CHAPTER 6
Limnology of the Main Valley Lakes

The main valley lakes are an integral part of the Okanagan Basin drainage system. They provide a temporary storage of water that falls as rain or snow on the watershed, and in turn provide a year-round supply of water for the residents of the basin. The lakes also offer recreational enjoyment in the form of swimming, boating and fishing which is becoming increasingly important to people and provides significant sources of monetary return to the Okanagan economy. The well being or maintenance of the quality of this lake water is therefore an important aspect in the management of the basin's water resources.

The productive capacity of a lake is a key to its beneficial use by people, particularly in respect to recreation and fishing. Lakes that are extremely deep, cold and have few nutrients provide little opportunity for water based recreation and generally are almost desert like. On the other hand extremely warm, shallow enriched lakes are subject to heavy algal blooms, unpalatibility and a lack of aesthetic appeal. These lakes will not produce desired sport fish in spite of their high productivity, and water based recreation is often unpleasant in these instances. A middle approach; moderately productive waters - but not too productive, warm - but not too warm, aesthetically pleasant and good producers of desired fishes is the most beneficial to man.

The biological community of a lake is composed of a very complex system of interdependent populations ranging from microscopic plants and animals to the much larger aquatic plants and fishes. These interdependent populations are very susceptible to subtle changes in their physical-chemical environment, and these changes require specific adaptations by the plants and animals inhabiting such waters. Most of these changes are not noticeable until the quality of lake waters has deteriorated to the point of becoming aesthetically unacceptable for recreation, or the cost of treating this water for consumptive use becomes exorbitant.

Local concern for the present and future trophic state of the basin lakes was one of the primary reasons for initiation of the Okanagan Basin Agreement. The limnological studies undertaken (limnology is the science concerned with the study of physical, chemical and biological conditions in freshwater lakes) provided a historical perspective of the main lakes aging processes, documented as completely as possible the present trophic state of the lakes, and included projections of what might be expected to happen to the water quality of lakes under varying economic growth conditions and water management alternatives. Ten different studies were carried out to determine the chemical and physical distribution of the major chemical elements in each of the main valley lakes, and the effect of these elements on biological populations and communities in these lakes. These results were also compared to past studies, particularly those of Clemens et al in 1935, (15) to assess changes in the condition of the lakes attributable to man's influence since 1935,

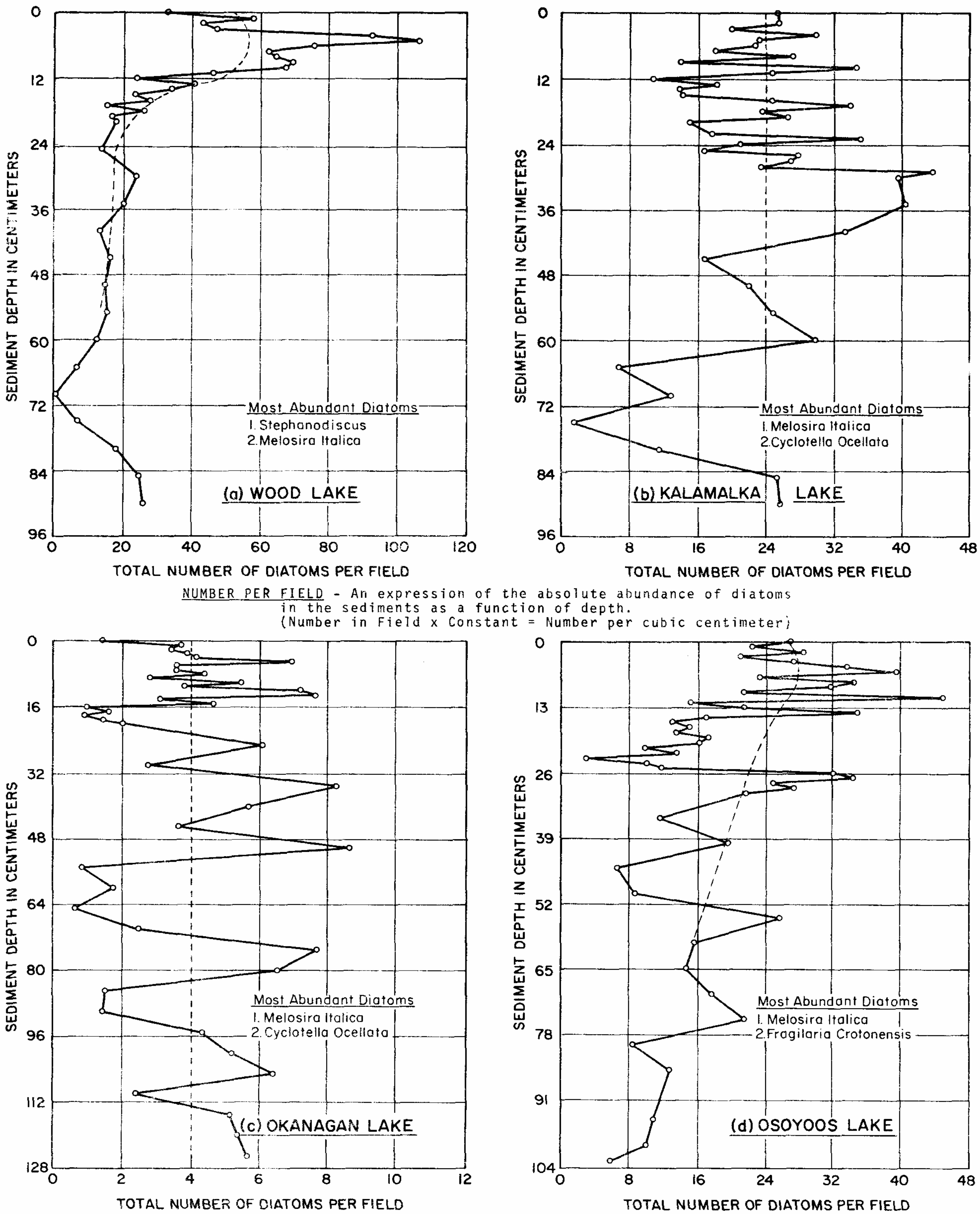
Major findings of these studies are presented in this chapter. Some of the key findings are also presented on drawings M3 to M10 in the Map Section at the back of this report. The effect of future economic growth on the quality of the lakes is discussed in Chapter 15.

6.1 GEOLOGICAL RESULTS

6.1.1 Historical Changes in Biological Growth (Paleolimnology)

Analysis of carbon content and diatom microfossils for sediment and core samples of the main valley lakes indicate that an increased rate of biological production commenced about 100 years ago in Osoyoos Lake and Okanagan Lake. This corresponds to the first major settlements in the valley and the development of land around these lakes for agricultural purposes, particularly beef cattle and horses. This activity is considered to have remained the dominant factor affecting lake productivity until the 1940's when the tree fruit industry became firmly established and orchard cover crops became widespread with the advent of sprinkler irrigation.

In more recent years, the rapid increase in population and resulting waste products, particularly sewage treatment plant and other positive waste discharges to the lake system, have become the dominating factor affecting lake productivity. Skaha Lake, which was not a center for agricultural development has shown a sharp increase in biological production over the past 25 years, with only minor changes before that time. This is considered to be due to urban development in the City of Penticton, and the discharge of it's treated waste effluent into Skaha Lake commencing in 1947. Changes in Kalamalka and Wood Lakes are also of more recent origin. A carbonate cycle in Kalamalka Lake appears to provide a unique self-cleansing system which is considered to have been effective in preventing any noticeable deterioration in the quality of this lake despite nutrient increases. A rapid deterioration in Wood Lake commenced about 40 years ago and is considered due in part to agricultural development in the Wood Lake, Vernon Creek area, and in part to the diversion of water from Vernon Creek upstream at Wood Lake for irrigation purposes. The latter decreased the average inflows to Wood Lake and increased the retention time of water in this lake from approximately 12 years to 30 years. These changes are indicated in profiles of carbon content and diatom abundance from core samples of the sediments of the main valley lakes (carbon content profiles are shown on Maps M2 to M10 at the back of this report, and diatom abundance as a function of depth is shown in Figure 6.1). Diatoms are one of the most ubiquitous forms of microscopic plant life found in freshwater lakes and are



ABUNDANCE OF DIATOMS IN LAKE SEDIMENTS AS A FUNCTION OF DEPTH FOR WOOD, KALAMALKA, OKANAGAN AND OSOYOOS LAKES. Figure 6.1

generally indicative of oligo-mesotrophic conditions when they are the most abundant species. Other forms of algae such as blue green replace diatoms as the most abundant species in enriched or eutrophic lakes.

The diatom analysis for Wood Lake sediments is the most revealing one in terms of our understanding of the eutrophication of this lake (Figure 6.la). Above a depth of about 18-20 centimeters, (8 inches) the lake rapidly increases in production to 110 diatoms per field, and then falls again at the sediment surface. The decline of diatoms at the surface is a clear indication of the predominance of blue green algae in recent years at the expense of diatom growth.

