Water Quality

WATER MANAGEMENT BRANCH
MINISTRY OF ENVIRONMENT

PHOSPHORUS IN THE OKANAGAN VALLEY LAKES SOURCES, WATER QUALITY OBJECTIVES AND CONTROL POSSIBILITIES

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SUMMARY

SUMMARY

Over the last 20 years phosphorus inputs to the Okanagan Valley lakes have affected water quality. The economic value of this water resource is high and a considerable effort has already been made to maintain a good level of water quality. This report analyses the present situation and investigates new ways of controlling phosphorus inputs in the future.

The phosphorus concentration in a lake is a measure of its biological productivity or trophic state. This is because phosphorus controls algal growth and hence major uses of the water. Phosphorus however does not affect the growth of nuisance weeds to any extent. The Okanagan Valley lakes are a combination of eutrophic lakes (Ellison and Wood), oligotrophic lakes (Okanagan and Kalamalka) and mesotrophic lakes (Skaha and Osoyoos). Over the past ten years there has been some increase in phosphorus concentrations. The increase has been most apparent in Kalamalka Lake, with lesser increases in Okanagan, Skaha and Osoyoos lakes and only minor changes in Ellison and Wood Lakes.

Water quality objectives for total phosphorus are proposed in this report for each lake. They are intended to protect. the major water uses and are, by necessity, a compromise between higher values required for fisheries and lower values required for recreation and drinking water use.

The main body of Okanagan Lake is the only lake where the phosphorus level presently equals the proposed objective level of 0.010 mg/L. Elsewhere, the objectives are exceeded to a greater or lesser extent. In Kalamalka Lake, the phosphorus level, 0.010 mg/L, is somewhat higher than the objective, 0.008 mg/L. Phosphorus levels in Skaha Lake, 0.025 mg/L, and Osoyoos Lake, 0.030 mg/L, are substantially higher than the objective which is set at 0.015 mg/L for both lakes. The level in Wood Lake, 0.075 mg/L, exceeds the objective, 0.015 mg/L, by an even greater margin.

The general relationships between phosphorus levels in a lake and critical phosphorus loadings do not appear to hold for the Okanagan Valley lakes. This is due to their relatively long water-residence time and other unique characteristics. However, measurement of lake phosphorus concentrations and comparison to the water quality objectives will serve as a measure of how well phosphorus loadings are being brought under control.

Since 1970, phosphorus loadings from municipal effluents have been reduced 70 percent to Okanagan Lake, 80 percent to

Skaha Lake and virtually 100 percent to Osoyoos Lake. Rough estimates indicate that with an expenditure of about $20 million, the main treatment plants can be upgraded and phosphorus removal can be maintained or improved to the 95 percent level for the coming decade. Spray irrigation of all treated effluents on land will achieve almost 100 percent removal of phosphorus from this source. However, the cost in addition to treatment plant upgrading would be at least a further $170 million, half of which would be needed for land acquisition.

Rough estimates indicate that phosphorus loadings from septic tanks and agriculture are of equal or perhaps greater importance than phosphorus from municipal effluent in Okanagan and Skaha Lakes. In Wood, Kalamalka and Osoyoos Lakes these diffuse sources presently constitute the most important source of phosphorus. Costs to reduce phosphorus loadings from septic tanks, the most important source of phosphorus from diffuse sources, are about $50 million for the valley as a whole. Costs to reduce agricultural loadings cannot yet be assessed due to lack of proper information.

Until now the major effort in reducing phosphorus loading to the lakes has been with municipal treatment plants. Although there is room for some improvement, the cost of removing the last fraction of phosphorus from this source is very high. Even with complete removal of phosphorus from municipal plants, phosphorus loadings from diffuse sources need to be reduced in the future in order to meet water quality objectives and thereby maintain important uses of the water. Reduction of phosphorus from septic tanks and agricultural sources would appear, from the analysis to date, to offer the most promise in the near future. A phased program for dealing with septic tanks could probably be drawn up fairly quickly. More site-specific and pertinent information on agricultural sources will be required before a plan to control them can be prepared, although feedlots and winter-feeding areas will be priority areas for control.

For Wood and Kalamalka Lakes a number of special control measures deserve consideration. These include lake precipitation and aeration techniques for Wood Lake and flow restriction methods. These methods will restrict water from Wood Lake, which contains relatively high levels of phosphorus, from flowing into Kalamalka Lake.

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1. INTRODUCTION

Because of the central role played by the water resources in the Okanagan with regard to tourism, agriculture and the industrial base, the economic value of the lakes is very high. Water quality is a major consideration in several important uses including drinking water, recreation and fisheries. This document discusses one of the main means of protecting the water quality of the Okanagan mainstem lakes.

The primary water quality concern is phosphorus inputs into the lakes, since phosphorus is the key nutrient controlling the amount of algae. Algal growth directly determines important aspects of the lakes such as water clarity, aesthetic attractiveness, recreational suitability, amount of drinking-water treatment required and aspects of fisheries production and habitat suitability. However, a reduction in phosphorus concentration is unlikely to affect nuisance weed growth.

The main issues which need to be considered are the sources of phosphorus to each lake, the options to control each source and the costs of these controls.

The approach taken is to specify provisional water quality objectives for phosphorus which will protect the present and future water uses of specific lakes or portions of lakes. Associated with the objectives is a discussion of the annual loadings of phosphorus and their likely effect on lake-phosphorus concentrations. Controls to limit loadings and costs of these controls are then presented.

Of all of the regions of the province, the Okanagan has probably been the most intensively studied with regard to water resources. There have been three major studies. The Okanagan Basin Study, a federal-provincial study, was done in 1969-

1974. The data gathered in this study provided the first basic technical information on the lakes. Next a provincial study of the Wood-Kalamalka basin was carried out in 1971-1974. Finally the federal-provincial Okanagan Basin Implementation Study (1977-1982) was undertaken to implement the recommendations of the Basin Study. Changes in water quality, which had taken place as a consequence of sewage treatment improvement at Penticton and Vernon, have been monitored. Numerous other studies have been carried out and the Waste Management Branch Regional office in Penticton has continued to monitor water quality at numerous sites on a routine basis.

In this report we have selected the best and most relevant information from the previous studies and applied it to the questions concerning phosphorus and water quality. Some difficulty was encountered in finding data completely suited to present needs. Some areas of present concern (*e.g.* non-point sources) had weak databases, and the previous studies were designed to answer questions which were important fifteen or ten years ago. However, our conclusions are based largely on the previous studies with some reinterpretation where possible. Future data needs are listed in relevant sections.

The view of water quality considered here is restricted to phosphorus. There are a number of other water quality characteristics which may be of concern (bacteriological content, suspended sediment, aquatic weeds) and they will be considered at some future time.

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2. HYDROLOGY

The Okanagan Main Valley lakes consist of a chain of lakes including Ellison (Duck), Wood and Kalamalka that flow north in the east sub-basin, and then south into Okanagan, Skaha, and Osoyoos Lakes. The Ellison-Wood-Kalamalka Lakes sub-basin discharges via Vernon Creek to Vernon Arm of Okanagan Lake. The outflow of Okanagan Lake becomes the Okanagan River which flows south into Skaha and Osoyoos Lakes. Some morphometric features of these lakes are given in Table 2-1. Vaseux Lake, located between Skaha and Osoyoos Lakes, has a short water residence time, about 11 days, and its water quality will be similar to that of Skaha Lake. It is therefore not discussed separately in this report.

Most of the water inflow to the lakes occurs from April to July mainly due to snowmelt in the higher portions of the basin. Since 1972 the Hiram Walker Distillery has continuously discharged cooling water diverted from Okanagan Lake to Vernon Creek above Ellison lake, and contributed significantly to flows at least within the Ellison-Wood-Kalamalka Lakes sub-basin. The regulation of the level of Okanagan Lake is of major importance to the southern part of the valley; about 80% of the inflow to the entire Basin occurs to this natural reservoir, and its control is used to moderate the extreme variations in year-to-year runoff within the basin.

About 130 headwater lakes provide both storage for the mainstem lakes (50 reservoirs, $150 \times 10^6 m^3$ storage) and support for valuable sports fisheries. The main tributary streams are listed in Table 2-2. With the exception of major tributary streams, most small streams are dry from July to November due to upstream storage in the regulated headwater lakes as well as irrigation requirements. The residual water entering Okanagan Lake, either through surface or ground water flow, is further reduced by up to about 30% through evaporation from the lake surface. Thus the actual water available (the net lake inflow) within Okanagan Lake or downstream is only a fraction of the gross inflow.

The main control structure for the mainstem lakes is the concrete dam on Okanagan Lake at Penticton. It allows 1.2 m of storage, equivalent to a volume of $420 \times 10^6 m^3$ which is about the same as the annual net runoff into Okanagan Lake ($467 \times 10^6 m^3$; gauge 08NM050 in Table 2-2). The discharge is limited by the channel capacity of the Okanagan River, which is $60 m^3/s$ at Penticton and $96 m^3/s$ at the inlet to Osoyoos Lake. Minor regulation of Skaha Lake is maintained by a concrete dam at Okanagan Falls, and at Vaseux Lake by a small concrete dam. Osoyoos Lake levels are maintained by the Zosel dam at the outlet in the State of Washington, although flooding can occur due to lack of a control structure on the

Similkameen River which joins the Okanagan River downstream.

Long-term mean flows for the Okanagan River and major tributaries (gauged) are given in Table 2-2. The mean annual discharges from the six lakes discussed (Ellison, Wood, Kalamalka, Okanagan, Skaha, and Osoyoos) are summarized in Table 2-3. Also presented in Table 2-3 are the calculated lake residence times, which are generally lower than those published in the Okanagan Basin Study (1974) due to a recent trend of high runoff years. Mean residence times are: 0.3 years for Ellison, 14 years for Wood, 36.6 years for Kalamalka, 52.8 years for Okanagan, 1.1 years for Skaha and 0.6 years for Osoyoos. These water residence times are important factors in estimating the time it would take for water quality to change due to changes in phosphorus loading.

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3. WASTE DISCHARGES

Phosphorus enters the lakes in the Okanagan Valley from sources associated with numerous anthropogenic activities which can be urban or rurally-based. Rurally-based activities include agriculture and logging. There is also a large base-level loading from "natural"sources (soils, vegetation, dustfall, etc.).

In and near urban centres located in the valley, domestic-type sewage can be a major phosphorus source, either from centralized sewage treatment facilities or septic tanks. As of 1985, no discharges of phosphorus from domestic sources directly enter Skaha or Osoyoos Lakes, while about 90% reduction has been achieved for phosphorus in municipal effluents discharged directly north from Skaha Lake (*i.e.* the remainder of the Okanagan Basin).

Much of the information contained in the following sections, except where noted, originates from the Report on the Okanagan Basin Implementation Agreement dated September 1982.

3.1 DIFFUSE SOURCES

A summary of present, past and projected loadings to the five main lakes is given in Table 3-1 . Diffuse (non-point) loadings come chiefly from septic tanks, agriculture (fertilizer and animal waste) and logging.

3.1.1 CALCULATION OF LOADINGS

In 1970 and again in 1980, estimates were prepared for phosphorus loadings from septic tanks, fertilizer application and animal waste. The maximum potential loading from each class of diffuse sources was calculated first, and then reduced by multiplying by a transmission coefficient which took account horizontal and vertical attenuation of nutrients in the soil.

In 1970, the maximum potential phosphorus loading from septic tanks was calculated. Data on the number of homes on septic tanks and the amount of phosphorus generated were used. In 1980, the 1970 figures were extrapolated, based only upon total population increases and assuming proportional increases by area in the use of septic tanks. Allowance was made for areas which had since been sewered. Figures for 1990 were again extrapolated similarly.

In 1970 and 1980, major distributors of commercial fertilizers and district horticulturists were contacted to estimate total fertilizer application rates. The numbers of several types of livestock were obtained by researching files of the Ministry of Agriculture, Ministry of Forests, and Marketing Boards. Phosphorus loadings were based on livestock numbers multiplied by phosphorus generated per animal. Estimates for 1990 were based upon projected growth of agricultural activities for the 1980-1990 period.

In 1980 and 1981, Shingle and Vaseux Creeks were monitored near forestry activities. This allowed loading estimates per unit area to be calculated. These estimates were then extrapolated to other areas of the Okanagan based upon an inventory of logged areas.

3.1.2 DISCUSSION OF LOADINGS

Estimated phosphorus loadings (1980) from septic tanks and agriculture are the two largest man-made diffuse sources to most of the lakes, with septic tanks usually being the larger of the two. However, this varies with each lake. For example, the estimated loading to Okanagan Lake from cattle (Table 3-1) exceeded the loading from septic tanks by 2.2 t/year in 1980, or by 33% of the septic tank load. At Kalamalka Lake, this difference was 0.3 t/year in 1980, or 100% of the septic tank load.

The estimated loadings from diffuse sources will vary on a year to year basis, according to the water balance for that year. Generally, more phosphorus will be leached from the soil in wet than in dry years. During dry years more phosphorus will be retained in the soil. However, this variability was not allowed for in the loading estimates.

The largest estimated loadings in 1980 from diffuse sources which might be controllable were to Okanagan Lake (23t), followed in decreasing order of magnitude by Osoyoos (4t), Skaha (3.1t), Wood (1.9t) and Kalamalka (1.1t) Lakes. An examination of phosphorus loadings from diffuse sources to each lake follows.

Wood Lake: Diffuse sources were estimated to contribute all the controllable phosphorus loading to Wood Lake in 1980. This lake received the second lowest phosphorus loading of the five major lakes, at only 4.6% of the 1980 phosphorus loading to Okanagan Lake.

The largest diffuse source of phosphorus to Wood Lake was septic tanks, which were estimated to contribute nearly 42% of the phosphorus loading to Wood Lake in 1980. Concentrated settlements adjacent to the lake, serviced by septic tanks, are Oyama and Winfield. Animal wastes contributed about 27%, and logging nearly 24% of the 1980 phosphorus loading.

Kalamalka Lake: Diffuse sources were estimated to contribute all the directly controllable phosphorus loading to Kalamalka Lake in 1980. This lake received the smallest phosphorus loading of the five major lakes, at only 2.7% of the 1980 loading to Okanagan Lake. This percentage does not include the relatively large mainstem loading from Wood Lake, which it may be possible to control directly.

The largest diffuse source of phosphorus to Kalamalka Lake was animal wastes, which contributed over 60% of the 1980 phosphorus loading. Of secondary importance was the estimated phosphorus loadings from septic tanks mainly in Oyama (nearly 30%), followed by the loading from logging (9%). An additional diffuse source since 1981 was the Vernon spray irrigation system, which is suspected of contaminating ground water in the Kalamalka drainage system. The loading from this source is presently estimated to be less than 100 kg/year (less than 10%) according to limited sampling.

Okanagan Lake: Diffuse sources were estimated to contribute 55 percent of the 1980 controllable phosphorus loading to Okanagan Lake. This percentage will increase to nearly 70 percent by 1990 due to reduced inputs from municipal sewage treatment facilities which had been realized by the end of 1984. Okanagan Lake received the largest phosphorus loading of the five major lakes.

The largest diffuse source of phosphorus to Okanagan Lake was animal wastes, which contributed 38% of the 1980 diffuse phosphorus loading to the lake. Of secondary and tertiary importance were the estimated phosphorus loadings from septic tanks (28.7%) and from logging (26.1%). Concentrated settlements serviced by septic tanks, and located adjacent to Okanagan lake, are Okanagan Landing, Okanagan Centre, Peachland, Summerland including Trout Creek and unsewered areas of Kelowna and Westbank.

Skaha Lake: Diffuse sources were estimated to contribute 56% of the 1980 controllable phosphorus loading to Skaha Lake. This percentage could increase slightly by 1990. Skaha Lake received the second largest controllable phosphorus loading of the five lakes, however it was only slightly over 13% of the 1980 loading to Okanagan Lake.

