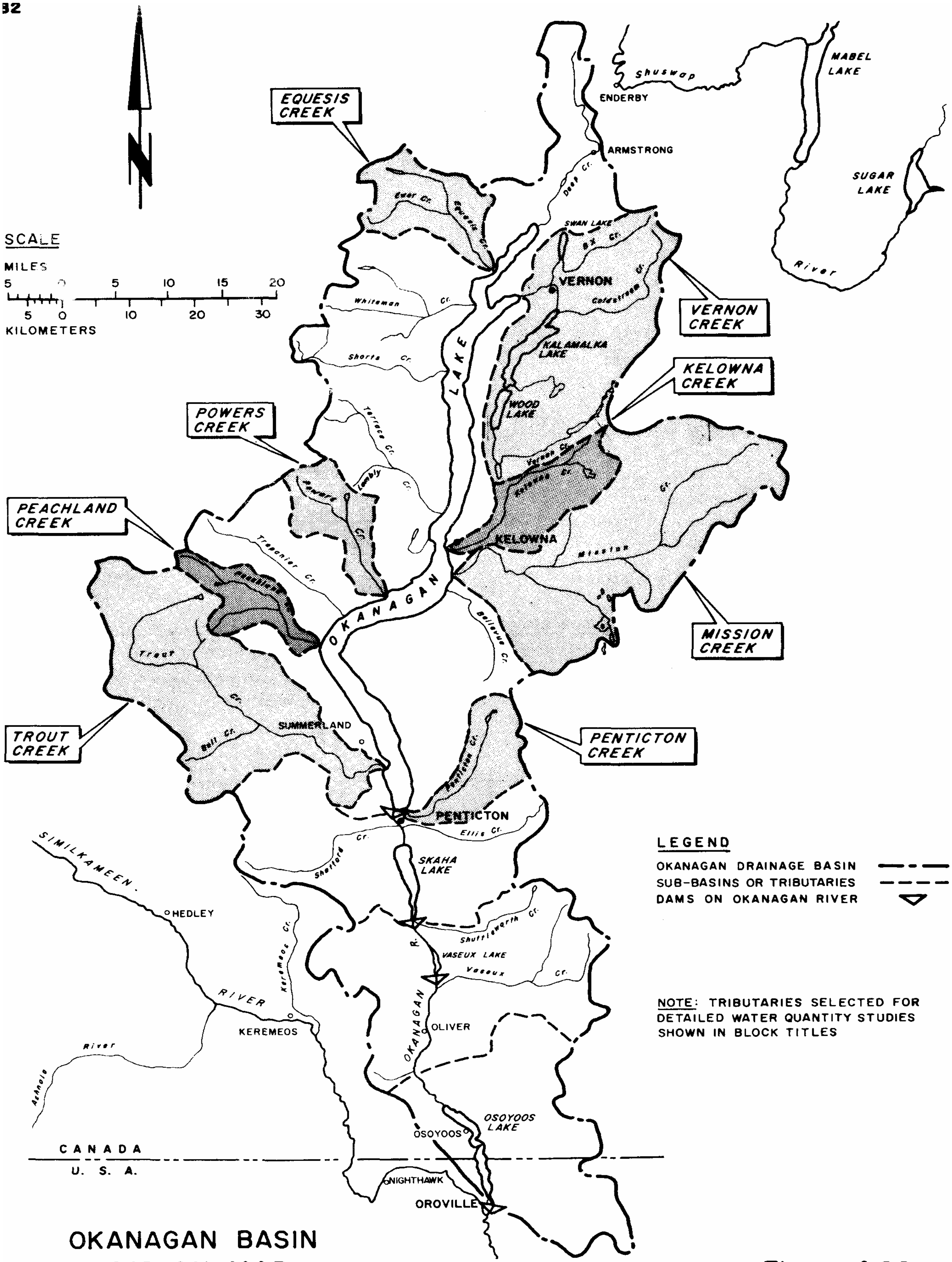
*See Figure 4.20 for Tributary Locations

These tributary watersheds contain 95% of all upland tributary storage within Okanagan Lake Basin and supply 60% of the total inflow to Okanagan Lake. About 37,000 acres out of the 45,000 acres of irrigated land within Okanagan Lake Basin are supplied from these sources.

The study was limited to three types of years:

Dry year - those falling within the five driest of the 50 year study period and roughly equivalent to the 1970 and 1973 runoff conditions.

Average year - those falling within the middle five years of the 50 year study period, and roughly equivalent to 1971 runoff conditions.



OKANAGAN BASIN LOCATION MAP

Figure 4.20

Wet year — those falling within the five wettest years of the 50 year study period and roughly equivalent to 1948 and 1972 runoff conditions.

Using 500 foot elevation band increments, the total annual runoff was computed and distributed by months to provide an estimate of the average monthly natural dry year flow at specific points in each of the selected tributaries. The 1970 runoff was used for comparison. Similar calculations were made with respect to average flows in which 1971 was equated to the long-term average for 1921 to 1970. A record high runoff occurred in 1972, and the flows that resulted agree reasonably well with the estimated flows developed for the flood year prior to it's occurrence.

Normally, natural runoff with minor releases from storage is adequate for water users during April and May. At the same time, the headwater reservoirs are filling and major releases from these reservoirs do not take place until the latter part of June. These releases continue through July and August and in some instances, most of September - at which time releases from headwater reservoirs are discontinued. The remaining carry-over storage water is either retained as a cushion against subsequent droughts, or released in the fail to draw the reservoir down to a predetermined safe level for the winter months. The latter releases could benefit fisheries as discussed in a later section, although additional storage water would also be required.

Estimated natural discharges as well as the regulated discharges, which allow for consumptive uses at the mouths of the eight selected tributaries, are listed in Table 4.13. The nature of these simulated flows are such that they include a groundwater component. However, the extent of groundwater flow within tributary streams is considered minor and less than 10% of the surface flow.

4.3.6 Matching Supply and Demand

In matching supply and demand for a tributary, it has been assumed there is no return flow to the tributary, although such water is included in the inflow to Okanagan Lake as indicated in the description of the mainstem model. There will be return flow to some parts of the tributaries, but where and how much is imposs-ibie to assess. Hence, these estimates of tributary discharges at selected points on each stream may be considered conservative.

Even with this rather extreme test, only two tributaries - namely Vernon and Kelowna Creeks - show consumptive use deficiencies (Table 4.14) in a 'dry' year under present (1970) day development.