Kalamalka Lake (Figure 6.1b) and Okanagan Lake (Figure 6.1c) show a considerable variation in total diatom numbers, but a reasonably constant average of 24 and 4 diatoms per field, respectively. The decline in diatom numbers in Okanagan Lake at a sediment depth of 16 centimeters may be associated with some physical-chemical change in the lake resulting in low nutrient availability.

The number of diatoms in Osoyoos Lake (Figure 6.1d) appear to have increased slowly over a long period of time to a maximum of 44 per field at a sediment depth of 8-12 centimeters. The average number in the surface sediments is about 24 per field, which indicates a decline in diatoms and an increase in blue-green algae in recent years.

6.1.2 Limnogeology of Main Valley Lakes

The Okanagan Valley is a structural trench overlying a system of sub-parallel, linked faults that separate the late Paleozoic or early Mesozoic Monashee groups of metamorphic rocks from the rocks of differing lithology but similar age west of the Valley. This trench is partially filled by several hundred feet of unconsolidated material. The thickness of this unconsolidated material underlying these lakes differs from place to place but typical minimum thicknesses under the centers of the lakes are presented in Table 6.1. The trench is apparently continuous under the Okanagan River between Skaha and Okanagan Lakes as well as under Vernon Creek between Wood and Kalamalka Lakes.

It is likely that the unconsolidated material in the trench was deposited in association with the earlier glaciations of the Pleistocene Epoch. The nature of the deposits is uncertain from seismic records alone, but it seems probable that during the Pleistocene geological period the Valley was the site of deposition resulting from glacial outwash, direct glaciation, and lacustrine fluvial sedimentation. During deglaciation of a number of terraces were formed as the lowering of post-glacial lake levels were repeatedly arrested. A previously undiscovered terrace 50 feet below the present lake level, appears to be a remnant of low stage of Okanagan and Skaha Lakes.

TABLE 6.1

THICKNESS OF UNCONSOLIDATED MATERIAL

UNDERLYING MAIN VALLEY LAKES

	THICKNESS IN FEET
Skaha Lake - north of Kaleden	1200
Okanagan Lake - Penticton to Squally Pt.	1500
Okanagan Lake - Squally Pt. to Westbank	1600
Okanagan Lake - Kelowna area	1200
Okanagan Lake - Wilson's Landing-Okanagan Centre	1200
Okanagan Lake - Ok Centre to Vernon	1200-2000
Okanagan Lake - Armstrong Arm	1300 +
Wood Lake	400 +
Kalamalka Lake	300-400

The prominent silt and clay cliffs that border Skaha and southern Okanagan Lake were formed during this period of glacial downwashing and degradation (16). It has been estimated that the deglaciation of the Interior Plateau of B.C. was well advanced by 9,750 B.P. (Before Present) and by 8,900 B.P. all ice was melted and the glacial lakes had been drained (17). From this time to the present day, the main valley lakes of the Okanagan Basin have been in existence. Data from these studies do not allow a direct calculation of total accumulation of recent lake sediment, but if one uses a sedimentation rate of 1 millimeter of compacted sediment per year, this would yield an accumulation of 8.9 meters (29 feet) of sediment in 8,900 years.

Bathymetric charts have been constructed from soundings gathered as part of the geological study (See map section at back of report). Wood Lake is the smallest of the mainstem lakes and consists of a single shallow basin with the maximum depth of 100 feet (34 meters). Kalamalka Lake contains two distinct basins separated by ridge in the unconsolidated material filling the structural trench. The most unusual feature of Kalamalka Lake is the presence of flat terraces of calcium carbonate ($CaCO_3$) in the littoral (near shore) zones that are found chiefly at the southern end of the lake. These terraces are formed by the precipitation of $CaCO_3$ from surface (epilimetic) waters during the summer.

The bottom of Okanagan Lake is characterized by irregular undulations that presumably reflect glacial modifications in the Valley from the last ice age. A large drumlinoid structure exists under 200 feet (61 meters) of water off Squally Point, and an underwater valley 700 feet (213 meters) deep was discovered just north of Trepanier.

Skaha Lake is composed of two distinct basins that are separated by a bedrock sill at a depth of about 80 feet (24 meters). Osoyoos Lake is, in fact, three lakes with sand deposits dividing them. The northern-most of these "lakes" has three distinct basins and attains a maximum depth in excess of 200 feet (61 meters), The central basin (about 100 feet deep) and the southern basin (about 75 feet deep) are hence partially shielded from significant sedimentation by the northern-most basins. This physiographic condition has resulted in greater accumulations of organic carbon and mercury in the sediment samples taken south of Osoyoos.

Approximately 150 surface sediment and core samples from the Okanagan main valley lakes were analyzed to determine particle size distribution. The highest silt content was noted in Wood Lake, while the highest clay content was observed in the deepwater sediments of Okanagan Lake. The sediment of Skaha and Osoyoos Lakes have very similar particle size distributions.

The terraces of Kalamalka Lake contained about 16 percent sand with the remainder essentially silt. Sedimentation rates, and the mean concentrations of carbon and phosphorus in the surficial sediments of the main valley lakes are shown in Table 6.2

Mercury content of the sediments of the Okanagan main valley lakes were determined, and surficial sediments of Wood Lake show the highest mercury content. Most of this mercury occurs as a sulphide and indications are that methylation(chem1cal process of introducing the methyl groups into) and hence its entry into the food chain, is unlikely to occur. The mercury content of Kalamalka Lake is also relatively high, and presents a potential danger if it enters the food chain. The mercury content in the sediments of most of Okanagan, Skaha and Osoyoos Lakes was considerably lower than values noted in Wood and Kalamalka (Figure 6.2).

6.2 PHYSICAL LIMNOLOGY

The principal physical features of the six main valley lakes are portrayed in Figure 6.3. Wood Lake, considered the most eutrophic of the six lakes, lies at the head of the chain, while Osoyoos Lake at the lower end straddles the International Border. Both Wood and Kalamalka Lakes, in terms of drainage, are part of the Vernon Creek sub-basin, which flows into the Vernon Arm of Okanagan Lake. The watershed of this sub-basin is small and hence most drainage water has had a relatively long residence time in these two lakes - 30 to 65 years respectively (1970 conditions). In 1971 the importation of water from Okanagan Lake to the Vernon Creek Basin, for industrial cooling purposes has significantly increased the flow into Wood and Kalamalka Lakes, lowering these theoretical residence times to 14 years and 45 years respectively. The flow into Okanagan Lake from the Vernon Creek sub-basin represents only about 10% of the total inflow to Okanagan Lake in an average year, so that any effect of this sub-basin on the whole of Okanagan Lake is small.

TABLE 6.2

LIMNOLOGICAL CONDITIONS OF THE, MAIN VALLEY LAKES

Recorded from Studies in 1970, 1971 and 1972*1

PARAMETER	UNIT OF MEASUREMENT	MAINSTEM LAKES				
		KALAMALKA	OKANAGAN	SKAHA	OSOYOOS*2	WOOD
PHYSICAL						
Secchi Disc Visibility-Seasonal Average*3	feet (ft) and meters (m)	29.5 ft (9 m)	26 ft (8 m)	14.8 ft (4.5 m)	10.8 ft (3.3 m)	8.2 ft (2.5 m)
- 1971 Maximum	feet (ft) and 1971 date	59 ft (Apr 25)	39 ft (Apr 26)	23 ft (Apr 29)	14.7 ft (May 20)	17.2 ft (May 5)
Maximum Summer Surface Temperature	degrees centigrade (C) and Fahrenheit (F)	28°C (82° F)	25.3°C (77° F)	25°C (77° F)	-	27.5°C (81° F)
Hypolimnion Warming Rate	degrees centigrade per month	0.18° C/month	0.06°C/month	0.37°C/month	0.54°C/month	0.26°C/month
Areal Oxygen Depletion Rates	milligrams per sq.cm.per day (mg/l/day)	-	-	0.148	0.038	0.065
Bottom Oxygen Concentrations in Late Summer	parts per million (ppm) with percentage saturation in brackets (% Sat.)	11.3 (89%)	10.7 (78%) Average	8.3 (70%)	4.0 (40%) Central Basin	2.2 (18%)
CHEMICAL						
Average Seasonal Concentration						
- Phosphorus (PO_4-P)	1 milligram per liter = part per million (ppm)	.004	.002	.015	.015	.083
- Nitrogen (NO_3-N)	" "	.023	.020	.010	.016	.026
- Calcium Ca^{++})	" "	37.9	32.9	32.8	34.2	28.8
- Magnesium (Mg^{++})	" "	17.1	8.4	8.4	8.7	17.3
- Sodium (Na^+)	" "	15.9	9.1	9.5	9.9	19.0
- Potassium (K^+)	" "	4.6	2.2	2.1	2.3	4.2
- Bicarbonate (HCO_3^-)	" "	177.3	131.8	129.9	138.1	177.4
- Sulphate (SO_4^{--})	" "	55.7	27.2	27.6	28.5	30.4
- Chloride (Cl^-)	" "	1.3	1.1	1.4	1.6	2.5
- Fluoride (F^-)	" "	0.3	0.2	0.2	0.2	0.3
BIOLOGICAL						
Chlorophyll - Mean Summer	Micrograms per liter (ug/l)	2.5	5.0	31.0	23.0	50.0
Phytoplankton Density, Average Annual*4	number per milliliter (#/ml)	400	1,800	3,740	5,500	7,900
Periphyton Production	milligrams per square meter per day (mg/m^2/day)	124	225	231	258	481
Zooplankton Average Density	number per square centimeter ($\#/cm^2$)	136	101	233	76	139
Bottom Fauna	number per square meter ($\#/m^2$)	1,087	2,178	6,913	5,502	753
Zooplankton Crustaceans	number per square centimeter ($\#/cm^2$)	136	101-188	236-238	76-161	139
Fish Species	number	14	15	15	20	10
Ratio of Coarse Fish to Salmonids	-	1.08:1	1.04:1	2.03:1	1.38:1	7.3 :1
Salmonids	percent (%)	49%	49%	33%	40%	12%
GEOLOGICAL						
Depth to Man's Influence in Sediments	centimeters (cm) and inches (in.)	29 cm (11.5 in)	10 cm (3.9 in)	21 cm (813 in)	28 cm (11 in)	20 cm (719 in)
Rate of Sedimentation	millimeters per year (mm/yr)	2.9	1.0	2.1	2.8	2.0
Carbon Content Surface Sediments-Organic	kilograms (kg)	not estimated	1,750,000	315,000	318,000	98,000
-Inorganic	kilograms (kg)	" "	500,000	71,200	57,700	113,000
Inorganic Phosphorus Accumulation in Surface Sediments	kilograms per year (kg/yr) and pounds per year (lb/hr) based on 1971 data	" "	76,700 kg/yr (170,000 lbs/yr)	11,500 kg/yr (25,300 lbs/yr)	11,800 kg/yr (26,000 lbs/yr)	1,640 kg/yr (3,600 lbs/yr)
CURRENT CONDITION						
Trophic State		Oligotrophic	Oligomesotrophic	Eutrophic	Eutrophic	Eutrophic
Water Quality Based on Present Use		Excellent	Good	Acceptable	Acceptable	poor