The largest diffuse source of phosphorus to Skaha Lake was septic tanks, which contributed nearly 58% of the 1980 diffuse phosphorus loading to the lake. Kaleden is serviced by septic tanks and is located along Skaha Lake. Of secondary and tertiary importance were logging (27.9%) and animal wastes (13.8%).

Osoyoos Lake: Loadings to Osoyoos Lake from municipal sewage treatment plants were discontinued by 1984, with the change to spray irrigation at Oliver and Osoyoos. The following discussion relates to total 1980 controllable loadings, corrected for this change.

Diffuse sources were responsible for all the controllable phosphorus loading to Osoyoos Lake. This lake received the third largest phosphorus loading of the five major lakes, at 9.7% of the 1980 controllable phosphorus loading to Okanagan Lake.

Septic tanks were estimated to contribute the largest diffuse phosphorus loading to Osoyoos Lake (50%). Logging (21.5%), livestock wastes (12.9%) and fertilizer (12.6%) contributed additional loading from diffuse sources.

3.1.3 LIMITATIONS OF THE DATA BASE

Many of the calculated 1980 loadings (Table 3-1) were based upon simple extrapolations of the 1970 data base. However, some recent checks by regional Waste Management staff suggest that there were errors both in the initial 1970 estimates and the 1980 update. For example, in a randomly selected sub-basin on Skaha Lake, an area where 900 septic tanks were supposed to be located according to population projections, only about 80 actually existed according to counts on recent air photographs. More important, however, was the fact that recently revised soil survey maps showed the area as having predominantly coarse and not the medium textured soils originally thought to exist. Both factors when combined resulted in a revised loading estimate of about 0.14 tonnes per year of phosphorus to the lake, compared to the 0.03 tonnes per year calculated for the 1980 update. This revision is not reflected in the loadings presented in Table 3-1.

This discrepancy is not surprising considering statements about the loading estimates made in the Implementation phase of the agreement (September 1982) and the original Preliminary Report Number 41 of the Canada-British Columbia Okanagan Basin Agreement (1973). The former cited the fact that a poor data base for septic tank estimates for 1970, extrapolated to obtain 1980 loadings, has doubled the problem of data reliability.

To quote from Report 41 (1973), "There is a significant number of shortcomings inherent in the calculations"... "This is especially true of calculations required to arrive at amounts of nutrients" to mainstem lakes and tributaries.

The most significant comment made in Report 41 was as follows: "If management alternatives for the basin are found to be sensitive to the calculated septic tank figures, then more work should be undertaken before any final decisions are made."

Loading figures for agricultural non-point sources are also questionable although not to the same degree as estimates related to septic tanks. Transmission factors were extracted from the literature with little field verification, numbers of animals were obtained from the Ministry of Agriculture (which would not necessarily have accurate figures), and only limited information on actual quantities of fertilizer could be obtained. This latter fact lead to "educated guesses" being made.

Major improvements in agricultural practices in the Coldstream watershed were made during 1977. However, the success of these improvements, the design of the study to measure their effects, and the accuracy of initial estimates, come into question in a 1978 report titled Water Quality of Coldstream Creek and Nearby Agriculture in 1977. This report made the following conclusions: " Any decrease in the amount reaching the creek due to improved agricultural waste management was not obvious in the water quality data of 1977."

This quote from the final report of the Okanagan Basin Implementation Program is pertinent:

> "In conclusion, although the loading estimates are the best that can be produced at this time, the limitations of the method will result in difficulties in predicting loadings to the lakes for individual years due to the absence of time variant factors such as runoff. Estimated loadings also may be in error due to the coarseness of the method and the omission of components such as erosion" (Alexander, 1982)."

Time limitations have not permitted diffuse loading estimates to be revised. A significant effort and amount of time will be required to get reliable information about diffuse sources. To quote from Alexander (1982), "It is recommended that future efforts to improve the estimates focus on those sources that can be feasibly controlled such as agriculture, septic tanks and logging to prioritize sources and locations for controlling nutrients."

3.2 MUNICIPAL AND INDUSTRIAL DISCHARGES

Loading estimates for discharges from municipal and industrial sites are the most accurate of any estimates, since flows and phosphorus concentrations have been measured frequently.

Municipal sewage treatment facilities have discharged only to Okanagan, Skaha, and Osoyoos Lakes. Table 3-1 shows loadings to these lakes for 1970 and 1980 with projections to 1990. These data show that loadings from municipal sources to the lake were:

1. Reduced significantly from 1970 to 1980, by factors between 75% and 100%;
2. Considerably more significant than any loadings from industry to the lake; and,
3. Similar in magnitude to phosphorus loadings from controllable diffuse sources in 1980.

The phosphorus loadings to these lakes have been reduced by construction of advanced wastewater treatment facilities at a number of centres in the valley. Most recently, secondary-treatment and spray-irrigation systems at Oliver and Osoyoos have eliminated direct discharges to Osoyoos Lake and the Okanagan River upstream. A summary of treatment facilities is given in Table 3-2, with relevant discussion provided below.

Hiram Walker Distillery: This operation discharges 22730 m^3/d of cooling water, pumped from Okanagan Lake, to Vernon Creek. It is suspected that this large discharge flushes nutrients from Ellison and Wood Lake into Kalamalka Lake and other downstream lakes. It has shortened water residence times from 0.6 to 0.3 years in Ellison Lake, 20 to 11 years in Wood Lake, and 46 to 37 years in Kalamalka Lake. The water balance for these lakes would be affected if the cooling water were returned to Okanagan Lake. This in turn would reduce the phosphorus loading from Ellison and Wood Lakes into Kalamalka Lake.

City of Armstrong: Municipal sewage from Armstrong receives secondary treatment prior to the discharge of 1950 m^3/d to Deep Creek, which enters the North Arm of Okanagan Lake. Provision exists for alum addition at the facility, however, the components to provide tertiary treatment are not being used effectively. This facility discharged significant phosphorus loading in 1984 (Table 3-2) and also discharged at times when there was low flow in Deep Creek. In 1984, it contributed 2.43 t/year or 20.3% of the phosphorus loading from municipal facilities that discharge to Okanagan Lake. Irrigation of the effluent to land is under consideration.

City of Vernon: Municipal sewage from Vernon usually receives secondary treatment prior to impoundment and spray irrigation. However, excess wastewater due to recent wet years and an insufficient land base in 1984, resulted in an emergency discharge of effluent containing 0.38 tonnes of phosphorus to Vernon Creek, following tertiary treatment. This was only
3.2% of the phosphorus load from municipal facilities, and was the second smallest phosphorus loading to Okanagan Lake in 1984. Unfortunately the land being used for irrigation has been over-irrigated in the past. This fact along with increasing population could result in larger volumes of wastewater being discharged to the lake in the future. The loading in Table 3-1 for municipal plants for 1990 would be increased significantly if all the wastewater were discharged again to Okanagan Lake. Continuous direct discharge could increase the municipal loading by 3.5 t/year. This would amount to an increase of about 40 percent in the total phosphorus loading to Okanagan Lake from municipal sources. Various options are discussed in Chapter 9 related to discharging wastewater from the City of Vernon.

City of Kelowna (industrial effluent): This effluent receives secondary treatment prior to discharge to Brandts Creek and Okanagan Lake. The wastes originate from a winery, beverage plant and fruit packers and processors, and are generally nutrient poor. Nutrients are therefore added to carry out biological treatment. This plant discharged 1.4 t/year or 12% of the municipal-source phosphorus in 1984. Tertiary treatment is to be added this year.

City of Kelowna: Municipal. sewage receives tertiary treatment prior to discharge to the lake through an open pipe, about 500m from the shore. The treatment process being used is the first of its kind in the province and is presently being optimized by various experimental means. This was the largest single source of phosphorus from a municipal treatment facility in 1984, contributing 6.74 t/year or 56.2% of the nearly 12 t/year of phosphorus discharged to Okanagan Lake from municipal treatment plants in 1984. When tertiary treatment at the Kelowna plant is fully optimized it will discharge 2.34 t/year of phosphorus, and the total loading to Okanagan Lake will be reduced to 7.6 t/year. Large portions of Kelowna are still unsewered and these contributions were included in the estimates for septic tanks discussed in section 3.1.

Westbank: Secondary treatment is provided to the municipal sewage prior to discharge to Westbank Creek. The 1984 loading from this facility was about 0.83 t/year or 70% of total loading to Okanagan Lake from municipal treatment facilities.

City of Penticton: Tertiary treatment is provided to the municipal wastewater prior to it being discharged to the Okanagan River and subsequently Skaha Lake. This is the only municipal-type discharge to Skaha Lake, although one industrial operation (a fish hatchery) does discharge some flow-through water which would have very little phosphorus associated with it. The loading from the City of Penticton was larger than any single estimated diffuse source to Skaha Lake. In 1984, 2.54 t/year of was discharged (see Table 3-2), or 21.1% of the total municipal phosphorus load to Okanagan Lake.

3.3 CONCLUSIONS

1. Loadings from direct discharge by municipal sewage treatment plants in 1984, when compared to 1970 loadings, have been reduced 70% to Okanagan Lake, 80% to Skaha Lake and 100% to Osoyoos Lake. No direct discharges exist to Ellison, Wood and Kalamalka Lakes. This leaves very little room for improving phosphorus removal at municipal sewage plants, other than by spray irrigation of effluent on land.
2. Loadings from agriculture and septic tanks are the most significant sources of controllable phosphorus to Wood, Kalamalka and Osoyoos Lakes. They are more significant than municipal sources in Okanagan and Skaha lakes.
3. The reliability of estimated loadings is best for municipal sources, followed by agriculture and septic tanks. Prior to any action being undertaken to reduce loadings from diffuse sources, more accurate estimates of these and of natural loadings will be required. The appropriate sources and locations of nutrient inputs can then be prioritized for corrective action.

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4. WATER USE

This chapter describes present uses of the water for each lake. It compares licensed uses (irrigation, industrial and domestic uses) to uses for Fisheries and recreation. The relative importance of each lake is thus put, into perspective.

4.1 ELLISON LAKE

4.1.1 WATER LICENSES
There are only two water licenses on Ellison Lake, both for irrigation (Table 4-1).

4.1.2 FISHERIES
Ellison Lake is a small shallow lake. Consequently, only coarse fish are present, reflected by the minimal angler effort of about 50 days (Table 4-2). There is a carp fishery, with the Kelowna Archery Club reporting a 900 kg harvest in 1981. The Regional Fisheries Branch (Ministry of Environment, Penticton) has considered the introduction of bass to Ellison Lake and subsequent fisheries development, however, the project is of low priority.

4.1.3 RECREATION
Water-based recreation use of Ellison Lake is minimal. There are some public recreation beach-oriented sites, commercial and residential developments. There is a water ski championship held on the lake each year.

Construction of condominiums and a trailer court was recently completed on leased Indian land, adjacent to the lake. This may, in the future, create a small recreational use of the lake where none has existed so far.

4.2 WOOD LAKE

4.2.1 WATER LICENSES
Wood Lake has 16 water licenses. These are for irrigation (9 licenses), domestic use (4 licenses), industrial use (1 license), and for waterworks (2 licenses; Table 4-1). Points of diversion are located along the west shore and in the southeast corner. Many residences are concentrated at the south end of the lake and obtain their domestic and irrigation requirements from wells that do not require licensing; others obtain irrigation water for gardens during the summer and are unlicensed (1979 water use survey, Ministry of Environment).

4.2.2 FISHERIES
Although the fish productivity of Wood Lake is greater than Ellison Lake, it is lower than the other Okanagan main valley lakes. Data show that Wood lake has the lowest percentage of salmonids, with the exception of Ellison Lake (Table 4-2). It was stocked with rainbow trout until 1981 but is now of low stocking priority due to the eutrophic condition of the lake. Although there has been a good fishery for rainbow trout and kokanee during some years (*e.g.* 1981 and 1982), the fishery is unpredictable (B. Jantz, Fisheries Branch, personal communication, March 12, 1985). There are some shore-spawning kokanee although most spawn in Vernon and Winfield Creeks, as do rainbow trout. The lake is not heavily fished. Most of this limited fishing is done by local residents including ice fishing during the winter.

4.2.3 RECREATION
There are no developed public recreation areas (parks) around Wood Lake. Only 9% of the shoreline is commercially developed (campsites, motels, marinas) and 6% has residences. This development is concentrated at the south end. Other than Ellison Lake, Wood Lake is the least developed of the Okanagan main valley lakes for these select uses (Table 4-3).

4.3 KALAMALKA LAKE

4.3.1 WATER LICENSES
Kalamalka Lake has 71 water licenses. These are for irrigation (21 licenses), domestic use (36 licenses), industrial use (2 licenses), and for waterworks (12 licenses including the City of Vernon; Table 4-1). Points of diversion are concentrated in the major areas of residential development at the north and south ends of the lake as well as the south shore of Cosens Bay. There is a lot of unlicensed domestic water use around the lake including temporary use for summer homes (1979 water use survey, Ministry of Environment).

4.3.2 FISHERIES
Kalamalka Lake is second only to Okanagan Lake in terms of fishing popularity, with an estimated 4 600 days of angler effort in 1980 (Table 4-2). The percentage of salmonids was equal to that of Okanagan Lake (49%) and higher than all the other main valley lakes. Dominant species are Kokanee and rainbow trout, both sought after by the sports fisherman; the total, estimated 1980 harvest was about 16500 fish, second only to Okanagan Lake.

Of the main valley lakes, only Kalamalka has lake trout (up to 9 kg). Kalamalka Lake was stocked with lake trout during most years in the 1970s but stocking was curtailed during 1978. This was due to the absence of a naturally spawning population, the difficulty of catching the fish, and their high pesticide content. The fishery is not expected to last as only old fish are being caught. The lure of large albeit hard to catch lake trout, however, still contributes to the fishing appeal of Kalamalka Lake.

In general, Kalamalka Lake has a popular but unproductive fishery, supporting a shall fish population with low growth rates. The main angler effort. is for kokanee, with rainbow trout caught incidentally. Lake trout are not a significant part of the total harvest. Kokanee spawn in both lake and tributary streams, whereas rainbow trout spawn only in tributary streams.

4.3.3 RECREATION

There are only two public recreation sites (parks) on Kalamalka Lake (Table 4.4). Kalamalka Lake and the Vernon area of Okanagan Lake contributed about 25% of total beach-oriented recreation in the Okanagan Valley during the Okanagan Basin Study (Technical Supplement VIII, Water Based Recreation in the Okanagan Basin, 1974). A total of about 25% of the shoreline is developed for recreation-oriented use. This includes 3.7% developed directly for recreation (with parks), 3.8% developed commercially (campgrounds, motels, and marinas), and 17.2% with residential development (Table 4-3). This total recreation-oriented shoreline development (25%) is greater than Ellison and Wood Lakes, but less than Skaha (32%), Okanagan (34%), and Osoyoos (38%) Lakes.

4.4 OKANAGAN LAKE

4.4.1 WATER LICENSES

There are about 670 water licenses on Okanagan Lake. These are for irrigation (206 licenses), domestic use (338 licenses), industrial use (27 licenses), and for waterworks (96 licenses; Table 4-1). There is more licensed water use of Okanagan Lake than any other main valley lake. There are also unlicensed withdrawals for domestic use around the lake (1979 water use survey, Ministry of Environment). Okanagan Lake is licensed for $4.2x10^8 m^3$ of reservoir storage.

4.2.2 FISHERIES

Okanagan Lake has the highest angler-effort of all the Okanagan main valley lakes; about 52000 angler-days in 1980 (Table 4-2). This is about 80% of the total fishing effort for all the main valley lakes. Such a result is due to the large size of the lake ($350x10^6 m^2$) as well as the existence of services including public access, boat launches, marinas, and alternate water-based recreational activities. Equal to Kalamalka Lake, Okanagan Lake has the highest percentage of salmonids (49%) of the main valley lakes. Although the main fishery is for kokanee, there is also a fishery for large rainbow trout as well as mountain whitefish. The estimated harvest of kokanee and rainbow trout exceeds the total for all the main valley lakes (Table 4-2) due to greater fish stocks as well as the highest fishing pressure.