4.3.7 Summary

Under current management practices, the Okanagan mainstem system is operated primarily for water conservation in drought years, when freshet inflows are less

TABLE 4.13

SELECTED OKANAGAN LAKE BASIN TRIBUTARY DISCHARGES AT MOUTH OF STREAMS

Tributary	Drainage Area in k.ac.	Discharge in K.A.F.					
		Dry Year		Average Year		Wet Year	
		Natural	Regulated	Natural	Regulated	Natural	Regulated
Trout Cr.	185.1	23.7	11.7	44.4	41.2	122.0	108.6
Peachland Cr.	37.8	8.9	6.9	15.0	12.2	27.5	24.3
Powers Cr.	35.3	8.0	2.9	13.8	8.5	25.8	20.5
Equesis Cr.	49.2	10.2	9.2	17.8	16.8	34.1	33.0
Vernon Cr.	228.6	38.5	11.1	67.1	29.0	137.2	80.9
Kelowna Cr.	55.4	9.9	2.1	17.0	7.3	34.3	23.2
Mission Cr.	214.0	97.0	66.0	143.0	107.1	239.3	201.8
Penticton Cr.	44.9	21.9	11.2	34.8	23.7	58.2	47.1

TABLE 4.14

WATER RESOURCE CAPABILITY IN 8 SELECTED TRIBUTARIES OKANAGAN LAKE BASIN UNDER PRESENT (1970) DEVELOPMENT

		TROUT CR.	PEACHLAND CR.	POWERS CR.	EQUESIS CR.	VERNON CR.	KELOWNA CR.	MISSION CR.	PENTICTON CR.	TOTALS
Area	Sq Miles	289	59	56	77	358	86	336	70	1,331
Natural Flow at Mouth Ac. Ft. X 100	Dry Year	237	89	80	102	391	99	969	219	2,186
	Av. Year	544	150	138	178	678	170	1,429	348	3,635
	Wet Year	1,220	275	258	341	1,382	343	2,392	482	6,793
Storage (Ac. Ft.)	1970	10,332	9,656	3,754	2,156	46,719	5,715	17,981	10,240	106,543
Area Under Irrigation (Acres)	1970	4,306	617	1,637	356	14,075	4,848	10,135	1,666	37,640
Population (Persons)	1970	5,960	1,444	3,490	90	24,360	10,420	10,340	18,146	74,250
Water Requirement (Diversion) Ac. Ft.	1970	13,384	3,416	5,293	1,021	33,525	12,888	31,814	11,173	112,514
Consumptive Use Deficiency in Dry Year Ac. Ft.	1970	0	0	0	0	1,540	2,296	0	0	3,836

than 244,000 acre-feet, and for flood control when freshet inflows are greater than 550,000 acre-feet. For years in which inflows fall between these two extremes, regulation tends to follow a more uniform procedure based on historic records of the lake levels and discharges.

The adequacy of the computer model to assess these water management practices in the mainstem is dependent on the quality of the hydrometric records available, and for the studies carried out, many of the monthly flow records were not available and had to be estimated or simulated. It would have been desirable to extend the records back to the 1894 record flood, but information prior to 1920 is very limited. Similarly, had time permitted the inclusion of data from the 1970 drought and the 1972 flood, the analysis would have been improved.

The study period does contain two major floods which occurred in 1928 and 1948, and several droughts including the three years of drought of 1929-31. Within these limitations, there appears to be no cyclic trend in the 1921-1970 period. The last 50 years of inflow in the sequence in which they occurred, does not imply that such a sequence may be repeated in the future.

Lake level fluctuations outside the normal operating range of Okanagan and Osoyoos Lakes have been relatively rare events and, because of this, shoreline developments have adjusted to this normal range. Consequently, extreme lake elevations may result in significant economic, social and environmental costs which must be taken into account in the overall management of the Basin's water resources.

Tributary flows that were developed are approximate and can be considered as 'first estimates' of probable discharges. White they point out the deficiencies under present day development, in the event of a single drought year they include no allowances for in-channel flows, such as are proposed for fisheries. The latter is discussed in more detail in Technical Supplement II and in Chapters 14 and 17 of this report.

4.4 FOREST HYDROLOGY

One forest hydrology study of the Okanagan Basin was carried out to provide a preliminary appraisal of the watershed in terms of cover and characteristics by major biophysical zones, and to outline the effects of timber harvesting on water quantity within these zones.

Prior to undertaking a field investigation, a brief office study was carried out to determine if there was any apparent trend in the 50 years of annual gross historic inflow to Okanagan Lake Basin which might be identified with forest harvesting. These inflows, together with the precipitation on the lake, as well as the nine year moving averages are shown in Figure 4.2] from which no discernable trend in runoff is evident.

While there appears to be no significant change in the overall hydrological conditions within Okanagan Lake Basin, it is possible that local tributary runoff may be affected by forest harvesting and fires. Unfortunately, such studies require a number of years of observations in relatively virgin watersheds which are undergoing forest harvesting. No such background information was available for the Okanagan Basin and in lieu of this a theoretical study was undertaken of Pearson Creek (a tributary of Mission Creek) on the eastern side of the Basin which is shown in Figure 4.22.

4.4.1 Pearson Creek

At present, Pearson Creek, with a drainage area of 120 square miles is relatively undisturbed and has the following desirable characteristics with respect to its use in the development of a simulation computer model on which various degrees of deforestation can be assumed and the resulting changes in runoff determined.

(i) Most of the watershed area is forested and suitable for commercial forest harvesting.

(ii) The area has yet to experience any major land use changes.