*1 - Extracts of Average Lake Conditions Only from Technical Supplement V - See Text

*2 - Portion of Basin in Canada Only

*3 - Monitoring Period Between April and October 1971

*4 - Stein, Coulthard, 1971 (18)

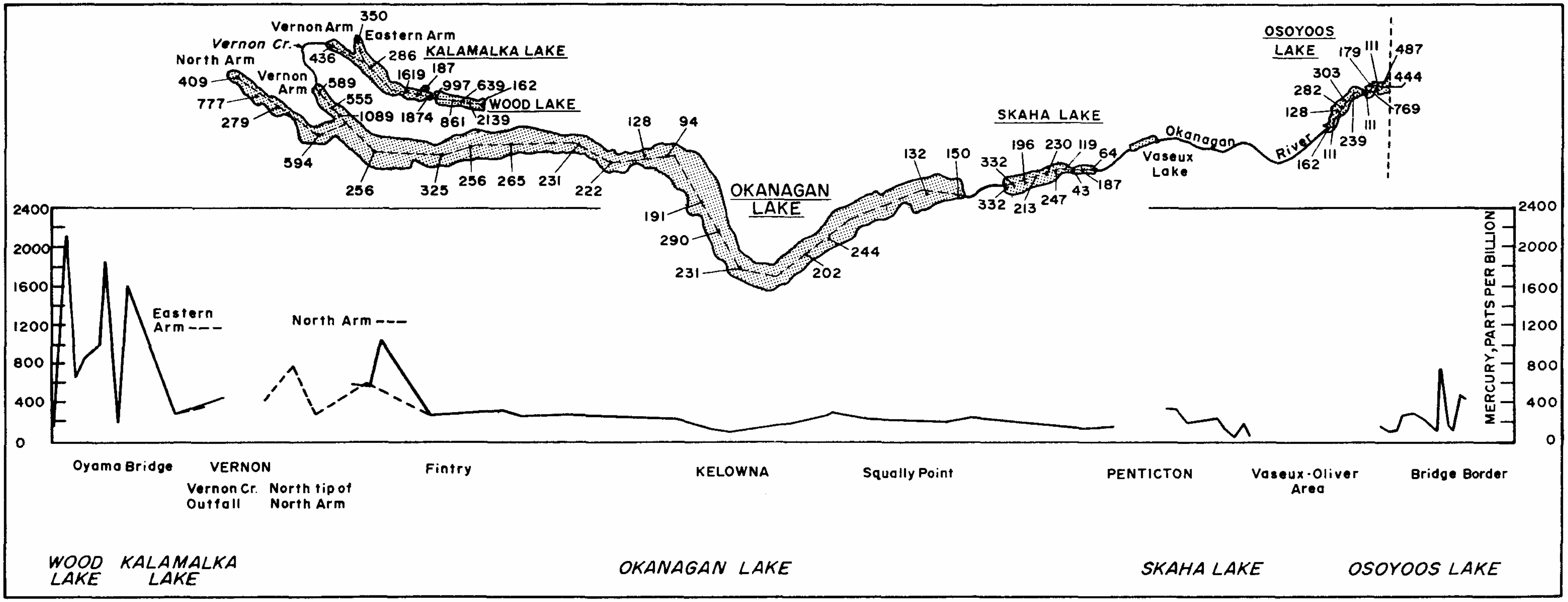
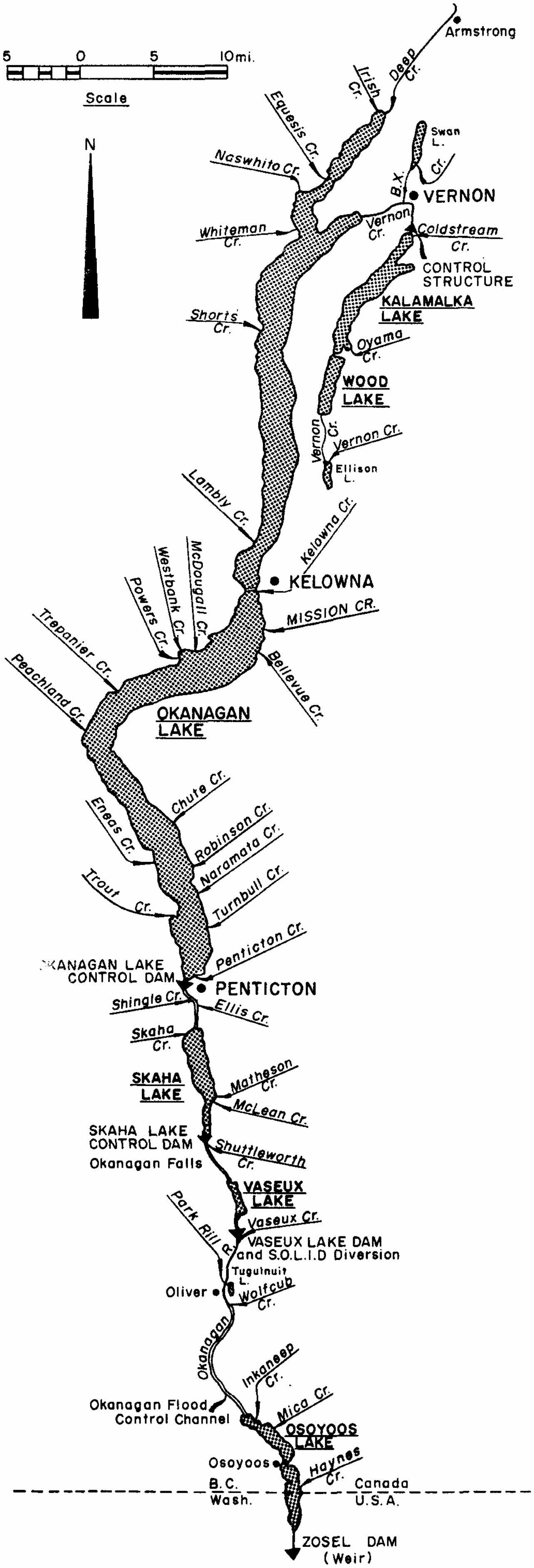


Figure 6.2

PROFILE OF MERCURY CONTENT OF SEDIMENTS IN THE OKANAGAN LAKES SYSTEM ALONG THE DEEPEST PART OF EACH LAKE. MERCURY IN PARTS PER BILLION.