4.4.3 RECREATION

Okanagan Lake contributes the majority of the total beach-oriented recreation of the main valley lakes, and has the largest number (28) of public recreation sites (Table 4-4). The main public beaches are at Penticton, Trout Creek (Sunoka Beach), along the Kelowna foreshore and near Vernon. About 6% of the shoreline is directly developed for recreation (parks), a further 3% developed commercially (motels, campgrounds, marinas) and 25% with residential development. The total percentage of shoreline with beach-oriented development is about 34%, which is higher than all the main valley lakes except Osoyoos (38%; Table 4-3).

4.5 SKAHA LAKE

4.5.1 WATER LICENSES

Skaha Lake has 112 water licenses. These are for irrigation use (42 licenses), domestic use (61 licenses), industrial use (1 license), and waterworks (8 licenses; Table 4-1). Points of diversion are distributed around the lake. The total volume of licensed withdrawals is second only to Okanagan lake, with irrigation being the major use ($5.3x10^6 m^3$). Skaha Lake also has a small amount of licensed reservoir storage ($1.2x10^5 m^3$).

4.5.2 FISHERIES

Skaha Lake has about 33% of its fish population as salmonids, which is greater than Ellison or Wood Lakes but less than Osoyoos, Okanagan, or Kalamalka Lakes (Table 4-2). Coarse fish species are dominant. The estimated 1980 angler-effort of 1600 days is similar to Osoyoos Lake (2000 days) but less than Kalamalka (4600 days) or Okanagan Lake (52000 days). The corresponding 1980 harvest of rainbow trout and kokanee was third of the main valley lakes, next to Kalamalka and Okanagan Lakes.

Skaha Lake provides excellent fish growth. It supports good kokanee, coarse fish, and mountain whitefish, and has occasional large rainbow trout. Some large kokanee have been taken from Skaha Lake, older than the natural spawning age but immature reproductively. This has prompted the Fisheries Branch of the Ministry of Environment to stock 100000 sterilized kokanee into Skaha Lake in 1984 in an attempt to establish a fishery for large kokanee (B. Jantz, Fisheries Branch, personal communication, March 12, 1985) .

4.5.3 RECREATION

Skaha Lake has only three public recreation sites, including the north end beach, but together with the south section of Okanagan Lake it contributed about 30% to the total participation in beach-oriented recreation in the Okanagan Valley (Table 4-4). About 32% of the lake's shoreline is developed for recreationally-oriented use, including 6.7% for direct recreation (parks), 5.2% with commercial development (motels, campgrounds, marinas), and 19.8% with private residences (Table 4-3). This amount of recreation-oriented shoreline development is greater than Ellison, Wood, and Kalamalka Lakes but less than Okanagan (34%) and Osoyoos (38%) Lakes. The Okanagan River between Okanagan and Skaha lakes is also heavily used for recreation.

4.6 OSOYOOS LAKE

4.6.1 WATER LICENSES

Osoyoos lake has 91 water licenses. These are for irrigation (70 licenses), domestic use (59 licenses), industrial use (2 licenses), and for waterworks (2 licenses; Table 4-1). The total volume of water committed for licensed withdrawals is less than Skaha and Okanagan Lake, but greater than Wood, Ellison, and Kalamalka Lakes. Points of diversion are concentrated around the central and south basins.

4.6.2 FISHERIES

Osoyoos Lake has the third highest percentage of salmonids of the Okanagan main valley lakes, 42% compared with 49% for both Kalamalka and Okanagan Lakes (Table 4-2). Kokanee and mountain whitefish are the dominant species. There are fisheries for kokanee, rainbow trout, and bass, which contributed to an angler effort of about 2000 days in 1981 (Table 4-2). This level of angler effort is about equivalent to the effort in Skaha Lake but less than in Okanagan and Kalamalka Lakes. No fish harvest estimates are available.

4.6.3 RECREATION

The amount of beach-oriented recreation use of Osoyoos Lake as determined by the Okanagan Basin Study (1974) was less than 10% of the total recreation in the main valley lakes. This is the lowest of the lakes studied (Table 4-4). There are only 2 public recreation sites, including Haynes Point Park which contributes the majority (12.2%) of the total shoreline developed for recreation use (Table 4-3). Commercially developed shoreline (motels, campgrounds, marinas) account for 6.5%, and residentially developed shoreline 19.7%. The total shoreline with recreation-oriented development (direct recreation, commercial, residential) is about 38% which is the highest of all the main valley lakes.

4.7 GENERAL DISCUSSION

Increases are expected in angler effort and pressure on fish stocks in the Okanagan Valley, with the future increases expected in both population and number of tourists. Because the present harvest of fish in the headwater lakes is approaching the maximum sustainable yield, it is assumed that the expected increase in angler effort will have to be met by the main valley lakes. To meet these future demands the regional fisheries management plan includes protection and enhancement of existing kokanee stocks with the objective of attaining the much higher pre-1974 levels of abundance. This would be followed by enhancement of rainbow trout (C. Bull, Okanagan Region Fisheries Management Statement, 1983).

The demand for water-based recreation in the Okanagan Valley approximately doubled between 1970 and 1980 and is expected to continue to increase in the future (Table 4-5). The estimated total beach days (residents and visitors) in 1980 was 7.15 million, with about 5% of the total lakes' shoreline developed for recreation, mostly as public beaches.

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5. WATER QUALITY

This chapter summarizes the trends in phosphorus concentration over the past ten years, for each lake. The relation to biological productivity is discussed. Water quality monitoring sites are shown in Figure 1.

The highest concentrations of total phosphorus (P) were found in Ellison and Wood Lakes, with concentrations between 0.040 and 0.080 mg/L. These lakes would be considered eutrophic. The next downstream lake, Kalamalka, had significantly lower total phosphorus concentrations, at about 0.010 mg/L, and would be considered oligotrophic. Similar values to those in Kalamalka Lake were found in Okanagan Lake, except for Armstrong Arm (also known as the North Arm), which had total phosphorus concentrations of about 0.025 mg/L. This latter value is indicative of mesotrophic conditions, approaching eutrophy. Downstream from Okanagan Lake, Skaha and Osoyoos Lakes had similar total phosphorus concentrations to that found in Armstrong Arm.

A comparison of the total phosphorus values in Okanagan Lake with values in other large lakes in British Columbia puts these values into perspective. Buttle and Adams Lakes have concentrations from 0.004 to 0.005 mg/L, Cowichan Lake is in the 0.005 to 0.006 mg/L range, Kootenay Lake is in the 0.007 to 0.008 mg/L range, while Quesnel Lake has only about 0.003 mg/L. Thus, for a lake of its size, Okanagan Lake has a relatively high total phosphorus concentration.

In preparing the discussion of water quality in the Okanagan Valley lakes, a thorough presentation of data could not be made due to time limitations. Thus only readily available data on microfiche were used in this assessment, resulting in the exclusion of several data from other jurisdictions and/or earlier studies. However, the data-set presented here gives the best consistent trend analysis needed to set provisional objectives.

Trends which may be apparent in the data base for total and total dissolved phosphorus at spring overturn since about 1975 are discussed below. At spring overturn, the water column should be homogeneous and values measured at the 2m and 20m depths should be approximately the same. The discussion will deal with lakes in a downstream direction from the uppermost lake in the watershed, Ellison Lake.

5.1 TRENDS IN LAKE PHOSPHORUS VALUES (1975-1984)

Ellison Lake: Water quality data have been collected in Ellison Lake since 1979 at two sites, Site 0500114 at the north end of the lake near the inlet from Vernon Creek, and Site 0500265 located near the lake centre. Total and total dissolved phosphorus data were collected at only one depth, at both sites because of the shallowness of the lake. The data are plotted in Figure 2 and Figure 3.

Ellison Lake is eutrophic, with total phosphorus values over different years ranging from about 0.03 to 0.16 mg/L. Total dissolved phosphorus values were significantly lower than this range at both sites, and were generally less than 0.02 mg/L.

The data for Site 0500265 (near the lake centre) indicate variation but no apparent trend for values taken in the spring for the past four consecutive years, for either total or total dissolved phosphorus. Such is not the case for Site 0500114, near the inlet from Vernon Creek, where the total phosphorus concentrations at spring time have increased in each of the four years. A similar trend of increasing values was not apparent for total dissolved phosphorus at this site. It is not known what has caused the increased total phosphorus concentrations.

Measurements of extinction depths in Ellison Lake at both sites indicate water clarity is relatively unchanged over time, being about 1m.

Wood Lake: Data have been collected near the lake centre (Site 0500245) since 1973. Most of these have been plotted in Figure 4, for total and total dissolved phosphorus at both the 2 m and 20 m depths.

The effect of the month in which samples were collected can be seen in Figure 4. Samples were collected in October on a yearly basis until 1981, thereafter they were collected in September. Lower total phosphorus values were recorded, since the amount of time for phosphorus to accumulate in the hypolimnion was less than in earlier years.

Total phosphorus values at 20m were generally higher than at the 2m depth, likely because of more phosphorus being associated with particulate matter which had settled through the water column. Total dissolved phosphorus at 20 m was also greater than values at the 2m depth.

Spring overturn values, when complete mixing of the lake occurred, are reflected on Figure 4 by approximately equal total and total dissolved phosphorus values for both the 2m and 20m depths. An examination of spring total phosphorus values revealed that if the peak values of 1978 and 1980, and the depressed value of 1979 are disregarded, spring overturn total phosphorus values in Wood Lake are unchanged from 1975, 1976 and from 1981 until the present at about 0.07 mg/L. An increase in spring overturn total dissolved phosphorus was evident in Figure 4. These increased from less than 0.02 mg/L in 1976 to about 0.07 mg/L in 1983 and 1984.

Associated with the increased total dissolved phosphorus has been an apparent decrease in particulate phosphorus concentrations. This appears to have occurred between 1975 and 1979, so that after 1979, at spring overturn, a much smaller proportion of the phosphorus in Wood Lake was present in the particulate form.

The water clarity of Wood Lake also seems to have increased since 1974, according to limited data. Between 1974 and mid-1977, water clarity values consistently were less than 2m. In October 1977 a reading of 3.2m was obtained. Most readings since that time have exceeded 3m, with average yearly readings of 3.75 m (1978), 5.4 m (1979), 5.5 m (1980), 5.2 m (1981), 7.7 m (1982), 9.4 m (1983) and 5.8 m (1984). Rawson (1939) had reported readings of 2 to 2.5m. The increased water clarity is believed to be the result of the input of large quantities of high quality cooling water from the Hiram Walker Distillery.

Kalamalka Lake: Several sites have been used to monitor water quality in the lake. However data for only one site have been included since it had the largest data base and seemed to be a representative data set for the lake. Data for total and total dissolved phosphorus at 2 m and 20 m, for Site 0500246 near the south end of Kalamalka Lake, are plotted in Figure 5.

The data show that until the end of 1977, total Phosphorus values were less than about 0.005 mg/L at spring overturn. Thereafter, values began to increase, with total dissolved phosphorus values having risen to about 0.008 mg/L and total phosphorus values to about 0.011 mg/L. The fact that rising values seem to be occurring differs from the interpretation of trends for the earlier data base made in the Implementation Report. Preliminary data indicate that phosphorus contributed by spray irrigation undertaken in 1981 by the City of Vernon on land in the Kalamalka lake drainage system, is probably not significant. The mainstem loading originating from Wood Lake may be an important factor.

Okanagan Lake: This lake can be divided into at least five distinct areas due to geography and bathymetry. Two Arms of the lake, Armstrong (North) Arm and Vernon Arm have similar mean water depths of 17 and 15 m, respectively, however the maximum depth in Armstrong Arm was significantly greater. The North Basin excludes these two Arms, and is that area of the lake to the north from the highway bridge at Kelowna. The Central Basin is that area between Squally Point and the Kelowna highway bridge, and the South basin, the remainder of the lake south to Penticton.

Phosphorus data for Armstrong (North) Arm are plotted in Figure 6a. Site 0500239 was located about 7 km from the influent from Deep Creek. A trend of increasing total phosphorus values was not readily apparent, at spring overturn between 1975 and 1981. Total phosphorus values were about 0.02 mg/L at spring overturn in 1975, decreasing in the following two years to about 0.014 mg/L, and then returning to about 1975 levels. These values indicate Armstrong Arm is in a mesotrophic state. It is difficult to extrapolate values for the 1982-1984 period, therefore it is not known if over-turn phosphorus concentrations in Armstrong Arm were increasing. Loadings of phosphorus to the Arm have not changed appreciably in the past few years.

Total dissolved phosphorus values followed a similar pattern, decreasing from about 0.01 mg/L in 1975 to about 0.004 mg/L before returning to about the 1975 levels. It is suspected that this pattern may be a function of increased flushing within the North Arm during low phosphorus years.

Site 0500238 in Vernon Arm was well removed from shoreline influences. Another site, located closer to the shore near the inlet from Vernon Creek, had data for only one depth but both sites were generally comparable. Spring overturn values at the near shore site were higher only in 1975 and 1976 when Vernon was still discharging without phosphorus removal to Vernon Creek. Therefore total and total dissolved phosphorus values for only Site 0500238 are plotted in Figure 6b.

Total phosphorus values measured at spring overturn have fluctuated but were generally in the order of 0.01 mg/L. Actual values were less than 0.01 mg/L in 1978 and possibly 1984; equal to about 0.01 mg/L in 1978 and 1980; and higher than 0.01 mg/L in 1976, in 1979 and from 1981 to 1983 (0.012 mg/L). These data indicate that Vernon Arm, away from the shore, is in an oligotrophic state, tending towards mesotrophy. Total dissolved phosphorus values at spring overturn have remained relatively unchanged over the period of record, at about 0.004 mg/L. Prior to 1976 Vernon Arm concentrations were much higher and these changes are related to discharges from the Vernon STP which had total discharge to land by August 1977. Discharges (infrequent) to Vernon Creek, after tertiary treatment, did not resume until the spring of 1984.

Data representative of several sites in the North and Central Basins (excluding Armstrong and Vernon Arms) are presented in Figure 6c for total and total dissolved phosphorus values at Site 0500236, located just south from the highway bridge at Kelowna. Total phosphorus values measured at spring overturn have remained relatively unchanged since 1977, at about 0.009 to 0.010 mg/L. Total dissolved phosphorus values at spring overturn followed a similar pattern, in the 0.005 to 0.006 mg/L range. Data for both total and total dissolved phosphorus in 1976 were considerably lower. This relative stability is to be expected due to the large lake volumes.

Data for the South Basin, possibly representative of water quality in the southern extent of the Central Basin, are plotted in Figure 6d for total and total dissolved phosphorus. These data show a trend of increasing total and total dissolved phosphorus values at spring overturn. Total phosphorus values measured at spring overturn increased from about 0.007 mg/L in 1977 to 0.010 mg/L in 1983. Total dissolved phosphorus values have risen from 0.003 mg/T. to nearly 0.007 mg/L during the same period. These data could reflect the influence of discharges from the Kelowna STP. Although tertiary treatment facilities were installed in early 1983, these data would not yet reflect the impact of these improvements.

Water clarity in Okanagan Lake is greatest in the North, Central and South Basins, and less in Vernon and Armstrong Arms. Values of extinction depths were about 9 m at Sites 0500236 and 0500729 in the Central Basin, 7m at Site 0500238 in Vernon Arm, and 4.5 m at Site 0500239 in Armstrong Arm.

Skaha Lake: Water quality data were collected at several sites in Skaha Lake, however data for only two sites were included. Site 0500453, near Penticton, likely would reflect phosphorus loadings from the Penticton STP, agricultural phosphorus loadings to Shatford and Shingle Creeks, and phosphorus loadings from septic tanks located near Penticton. Site 0500615 was located towards the lake centre, and likely would reflect the general lake water quality.

The total and total dissolved phosphorous data for Site 0500453 are plotted in Figure 7a. Values measured at spring overturn increased between 1976 and 1979, stayed at the 1979 level in 1980, thereafter declining slightly. Present values are about 0.026 mg/L and have been so since 1981. Values for total dissolved phosphorus have followed a similar pattern, with present spring overturn phosphorus values being about 0.01 mg/L.