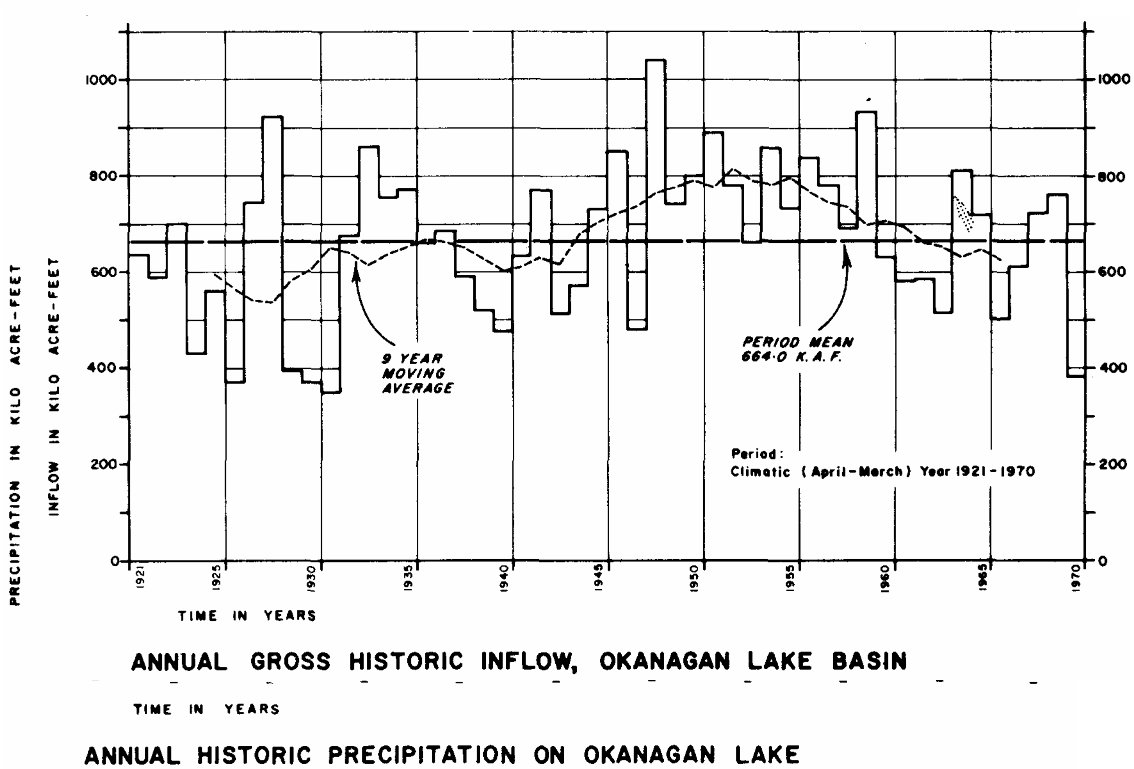
(iii) A reasonable spatial representation of the climate, soils, forest cover and drainage is present.

(iv) Preliminary analysis indicated that the main part of the watershed exhibited conditions of water surplus with no major portion exhibiting water deficits.

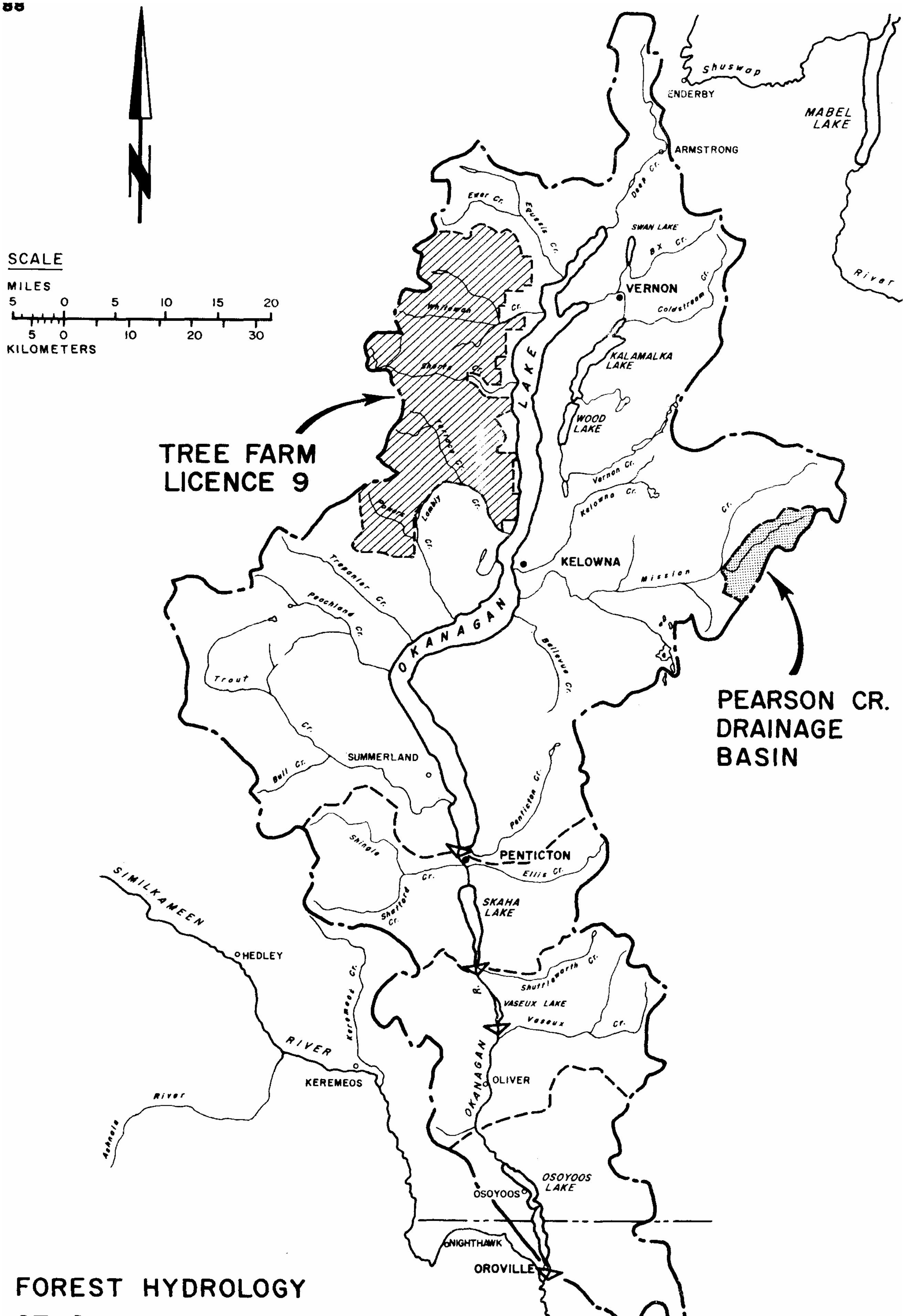
(v) The watershed is of a nature which makes it attractive for the establishment of a research basin for future studies.

Runoff for the period October 1970 to September 1971 was developed in a computer model based on precipitation, computed evapotranspiration and soil water storage changes. The simulated flows compare favorably with the total measured inflow for the year, but showed relatively large differences in April, May and June. These differences were due - in part - to the estimated large groundwater flow at the gauging site, and the crudeness of the model with respect to the rain-on-snow events. For the purpose of simulating the hydrologic effects of landuse, it was felt that the differences in basin yields, as shown by the simulation model, were sufficiently accurate to indicate trends.