WOOD LAKE	
Surface Water Level - High	1284.0 *2
- Low	1282.6 *2
Surface Area - Acres	2300
Mean Depth - Feet	72
Maximum Depth - Feet	112
Total Volume - Acre Feet	162,200
Mean Annual Outflow-Acre Feet	14,000 *1
Water Residence or Renewal Time - Years	14 *1

KALAMALKA LAKE	
Surface Water Level - High	1284.0
- Low	1282.6
Useable Storage - Acre Feet	13,100
Surface Area - Acres	6,400
Mean Depth - Feet	193
Maximum Depth - Feet	465
Total Volume - Acre Feet	1,233,000 *1
Mean Annual Outflow - Acre Feet	33,000
Water Residence or Renewal Time - Years	45 *1

OKANAGAN LAKE	
Surface Water Level - High	1123.8
- Low	1119.8
Useable Storage - Acre Feet	337,000
Surface Area - Acres	86,000
Mean Depth - Feet	250
Maximum Depth - Feet	800
Total Volume - Acre Feet	21,250,000
Mean Annual Outflow-Acre Feet	356,000
Water Residence or Renewal Time - Years	60

SKAHA LAKE	
Surface Water Level - High	1108 *3
- Low	1106 *3
Surface Area - Acres	4,970
Mean Depth - Feet	85
Maximum Depth - Feet	187
Total Volume - Acre Feet	453,000
Mean Annual Outflow-Acre Feet	385,000
Water Residence or Renewal Time - Years	1.2

VASEUX LAKE	
Surface Water Level-Normal-Feet	1073 *3
Surface Area - Acres	680
Mean Depth - Feet	21
Maximum Depth - Feet	83
Total Volume - Acre Feet	14,300
Mean Annual Outflow-Acre Feet	429,000
Water Residence or Renewal Time - Years	.03

OSOYOOS LAKE (including portion in U.S.A.)	
Surface Water Level-Normal-Feet	913 *3
Surface Area - Acres	5,800
Mean Depth - Feet	49
Maximum Depth - Feet	206
Total Volume - Acre Feet	323,000
Mean Annual Outflow-Acre Feet	479,000
Water Residence or Renewal Time	0.7

*1 Values based on theoretical estimates of average flows in Vernon Creek (Technical Supplement 1) plus effect of cooling water pumped from Okanagan to Hiram Walker Plant and discharged to Vernon Creek (18.5 acft/day)

*2 Includes Surface Storage from Wood Lake

*3 Water Levels not Controlled for Storage

THE MAIN VALLEY LAKES and THEIR PHYSICAL FEATURES Figure 6.3

Okanagan Lake is by far the largest of the main valley lakes in both volume and surface area, and receives the drainage waters from over 75 percent of the watershed of the Basin. While the residence time of this drainage water in Okanagan Lake is approximately 60 years, this water has retained a very high quality with the exception of shoreline areas affected by local waste sources. This lake is also the key with respect to quality in the downstream lakes - Skaha, Vaseux and Osoyoos, because nearly all the water flowing into these lakes is from discharges from Okanagan Lake. Both Skaha and Osoyoos have much smaller volumes and residence times of one year or less. Vaseux Lake is considered more an enlargement of the Okanagan River Channel with a residence time of only a few days.

The residence time of water in a lake has important consequences in terms of water resource management. Large lakes with long resident times (small inflows) will generally take longer to deteriorate because of their size and limited natural stream loadings. However, once they have regressed to a state of poor quality, it will take many years for them to recover, even under rigorous waste control programs. Alternatively, lakes with a short residence time will reflect changes much more quickly, providing the drainage water entering the lake is of a high quality itself. It is therefore important, if not essential, that the quality of Okanagan Lake be maintained in as good a condition as possible, not only to maintain the present value of this lake itself, but also to ensure a reasonable quality of water in the lower lakes - Skaha, Vaseux and Osoyoos. Kalamalka Lake is also in the same category as Okanagan Lake, but it does not have the same effect on the downstream system.

The results of other physical observations are shown in Table 6.2 including water transparency, temperature and heat budgets.

6.3 MATER CHEMISTRY RESULTS

The relative abundance of major ions in a lake is a reflection of natural lake processes modified by the addition of soluble elements and compounds from the watershed. The distribution of ions within a given lake or among lakes is a result of biological activity, surface runoff, groundwater, precipitation and most importantly, the lake sediment-water interaction.

The relative abundance of major ions within each of the main valley lakes was similar to the average of the world's freshwater lakes. Major ions include bicarbonate, calcium, sodium, potassium, magnesium, sulphate, and chloride. Concentrations of major ions in the main valley lakes (1970-71) varied from lake-to-lake but showed little seasonal variation (Table 6.2).

The concentrations of major ions in the lakes of the Okanagan Drainage basin are quite high, an order of magnitude higher than lakes on the Canadian Shield (19), and higher than the world average for fresh water (20). These concentrations normally come from soluble geological materials in the watershed, including limestone, glacial drift, clay-silt terraces and conglomerate rock or basaltic areas, but within the Okanagan Basin, evaporation may also be an important reason for the high concentrations found.

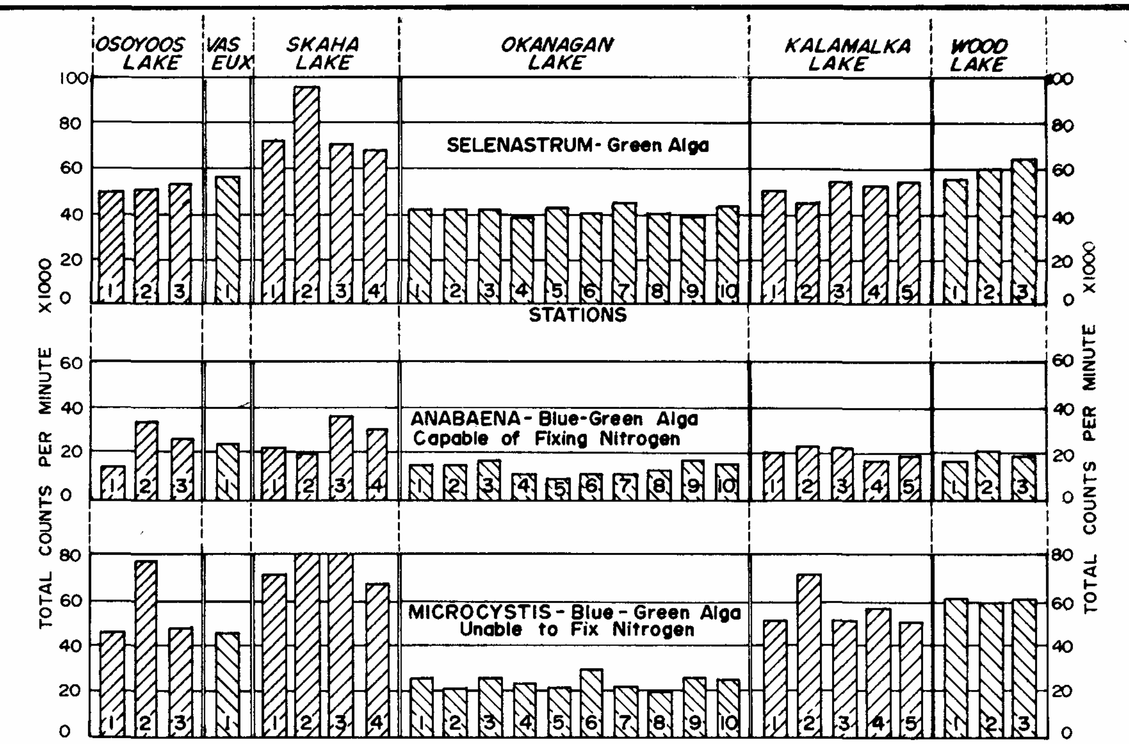
The main valley lakes also exhibit seasonal, and lake-to-lake variation in average nutrient (nitrogen and phosphorus) content. The seasonal variations generally correspond to observed increases in algal biomass. The relative fertility of water from various sampling points in each of the fakes is shown in Figure 6.4a for the three different species of test algae. Skaha Lake appears to possess by far the most suitable conditions for algal growth, while Okanagan Lake has the least potential of the main valley lakes. Of more interest however, is the growth potential of Kalamalka Lake waters under laboratory conditions. The fact that, such growth has not occurred under natural conditions support the premise that the quality of Kalamalka Lake has been preserved through its important calcium carbonate cycle. Each summer calcium carbonate is actively precipitated from the surface waters which accumulate on terraces around the shores of the lake. It is likely that the calcium carbonate also co-precipitates an abundance of the trace elements in the lake, including phosphorus, as hydroxyapatite.

There are also indications from sediment studies, that the waters of Skaha Lake may be actively precipitating phosphorus as an apatite at the present time (1971). It is possible therefore that this lake could clean itself of biologically reactive phosphorus if inputs of this element were significantly reduced.