The total and total dissolved phosphorus data for Site 0500615 are plotted in Figure 7b. The data indicate increasing total phosphorus values at spring overturn. This trend of increasing values was not apparent for total dissolved phosphorus.

Total phosphorus values have risen from 0.012 to 0.025 mg/L compared to total dissolved phosphorus values of only 0.006 to 0.008 mg/L. This may indicate that there are increased particulate phosphorus concentrations in the lake. This is not confirmed by water clarity data which have remained relatively unchanged.

The increased phosphorus concentrations were unexpected. The installation of tertiary treatment at Penticton and the input of low phosphorus water from Okanagan Lake should have resulted in a long-term reduction of lake phosphorus concentrations. The increase after 1976 could be explained by any or all of the following factors:

1. Nonpoint source 'cultural' loadings have been increasing.
2. Total loadings may have been higher than estimated for the pre-and post-tertiary period (see Section 3.1.3).
3. Dilution from Okanagan Lake would depend upon the time period of elevated flow and the physical limnology of Skaha Lake (*i.e.* how the inflow mixes in with the rest of the lake).

Osoyoos Lake: Water quality data were collected at several sites in Osoyoos Lake. Data for total and total dissolved phosphorus at two of the sites, Site 0500249 in the north basin and Site 0500248 in the south basin, are plotted in Figure 8a and Figure 8b, respectively.

At Site 0500249 (Figure 8a) spring overturn total dissolved phosphorus values have not shown any trend. Although yearly fluctuations occur, total dissolved phosphorus at spring overturn was around 0.005 mg/L. Total phosphorus values measured at spring overturn have also fluctuated on a year-to-year basis, however no trend appears to exist. At spring overturn, total phosphorus values were typically 0.025 mg/L, similar to those found in Skaha Lake.

Similar spring overturn total and total dissolved phosphorus values were seen at Site 0500248 (Figure 8b) as at Site 0500249. However, between the sites, total and total dissolved phosphorus values at the 20 m depth during the summer months were significantly different. This can be explained in part by the bathymetry of the north and south basins. The mean and maximum depths were 21 m and 63 m, respectively in the north basin, and 10 m and 29 m respectively in the south basin. Thus at Site 0500248, data were collected at a depth nearer the bottom where more algae had settled out.

5.2 NITROGEN : PHOSPHORUS RATIOS

The ratio of the concentration of total nitrogen to total phosphorus (N:P) can indicate which of these nutrients is the limiting factor in algal. production. Ratios greater than 10:1 or 1:1 generally indicate a phosphorus limited system, while ratios of less than 5:1 indicate a nitrogen limitation. When nitrogen is limiting, decreasing the phosphorus level increases the N:P ratio and causes phosphorus to become the limiting nutrient again. For this reason, and because of the difficulty in controlling nitrogen loadings, phosphorus levels rather than nitrogen levels are always managed in lakes. The ratios found in the various lakes are discussed below.

Ellison Lake: A wide range of N:P ratios existed for Ellison Lake, from about 2:1 to over 20:1. This indicates that at certain times of the year, the algae may be limited by either or both nutrients.

Ratios less than 10:1 or 12:1 have been measured during both the spring (late March or April) sampling and the summer (August) sampling during several years. During 1979, samples were collected monthly or twice per month from April through August at Site 0500265. No ratios less than 12:1 were recorded during the period, therefore it is not known if the months between April and August are always phosphorus limited or if 1979 was an atypical year.

Wood Lake: A wide range of N:P ratios have existed in Wood Lake, indicating that at certain times of the year the lake can be limited by either nutrient.

In the spring (March or April), at overturn, when the water column was evenly mixed, ratios were often below 10:1 indicating a relatively shall supply of nitrogen. The increased total dissolved phosphorus (Section 5.1) and the increased water clarity in Wood Lake are likely manifestations of these changes in N:P supply which have apparently occurred since 1978.

Kalamalka Lake: Phosphorus is always the limiting nutrient in Kalamalka Lake, with N:P ratios from 18:1 to 67:1 at all depths.

Okanagan Lake: Phosphorus is almost always the limiting nutrient in Okanagan Lake. On occasion, N:P ratios have been below 12:1, however these infrequent low N:P values were recorded at depths of about 20 m in Armstrong Arm and between 10 and 20 m in Vernon Arm.

Skaha Lake: Skaha Lake reflects N:P ratios generally greater than 12:1. When the ratios fall below 12:1, it is usually at a depth of about 20 m.

Osoyoos Lake: Both nitrogen and phosphorus can be the limiting nutrient for algal production in Osoyoos Lake. This depends upon the station and/or depth. For example, at the lake narrows, N:P ratios are frequently less than 12:1, indicating that nitrogen is limiting. At other sites, N:P ratios declined below 12:1, most frequently at depths of 20 m or more. Ratios in surface samples seldom fell below 12:1.

5.3 SUMMARY

Ellison Lake is eutrophic, with total phosphorus values increasing at spring overturn. Algal production can be either nitrogen or phosphorus lmited. Only diffuse sources contribute phosphorus to Ellison Lake.

Wood Lake is also eutrophic. Total phosphorus values at spring over-turn are unchanged, however total dissolved phosphorus has increased. A decrease in particulate matter has resulted in a significant improvement in water clarity. Either nitrogen or phosphorus can limit algal production. Diffuse sources contribute phosphorus to Wood Lake.

Kalamalka Lake is oligotrophic. After 1977, total and total dissolved phosphorus values have increased. Kalamalka Lake is presently phosphorus limited.

Most of Okanagan Lake is oligotrophic. Vernon Arm is oligotrophic and tending to be mesotrophic, while Armstrong Arm is mesotrophic. Phosphorus values at spring overturn generally seem to be unchanged although both total and total dissolved phosphorus in the South Basin have increased. This may be due to the discharge from Kelowna which did not receive tertiary treatment until 1983. The effect of removing the City of Vernon discharge from Vernon Creek was evident in reduced phosphorus values in Vernon Arm. Water clarity is best in the main basins of the lake, and not as good in Vernon and Armstrong Arms. Phosphorus is the limiting nutrient to algal production in the main basins, while either nitrogen or phosphorus can be the limiting nutrient in Vernon or Armstrong Arms.

Skaha Lake is mesotrophic, showing increased values in spring overturn phosphorus. This is unexpected since there is flushing of the lake by low phosphorus Okanagan Lake water and tertiary treatment is carried out at Penticton. The result might be due to increasing diffuse "cultural" loadings, higher loadings to the lake than initially estimated, or the mixing pattern of Okanagan Lake water in Skaha Lake. The growth of algae in the lake is limited by phosphorus.

Osoyoos Lake is mesotrophic. No trends in phosphorus values have been apparent, although higher values existed in the south basin. Algal growth can be limited by either nitrogen or phosphorus.

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6. WATER QUALITY OBJECTIVES

Water quality objectives are guidelines to protect water quality from deterioration. For the purpose of this report the only water quality characteristic to be considered is phosphorus. The site-specific objectives for different lakes which are considered below are based on general criteria which have been proposed after a review of the literature and phosphorus related problems in British Columbia. The criteria and their derivation are contained in a document currently in preparation entitled *Water Quality Criteria for Nutrients and Algae*. Criteria are proposed to protect various water uses. For phosphorus, the water uses for which criteria could be set were drinking water (including food processing), aquatic life (including fish), and recreation and aesthetics. Criteria were set for lakes and streams, however only the lake criteria are tabulated below.

Water Quality Criteria for Lakes (Total Phosphorus in mg/L)**

Recreation and Aesthetics	0.010
Aquatic Life (including fish)	0.005-0.015*
Drinking water	0.010

* value given is for salmonid species in coastal lakes. Lakes where the important species are different or in other geographical areas may require evaluation before criteria are selected. A range is given since each lake must be considered-individually.
** all values cited in this chapter are for total phosphorus. For deep lake stations total phosphorus is the best approximation of biologically available phosphorus.

The objectives which are proposed in this chapter for each lake are based on the water uses-typically the most sensitive use-but take into account several other factors specific to the lakes which are discussed below.

Both "loading criteria" and "maximum desirable concentrations" (*i.e.* objectives) for phosphorus were set out in the Okanagan Basin Study Report (1969-1974). Since then only the maximum loading values have ever been quoted or used; no use of the recommended concentration objectives has ever been made. The objectives have several advantages over the loading values and this issue is discussed in detail in Chapter 7.

6.1 ELLISON LAKE

Ellison Lake is generally considered to be eutrophic at present. However, because of the limited uses made of the lake (two small irrigation licenses and restricted recreation-archery fishing, some beaches and a water ski tournament), it is unlikely that the present high phosphorus concentrations (0.030-0.160 mg/L) would have a negative effect on these uses. On the basis of these uses, there seems to be no reason for making any special efforts to improve Ellison Lake, although a recently completed development may create some recreational demand in the future. One consequence of Ellison Lake's high nutrient concentration is a relatively high loading of phosphorus and nitrogen to Wood Lake via Vernon Creek. It is difficult to set an objective concentration which would protect Wood Lake, although a reduction in the nutrient concentration in Ellison Lake would result in some improvement to Wood Lake water quality. The cost and benefit of an improvement to Ellison Lake water quality is difficult to assess. The mean annual flow out of Ellison Lake is approximately 17000 dam^3. At a concentration of 0.060 mg/L this would amount to approximately 1 tonne of phosphorus loading per year to Wood Lake.

Without any water use to justify a change in water quality, no objective for phosphorus for Ellison lake is proposed at this time. However, a reduction of phosphorus levels in Ellison Lake would help to reduce phosphorus loadings entering Wood Lake.

6.2 WOOD LAKE

The present phosphorus concentration of Wood Lake is approximately 0.075 mg/L and the lake is generally considered eutrophic. The consequences of the high nutrients (sporadic algal blooms, hypolimnetic oxygen depletion, relatively poor water clarity) significantly reduce the potential value of the lake for some uses. The lake is presently used as a water supply (primarily irrigation), for fish habitat and for recreation. Fish production is limited by the summer oxygen deficit in the hypolimnion which thus cannot be used as a cool water refuge for salmonids in summer. Recreational use is reduced because of algal blooms and consequent poor water clarity.

For a water use such as salmonid fish production, an objective for phosphorus concentration of much lower than the present 0.075 mg/L would be required. The proposed criterion for phosphorus to protect salmonid fish in lakes is 0.005 to 0.015 mg/L. Above 0.015 mg/L the risk of hypolimnetic oxygen depletion usually becomes significant depending on lake and watershed characteristics. For recreation a criterion of 0.010 mg/L has been proposed. A reduction in lake phosphorus concentration from 0.075 mg/L to 0.010 or 0.015 mg/L represents a very large reduction in phosphorus loading and will only be achievable with drastic measures. However, a long-term objective of 0.015 mg/L is suggested for Wood Lake based on the combined water uses of aquatic life (including fisheries) and recreation and aesthetics. The Okanagan Basin Study suggested a maximum desirable concentration of 0.020 mg/L for multiple use.

In a practical time frame (short term: 5-20 years) a more realistic goal might be to reduce the phosphorus concentration by one half (to for instance 0.040 mg/L). There are no point source discharges to the lake and the existing diffuse sources are likely to be difficult to control. Wood Lake has been examined previously to determine the feasibility of treatment of the lake itself to reduce phosphorus (alum treatment, aeration, etc.) and reevaluation might be advisable to determine the present costs and benefits of such techniques (see Section 9.5). The possibility exists that a significant portion of the phosphorus loading to Wood Lake originates as "internal loading" *i.e.* release of phosphorus from lake sediments.

Setting water quality objectives for other characteristics may be possible in the future when sufficient understanding of the lake ecosystem has been achieved. Such characteristics would include water clarity and amount of blue-green algae.

6.3 KALAMALKA LAKE

The water uses for Kalamalka Lake (irrigation/drinking water, aquatic life, recreation) are not all of equal importance. Because of the lake's extraordinary physical beauty, recreation and aesthetics have become one of the most important (most sensitive) uses of the water resource. Fisheries is important but is likely limited by the overall biological production of the lake. However, to increase the biological production by allowing an increase in phosphorus concentration would likely cause an undesirable change in water clarity and likely the water colour of the lake, thus reducing the recreation and aesthetic value. The increases since 1970 in nutrients appear to be a cause for major concern and provide a good reason to at least maintain the present water quality, or preferably consider some action to reduce phosphorus loads.

The present phosphorus concentration averages about 0.010 mg/L. However there appears to have been a significant increase in the past ten years (see section 5) since the Okanagan Basin Study reported a spring phosphorus concentration of 0.008 mg/L. Although at present the average lake concentration is 0.010 mg/L and may be acceptable, Kalamalka Lake because of its very special nature, deserves an extra margin of safety to protect it from deterioration. Significant degradation such as decreased water clarity or changes in water colour would represent a major loss of an invaluable water resource. Of all the lakes examined at this time, it is apparent that major changes are taking place here and some effort should be made to reverse these trends. An objective concentration of 0.008 mg/L is therefore proposed for Kalamalka Lake.

The Okanagan Basin Report used 0.007 mg/L as an average lake concentration and suggested a maximum desirable concentration of 0.065 mg/L.

One mechanism which naturally eliminates phosphorus from the water column is marl precipitation. The marl deposition areas of the lake attest to the major role of this process. However, we do not know the amount of phosphorus lost by this process, the protection afforded by marl precipitation and the sensitivity of the mechanism to increasing phosphorus concentrations.

6.4 OKANAGAN LAKE

Proposing a water quality objective for Okanagan Lake requires an evaluation of the three major water uses and their relative importance. As with Kalamalka, recreation and aesthetics are the most sensitive use. Despite an obvious advantage in having a higher phosphorus concentration to enhance fish production, the most valuable water use (recreation) would likely suffer if a certain limit were exceeded. The present phosphorus concentration in the three major basins of Okanagan Lake is similar, thus it would seem to be unnecessary to recommend different water quality objectives for each basin. The phosphorus concentration which is most appropriate to protect Okanagan Lake recreation and aesthetics is 0.010 mg/L. The Okanagan Basin Report gave an average lake phosphorus concentration of 0.007 mg/L for 1971 and a desirable concentration of 0.005 mg/L.

Two other parts of the lake which are geographically distinct and deserve separate consideration are Vernon Arm and the North (Armstrong) Arm. Vernon Arm has undergone substantial reductions in phosphorus concentration in the past ten years due to the removal of the City of Vernon's discharge from Vernon Creek. During the period of discharge (before 1977) concentrations in the arm at the mouth of Vernon Creek often exceeded 0.050 mg/L. The Arm concentrations are now generally in the 0.010 to 0.012 mg/L range. The objective proposed for Vernon Arm is therefore 0.010 mg/L. The North Arm has a much higher concentration at present: 0.010 to 0.040 mg/L. This is due to the Armstrong sewage treatment plant discharge to Deep Creek as well as non-point sources (primarily agriculture). Since the North Arm is used for recreation, this water use should be protected. The objective proposed is therefore 0.010 mg/L.

The shoreline areas of Okanagan Lake are the areas which are in greatest need of protection in the short term. The near-shore areas receive the greatest use, be it fishing, recreation or water withdrawal. These shore areas are also most subject to a variety of watershed inputs and are most susceptible to degradation. Water quality objectives would need to be very specific (for particular areas of shoreline) and such objectives will be the subject of a future report. Checking objectives at open water stations, which represent overall lake quality, will ensure long-term protection of the lake.

6.5 SKAHA LAKE

The present phosphorus concentration at spring overturn for Skaha Lake is approximately 0.025 mg/L. A major change in loading to Skaha Lake occurred in 1972 when the City of Penticton began removing phosphorus from its sewage discharge. Prior to 1972 phosphorus concentrations were in the range of 0.020 to 0.040 mg/L, probably more typically 0.030 to 0.040 mg/L. For a few years after phosphorus removal (1974-1978) lake concentrations varied between 0.011 to 0.016 mg/L, suggesting a significant reduction in phosphorus concentration. However since 1978 spring overturn phosphorus has risen to remain in the 0.023 to 0.030 mg/L range.