In the Pearson Creek Watershed model, a systematic cutting pattern was assumed involving the removal of forest cover at the rate of one grid square of mature forest (640 acres) per year for the 17 years for which mature timber was available for harvesting. Assuming a clearcut and slashburn harvesting system and accounting for sequential changes in regrowth of cut-over areas, the yearly incremental and total basin yield were calculated by the model.



ANNUAL HISTORIC PRECIPITATION AND GROSS HISTORIC INFLOW TO OKANAGAN LAKE. Figure 4.21



FOREST HYDROLOGY
STUDY AREAS

Figure 4.22

After 17 years of sequential forest harvesting in the Pearson Creek watershed, a total basin yield increase of 2.91 inches or 13.68% was obtained. In this particular watershed the estimated streamflow difference from natural conditions would decrease as a result of a gradual increase in the evapotrans-piration as forest regrowth occurred. First year yield increase is the largest with subsequent years reflecting the effects of gradual regrowth of the cut-over areas and the redistribution of water surpluses from the cut-over areas to the water deficit areas supporting vegetal growth.

From comparative studies of Terrace and Esperon Creeks, it was estimated that the water yield increases from forest harvesting in Tree Farm Licence No. 9 for different rotation length and also for the simulation model of Pearson Creek, would be as shown in Table 4.15. Tree Farm Licence No. 9 is located between Lambly Creek in the south and Nashwito Creek on the north with Okanagan Lake and Okanagan Lake Basin divide to rising its eastern and western boundaries, respectively (Figure 4.22).

TABLE 4.15

WATER YIELD INCREASES FROM FOREST HARVESTING ON FOREST LAND OF TREE FARM LICENCE NO. 9 AND PEARSON CREEK FOR DIFFERENT ROTATION LENGTHS

Rotation Length (Years)	(120 Square Mile Basin) %	Tree Farm Licence No. 9 (309 Square Miles) Basin Yield Increase %
120	3.87	4.9
100	4.64	5.8
80	5.80	7.3
60	7.74	9.8
40	11.60	14.7

4.4.2 Conclusions

In the extrapolation of the above data to the three major zones of the Okanagan Basin, the following water yield increases may accrue:

South of Penticton

In this zone, any water yield increases accruing from high elevation forest harvesting will not be reflected in increased streamflow. This is due to *in situ* redistribution of water from surplus sites to deficit sites. Any increase in harvesting intensity would be reflected in localized site improvement by increasing the available soil water.

North of Penticton below 4,000 feet elevation

This zone is typified as the Ponderosa pine-parkland community and is a water deficit hydrologic system. As such, any forest harvesting would not reflect any water yield increases to streamflow. Localized harvesting is probably best directed towards improving the carrying capacity of incorporated range lands. However, in this region soils are particularly sensitive to the disturbance effects of harvesting activities and extreme caution should be exercised in the location and construction of roads to ensure that adjacent streams do not receive high discharges of sediment. This area, because of its generally dose proximity to Okanagan Lake, is particularly sensitive to stream temperature increases (approaching lethal limits for fisheries) following their exposure by forest removal.

North of Penticton above 4,000 feet elevation

It is in this zone that the greatest potential for water yield increases exists, as a consequence of forest, harvesting. It is also the region of most intensive forest harvesting, both at present and in the predicable future. Within this zone, snowpack management considerations are an important aspect of landuse hydrology. The zone includes approximately 300,000 acres of merchantable timber.

Water yield increases accruing from forest harvesting in this zone on a 120 year rotation basis, have been estimated to be between 3.31% and 4.20%. These increases would only be realized within this zone (Englemann spruce and subalpine fir forest type) and would likely be consumed in water deficit sites at lower elevations. This includes correction for sequential regrowth effects on increasing evapotranspiration from the time immediately following logging to pre-logging evapotranspiration: a period of approximately 40 years for most sites. Similarly, for a hypothetical 40-year rotation, the increases are between 9.93% and 12.60%.

Forest fires may effect an increase in water yield through reduction of evapotranspiration. The average annual acreage burned over in the Okanagan Basin is 5,377 with a range between 81 acres (1964) and 25,856 acres (1970). Yield increases calculated on the basis of water yield from the area north of Penticton and above 4,000 feet, have been estimated to be between 1.24% and 1.55% annually.

However, as large as these streamflow increases may be, they are only for that area designated as merchantable forest north of Penticton above 4,000 feet (approximately 1/4 of the total merchantable forest and 15% of the total area of the Okanagan Basin). Forest harvesting in other zones of the Basin would have no net effect on streamflow quantity. By adjusting the reported percentage water yield increases to a Basin basis for a 120-year rotation, levels by which comparisons can be made and effects evaluated, are made possible. Thus, on the basis of the total Okanagan Basin, annual water yield increases accruing from forest harvesting range from 0.50% to 0.64%. Similarly, the figures for the effect of fire are adjusted to be between 0.19% and 0.23%. Respective figures for the hypothetical 40-year rotation are 1.50% and 1.91% for forest harvesting and 0.19% and 0.23% for forest fires. These reported annual increases are not cumulative due to the effects of regrowth on evapotranspiration consumption.

The values reported for the 40-year rotation are never likely to be achieved because a 40-year rotation is too close to the regrowth time of 40 years and it is only relevant to discuss the values reported for the existing and future 120-year rotation forest harvesting rates. The following limitations must be noted with respect to the reported increase in water yields following forest harvesting and/or fire:

(a) Reported increases are too small to be measured by existing streamflow measurement techniques.

(b) Total water yield increases in major tributaries of the Okanagan Basin will very likely go undetected due to the low percentage yield increase from sustained yield forest management. Any yield increase would only be reflected in very small (89 square miles) basins, over which significant portions (75%) have been harvested or burned.

(c) Water yield increases accruing from forest harvesting in the area only become usable if they reach a stream channel. Increased water transmitted downslope through the soil mantle would likely be consumed in water deficit sites below 4,000 feet elevation, thereby proving useless in augmenting water supplies for other purposes. It has been shown that most of the annual water yield increases occur in the spring and fall months, thereby necessitating improvement and/or extension of reservoirs to hold water over to peak demand periods in the summer season.