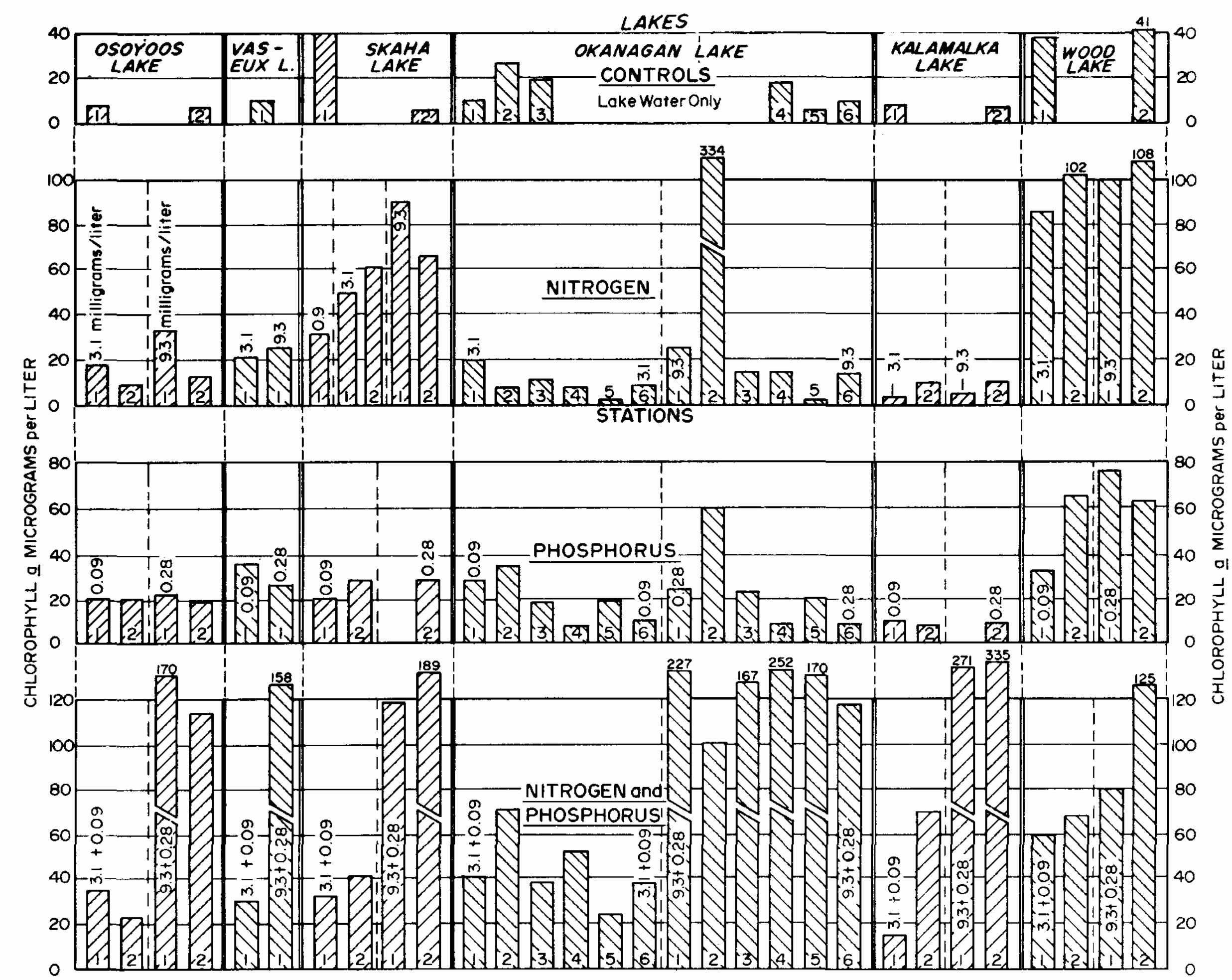
Mean oxygen concentrations in the epilimnion and hypolimnion vary considerably among the main valley lakes. Oxygen concentrations in the epilimnion of all lakes was near saturation throughout the summer season; however, values for the hypolimnion of Osoyoos, Wood and Skaha Lakes were well below saturation levels. Calculation of the areal rate of oxygen depletion (rate per unit of area) of hypolimnetic water during summer stratification provided an estimate of annual biological production for comparison among lakes. Skaha Lake exhibited the most rapid hypolimnetic depletion rate, followed by Wood and Osoyoos Lakes, respectively (Table 6.2). There has been little change in oxygen concentrations in Okanagan Lake since Clemens et al (15) measurements in 1935; however Skaha Lake has exhibited an increase in its oxygen deficit in the bottom waters over the past 25 years. Ferguson (21) in July 1948 recorded an 85% oxygen saturation in the hypolimnion of Skaha Lake, white the current survey showed only 70% saturation. The low oxygen content of the hypolimetic water of Wood Lake has not changed appreciably from values noted by Clemens et al (15) in 1935. Osoyoos Lake has also exhibited low hypolimnetic oxygen values, especially in the central Basin.

6.4 BIOLOGICAL STUDIES

The types and dominance of various forms of plant and animal populations and communities living within the lakes provide a good indication of (a) the present



PURE CULTURE BIOASSAY
RELATIVE FERTILITY of VARIOUS LAKE WATERS to GROW ALGAE in 1971.
Figure 6.4 a



NUTRIENT ENRICHMENT BIOASSAY, 1971
EFFECT OF THE ADDITION OF NITROGEN AND PHOSPHORUS TO VARIOUS LAKE WATER SAMPLES ON CHLOROPHYLL CONTENT. Figure 6.4 b

trophic state of a lake, and (b) changes that have occurred due to enrichment by comparison with previous biological records. The results of biological studies under the Okanagan Basin Agreement are summarized below under the sub-headings of phytoplankton, attached algae and rooted aquatic vegetation, bottom fauna, Zooplankton and fish. Each of these communities represent different populations and trophic (food) levels in the environment of a lake, and therefore provide a more detailed assessment of the extent to which eutrophication has occurred in a particular lake. A laboratory nutrient bioassay study was also carried out, which was designed to test the role of nutrients in regulating algal growth.

6.4.1 Role of Nutrients in Biological Production

Photosynthetic plants require light and a number of elements for their maintenance and reproduction. The more important requirements are carbon (C), hydrogen (H), oxygen (0), and nitrogen (N), since these elements make up the predominant mass of cellular substance. Of most interest however, are those essential elements that limit plant (algal) growth when in short supply. Past studies indicate overwhelmingly that phosphorus (P) and nitrogen (N)are of particular importance in lakes, Of these P is considered to be the more easily controlled element especially in north temperate lakes, for the following reasons:

(1) The element nitrogen accounts for approximately 75% of our atmosphere by weight, whereas the element phosphorus is a trace element accounting for less than .1% of the earths crustal composition. The control of the element nitrogen is therefore more difficult than the control OF trace elements such as phosphorus.

(ii) Certain bacteria and algae are capable of obtaining their nitrogen requirements directly from the atmosphere by the process of nitrogen fixation. Limiting nitrogen therefore would not control such growth and these algae are one of the main types producing nuisance blooms in the Okanagan system.

(iii) Nitrogen is considered a transient element which travels readily through a soil column to groundwater and eventually to surface waters. Conversely, phosphorus is readily bonded into a soil column and leaching or movement of this element occurs only when the amount of phosphorus exceeds the bonding capability of the soil. This difference is evidenced by the fact that most soils in the Okanagan contain adequate phosphorus concentration for plant growth, while nitrogen must be continually added as a fertilizer to ensure normal crop production.

(iv) Invasion of atmospheric nitrogen is constantly occurring in lakes at the air-water interface.

While the control of phosphorus is currently considered to be the most feasible method of regulating biological production in a lake, other elements and compounds may still cause specific problems if their amounts exceed certain safe levels. Both mercury and the pesticide DDT are two materials that have adversely affected the environment of certain Okanagan Lakes. Mercury levels in fish, particularly trout, have reached levels in Kalamalka Lake and Okanagan Lake which are affecting the reproductive capability of this species. High DDT levels have apparently been detrimental to certain animal communities within Kalamalka and Okanagan lakes, while allowing other less desirable species to flourish. The specific effects of all elements must therefore be considered in accessing the condition of a lake, along with the overall biological production that the control of phosphorus may provide.

6.4.2 Phosphorus Forms and Budgets

Phosphorus compounds in water are normally classified on the basis of separation techniques. Data reported in these 1imnological investigations are in terms of "orthophosphates" (P0») and "total phosphorus" (TP). Total phosphorus is a measure of all the phosphorus in the water whether in a soluble form or contained in plant an animal cellular matter or inert particulate matter (insoluble). Ortho-phosphorus is that portion of total phosphorus which is in a soluble form and immediately available to plant life for synthesis (Table 6.3). While it would have

TABLE 6.3

FORMS OF PHOSPHORUS PRESENT IN SURFACE AND WASTEWATERS

DISSOLVED PHOSPHORUS		PHOSPHORUS IN SUSPENSION	
Ortho-phosphate (PO_4)	As organic colloids and/or combined with an adsorptive colloid.	As mineral particles (e.g. apatite) and/or adsorbed on inorganic complexes such as Fe (OH_3)	Organisms Adsorbed on detritus and/or present in organic compounds.
Dissolved Inorganic Phosphorus			
Total Phosphorus in Filtrate			
TOTAL Phosphorus Content of Unfiltered Water			

been desirable to use orthophosphorus to establish criteria for acceptable lake loadings, this was not possible because of the following factors:

(i) In lakes orthophosphorus is in a perpetual state of flux, with release and uptake occurring in minutes, hence it is difficult to know what percentage of the available orthophosphorus one is measuring at any given time.

(ii) The concentrations of phosphorus required for optimum growth vary with species and environmental conditions. In lakes optimum growth may occur at levels below 0.01 milligrams per liter. This figure corresponds closely to the limit of available analytical procedures used in this study to measure phosphorus. In most instances, values of orthophosphorus in the lakes and streams discharging into the Okanagan Lakes were below this level of sensitivity.

Total phosphorus has therefore been used as an indicator of the biological productivity of each lake, and has been used to establish loading criteria which may achieve, within limits, an optimum level of biological production for multiple water use.