The primary water use for Skaha Lake is recreation, although fisheries is also important and many water licences exist for water withdrawal including Kaleden's drinking water supply. The objective which is proposed is a promise between the recreation and drinking water uses (criterion 0.010 mg/L) and fisheries which would probably be optimized by a concentration of 0.020 mg/L. The present 0.025 mg/L concentration results in a dangerous hypolimnetic oxygen depletion (dissolved oxygen is 1-2 mg/L in the deepest parts of the basin in late summer) which threatens to cause major changes in fish food supply or to reduce the summer cold water habitat refuge for fish. A further decrease in oxygen could also allow phosphorus presently trapped in the sediments to be released back into the water column, thereby increasing the phosphorus loading. For these reasons it seems prudent to reduce the phosphorus concentration from the present 0.025 mg/L to 0.015 mg/L. Such a reduction seems to be an achievable goal since a similar concentration did exist for a period in the mid 1970s after tertiary treatment was put into effect at Penticton. Favourable hydrologic conditions (high flushing) which were also a factor can be expected to continue. The present water quality objective of 0.015 mg/L can be compared to the Okanagan Basin Study maximum desirable concentration of 0.012 mg/L.

6.6 OSOYOOS LAKE

Osoyoos Lake presently has a phosphorus concentration of 0.030 mg/L. Some effect was shown in Osoyoos Lake from the reduction of phosphorus loading at Penticton in 1972, and the Osoyoos Lake concentration appears to parallel the increases and decreases that occurred upstream in Skaha Lake.

Water uses for Osoyoos Lake are the three same basic categories considered for the other lakes: recreation, fisheries and water supply. The fisheries in Osoyoos Lake include a somewhat different mix of species, with warm water species (bass) being an important component of the sport fishery. Warm water species have higher optimum phosphorus concentrations since no cool water oxygenated refuge is required as is the case with salmonids. However, too high a phosphorus objective would have a negative effect on other sport fish species, particularly salmonids.

The water quality objective which is proposed for Osoyoos is 0.015 mg/L. It represents a compromise between uses which would benefit from low phosphorus (<0.010 mg/L), such as recreation or water supply and uses which would benefit from higher phosphorus concentration, such as fisheries. In particular, a fish species such as bass would benefit from much higher concentrations.

6.7 SUMMARY

The objectives which have been proposed are designed to protect water quality of the main Okanagan lakes based on their principal water uses. The values for the lakes are tabulated below.

Total Phosphorus Water Quality Objectives for the Okanagan Lakes

Lake	Objective	1985 Concentration (Approx.)
Ellison	none proposed	0.080
Wood	0.015	0.075
Kalamalka	0.008	0.010
Okanagan (main basins)	0.010	0.010
Okanagan (Vernon Arm)	0.010	0.012
Okanagan (North Arm)	0.010	0.020
Skaha	0.015	0.025
Osoyoos	0.015	0.030

Note: The objectives can be checked by averaging the results from several samples taken at spring overturn, at sites located over the deepest portion of each lake.

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7. CONCENTRATION/LOADING RELATIONSHIPS

There are two basic approaches which can be taken to manage water quality. These are:

1. establishing the amount of phosphorus entering a lake which should not be exceeded. This is generally referred to as establishing "critical" or "acceptable" loadings. They are based on required phosphorus concentrations which are not to be exceeded.
2. establishing water quality objectives which specify phosphorus lake concentrations. By taking management actions

ensuring that these concentrations are not exceeded, water quality is protected. Since in this case the relationship between phosphorus concentration and source loading is not known, monitoring is used to check the result of control measures.

Aspects of both these approaches are discussed below and it would appear that for the Okanagan Lakes at this time, the water quality objectives approach has a number of advantages over the critical loading approach.

7.1 CRITICAL LOADING

The primary strategy which has been used in the past to guide maintenance or improvement of lake water quality affected by nutrients, is to establish critical loadings below which acceptable water quality should exist. This approach was based on the work of Vollenweider who identified the relationship between lake trophic status, phosphorus loading and the key lake characteristics which bear on this relationship. The relationship, it should be emphasized, is a general one, based on the overall interpretation of a large sample-set of lakes. There are a number of fundamental difficulties in using the approach of critical loadings for the Okanagan Lakes. These include the uncertainty associated with present loading data, since loading estimates for diffuse sources are inaccurate. Also, the lakes are probably not suitable for such an evaluation procedure. This latter possibility is discussed below.

There is some indication that the loading rates for the Okanagan Lakes, calculated from the Vollenweider curve, differ from present estimates which are based on examination of sources. For example, using Okanagan Lake, the estimated 1980 load was 69 tonnes of phosphorus and the known lake concentration was 0.010 mg/L. According to the Vollenweider curve, a concentration of 0.010 mg/L should correspond to a loading of 42 tonnes, implying that the present loading estimate is far too high. Similar discrepancies are evident when comparing loading estimates,and known concentrations for other lakes in the system. Skaha Lake's 1980 estimated loading is approximately 13 tonnes of phosphorus and measured lake phosphorus concentration is 0.025 mg/L. Using the Vollenweider curve a concentration of 0.025 mg/L corresponds to a loading of approximately 21 tonnes. In this case an apparent underestimation has been made if the Vollenweider curve results are accepted.

The other difficulty in using Vollenweider's critical loading approach is the application to the Okanagan lakes specifically. All the lakes have particular features which make them less than ideal candidates for such an appraisal procedure. Vollenweider's "curve" was derived from a large number of lakes, the vast majority of which were relatively small and with short water-residence time. However the Okanagan Lakes (with the possible exception of Osoyoos) have features which place them on the periphery of the data-set, or have features which are unusual enough to call into question application of Vollenweider's relationship. For example, Okanagan Lake's long water-residence time (53 years) is very unusual in the context of limnological scale. It is quite rare for lakes to have water residence times of more than 5 years. Even a very large lake such as Lake Erie has water residence time of only 2.6 years. Other examples might include Kootenay lake (1.6 years), Kamloops Lake (60 days) and Shuswap Lake (2.1 years). Because of this unusual feature, and Okanagan Lakes relatively large size in comparison to the lakes Vollenweider used to derive the curves, there is some question as to whether or not the lake response is similar to the general relationship represented by the curve. There are certainly several examples in the literature where the link between lake loading and response (concentration) is affected by a variety of factors. These provide a result very different from that predicted by Vollenweider's curves.

Kalamalka Lake is a very large example of a lake of a particular type, known as a "marl" lake, in which annual precipitation of calcium and phosphorus occurs from the water column. One of the key characteristics, upon which Vollenweider's curve is based, is phosphorus sedimentation rate (quantified on the curve as mean depth divided by water residence time). Therefore, because of the modified (enhanced) phosphorus sedimentation rate, Kalamalka will probably not respond as might be expected for more "typical" lakes.

Wood Lake is also unusual in that part of the phosphorus load to the lake is derived from the sediments (internal loading). Lakes which derive a portion of their phosphorus supply in this manner would not be expected to behave as more "normal" lakes. For these, estimates of phosphorus derived from watershed sources are used to establish their place on Vollenweider's curve.

Skaha Lake is directly downstream from Okanagan Lake and nearly all of its water is supplied from this source. The present phosphorus concentration of Skaha Lake is 0.025 mg/L. However, the inflowing water from Okanagan Lake contains 0.010 mg/L phosphorus and thus dilutes the Skaha Lake concentration. This is a very unusual situation and is not dealt with by most lake nutrient-models. This situation appears to indicate that a relatively high loading must be occurring from other sources in the Skaha watershed to account for the maintenance of such a high lake concentration. Most lakes (particularly well flushed ones with dominant inflows such as the Okanagan River) have inflow concentrations which are similar to the lake concentration. Thus, it is unclear how Skaha Lake could be evaluated on a Vollenweider curve, to derive a critical loading that could be used with confidence.

Another difficulty in using critical loadings as a means of planning for the protection of water quality is the precision of the estimated loadings. Decisions would need to be made on allowing or disallowing loadings of one or two tonnes from particular sources. However, since the overall estimated loading of about 69 tonnes for a lake such as Okanagan is not accurate to within 1 or 2 tonnes, such decisions would not be too meaningful and might be difficult to justify.

For some of the reasons cited above, no attempt is made in this document to set "critical" or "allowable" loadings. A similar decision was made in the Okanagan Basin Implementation Study Report. There seems to be no reason to reverse this judgment at this time.

7.2 WATER QUALITY OBJECTIVES

Water quality objectives for nutrients are used in a number of jurisdictions as the primary means of planning for the protection and evaluation of water quality. For water quality properties other than nutrients (*e.g.* metals, organic pollutants), "critical" loadings are very rarely used and objectives (concentrations) are the overwhelming choice of agencies responsible for water quality.

Objectives avoid the need for extremely costly and high precision loading studies to be carried out. Such studies are necessary to establish loadings to the level of accuracy needed in specifying "critical" loadings. Loading estimates in the context of water quality objectives are only used to determine the relative contributions from various sources. When loadings are used merely to prioritize the importance of various inputs, less accurate (and less expensive) loading estimates can be used. However, they should be somewhat more precise than those used in this report for diffuse loadings.

The following discussion illustrates how water quality objectives could be applied in the Okanagan. The objectives proposed for each lake are discussed in Chapter 6. For example, for Okanagan Lake the objective is 0.010 mg/L. For Vernon Arm and the North Arm some reductions in phosphorus loadings would need to be made to meet this objective. Reductions from agriculture, sewage etc. would be made on the basis of cost-effectiveness. Results would be evaluated by a water quality monitoring program designed to determine whether the objective was achieved and whether water quality was being maintained.

For the main lake-body, the objective of 0.010 mg/L is approximately equal to the present concentration. Present water quality must therefore be maintained by ensuring that no net addition of phosphorus enters the lake. As population and development increase more phosphorus will be generated from municipal effluent. However, if no economical means of preventing lake input from this source is possible, some compensating reduction from some other source must be undertaken. For example, if no alternative exists to increased lake discharge from a municipal treatment plant caused by population increase, then some reduction of an agricultural source or a septic tank source may make the sewage treatment plant discharge acceptable. The result will be no net increase in loading.

For a lake such as Kalamalka, where a reduction in loading is required, an evaluation of the cost of reductions from potential phosphorus sources such as Coldstream Creek, the Vernon Spray Irrigation system, or from Wood Lake can be made. The most economical alternative in terms of cost per kilogram of phosphorus loading would then be pursued until the objective lake concentration has been met, or it becomes no longer reasonable to continue.

Specific strategies for each individual lake as well as an overall management plan for all the valley lakes is necessary. We recommend that these strategies and management plan based on the principle discussed here, rather than on the single policy of only reducing phosphorus inputs from municipal effluents. Chapter 9 compares the costs of various phosphorus reduction alternatives and thereby suggests the most promising directions which should be followed.

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8. PHOSPHORUS CONTROL OPTIONS

Phosphorus control options for waste discharges are listed in this chapter. From this list, control measures can be chosen which will help water quality in the Okanagan Lakes meet the objectives proposed in Chapter 6 of this report.

8.1 SEWAGE TREATMENT AND INDUSTRIAL TREATMENT PLANT CONTROLS

8.1.1 CHEMICAL AND BIOLOGICAL REMOVAL

Chemical or biological removal of phosphorus in the sewage treatment plant can attain removal efficiencies in the range of 85% to 95% depending on the facilities provided (*i.e.* Penticton and Kelowna).

8.1.2 IRRIGATION OF RECLAIMED WASTEWATER

A phosphorus removal efficiency close to 100% is attainable for some of the smaller municipalities (*i.e.* Osoyoos and Oliver) by use of effluent irrigation. A combination of irrigation and chemical phosphorus removal at the treatment plant, prior to lake discharge of a portion of the effluent, at selected times, can provide a high overall degree of phosphorus removal (96% to 99%) for larger municipalities (*i.e.* Vernon). It is usually not possible to irrigate all of the effluent from a large municipality as the land base required is too large.

8.1.3 INFILTRATION BASINS

Infiltration of sewage effluent into the ground can provide a high degree of phosphorus removal (95%) at some smaller municipalities (*e.g.* Okanagan Falls) where sites are carefully chosen. This method is normally for smaller discharges due to the limited infiltration rates which must be used to avoid ground water surfacing problems, or nitrate contamination in adjacent wells.

8.2 ONSITE HOUSEHOLD WASTEWATER TREATMENT

A range of alternatives have been developed for household wastewater disposal in unsewered areas. Some alternatives with phosphorus reduction potential are reviewed below. Onsite disposal may be more cost-effective than collection and treatment. Costs associated with use of these options are reviewed in Chapter 9.

8.2.1 CONVENTIONAL SEPTIC TANK/SOIL ABSORPTION FIELD SYSTEMS

If a septic tank and tile field system is located an adequate distance from the stream or lake, little or no phosphorus will reach the water body. The distance required depends on the texture of the soil and the depth of unsaturated soil above ground water.

A minimum horizontal distance of 30 m is required in order to remove 80% of the phosphorus, but up to 300 m may be required depending on soil and ground water conditions.

Effective control of phosphorus entering water bodies from conventional septic tank/soil absorption systems could be attained by introducing regulations incorporating revised distance requirements, suited to site conditions.

8.2.2 SEPTIC TANK/SOIL ABSORPTION SYSTEMS WITH CHEMICAL REMOVAL

A facility for removing phosphorus using chemical addition could be installed between the septic tank and the tile field. The overall removal efficiency of such a system should exceed 80%, considering both chemical precipitation and additional soil retention. While this type of facility is still in the development stage, it is believed that the equipment is available to allow sludge removal, replenishment of chemical and maintenance to take place on a quarterly basis.

To ensure that consistent operation and regular maintenance is carried out, the supervision of a Municipality, Regional District, Water Board or other management entity would likely be required. Authority to levy appropriate taxes may also be necessary.

8.2.3 SEPTIC TANK/SOIL ABSORPTION MOUND OR FILL SYSTEMS

Mound systems for disposal were originally designed to overcome problems with slowly permeable soils or high water tables. With proper design-sizing, fill election, siting-such systems have application for phosphorus removal.

A mound system is a soil absorption system in a suitable fill material that is elevated above the natural soil surface. The mound can provide the necessary depth of soil above a high water table or rapidly permeable native soil to provide adequate phosphorus removal and other treatment of the wastewater. Effluent is pumped or siphoned into the distribution system from the septic tank and percolates downward through the unsaturated soil where phosphorus removal (and other treatment) occurs. An 80% removal efficiency should thus be possible.

Fill systems are a variation of mound systems. Native soil materials are excavated and replaced with soils having better treatment capabilities. A variation of the fill systems is a conventional drainfield, bed, or trench system with the distribution network surrounded with backfill material having a particularly high capacity for phosphorus retention (*e.g.* high iron and aluminum oxide materials).

Mound and fill systems may be feasible options where site conditions are suitable. Their simplicity, stability and low operating cost may make them attractive. Inadequate maintenance of the septic tank, poor design or construction, or a combination of these factors may result in failure or poor performance. Difficulty of monitoring the phosphorus removal efficiency of mound and fill systems may also make them less attractive for enhanced onsite phosphorus removal.

8.2.4 IN-HOUSE PROCESSES

Major sources of phosphorus in the home are laundry, dishwashing, and toilet wastewaters. Consistent use of low phosphate detergents could reduce to one-half the contributions of phosphorus in the home. Segregation of toilet wastewaters can reduce phosphorus in the graywater stream. Waterless and low-water carriage toilets are then needed along with dual plumbing systems and a means of disposal of the residues. Recycling systems for wastewater in the home may also be used to reduce total phosphorus loading from the household (*e.g.* graywater may be treated to a quality that is acceptable for flushing toilets and watering lawns).

Any in-house measures to reduce phosphorus loads depend upon homeowner Commitment, installation of alternative plumbing equipment, and a variety of regulations to enable and/or require revised practices or equipment. It is for these reasons that in-house processes are often considered to be unfeasible.