In conclusion, it can be stated that although streamflow increases will accrue from forest harvesting in the Okanagan Basin, the reliability and predictability of these increases will be inhibitory to planning for water supply. Forest harvesting, with respect to water supply should be concentrated in the area of minimizing water quality deterioration and increasing the general environmental stability of those lands upon which forest land management is occurring.

4.5 GROUNDWATER HYDROLOGY

Groundwater investigations and studies within the Okanagan Basin have been carried out to meet the following objectives:

1) Determination of the groundwater contributions from tributary sources.

2) Determination of the extent of and recharge rate to groundwater aquifers in the northern portion of the basin, the sources of recharge water to these aquifers, and whether the yields from such aquifers are large enough to meet water deficits in the Okanagan Basin in a series of drought years.

3) The yield, quality and cost of developing the northern aquifers.

4.5.1 Geology

The Okanagan Basin is underlain by a diversity of rocks. On the east side, hard, resistant, gently dipping metamorphic rocks including gneiss, schist, quartzite, calcareous gneiss and marble, present pronounced gentle slopes due to differential weathering. The west side is underlain-by two groups of rocks;

one - north of Vernon-includes mostly schists and quartzites with gentle rounded slopes, and the south groups include argillites, andesite lavas and limestone exposed in more rugged relief. In places these rocks are covered by flat lying or gently dipping lavas. In general, storage and movement of groundwater in this complex of crystalline rocks is limited to the interconnected fracture and fault systems. It is realized that major fault zones will provide conduits for the movement of groundwater, but the main concern here is largely with aquifers belonging to the unconsolidated surficial deposits.

The unconsolidated surficial deposits consist of clay, silt, gravel, sand and mixtures of these that overlie the bedrock. They are of glacial origin and their deposition is related to the glacial ice that occupied the valley or to the meltwaters that issued therefrom during the wasting stages of the ice. Although the glacial ice filling the valley may have reached elevations as much as 7,200 feet, it left only a thin blanket of unconsolidated materials at the higher elevations.

4.5.2 Tributary Groundwater Sources

The following six tributaries to Okanagan Basin were selected for hydro-geological reconnaissance studies (Figure 4.23).

Greata Creek - a tributary of Peachland Creek

Lambly Creek

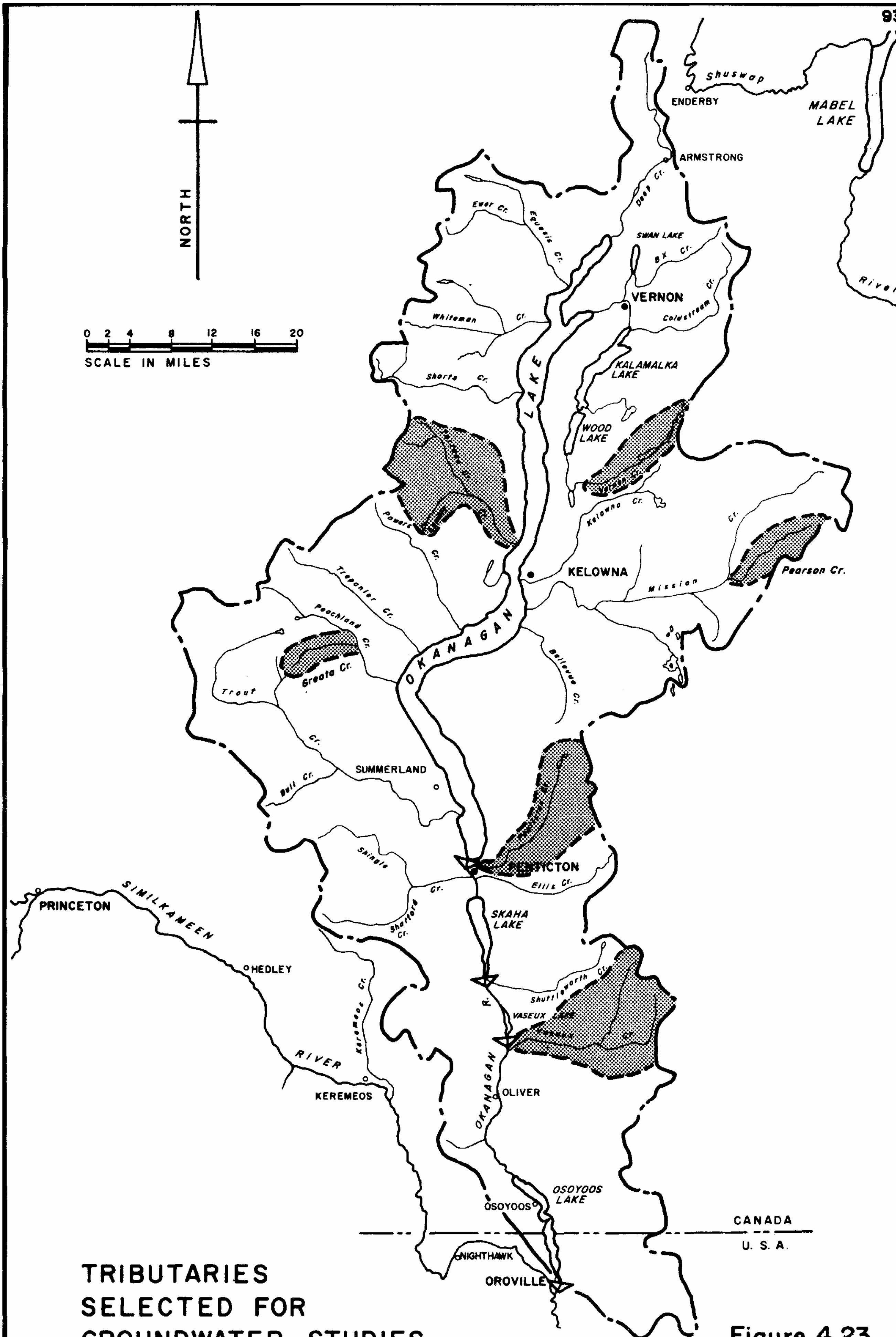
Upper portion of Vernon Creek above Ellison Lake

Pearson Creek - a tributary of Mission Creek

Penticton Creek

Vaseux Creek

These tributaries are virtually unsettled in their upper reaches and investigations were therefore directed towards a qualitative appraisal and mapping of natural phenomena such as springs. Most of the precipitation in these sub-basins occurs above the 4,000 foot level and most of the groundwater discharge observed was above this elevation. Only small increases in total mineralization to streams in conjunction with only limited increases in streamflow, support earlier opinions that the nature of the bedrock and surficial geology are such that the groundwater component of total runoff is small, and that there is very little groundwater discharge from these sub-basins that is not measured as streamflow. Fan deposits at the mouths of tributary creeks may provide limited sources of groundwater for local use and there is strong evidence to suggest that subsurface flows from tributaries in the southern part of the Basin, such as Vaseux Creek, may contribute a fair portion of that particular sub-basin discharge.