Already in some of the takes there is an overabundance of phosphorus, and other nutrients such as nitrogen are actually limiting biological production. In these cases however, phosphorus still is considered the key element and measures must be taken to reduce the supply of phosphorus to these lakes to levels where it again exerts a controlling influence on plant (algal) growth.

6.4.3 Nutrient Bioassy

To obtain a better understanding of the role of nutrients and trace metals in regulating algal growth in the main valley lakes, laboratory studies were designed to test the effect of additions of varying amounts of nitrogen and phosphorus to lake waters under controlled conditions. The results of nutrient studies are given in Figure 6.4b. The greatest growth of algae was observed in flasks receiving moderate additions of both nitrogen and phosphorus - .09 milligrams per liter of orthophosphate and 2.10 milligrams per liter of nitrate. Lower additions, though stimulatory, were well below the optimum level of growth in flasks, as was the addition of only one of these nutrients.

The above studies indicate most lakes are still well below their optimum production level, that both nitrogen and phosphorus are required before increased productivity can occur, and that the control of phosphorus input to the lake system should control biological growth.

In the more eutrophic takes (Wood and parts of Skaha and Osoyoos) nitrogen additions alone stimulated growth while phosphorus did not. This indicates that phosphorus levels in these lakes is sufficiently high to maintain optimal growth, however nitrogen is in short supply and as such limits growth.

Preliminary tests were also carried out on the effect of four trace metals on algal growth. These four were considered the more important elements other than nitrogen and phosphorus in regulating growth. Additions of boron provided little or no response even when added in combination with phosphorus and nitrogen to the lake waters. The addition of molybdenum increased the growth of algae in Osoyoos and Wood Lake waters but not for Okanagan and Skaha Lake water. Molybdenum is required for nitrogen fixation by algae. The greatest response in all lakes occurred with the additions of EDTA (organic chelating agent) and iron. Osoyoos Lake water in particular responded to the addition of iron and indicates an iron deficiency in this lake. Iron plays a key role in the synthesis of chlorophyll and in some enzymatic reactions and if deficient, may limit algal growth. EDTA additions, separately and in combination with nutrient additions stimulated growth, particularly when added in combination with iron. These trace metal tests were limited in scope, but indicate a secondary role in the control of algae growth to that of phosphorus and nitrogen, as none of the trace metals by themselves stimulated growth of any significance.

6.4.4 Phytoplankton

Those lakes dominated by blue green algae throughout most of the summer months e.g. Wood Lake - exhibited eutrophic characteristics (high biological production). Lakes in which diatoms and phyto-flagel1ates were the most abundant groups - e.g. Okanagan and Kalamalka Lakes - were generally Oligotrophic or had a low biological production. In Skaha and Osoyoos Lakes there was normally a rapid growth of diatoms in the spring followed by a pulse of blue green algae whose density appeared to a large extent dependent upon the initial concentration of available phosphorus. There was a return to diatoms in the fall period. The productivity of these lakes therefore falls somewhere between the eutrophic and oligotrophic state, with the extent of productivity closely related to the amount of available phosphorus in any one year.

6.4.5 Attached and Rooted Aquatic Vegetation

A marked increase has occurred in the abundance of rooted aquatic plants and attached microalgae (periphyton) along the shorelines of most of the main valley lakes where high biological production is caused by local sources of pollution.

Areas currently exhibiting extensive rooted aquatic plants, where harvesting has either been carried out or has been proposed, are: Vernon Arm and Kelowna shoreline south of the floating bridge on Okanagan Lake; south end of Wood Lake, patches along the east shore of Skaha Lake, Vaseux Lake, and along the west shore north and middle basin of Osoyoos Lake.

Results of periphyton studies indicate that on the average, Wood Lake produces the greatest yield of periphyton per square meter of littoral zone, and the Vernon Arm of Okanagan Lake produces the second highest yield. Growth of periphyton at both stations in Vaseux Lake and off the mouth of the Okanagan River in Skaha Lake and in Osoyoos Lake was also high. The average periphyton growth at other lake stations was substantially less, with values varying from 0.3 to 0.8 milligrams per square centimeter.

The heavy periphyton growth noted in Wood, Skaha, Vaseux and Osoyoos Lakes, was in most cases at stations located either in the vicinity of direct known sewage effluent discharges or very close to the plume of the Okanagan River. The lowest average yield of periphyton was noted in Kalamalka Lake and Okanagan Lake. Low growth was also noted along the east shore of Skaha Lake, probably due to a paucity of nutrients along this shoreline as the main flow of the Okanagan River is directed to the western shoreline by a small training dyke. The situation noted in Skaha Lake, where one sampling station exhibited high growth and others very low growth, is similar to that noted in Okanagan Lake where most stations showed very low growth while those in more eutrophic situations, located adjacent to the Kelowna and Vernon Arm areas, showed much higher growth.

The maximum growth rate of periphyton occurred in May or early June and consisted chiefly of diatoms. A second smaller pulse dominated by green or blue green algae occurred in late August, with a return to diatoms as the dominant species in the fall. Results of tests made to relate the concentrations of nitrogen and phosphorus contained in the attached algae cells to available external supplies, indicated that the ratio of nitrogen to phosphorus was 5 to 1 for periphyton growing in eutrophic waters compared to 14 to 1 in more Oligotrophic waters. Highest phosphorus values were noted in the spring samples in eutrophic locations, while nitrogen concentrations in the attached algae cells tended to be higher in late summer and early fall in all lakes.

Periphyton communities play a very important role in the nutrient balance of lakes by trapping considerable quantities of nutrients as they enter a lake. The littoral zone with its diverse biological communities also affords protection and periphyton and associated aquatic insects serve as a valuable food source for juvenile fish. In other areas, shore spawning kokanee utilize the rocky shorelines of Okanagan Lake. Any nuisance growth of attached algae in these locations, resulting from man-made nutrient inputs, would jeopardize the reproductive success of these fish.

Bottom Fauna (Bottom Living Invertebrate Animals)

For several decades limnologists have studied the relation between density and species composition of invertebrates living in the bottom sediments of lakes. Because bottom fauna tend to be sedentary organisms, they integrate temporal and environmental change and as such serve as sensitive barometers of lake change.

A comparison of 1971 data with that obtained by demons et al (15) in 1935 indicates that Okanagan Lake has become more productive over the past 35 years. Clemens et al found only 15% of the bottom fauna comprised of o1igochaetes, whereas currently they comprise over 50-60% of the fauna. There has also been a significant increase in the total number of chironomids, Pisidium, and other miscellaneous groups. The increase in abundance of oligochaetes together with the occurrence of deformed chironomids in certain regions of Okanagan Lake, is suggestive of some degree of insecticide pollution.

The current trophic conditions as deduced by distribution of benthic organisms indicates that the northern region (Vernon and Armstrong Arms) is currently mesotrophic. Evidence of pollution of the Vernon Arm by the Vernon Sewage Treatment Plant effluent was obtained in a series of samples taken from the mouth of Vernon Creek west to the vicinity of Okanagan Landing. The character of the fauna changed from one dominated by oligochaetes - Limnodrilus hoffmeisterii (eutrophic) to more mesotrophic indicators in the station just adjacent to Okanagan Landing. The mid-portion of the north basin between Okanagan Landing and Kelowna showed little change from the condition observed by Clemens et al (15) nearly 40 years ago, and can still be considered Oligotrophic. Six stations in Okanagan Lake were located in the vicinity of the pipe which discharges sewage from the City of Kelowna to Okanagan Lake. One station, located very close to the pipe, contained no organisms, but in stations further removed from the pipe, there was a tremendously large number of organisms of the Oligotrophic type. The area near the boat landing in Summerland also indicated a source of pollution at this location, but adjacent to Penticton the deeper waters were typically oligotrophic in faunal composition. While the bottom fauna in the littoral zone of Okanagan Lake has shown considerable change since the investigation over 38 years ago (15), the fauna in the deep water sediments have not been affected to the same extent, and the lake as a whole must still be classified as oligotrophic in terms of the distribution and abundance of benthic organisms.

The bottom fauna in Skaha Lake are complicated by the presence of both Oligotrophic and eutrophic indicator species. This type of distribution of benthic fauna is not unusual for formerly oligotrophic lakes which are rapidly changed to the eutrophic state by the sudden introduction of nutrients. The unusual occurrence of Oligotrophic forms may be explained by the short residence time of water in this lake, with the possibility of continuous re-colonization from outflow water from Okanagan Lake. This, in combination with relatively good oxygen levels in the hypolimnion, may account for the strange faunal distributions noted in Skaha. There was also a predominance of oligochaetes in Skaha Lake. Over 9,000 invertebrates per square meter were noted in 1971, which was the highest density recorded for all lakes sampled. In 1969 the density was 3,892 per square meter which was second only to Osoyoos Lake. Of six chironomid species found, very few were indicative of eutrophic conditions.

The north and central basins of Osoyoos Lake are, according to the composition of the bottom fauna, moderately eutrophic and strongly eutrophic, respectively. The central basin appears to have been enriched by wastes discharged from the surrounding communities. The northern basin is divided into two basins with a pronounced underwater ridge between the two northern sub-basins. The average number of bottom fauna per square meter of sediment surface in Osoyoos Lake was the highest recorded in the main valley lake system in 1969.