8.2.5 OTHER METHODS

There may be other methods of controlling phosphorus from septic tanks which will work in the Okanagan. Future research may provide other solutions for removing phosphorus from septic tanks. However, for the present, the methods outlined in the above or variations of these methods should solve the problem in a cost-effective manner.

8.3 SEWER TRUNK EXTENSIONS AND CLUSTER SYSTEMS

8.3.1 SEWER TRUNK EXTENSIONS

An alternative for areas presently on septic tank systems is sewering and central treatment. To be effective, central treatment will have to remove a higher proportion of phosphorus than the septic tank tile field system it is replacing. This will be the case only in certain areas of poor site conditions.

Sewer trunk extensions may be possible from adjacent sewered areas with sufficient capacity and good phosphorus removal. Capacity of the existing facilities and actual systems needing replacement would have to be investigated first.

8.3.2 CLUSTER SYSTEMS

Small scale community collection and treatment systems (*e.g.* pressure or vacuum sewers; package plants) may be applicable in isolated problem areas. As in the case of sewer trunk extensions, suitable local sites would need to be identified.

8.4 AGRICULTURE

8.4.1 FEEDLOTS AND WINTER FEEDING AREAS

Feedlots or winter feeding areas for cattle located close to or in streams can contribute phosphorus to the stream. The amount contributed depends on a variety of factors such as slopes, presence of frozen ground at snowmelt, rate of spring thaw, proximity to the stream, number and size of cattle, amount of manure accumulated and location of feeding and water facilities.

It would appear from a few random site inspections that collection and treatment of runoff from such areas would be very difficult, although in some cases not impossible. The solution for each farm would have to be site-specific. In many cases, it would require relocation of facilities.

It may be possible to develop regulations incorporating acceptable distances to water bodies for such feeding areas. It is likely that they would need to be conservative and many special-case situations, although in fact acceptable, could be out of compliance with such broad regulations. An option for such situations could be to apply for a permit under the Waste Management Act.

Farming activities under Class B agricultural-type operations are an alternative worth considering would be to remove this exemption from feedlots, cattle wintering areas or other concentrated animal-use areas in the Okanagan Basin. The potential for phosphorus entry into tributary streams from this source is very large. In spite of large amounts of money spent on controlling municipal discharges and septic tanks, overall lake phosphorus loading may be increasing due to increasing inputs from this source, as described in Chapter 3.

8.4.2. CALVING PASTURES AND IRRIGATED PASTURES

Cattle in calving pastures, irrigated pastures and open range with access to the streams can contribute phosphorus to the Okanagan lakes. Fencing cattle out of streams and areas immediately adjacent and/or providing stock-watering facilities and salt licks away from the streams are good management practices. This prevents high concentrations of cattle and manure accumulations in and near the streams, and reduces soil erosion along streambanks due to animal trampling.

The need for a regulation requiring that all streams be fenced and watering facilities provided elsewhere may be worth examining.

8.4.3 HOBBY FARMS

There is also a problem with hobby farms located along streams where the animals have access to the water. A public education program might help but probably would not be sufficient to cause a significant reduction in phosphorus from this source. Further information is required in this area in order to determine practical solutions to the problem.

8.4.4 FERTILIZER SOURCES AND IRRIGATED LANDS

Fertilizers applied to orchards and other irrigated lands contribute phosphorus to the Okanagan Valley Lakes as noted in chapter 3. Fertilization and irrigation are integral to intensive management and high productivity of hayland, orchards, vineyards, etc. Controls on phosphorus from these sources should ideally be directed at management practices which provide best possible production consistent with minimum phosphorus losses.

Education and research to improve methods and timing of application of fertilizer to crops to minimize transport of phosphorus to the lake system will presumably continue. Research and education will hopefully emphasize the need to minimize losses of phosphorus since this is not a primary concern of Federal and Provincial Ministries of Agriculture.

Development of large acreages of vineyards on coarse sandy and gravelly terrace soils in the Osoyoos Lake drainage basin may present a special case for nutrient budget research and extension. Irrigation scheduling and strict fertilization timing and soil and crop testing may be required.

Because phosphorus moves from eroding lands, attached to sediments, improved conservation practices will help minimize erosion of soil from agricultural lands.

The Ministry of Agriculture and Food and the Canada Department of Agriculture have primary responsibilities in the above areas. Their continued cooperative effort with other agencies and particularly the Ministry of Environment, will provide effective delivery of these programs.

8.4.5 DESIGN OF SITE-SPECIFIC IMPROVEMENTS AND REGULATIONS

Generally the problems associated with agricultural inputs of phosphorus will need to be further defined before cost-effective solutions can be developed. This applies both to existing problems as well as developing a mechanism for avoiding costly problems in the future. The methods outlined above should help correct the situation but will probably not provide the total solution.

Regulation of the farming industry is not popular. There may be ways to avoid regulation and still solve the problem of phosphorus inputs to the lakes; however, such methods are not readily apparent at this time. Many of other present problems have developed because there are no regulations to follow in siting facilities.

8.5 FORESTRY

Forestry practices are a significant source of nutrients to Okanagan Valley Lakes, but it is often difficult to separate these contributions from natural runoff. Chapter 3 has indicated that logging activities contribute roughly a quarter of the phosphorus loading to each of the lakes except Kalamalka. These nutrients are often sediment-associated and only the biologically available portion is of concern.

Logging and particularly road construction in a Limited number of locations generate the largest proportion of nutrients from forestry. The remaining activities contribute a relatively small and difficult to control amount of phosphorus loading.

To control phosphorus, areas sensitive to increased nutrient export must be avoided or managed with care. This requires adequate climate, soils, terrain and vegetation data, so satisfactory planning can take place. The Ministry of Forests has a program for identification of Environmental Protection Areas and also a biogeoclimatic mapping program. Data developed under these programs can assist in reducing phosphorus. However, they have been developed for other purposes. The Ministry of Environment has carried out a pilot project for data collection to assist in sediment generation control and has assisted the Ministry of Forests in other situations.

Regulations or guidelines to control the effects of forestry practices can relate to:

- design, construction, drainage and maintenance of haul roads
- type of cutting pattern
- yarding techniques in logging
- burning of slash

Regulation of practices such as these are under the jurisdiction of the Ministry of Forests. Restriction of operations in sensitive areas or requirements for operations are incorporated in cutting and management plans and individual tenure, lease or cut arrangements.

8.6 CONCLUSIONS

1. Technical options for control of municipal and industrial discharges (point sources) fall into several groups, all having the potential for a high degree of phosphorus removal:
   - chemical or biological removal-80-95 percent removal
   - spray irrigation to land after STP
   - without any lake discharge-95-100 percent
   - with partial lake discharge-95+ percent (depending on proportion)
   - infiltration basins
   - 95-100 percent
2. Control options for onsite household wastewater disposal (non-point sources) include:
   - properly sited conventional septic tank/soil absorption field systems supported by revised regulations for new developments (80+ percent minimum removal expected; many systems with 95+ percent)
   - conventional septic tank/soil absorption field systems with chemical phosphorus-precipitation facilities between the septic tank and the drainfield (80+ percent removal expected)
   - septic tank/soil absorption mound or fill systems (80+ percent removal expected)
   - in-house processes including low phosphate detergent use, segregation of blackwater and graywater, and wastewater recycle systems.
3. Control options regarding feedlot, winter feeding and calving areas and pastures include:
   - relocation of the entire operation
   - collection and treatment of runoff
   - diversion of inflowing waters
   - relocation of feeding and watering areas
   - closing down operations entirely
   - development of regulations and support legislation for new operations
   - fencing streams
   - providing alternate watering, shade and salt lick areas away from streams
   - scheduling of fertilizer and irrigation as indicated by measured crop needs and soil supply
   - research and extension relating to phosphorus losses and best management practices associated with intensive cropping
   - special studies and ongoing monitoring of receiving waters in relation to specific concerns and improvement actions
   - ongoing education to maintain awareness of producers and the public.
4. Control options for forestry generally involve the following:
   - adequate climate, soils, terrain and vegetation data to aid long-term and operational planning
   - regulations and guidelines (which may be developed and implemented by the Ministry of Forests) to protect areas sensitive to high nutrient losses (erosion in particular)

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9. COST OF PHOSPHORUS CONTROL OPTIONS

9.1 SEWAGE TREATMENT PLANTS

In the total cost of any sewage collection and treatment system the cost of phosphorus removal is only a very minor part. A major portion of the cost is in the collection and trunk sewers. A further major cost is in the construction of a treatment plant capable of treating the wastewater to general environmental and health standards prior to discharge. These standards are high in the Okanagan because of the high quality water uses of the Okanagan Lakes. This in turn necessitates the construction of a well designed fully equipped treatment plant. For the most part the present treatment plants in the Okanagan meet this requirement. Following is a brief discussion of the sewage treatment plants and processes in the Okanagan with estimated costs to make the plants conform to general environmental and health standards and provide phosphorus control.

9.1.1 ARMSTRONG

Armstrong has an aerated lagoon system equipped with an alum phosphorus removal facility. The phosphorus removal equipment is not used effectively at the present time due to inadequate sludge storage facilities. In 1984, the plant discharged 2.43 tonnes of phosphorus to Deep Creek. In periods of low flow in Deep Creek a dilution ratio of 1 to 1 exists with the effluent. From a general environmental and health point of view the dilution afforded by Deep Creek is far too small for a discharge with this degree of treatment.

Armstrong's long range plan is to implement a spray irrigation scheme. The effluent reservoir site has been purchased and 3000 acres of farmland has been volunteered by the area farmers. The scheme is expected to cost about $3.3 million. It is not really practical for a small town like Armstrong to build and operate the kind of treatment facility which would be required to allow discharge to Deep Creek at low flow. From a general environmental and health protection point of view, the irrigation scheme seems to be a practical and reasonable option at this time. The phosphorus removal efficiency of such an irrigation scheme would approach 100%, with the removal of 2.4 tonnes of phosphorus per year.

9.1.2 VERNON

Vernon utilizes a trickling filter type of secondary sewage treatment plant with spray irrigation for effluent disposal. More recently Vernon has installed an alum phosphorus removal system to treat surplus effluent that must be discharged to Vernon Creek. In 1984 there was about 0.37 tonnes of phosphorus discharged directly to the Okanagan Lake system--a 99% reduction in phosphorus loading to the plant.

Long-term problems stem from a restricted land base for irrigation, a lower than expected average irrigation rate and recent wetter than normal summers. Some release of surplus effluent to the lake system will be necessary for the foreseeable future. A Waste Management Plan is currently under preparation.

The Waste Management Plan has looked at 15 different options for disposing of Vernon's future effluent. Complete irrigation schemes have been investigated and found to be very costly. Complete lake disposal schemes have also been investigated and while less costly they are still expensive. A combination of irrigation and lake disposal seems likely for Vernon. One proposal is to operate the present irrigation scheme at full capacity and discharge tertiary treated effluent to Okanagan Lake via an outfall only during the summer months. Tertiary treatment would remove 90% of the phosphorus while irrigation removes close to 100%. The combination is expected to remove 99% now, decreasing to 95% as the treatment plant nears its 40 000 person capacity. This capacity is not expected to be reached for another decade.

The present tertiary discharge is to Vernon Creek. Because of low dilution and of the beaches downstream at Okanagan Landing it is not desirable from either an environmental or health aspect to allow continued long-term discharge to Vernon Creek, therefore a trunk line and outfall would have to be built. It is anticipated that the trunk line would extend to the Marshall property, a site where the future sewage treatment plant would be built, and from there an outfall would carry the effluent well out into Vernon Arm. The cost to construct the trunk line and outfall has been estimated at $9 million. The cost to upgrade the present treatment plant has been estimated at $1.3 million. The existing phosphorus removal facilities will be used until a new treatment plant is constructed at the Marshall property. The phosphorus discharged to the lake over the next decade is expected to rise from 0.37 tonnes/year to 2.32 tonnes/year. The addition of a filtration process would likely reduce this quantity to 1.16 tonnes/year by the end of the decade at a cost of approximately $1.6 million. This is a unit cost of $1379 per kg of phosphorus removed per year.

Alternatively, if irrigation were used to increase the phosphorus removal efficiency to almost 100%, the cost of equipment has been estimated at approximately $16 million provided the Coldstream Ranch would take the reclaimed water. The incremental cost of equipment to achieve this degree of phosphorus removal would be:

> $16 000 000/1160 kg = $13 793/kg of phosphorus removed per year.

If the extra land required for total irrigation were purchased, its cost is estimated to be a further $36 million.

9.1.3 KELOWNA

Kelowna utilizes the Bardenpho process to remove biologically both nitrogen and phosphorus from the wastewater. Phosphorus removal is basically accomplished by causing the bacteria to take up phosphorus and then removing them.

The plant involves a process that is new to our cold winters and much of the knowledge of operation has been acquired by operating the plant in deliberate failure mode. This has led to somewhat higher than anticipated phosphorus loadings to the lake. Loadings were 4.04 t in 1983 and 6.74 t in 1984, but indications are that levels of 2.4 t (0.6 mg/L or less in the effluent) are readily attainable (90 to 95% removal efficiency).

The effluent is extremely well treated and is non-toxic as was demonstrated during the fish rearing test last year. Fish were raised in the effluent from fingerlings to in excess of 35 cm in length. The filtration and disinfection facilities at this plant are capable of producing a pathogen-free effluent.

The Waste Management Permit presently calls for the removal of the lake outfall by 1989 and utilization of the effluent on farm lands in Southeast Kelowna-an undertaking estimated to cost about $20 million for the equipment and $53 million for purchase of the land.

In view of the top quality effluent produced by this plant and the high cost associated with the irrigation scheme it may be best for the City of Kelowna to continue to discharge to the lake.

A Waste Management Plan will be required to ascertain the city's best course of action, but if lake discharge is acceptable a sum of $0.5 million to repair the outfall may be all that is necessary in the way of expenditures.

Assuming that an average efficiency of 95% can be maintained at this plant, the phosphorus contributions to Okanagan Lake would be expected to rise from the present expected 2.4 tonnes to 2.9 tonnes over the next decade, due to population increases. Irrigation of the effluent would produce an efficiency of nearly 100% phosphorus removal but at an additional cost of $20 million for the equipment. The incremental cost of equipment to achieve this degree of phosphorus removal would be:

> $20 000 000/2900 kg = $6896/kg of phosphorus removed per year.

Since it is debatable if all the effluent could actually be used in the irrigation scheme the unit cost above might actually be higher.

9.1.4 WESTBANK

Westbank utilizes an aerated lagoon system with no nutrient removal. The plant effluent is discharged to Westbank Creek which flows into Okanagan Lake.

In 1983 with some irrigation of the effluent on lands that have since been returned to the Westbank Indian Band as "cut off lands", the phosphorus contribution to the lake system was only 0.44 t, but in 1984 with no irrigation 0.83 t of phosphorus entered the lake.

Westbank, which is presently working on a Waste Management Plan, has been attempting unsuccessfully for the past decade to utilize its effluent on land for spray irrigation or infiltration.

It is anticipated that Westbank will build a new treatment plant with phosphorus removal and filtration and an outfall to Okanagan Lake. The cost of these facilities will likely be about $1.8 million and should remove 90 to 95% of the influent phosphorus. With the present population this would mean that Westbank would discharge about 0.12 t of phosphorus per year.

9.1.5 PENTICTON

Penticton has an activated sludge sewage treatment plant with in-plant phosphorus removal using ferrous chloride (spent pickling liquor). The plant achieves an efficiency of between 85 and 90% phosphorus removal.

Several land disposal and irrigation schemes have been proposed for Penticton but all are costly (about $40 million) and all still require an outfall to the lake as the land base is not large enough to handle all the effluent in wet years.