TRIBUTARIES SELECTED FOR GROUNDWATER STUDIES

Figure 4.23

4.5.3 Groundwater Inflow to Okanagan Lake

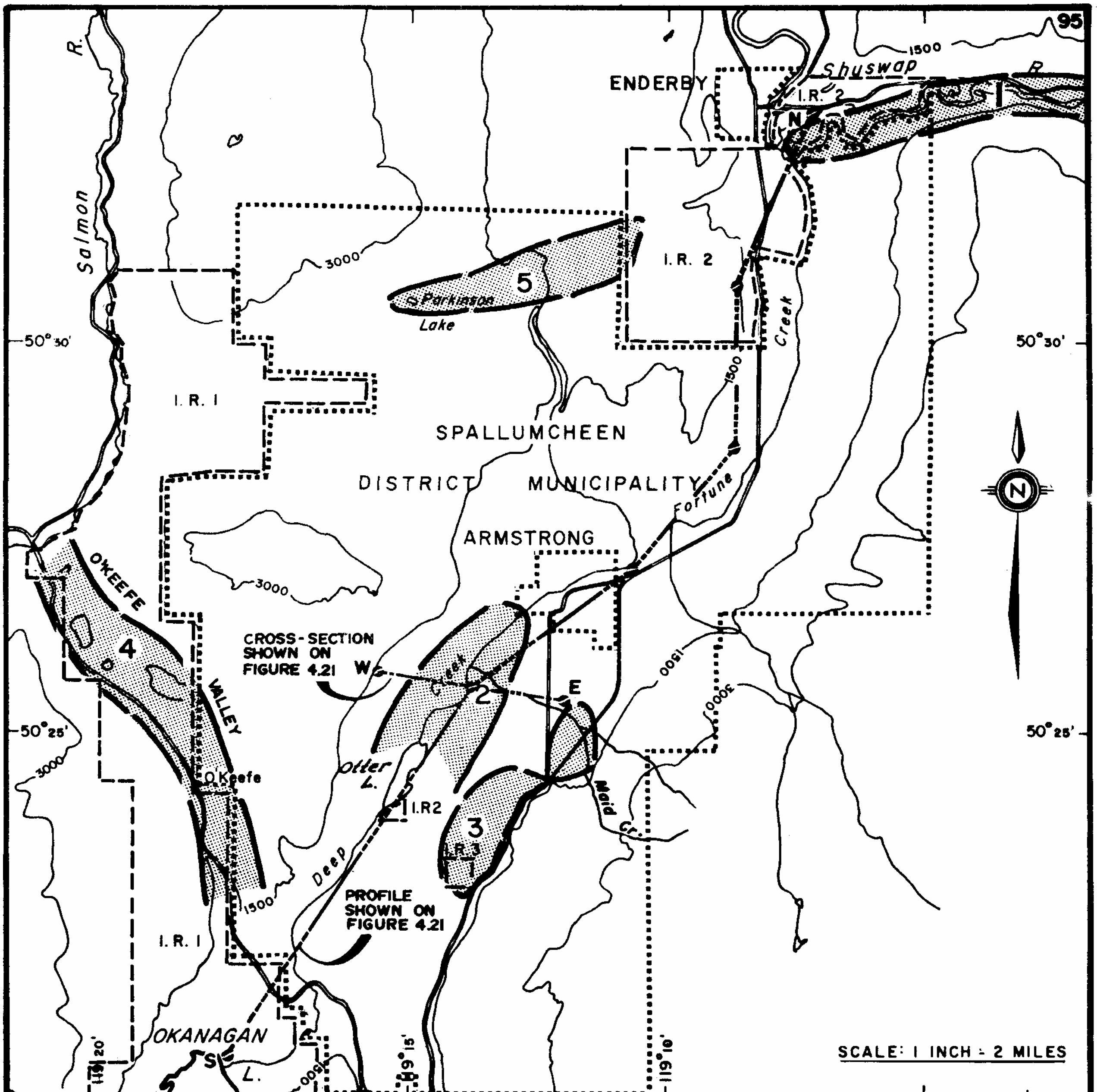
Concurrent with the investigations of the relative magnitude of groundwater flows in selected tributaries, a seismic survey and drilling program was undertaken in the Spallumcheen Valley, between the north end of Okanagan Lake and the Shuswap River at Enderby, and in the O'Keefe Valley extending to the northwest to determine if there was significant groundwater inflows from these areas to Okanagan Lake (Figure 4.24). Some seismic work and test drilling was also conducted in the south end of the Okanagan Valley near Okanagan Falls.

In the northern portion of the Okanagan Basin, bedrock appearing on the surface at about 2,500 foot elevation is covered with thin unconsolidated deposits down to the 1,500 foot ground contour. Below elevations of 1,500 feet numerous fan-delta deposits of gravel and sand occur, particularly on the east side of the Valley. Coarse sand and gravel deposits on the west side are associated almost entirely with the O'Keefe tributary valley and the lower part of the Deep Creek valley. The deposits of the main valley found at or near the surface are commonly silt and some clay.

The thickness of the valley fill is known in the north end of the Okanagan Valley, where seismic profiles were obtained to determine the position and shape of the bedrock beneath the valley floor. The lowest elevation was found to be south of Armstrong, where the bedrock floor is about 600 feet below sea level. The thickness of the valley fill near Armstrong (elevation 1,200 feet), is therefore about 1,800 feet.

An important result of the test drilling has been the regional picture which car. be constructed of the surficial deposits of the main valley (Figure 4.25). These can be divided into a lower and upper part. The lower part of the sediments show an alternating sequence of till, day and silt, sand and gravel zones divided into units A to F. This sequence ranges from about 300 feet thick in the north near Enderby to about 750 feet thick south of Armstrong. The till zones range from about 40 to 100 feet thick; silt, sand and gravel zones are about 80 to 220 feet thick; and a clay-silt zone is about 100 feet thick. Changes within these layers may be due to non-deposition in some parts of the valley, or to removal and subsequent replacement by later glaciations. The uppermost of these silt, sand and gravel zones is the one in which most of the deep test holes were completed as observation wells. The units A to F have been denoted in ascending order.