In 1935 demons et al (15) found Kalamalka Lake to be a typical Oligotrophic lake, slightly richer than Okanagan Lake. He also noted that chironomids made up over 95% of the benthic fauna in the lake, while studies in 1971 showed that chironomids made up only 55% of the fauna. Thus, a significant shift in the faunal composition has taken place over the past 35 years. The abundance of organisms per square meter seems to be of the same order of magnitude as those fond in 1935. One station, situated near the mouth of Coldstream Creek in the northern part of Kalamalka Lake, showed some degree of mild pollution. This finding correlates well with observations of nuisance weed growth off the mouth of Coldstream Creek in 1971-72. Kalamalka Lake, on the basis of the distribution and abundance of benthic invertebrates, remains a typical Oligotrophic lake, relatively rich in calcium. The changes that have occurred in Kalamalka Lake since Clemens et al (15) investigations in 1935, are of much smaller magnitude than those found in Okanagan Lake.

In 1935, Clemens et al (15) found that the benthic fauna of Wood Lake was characteristic of that of a eutrophic lake with very high densities of oligochaetes and chironomids. He noted that in all samples he collected there were always more than 1,000 oligochaetes per square meter, and at a depth of 23 meters he found as many as 23,000 per square meter. Today, the lake has very few organisms in the sediment. In most areas no oligochaetes occur at all, and only a few species of Chironomus attenuatus were found. Two stations located near the outlet are obviously influenced by water from Kalamalka Lake but nevertheless have fauna typical of a eutrophic lake. Even at these stations the number of oligochaetes was very much less than 1,000 per square meter. The current limnological condition of Wood Lake does not alone explain the disappearance of what was undoubtedly a formerly rich fauna. The rate and duration of oxygen depletion is not so high as to explain the apparent paucity of invertebrates in Wood Lake. One possible explanation is the existence of some yet unidentified toxic compound in the sediments.

6.4.7 Zooplankton

Studies of Zooplankton populations in Okanagan Lake indicate that little change has occurred in the species composition of crustacean plankton since 1935. The only significant difference involves Zooplankton abundance. The average density of settled plankton from eleven vertical hauls taken by Clemens et al (15) between July and August 1935 in southern, central and northern regions of Okanagan Lake was 2.8 cubic millimeters per square centimeter. Samples taken in September, 1969 and in August 1971,using a comparable net showed an average density of 13.3 and 7.8 cubic millimeters per square centimeter, respectively, or approximately 4.8 and 2.8 times more Zooplankton now than were present in 1935. Even assuming some sampling error or incompatibility of methods, these values do indicate that there has been an increase in abundance of Zooplankton in Okanagan Lake since 1935 (15). As noted previously, this increase in the density of Zooplankton is paralleled by an 8-fold increase in the total abundance of bottom organisms between 1935 and 1969.

It is of interest to compare the number of crustacean Zooplankton in the Okanagan Lakes to those of several Laurentian Great Lakes. Lakes of the Okanagan Valley appear richer in plankton than Lake Superior, but certainty poorer than Lake Erie and Ontario. Figures for Skaha, Osoyoos and Mood Lakes can be interpreted as being quite high if one bears in mind that the very high flushing rate of Skaha and Osoyoos does not favour the accumulation of plankton produced in the lake. In addition, very low oxygen concentrations in the hypolimnion of Osoyoos and Wood Lakes restrict the inhabitable layer to approximately the upper 20 meters as compared to 50 meters in the remaining Okanagan Lakes.

8 Fish

Fish serve as convenient summators both temporally and spatially, of the more general effects of eutrophication in lakes It has been known for some time that fishes respond to changes in the trophic nature of lakes, but their use as indices of eutrophication has only recently been developed.

A total of 26 species of fish were taken during the 1971 sampling program on the Okanagan Basin Lakes. Nine of the twenty-six species were caught in all lakes sampled. These nine include mountain whitefish, rainbow trout, kokanee, largescale sucker, carp, squawfish, peamouth chub, chiselmouth, and prickly sculpin. Representatives of the catfish, perch, bass and sunfish families were confined to Vaseux and Osoyoos Lakes, with the exception of the pumpkinseed, which was found in Skaha Lake as well.

There were marked differences among lakes in the total number of fish netted. The lowest catch was from Wood Lake, while catches in Skaha and Vaseux Lakes were almost double those from the other lake sampling points.

The seasonal distribution showed some variation in catch with summer catches tending to be much lower than those in either the spring or autumn. In some cases, notably from central Okanagan stations, autumn catches far exceeded those in spring and summer combined (chiefly because of the domination of mature kokanee in the catch).

A comparison of the relative abundance of salmonids (trout and kokanee) to coarse fish, showed the highest percentage of salmonids in Okanagan and Kalamalka Lakes, while the greatest abundance of coarse fish came from Skaha, Vaseux and Osoyoos Lakes. This trend applied to catches during each of the three seasons, even when considered separately.

A comparison of 1971 results with those of Ferguson (21) in 1948 for Skaha Lake show the combined catch and the number of salmonids and whitefish to be lower in 1971 than they were in 1948, although several were caught by lake netting in 1971.

The data of demons et al (15) indicates marked differences in the relative abundance of fish in Wood Lake between 1935 and 1971. No carp were netted in the summer of 1935, (although they were in the lake) but 12 were caught in 1971. The contribution of salmonids to the total catch in each of the years sampled was small, but about the same.

Comparisons of the relative abundance of fish in Okanagan Lake between 1935 and 1971 showed little difference in total catch (combined stations) between the two years. No carp were netted in any of the stations in 1935, whereas single summer sets in 1971 took carp at three of the four sampling stations. Apparently the change in the trophic structure of the lake since 1935 has not yet affected the fish population. This is to some extent borne out by the fact that many of the eutrophication problems of Okanagan Lake are location affecting mostly shoreline areas.

Rainbow trout from Kalamalka Lake were significantly smaller than those from Okanagan Lake, but not significantly smaller than those from Skaha or Osoyoos. Kokanee from Wood and Kalamalka Lakes were significantly smaller than those from the other lakes with the exception of Osoyoos. Kokanee from Skaha were the largest in the system. The average length of whitefish generally increased toward the south. Those from Skaha Lake were significantly larger than any other.

It is informative to compare length estimates of several species from Skaha Lake between 1948 and 1971. Although few kokanee were netted in 1948, even the largest of these did not attain the average length of those netted in 1971. Lake whitefish were also much larger in 1971, as were the large-scale suckers. It should be kept in mind that the sewage treatment plant at Penticton did not commence operation until 1948. Hence, eutrophication cannot be considered to be prevalent in this lake at the time of the 1948 sampling. The increase in average size of these species between 1948 and 1971 is likely a real indication of the effects of lake enrichment from nutrients in the treated sewage effluent being discharged into this lake.

Although present fisheries data do not indicate a significant shift in species composition, the high growth rate of fish in Skaha Lake, particularly kokanee, indicates a rapid increase in the biological productivity of this lake since 1948. Conversely, the decline in the fishery in Wood Lake, along with other biological indicators, suggest that it has reached this condition after passing through a more eutrophic stage, and fish productivity has been limited by undesirable habitat rather than food, e.g. low oxygen in the lower cooler waters, and excessively high temperatures in the upper waters.

6.5 <u>RELATIONSHIP OF NUTRIENT LOADINGS TO TROPHIC LEVELS</u> A separate set of tasks under the Okanagan Basin Study involved the monitoring of significant sources of pollutants to the main valley lakes. These studies are discussed in more detail in Chapter 5. The main objectives of these studies were (1) to identify the major sources of various elements including nitrogen and phosphorus, to the main valley lakes, particularly those sources which are controllable, and (2) to provide a base for projecting future loadings to the system under various economic growth projections and to assess the probable effect of these increased loadings on the lakes. The known sources and their contribution for the two year monitoring period 1969 to 1971 are shown in Table 5.15, Chapter 5.