Because of the high cost associated with irrigation, it is probable that Penticton will continue to discharge to the Okanagan River entering Skaha Lake. Other possibilities include direct discharge to either Skaha or Okanagan Lake. It may be possible for the outfall to remain in the Okanagan River channel provided a top quality, pathogen-free effluent can be consistently produced. Further facilities will be required at this plant in order to produce such an effluent quality. These facilities would include additional clarification, filtration, disinfection and sludge thickening facilities. With such facilities added the phosphorus removal efficiency should rise to close to 95% and the plant capacity would be expanded to handle Penticton sewage flow for at least the next decade. These facilities would likely cost about $5 million. If an outfall to Okanagan Lake were required this would likely cost an additional $4 million. Should an outfall to Skaha Lake be required the cost would also be about $4 million, but in addition nitrification facilities would be required and these would necessitate another large capital expenditure at the plant, possibly in excess of $4 million.

Penticton presently has about $3 million borrowed under the previous grant program for upgrading its sewage treatment plant which has not been spent. If discharge to the Okanagan channel is acceptable for the next decade Penticton would only need to borrow an additional $2 million for the necessary upgrading. These options will need to be examined carefully through the Waste Management Planning process in order to select the best course of action. Assuming that 95% phosphorus removal is achieved the discharge of phosphorus to the lake would be about 1.3 tonnes per year at present rising to 2.3 tonnes in 1995. It may be possible in the future to use a small amount of the upgraded effluent for irrigation purposes around the Penticton area during the summer months. However, if a major thrust toward irrigation is desired the scheme at White Lake, Meyers Flats, Leir and Covert Farm must be implemented. Depending on which portion of the scheme is implemented the extra cost to irrigate a substantial part or all of the Penticton effluent would be about $40 million ($32 million for equipment and $8 million for land). The $40 million would increase the phosphorus removal efficiency to almost 100%. The incremental cost of equipment to achieve this efficiency of phosphorus removal would be $13 900 per kg of phosphorus removed per year.

9.1.6 OKANAGAN FALLS

Okanagan Falls has an oxidation ditch and ground-infiltration system. It works well at present although initially a nearby depression was affected by the local rise in the water table. There is no direct discharge to the lake system from Okanagan Falls. The existing system appears adequate for the foreseeable future. The phosphorus removal efficiency is estimated to be greater than 99%.

9.1.7 OLIVER

Oliver has an extended aeration sewage treatment plant with spray irrigation of the effluent to land. The irrigation system was started up in 1983 and there has been no direct discharge since then.

The golf course should provide sufficient lands for irrigation for the foreseeable future.

The phosphorus removal efficiency is nearly 100%.

9.1.8 OSOYOOS

Osoyoos has an aerated lagoon system, with spray irrigation on the golf course, race track and a test orchard.

The reservoir is not large enough to hold the winter flow due to people leaving water taps running to prevent their water lines from freezing. This problem has led to some discharge of effluent to an infiltration basin during winter. The water resurfaces in a creek near the infiltration site. Because of the effects of ground water dilution it is difficult to know how much phosphorus gets into the creek and then to Osoyoos Lake from this source. To overcome this problem phosphorus removal facilities could be installed at the lagoon and the effluent could be treated prior to discharge to the infiltration basin. Such phosphorus removal facilities combined with the land treatment in the infiltration basin should have an efficiency of 95% phosphorus removal. This system combined with the irrigation scheme should give a total phosphorus removal of greater than 98%. Ultimately it may be best to expand the storage reservoir capacity to accept the future effluent flows from Osoyoos as extra land appears to be available for irrigation. The cost to provide phosphorus removal facilities is estimated at $50 000.

About 1000 campsites exist on the east shore of Osoyoos Lake. Sewering this area with low pressure sewers and constructing another reservoir for spray irrigation is a strategy worth considering for phosphorus control.

9.1.9 FILTRATION PROCESSES

The discussion of the Okanagan treatment facilities and phosphorus control options shows that phosphorus removal of 90% is readily attainable at an insignificant capital cost. This removal efficiency can be increased to 95% by the addition of filtration equipment in most cases. Filtration equipment greatly enhances the disinfection process and would certainly be required if a pathogen-free effluent is desired for health reasons. Filtration can assist in regulatory surveillance because treatment facilities which do not produce a good quality effluent will be unable to keep their filtration process operating correctly. Filters tend to improve a good quality effluent but will have operational problems if the effluent is of poor quality. Thus a plant which has a problem operating a filter needs to be thoroughly checked out in order to produce a consistently good quality effluent. These points have been emphasized because it may well be in the best interests of the Ministries of Environment and Health to have filtration equipment installed at all the Okanagan treatment plants which discharge to the lakes.

The cost of filtration equipment would be about $4.5 million divided as follows: Armstrong: $0.8 M, Vernon: $1.6 M Westbank: $0.5 M and Penticton: $1.6 M.

9.1.10 EFFLUENT IRRIGATION & LAND DISPOSAL

Most of the smaller municipalities have been able to design and develop irrigation or land infiltration schemes (*i.e.*

Osoyoos, Oliver, Okanagan Falls and Armstrong). They have the surrounding land base to support such a scheme. Unfortunately this is not the case for the larger municipalities. Only Vernon has been able to develop a significant land base close enough to be economically attractive, but it has been unable to expand to keep up with growth. Irrigation with reclaimed water (very high quality effluent) may be possible around these cities in the future but the distribution and transmission pipelines, pump stations and storage reservoirs required for any appreciable amount of irrigation will always be expensive. The effluent also needs to be well-treated to be suitable for spray irrigation. Thus plant upgrading, discussed in sections 9.1.1 to 9.1.9 would presumably be required first, in some form.

Any effluent irrigation scheme must be designed with an outfall to the lake to handle effluent which is in excess of that used for irrigation purposes. If this is not done then all the irrigation land required for the scheme must be purchased by the Municipality to ensure that the effluent can always be disposed of by irrigation. Such land purchase would be extremely expensive, even if it were practical, which is unlikely as much of the land might have to be expropriated. The land cost for the Penticton scheme was estimated at $8 million. The land cost for Vernon might be $12 to $36 million depending on size of the scheme. The land cost for Kelowna was roughly estimated at $53 million. The Penticton estimates are relatively close but the estimates for Vernon and Kelowna could be considerably in error depending on a number of factors. The cost of plant upgrading, total land disposal and outfall removal from the lakes for the major cities could exceed $190 million.

9.1.11 SUMMARY OF COSTS TO IMPROVE MUNICIPAL TREATMENT

A summary is provided in Table 9.1. It indicates that about $20 million would be required to ensure at least 95% removal of phosphorus at existing plants. To attain almost 100% removal of phosphorus, spray irrigation at an extra cost of at least $170 million would be required, for a total of about $190 million. About half of the cost of spray irrigation is for land purchase.

9.1.12 OPERATING COSTS

The cost of operating treatment plants varies a good deal depending on the type of plant and how it is designed. Lagoons and aerated stabilization basins are the cheapest to operate and activated sludge advanced wastewater treatment plants are generally the most expensive. Costs can vary significantly depending on the method used for sludge handling and disposal and the chemicals used for phosphorus removal. The spent pickling liquor which Penticton uses for phosphorus removal is obtained free of charge from Tree Island Steel in Vancouver because it is a waste byproduct. Penticton only pays the transportation cost and this amounts to about 1/20 per 1000 litres of wastewater treated.

The alum which Vernon uses must be purchased from Allied Chemicals or CIL. The cost of using alum in Vernon is about 30 per 1000 litres treated.

The total cost of operating the Vernon treatment plant is 200 per litres treated. The Bardenpho plant at Kelowna uses no chemicals for phosphorus removal and its total operating cost is approximately 12.50 per 1000 litres treated. The cost of operating a filtration process is approximately 1.25 per 1000 litres treated.

9.2 SEPTIC TANKS

Septic tanks contribute a significant portion of total phosphorus to Okanagan Valley Lakes (Chapter 3). They constitute the largest controllable diffuse source, contributing 42% of total phosphorus to Wood Lake, 30% to Kalamalka Lake, 30% to Okanagan Lake, 58% to Skaha Lake and 50% to Osoyoos Lake.

All septic tank/soil absorption systems have the potential to contribute some phosphorus to ground and surface receiving waters. However, some combinations of site conditions (*e.g.* soil texture, depth to ground water, distance to receiving water) have a much higher potential and contribute a disproportionately large part of total phosphorus. Transmission coefficients used in previous Okanagan Basin studies (1970 and 1980) to estimate proportions of applied phosphorus that enter lake water reflect this potential. Specifically, conditions of short distance to the lake or stream, and coarse textured soils are critical. Additionally, shallow ground water tables increase the transmission factors.

9.2.1 STRATEGY FOR CONTROL

The aim for control of phosphorus in municipal wastewater discharges in the Okanagan Basin has been 90% removal. It is presumed that the aim for household wastewater should not be significantly different, with an estimated 33 100 septic tank units in the Okanagan Basin in 1980 and assuming a household phosphorus loading of 3.2 kg/household/year, 105 920 kg/year are discharged. If an average removal efficiency of 95% were achieved by all systems, 5 296 kg/year would still be discharged to the lakes. This is 45% of the total 11 500 kg/year of phosphorus estimated to be contributed by septic tanks. By lake, amounts discharged per annum would be as follows:

Lakes	kg Phosphorus	% of total septic tank phosphorus contributed
Wood	384 kg	48%
Kalamalka	160 kg	48%
Okanagan	3888 kg	59%
Skaha	480 kg	27%
Osoyoos	384 kg	19%
Totals	**5296 kg**	**45%**

It must be concluded that the aim can only be to control at maximum 55% of the estimated septic tank phosphorus loading.

A minimum number of 24 062 (73.15%) of existing septic tank/soil absorption systems already achieve 95+% phosphorus removal, as reflected by vertical soil transmission coefficients used in previous Okanagan Basin studies (1970 and 1980). The remaining septic tank/soil absorption field systems (8825; 26.8%) should therefore be the primary focus for control measures. However, it must be noted that of these 8825 systems, 720 are estimated to have the potential to remove in the range of 70-85% phosphorus. The remaining 8105 or 24.6%, have an estimated removal efficiency between 0 and 55%. The 560 units (1.7% of total) which are estimated to have near 0% removal efficiency, contribute about 15% of total phosphorus from septic tanks.

9.2.2 PRIORITY CONTROL AREAS

Priority areas for control include coarse textured soil areas and particularly those falling in the <150 m to receiving water class. Though numbers of systems falling within this combination of conditions cannot be defined exactly due to methods of data reporting, the following estimates by lake basin provide a reasonable summary. These numbers include uncertainty due to estimating done here in addition to uncertainties mentioned in Chapter 3.

	Septic tank units and removal efficiencies		
Lakes	**Near 0%**	**25% to 70%**	**70% to 85%**
Wood Lake	-	496	-
Kalamalka Lake	-	224	-
Okanagan Lake	378	4239	430
Skaha Lake	-	1253	208
Osoyoos Lake	179	1336	82

Totals	**557**	**7548**	**720**

Figure 9 highlights sub-basins within the Okanagan Valley in which high concentrations of septic tanks with poor phosphorus removal efficiency are located. Within the areas indicated on the map are the following communities expected to be contributing the largest proportions of phosphorus loadings.

Smaller areas possibly contributing comparable unit amounts are not included.

Wood Lake	- Winfield
	- Oyama (part)
Kalamalka Lake	- Oyama (part)
Okanagan Lake	- Okanagan Landing
	- Okanagan Mission
	- Rutland
	- Summerland, including Trout Creek
Skaha Lake	- Kaleden
	- S.E. of Penticton
Osoyoos Lake	- Osoyoos (part)

9.2.3 CONTROL COSTS

A number of different control costs could be calculated depending on the method of control selected. Applicable onsite methods noted in Chapter 8 include:

- phosphorus removal from septic tanks using chemical addition
- conventional septic tank/soil absorption mound systems
- septic tank/soil absorption fill systems

In addition to the above onsite methods, the following may have applicability in selected areas:

- sewer trunk extension from adjacent sewered areas and sewer collection system development
- small-scale community collection and treatment systems (*e.g.* pressure or vacuum sewers; package plants)

These latter options are not costed here since capacities of existing sewered area facilities, catchment areas etc. would have to be investigated in detail.

Based on an estimated unit cost of $6000 per unit, total costs for onsite phosphorus removal using conventional septic tank/soil absorption systems with chemical removal would be:

	Total Removal Costs by Current Removal Efficiencies		
Lakes	**Near 0%**	**25-70%**	**70-85%**
Wood Lake	-	$2 976 000	-
Kalamalka Lake	-	$1 344 000	-

Okanagan Lake	$2 268 000	$25 434 000	$2 580 000
Skaha Lake	-	$7 518 000	$1 248 000
Osoyoos Lake	$1 074 000	$8 016 000	$492 000
Totals:	**$3 342 000**	**$45 288 000**	**$4 320 000**

Costs per unit of phosphorus removal using the indicated method would vary widely since original. removal would depend on actual site conditions. Assuming, however, that original removal varies between 0% and 70% and the indicated scheme could remove 85%, the costs would range between $2200/kg P and $12 500/kg P. The three cost groups identified above would therefore have unit costs as follows:

Near 0% present removal	$ 2 200+/kg P
25-70% present removal	$ 3 125 - $12 500/kg P
70-85% present removal	$12 500 - $200 000+/kg P

If an average present removal efficiency of 30% is assumed for the 25-70% class (largest number of units are estimated to have approximately this efficiency) then a unit cost of about $3 400/kg P may be applicable to the majority of systems.

On a basin-wide basis, assuming 0, 30 and 70% present removal for the three groups, total phosphorus removal and unit costs might be as follows:

P Removal	% of all septic Tanks	Cost/kg P
1780 kg	15%	$2 200+
4300 kg(??)	38% (??)	$3 400+
245 kg	2%	$12 500+

9.2.4 CONCLUSIONS

Original inventory data (1970 and 1980) incorporate considerable uncertainty due to methods used. The present attempts to identify septic tank systems according to the potential for phosphorus removal incorporate additional uncertainty.

Existing inventory data and a cost-estimate for one type of onsite system incorporating phosphorus removal have been used here. A small group of systems have been identified which would be most cost-effective to replace with new onsite systems. As well, a small group was identified which was least cost-effective to replace. The largest group proposed for control incorporates a very wide range of anticipated present removal efficiency and therefore a wide range of costs per unit of phosphorus removal.

The largest group (73%) of septic tank/soil absorption field systems does not require phosphorus control. Their efficiency is believed to meet or exceed that of large (municipal-type) sewage treatment plants as well as community or cluster-type systems.

Since these conclusions are based on limited knowledge, information on both site characteristics and numbers of septic tank units should be improved before site-specific allocation of any funds are made for rehabilitation. Present data are adequate, however, to indicate priority conditions for phosphorus control.

Initial cost estimates of alternate onsite systems for phosphorus control (*e.g.* mound and fill systems) do not appear to be significantly different from the system used in estimating above costs. Their success and cost is highly dependent on local availability of suitable fill materials. Site-specific application may have cost advantages.

9.3 AGRICULTURE

Inventory estimates for phosphorus contributions from animals and from fertilizer and irrigation waters are available from previous Okanagan Basin studies (1970 and 1980). Source data for these estimates are numbers of cattle and fertilizer phosphorus applied and transmitted to receiving water.

Applicable control methods are discussed in Chapter 8. Neither basic source data available nor loading estimates are suitable for determining costs of proposed control methods. Relocation of feedlots or required fencing of streams for example cannot be costed on an animal-number basis. Information on numbers and locations of animals per operating unit, and on stream length accessible to cattle will need to be developed to estimate such costs. Neither can costs of research, extension and education be developed from the existing data base. Furthermore, proposed regulations on new installations must be costed in an entirely different context.

The objective for control of phosphorus from agriculture might best be defined in terms of best management practices to be implemented rather than in terms of phosphorus reductions to be attained. Incremental costs of phosphorus removal by fencing, feedlot relocation, research or extension etc. will not likely become available in the near future.

We should consider placing a priority on development of regulations or refinement of existing guidelines for new feedlots and winter feeding areas. Options could include efforts directed at defining agency roles and responsibilities and putting in place enforcement mechanisms and capability. We could also consider defining information items to which implementation, design and costing are sensitive (*e.g.* locations and length of stream fencing requirements; locations of feedlots or winter feeding areas in direct contact with receiving waters; alternate locations for cattle operations on existing property holdings of an operator). Other possibilities worth considering are designs and associated costs for areas that present data (and possible further field inspection) show are contributing significant amounts of phosphorus.