Overlying the succession of tills and sands, and comprising the upper part of the main valley deposits, is 500 to 1,000 feet of sediments that are mainly silt. There are some sand beds in the upper part of the sequence, and of particular importance to this study, are the thick sands occurring in the Maid Creek area south of Armstrong. The sands in the upper part of the surficial deposits are commonly fine to medium-grained angular sands.



LEGEND

5	PARKINSON LAKE BEDROCK CHANNEL AQUIFER
4	O'KEEFE VALLEY AQUIFER
3	UPPER PART OF SURFICIAL DEPOSITS — FAN DEPOSITS
2	UPPER PART OF SURFICIAL DEPOSITS — VALLEY CENTRE
1	LOWER PART OF SURFICIAL DEPOSITS
— —	AREA BOUNDARIES, APPROXIMATE

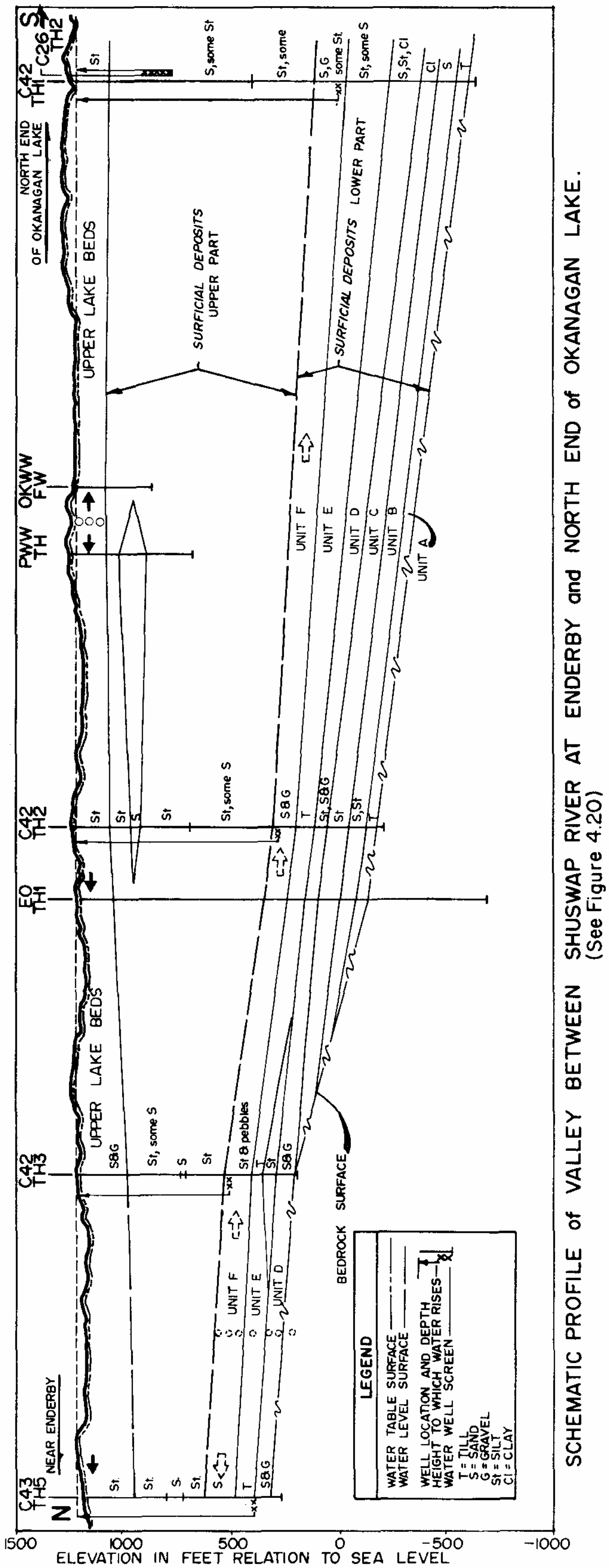
INDIAN RESERVE BDY.

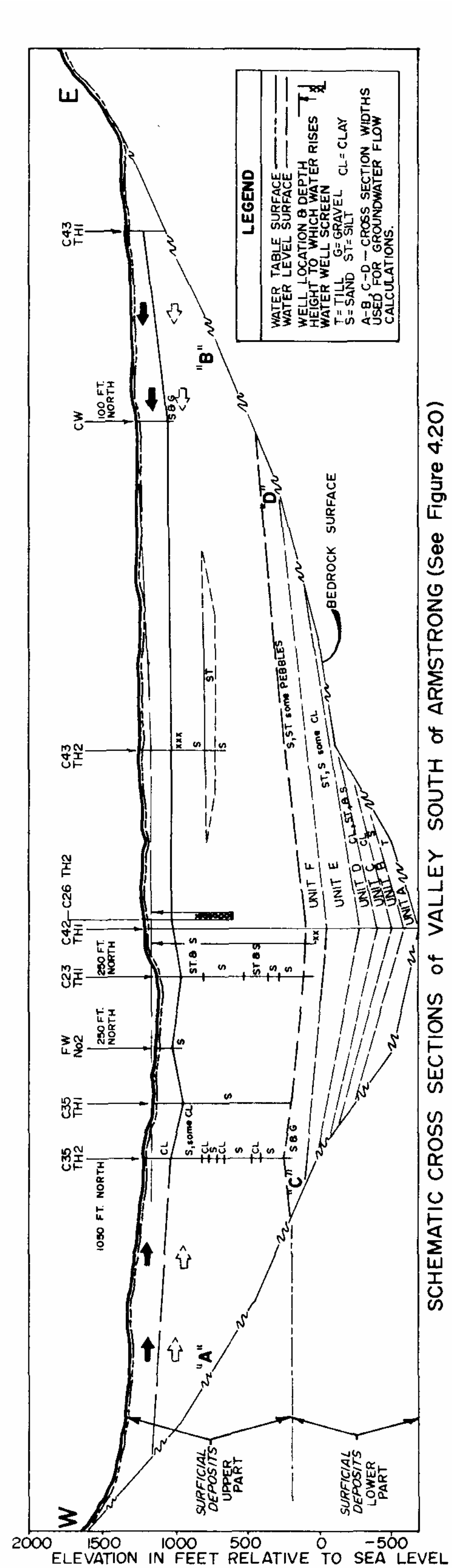
DISTRICT MUNICIPAL BOUNDARY

CROSS-SECTION & PROFILE VIEWS.