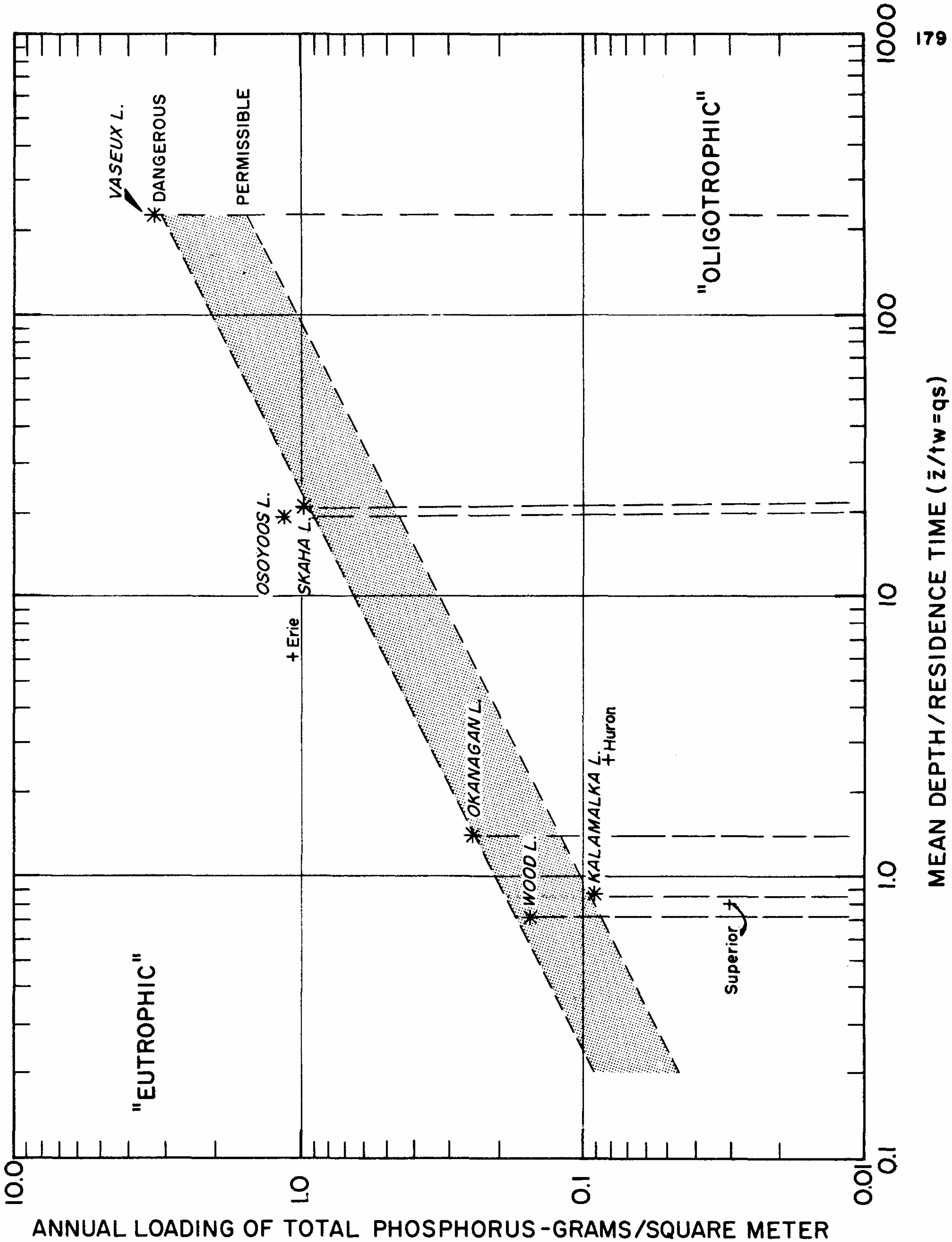
Limnologists have found that the annual input of total phosphorus to a lake is strongly related to the trophic level of a lake (22). These data on annual phosphorus input, when expressed on an areal basis and plotted as a function of lake mean depth and residence time, provide an informative comparison of the current trophic state of the main valley lakes (Figure 6.5). This shows all lakes with the exception of Kalamalka Lake to be in the dangerous zone with respect to the present (1971) total phosphorus loadings to each lake. The plots for three of the Great Lakes are also shown for comparative purposes.

6.6 SUMMARY

Limnological studies of Okanagan, Wood and Osoyoos Lakes indicate an increase in biological productivity (algae and aquatic plant growth) and resultant decline in water quality, commencing about 100 years ago, when the first major settlement and development of land in the Valley occurred. The decline in quality of Skaha Lake, and to a lesser extent Kalamalka Lake, is of more recent origin. This decline in quality is confirmed by recorded changes in the main valley takes between conditions documented in 1935 (15) and those of the Okanagan Basin Study in 1971. The present (1971) trophic conditions of each of the main valley lakes is summarized in Figure 6.6.

A number of significant points are evident from these limnological studies. Okanagan Lake is the key lake in the basin. It commands over 75% of the tributary runoff; is by far the largest lake in both volume and surface area; and controls the quality of water in the downstream lakes of Skaha, Vaseux and Osoyoos. As long as the central water mass in Okanagan Lake remains in its present excellent condition the downstream system will benefit. However as soon as this central water mass deteriorates, the downstream system will deteriorate with it. Skaha Lake currently has the highest relative fertility and biological growth rate, combined with the highest oxygen depletion rate in bottom waters. Its present level of enrichment may be compared to that of Wood Lake in 1935, when the kokanee caught in Wood Lake were the largest in the system. The existing quality in Skaha however, has so far been maintained by the high quality and quantity of water flowing in from Okanagan Lake, its short retention time in the lake, and the probable precipitation of phosphorus as an apatite by these waters. The reduction of phosphorus inputs to this lake should result in a rapid improvement of its quality.

The relative fertility of Kalamalka Lake water under laboratory conditions is high and yet the lake has a very low biological productivity. This is considered to be due to the important calcium carbonate cycle which co-precipitates large amounts



THE ANNUAL TOTAL PHOSPHORUS LOAD TO THE MAIN VALLEY LAKES OF THE OKANAGAN BASIN, 1969-1971. Figure 6.5

CONDITIONS OF MAIN VALLEY LAKES-1971

LAKE	Trophic Condition	Water Quality	COMMENTS ON 1971 CONDITION
Kalamalka	Oligotrophic	Excellent	Relative fertility of lake is high, but condition has been preserved by unique calcium carbonate cycle which co-precipitates phosphorus and other heavy metals each spring. High mercury content in sediments. High pesticide (D.D.T.) levels found in trout and kokanee over 3 pounds in weight
Okanagan	Oligo - meso-trophic	Good	Central water mass of lake is still in excellent condition but serious deterioration has occurred around shoreline areas of lake which are affected by wastewater outfalls and shoreline development. High mercury content in sediments. The maintenance of a high water quality in this lake is essential if the water quality in the lower lakes is to be maintained or improved from their present trophic levels.
Skaha	Meso-Eutrophic	Acceptable	This lake has the highest relative fertility and biological growth rate of the main valley lakes and consequently its quality has deteriorated the most rapidly. The main cause of this deterioration is considered to have been the effluent from the Penticton Municipal Waste Treatment Plant. The high quality of inflow water to Skaha Lake, its short retention time in the lake, and the probable precipitation of phosphorus as an apatite have kept this lake from deteriorating further, and provide the means for improving the quality in a short period of time if nutrient inputs to the lake are significantly reduced.
Osoyoos	Meso-Eutrophic	Acceptable	Lake first affected by development as early as 1870. Osoyoos Lake is, in fact, three lakes with sand deposits between them with the quality generally deteriorating in a southward direction. Over 65% of all nutrients entering this lake come from Okanagan River including surface and subsurface drainage to Okanagan River between Skaha and Osoyoos Lakes. The short retention time of the water in this lake may be preventing serious over-enrichment. Low oxygen concentrations in bottom waters during summer months. High mercury levels in sediments. Osoyoos Lake serves as an important rearing ground for small sockeye salmon.
Vaseux	Eutrophic	Acceptable	Vaseux has always been a productive lake and the extensive weed growth covering much of the lake's surface will remain an integral part of the lake's environment regardless of a varying nutrient input from Okanagan River.
Wood	Eutrophic	Poor	Most eutrophic lake in Okanagan Basin. Severe oxygen deficiency in lower waters in summer months along with high temperatures in surface waters provide an unsuitable habitat for most fish. High mercury content in sediments, and paucity of benthic fauna due to unidentified toxic substance. Increased inflow from industrial cooling water pumped from Okanagan Lake and discharged to Vernon Creek, commencing in 1971, has reduced renewal time to historical levels and may speed the recovery of this lake.

Figure 6.6

of trace elements including phosphorus to the lake sediments in the early summer. The same cycle does not occur in Wood Lake which has deteriorated in recent years to the point where the severe lack of oxygen is limiting the productivity of certain faunal components, including fish. Increased inflow from industrial cooling water pumped from Okanagan Lake and discharged to Vernon Creek, commencing in 1971, has reduced the renewal time of water in this lake to historical levels (30 years to 14 years) which may speed the recovery of this lake providing phosphorus loadings are reduced. However, the effect of these increased flows and any resulting nutrient transport, on Kalamalka Lake remains a concern and should be closely watched.

Osoyoos Lake has oxygen deficit problems because of its meso-eutrophic condition and natural division of the Lake into small isolated basins. The present quality however, is being maintained by the short retention time of water in the lake.

All the main valley lakes in the basin have shown some increase in biological productivity since the studies of 1935. In the case of Kalamalka and the central mass of Okanagan Lake, the small increase noted may actually be beneficial with respect to sport fishing without impairing the quality of the water. Other increases in biological productivity, especially around the shoreline of Okanagan Lake is definitely detrimental to the quality of that lake and the mainstem system downstream. There will be a continuing decline in quality in all lakes unless condition are corrected by a reduction of phosphorus inputs to the system.

Two other materials that have been found in excess in some of the lakes are mercury and the pesticide D.D.T. The concentration of mercury found in parts of Okanagan, Kalamalka and Osoyoos Lake sediments are extremely high, and when conveyed through the food chain to larger fish, pose a potential health problem. Mercury has also affected the reproductive capacity of the salmonid species. D.D.T. has been found in concentrations exceeding safe levels in larger fish. The use of this pesticide in British Columbia was banned in 1971.