GEOLOGY IN SPALLUMCHEEN VALLEY
NORTH OKANAGAN LAKE

Figure 4.24





SCHEMATIC OF

HYDROGEOLOGICAL SECTIONS SHOWING SURFICIAL DEPOSITS and GROUNDWATER FLOW in the NORTH END of the OKANAGAN VALLEY.

Figure 4.25

Considerable local variations are anticipated within the upper part of the surficial deposits. Local deposits of gravel and sand on the east side of the valley are attributed to melt-waters from tributary valleys, and sands on the west side of the maid creek cross-section may have been derived in association with melt-waters discharging to the south from Deep Creek. It may also be observed that there is down-valley thickening of both the upper and lower parts of the valley fill deposits.

The probability of large quantities of groundwater flow from adjacent valleys,.the Shuswap River Valley and the Salmon River Valley, is remote. Some water may enter the Okanagan River Basin down the O'Keefe Valley, but it is unlikely that there is groundwater flow from the Shuswap Valley.

From the underflow calculations, a total rate for groundwater movement towards Okanagan Lake of about 3-1/3 cfs (2,370 acre-feet per year) has been determined. This figure seems reasonable compared to a recharge rate of 6 cfs (4,350 acre-feet per year) from one inch of precipitation, which is assumed to reach the water table over a recharge area estimated as 80 square miles.

4.5.4 Aquifers in the Surficial Deposits

The surficial deposits described in the previous section contain the important aquifers in the area. Aquifers in the units D and F of the lower deposits may extend from Enderby on the Shuswap Rive to Okanagan Lake. The aquifers consisting of sand and gravel with silt, vary in permeability from a low of 10 Imperial gallons per day per square foot, to a high of about 300 Imperial gallons per day per square foot. These variations in permeability occur from localities where the aquifers consist of dean sand and gravel. Aquifer thicknesses range from about 80 to 150 feet.

Aquifers in the upper part of the surficial deposits are smaller in area, but vary more widely in thickness. In the area south of Armstrong, aquifer materials average about 600 feet thick towards the center of the valley. Near the valley sides, fan deposits form sand and gravel aquifers having known thicknesses from 10 to 50 feet and are probably thicker.

The aquifers in both the upper and lower parts of the surficial deposits are confined, and the water level rises above the top of the aquifer. At some locations, the aquifers are artesian. Conditions of local artesian flow are associated with the fan deposits flanking parts of the east valley wall.

The O'Keefe Valley aquifer extends throughout the entire length of the O'Keefe Valley. The maximum known thickness of the deposits in this valley is 575 feet. of which the saturated thickness is close to 350 feet. A second important aquifer trending from southwest to northeast, occurs in a bedrock channel about four and one half miles north of Armstrong. The aquifers in this valley and in the O'Keefe Valley are unconfined (or water table) aquifers.

4.5.5 Well Yields, Quality and Cost

(a) Melt Yields

Well yields, in the depth range 700 to 1,200 feet, vary considerably in the main valley area. Yields range up to 10 Imperial gallons per minute for wells suited to domestic supplies, to 500 Imperial gallons per minute or possibly more for wells suited to industrial or irrigation requirements. In the Enderby area, yields of 500 Imperial gallons per minute or over are anticipated from wells 800 to 875 feet deep. Yields from similarly deep wells elsewhere in the main valley are anticipated to be low, from 30 to 250 Imperial gallons per minute.

Wells in the depth range of 300 to 600 feet in the Armstrong area may produce from 200 to Q50 Imperial gallons per minute. In the O'Keefe Valley yields of up to 500 Imperial gallons per minute are anticipated from wells completed to depths of about 550 feet. The narrow unconfined aquifer four and one half miles north of Armstrong is expected to have well yields of about 50 Imperial gallons per minute.

The total quantity of recoverable water available by water mining has been calculated as 66,500 acre-feet, most of which is located in the O'Keefe Valley. However, as the recharge from precipitation in the O'Keefe Valley is equivalent to only about 3/4 cubic feet per second (540 acre-feet per year), the length of time required to replenish this supply would be about 100 years.

The potential available for groundwater withdrawal without depleting supplies is estimated at from 3-1/3 to 6 cfs. It is believed that present utilization of groundwater is well below the lower figure. This potential does not include that of the Enderby area which falls in the hydrologic regime of the Shuswap River Valley.

(b) Quality

Analysis of groundwaters sampled in the study area show the chemical quality of the water is very good. The total dissolved solids content is commonly in the range of 200 to 500 parts per million, with the dissolved constituents being primarily calcium and magnesium bicarbonates. The water is quite suitable for human consumption and for irrigation use and should require little or no treatment for industrial purposes.

(c) Cost at Well Head

The economics of groundwater development indicate that for one locality, limited preliminary groundwater investigations, including seismic work, test drilling and pump testing, may cost about $45,000. High yield production wells producing about 800 Imperial gallons per minute, and including pump and pump house, are estimated to cost from $25,000 to $50,000. The actual costs will vary with such factors as drilling conditions and well diameter.

Annual costs including amortization, interest charges over 25 years, and power, operation and maintenance will vary between $3,600 to $7,600. These well costs are based on the production of four acre-feet per day over a period of 90 days, and are equivalent to a cost of $10 to $20 per acre-foot at the well head.

Equivalent capital cost for a small domestic water supply yielding about 10 Imperial gallons per day, may run between $4,000 and $6,000.

4.5.6 Summary

The total quantity of groundwater available from water mining in the North Okanagan is estimated to be about 66,500 acre-feet, most of which is located in the O'Keefe Valley aquifer. However, as the recharge from precipitation to the O'Keefe Valley is only about 540 acre-feet per year, the length of time to replenish this aquifer would be about 100 years.

The potential available for groundwater withdrawal in the North Okanagan without depleting supplies is estimated to be 3-1/3 cubic feet per second, or 2,370 acre-feet per year.

The total groundwater flow in six tributaries examined is small and not considered significant when compared to the surface flows of these tributaries. Fan deposits at the mouths of these creeks may provide limited sources of groundwater for local use.

Groundwater studies within the main valley have been confined almost entirely to the north end, and no studies have been carried out with regard to groundwater return flow from irrigation, nor has any work been done on which to base estimates of groundwater flow at the south end of Okanagan Lake.