9.4 FORESTRY

Proposed controls on phosphorus generated by forestry activities focus primarily on sediment generated froth logging practices and particularly road construction. These activities are carried out by a limited number of forest companies primarily on Crown land under control of the Ministry of Forests. Mechanisms for control have dealt primarily with better planning and operations in erosion-sensitive areas, and development and enforcement of' regulations by the Ministry of Forests.

To estimate the cost of phosphorus removal, costs will have to be developed for a range of activities including:

- interagency referrals
- coordinated resource management
- regional resource management
- guidelines and regulation development and enforcement by the Ministry of Forests
- studies to determine reductions of sediments and phosphorus from alternate practices, regarding road construction and drainage works
- resource data gathering (*e.g.* climate, terrain) to improve planning.

Though such costs may be developed, costs per unit of phosphorus removed will depend on site-specific improvements and phosphorus removal.

9.5 SOME SPECIAL METHODS OF REDUCING PHOSPHORUS IN WOOD AND KALAMALKA LAKE

This section deals with in-lake methods of reducing phosphorus levels, as compared to direct control of phosphorus inputs. Each method will require some detailed work to confirm feasibility and costs. The methods deserve serious consideration if the high phosphorus levels in Wood Lake are to be reduced within a reasonable time to meet the proposed water quality objectives. They are listed here in rough order of priority.

9.5.1 NITROGEN FERTILIZATION IN WOOD LAKE

Wood Lake is nitrogen limited in spring. Thus, the addition of nitrate in the spring would enhance the algal bloom, at a time when recreation is of low importance. This action will produce phosphorus up-take and thus reduce phosphorus levels for the remainder of the summer. Good water clarity will result at a time when it is important for recreation.

The cost of the treatment is quite low, about $20 000 for the chemicals and $5000 for their application. It would need to be repeated each year. The procedure would benefit recreation, although it would not reduce phosphorus loading or improve fish habitat.

9.5.2 SEDIMENT TREATMENT IN WOOD LAKE

The sediments of Wood and Kalamalka Lakes do not appear able to bind and retain phosphorus. The addition of iron, alum, lime or manganese would improve the phosphorus-binding ability. The addition of a product such as pickling liquor to Wood Lake may be suitable, and its cost would probably be in the same range as fertilization. The treatment has the potential of immobilizing several hundred kilograms of phosphorus in Wood Lake.

9.5.3 HIRAM WALKER & SONS LTD.-DIVERSION OF COOLING WATER

The Hiram Walker Distillery discharges 22 730 m /d of cooling water to Vernon Creek upstream from Ellison Lake. The cooling water has a low phosphorus concentration because the water was originally pumped from Okanagan Lake. However the water in Ellison and Wood Lakes has a higher concentration of phosphorus most Of the year. The cooling water essentially flushes the high phosphorus water from Wood Lake into Kalamalka Lake. It is estimated that a loading of 0.69 tonnes of phosphorus per year is flushed into Kalamalka Lake as a result of discharging the cooling water to Vernon Creek. The cost to divert the cooling water discharge to Kelowna Creek which flows back into Okanagan Lake has been estimated at $1.3 million. This diversion would result in a phosphorus loading reduction of 0.69 tonnes/year to Kalamalka Lake. The diversion would not affect any water licenses now in use. The unit cost for this reduction is $1 884/kg of phosphorus removal per year.

9.5.4 AERATION OF WOOD LAKE

Maintenance of a good level of oxygen in the hypolimnion of Wood Lake will improve the fish habitat. It may also reduce the internal loading of phosphorus from the sediments. The capital cost of such a scheme for Wood Lake is likely to be at least $1 million.

9.5.5 REGULATING THE FLOW FROM WOOD LAKE TO KALAMALKA LAKE

Restricting the flow between the lakes in the winter, when phosphorus concentrations in Wood Lake are at their highest, will reduce the loading entering Kalamalka Lake. Flow control could be achieved by a structure on the Oyama Canal which links the two lakes. Such a structure, consisting of two abutments and stop logs could hold water back at a time when the need for boat passage is minimal. Such a scheme may not be readily accepted by residents.

9.5.6 CONTROLLING THE FLOW FROM ELLISON LAKE TO WOOD LAKE

Control of the flow between these lakes could reduce the phosphorus loading from Ellison Lake. The concept is to redirect water from the creek entering Ellison Lake using a training dyke and some form of control structure. When inflowing water to the lake has a high phosphorus concentration, it would be directed away from the lake outlet. When the inlet water has a low phosphorus concentration it would be short-circuited to the outlet. The cost of the dyke is estimated to be $150 000.

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10. CONCLUSIONS

10.1 PHOSPHORUS TRENDS

Over the past ten years, phosphorus concentrations have increased in the Okanagan Valley lakes. The increase was most noticeable in Kalamalka Lake, less in Skaha and Osoyoos Lakes and minor in Wood and Ellison Lakes. As a whole Okanagan and Kalamalka Lakes are classified as oligotrophic, Skaha and Osoyoos as mesotrophic and Wood and Ellison as eutrophic.

10.2 WATER QUALITY OBJECTIVES

The lakes have a high value for recreation, fisheries and drinking water, use. Water quality objectives are proposed to protect these uses. The objective is equalled by the present phosphorus level in Okanagan Lake, exceeded by 25 percent in Kalamalka Lake, exceeded by about 50 percent in Skaha and Osoyoos Lakes and exceeded by 500 percent in Wood Lake.

Critical or allowable phosphorus loadings cannot be calculated for the lakes at this time because existing loading-response relations do not apply. Water quality objectives will serve as a good measure of how well phosphorus loadings are being controlled.

10.3 MUNICIPAL EFFLUENTS

Since 1970, phosphorus loadings have been reduced 70 percent to Okanagan Lake, 80 percent to Skaha Lake and virtually 100 percent to Osoyoos Lake. The main treatment plants could be upgraded, to remove 95% of their phosphorus, at a cost of about $20 million. Near total removal of phosphorus would require spray irrigation of all effluents on land at an additional cost of at least $170 million, half of this cost being for land acquisition.

Kalamalka, Osoyoos, Wood and Ellison Lakes do not receive any direct discharges of municipal effluent. Even with total removal of municipal effluents now entering the lakes, water quality objectives for phosphorus would not be met everywhere.

10.4 SEPTIC TANKS AND AGRICULTURE

These diffuse sources are the most important contributors of phosphorus to Ellison, Wood, Kalamalka and Osoyoos Lakes. In Okanagan and Skaha Lakes they are about equal in importance to direct municipal discharges, as a source of phosphorus. Costs to reduce phosphorus loadings from septic tanks by a factor of 50 percent, are about $50 million for the valley as a whole. Costs to reduce agricultural loadings cannot yet be assessed due to lack of proper information.

Action to reduce phosphorus from septic tanks and agriculture has never been undertaken. Such action, together with upgrading of municipal treatment plants offers the most promise, both from the point of meeting water quality objectives in the near future and from the economic point of view.

10.5 SPECIAL CONTROL MEASURES

In Wood and Kalamalka Lakes a number of in-lake techniques can be used to control phosphorus. These include yearly chemical treatment costing less than $50 000 and lake aeration costing $1 million for Wood Lake. Diversion of the Hiram Walker Distillery cooling water, costing $1.3 million, and methods to regulate the flow of water between Ellison and Kalamalka Lake, costing about $200 000, should also be considered.

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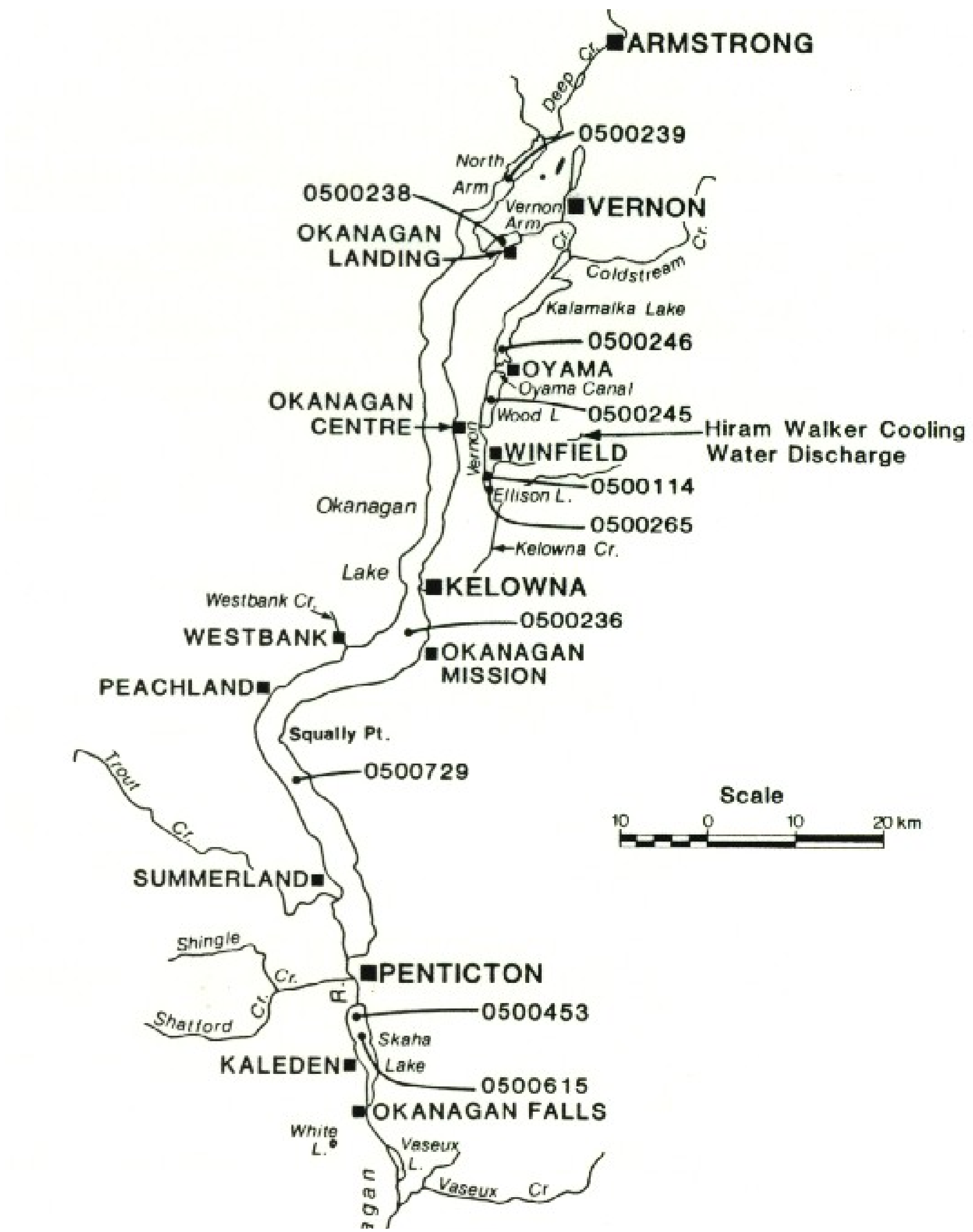
FIGURES

Figure 1. Ambient Water Quality Monitoring Sites



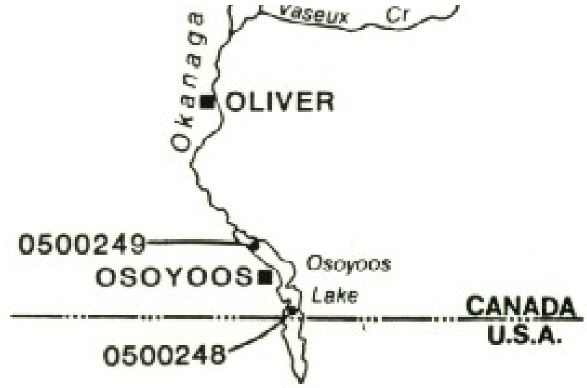


FIGURE 1 Ambient Water Quality Monitoring Sites

Figure 2. Phosphorus Concentrations, Ellison Lake Center

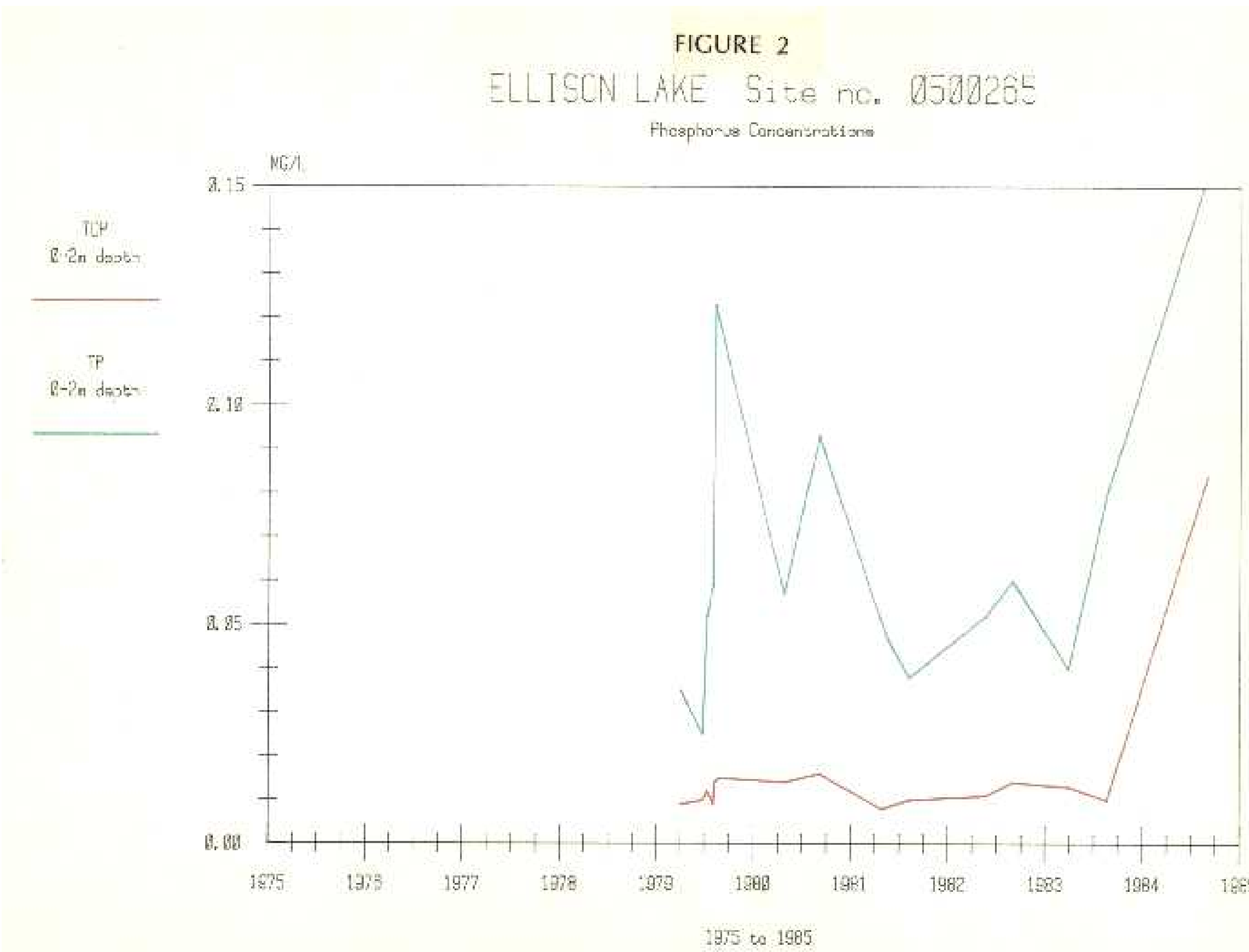


Figure 3. Phosphorus Concentrations, Ellison Lake North End

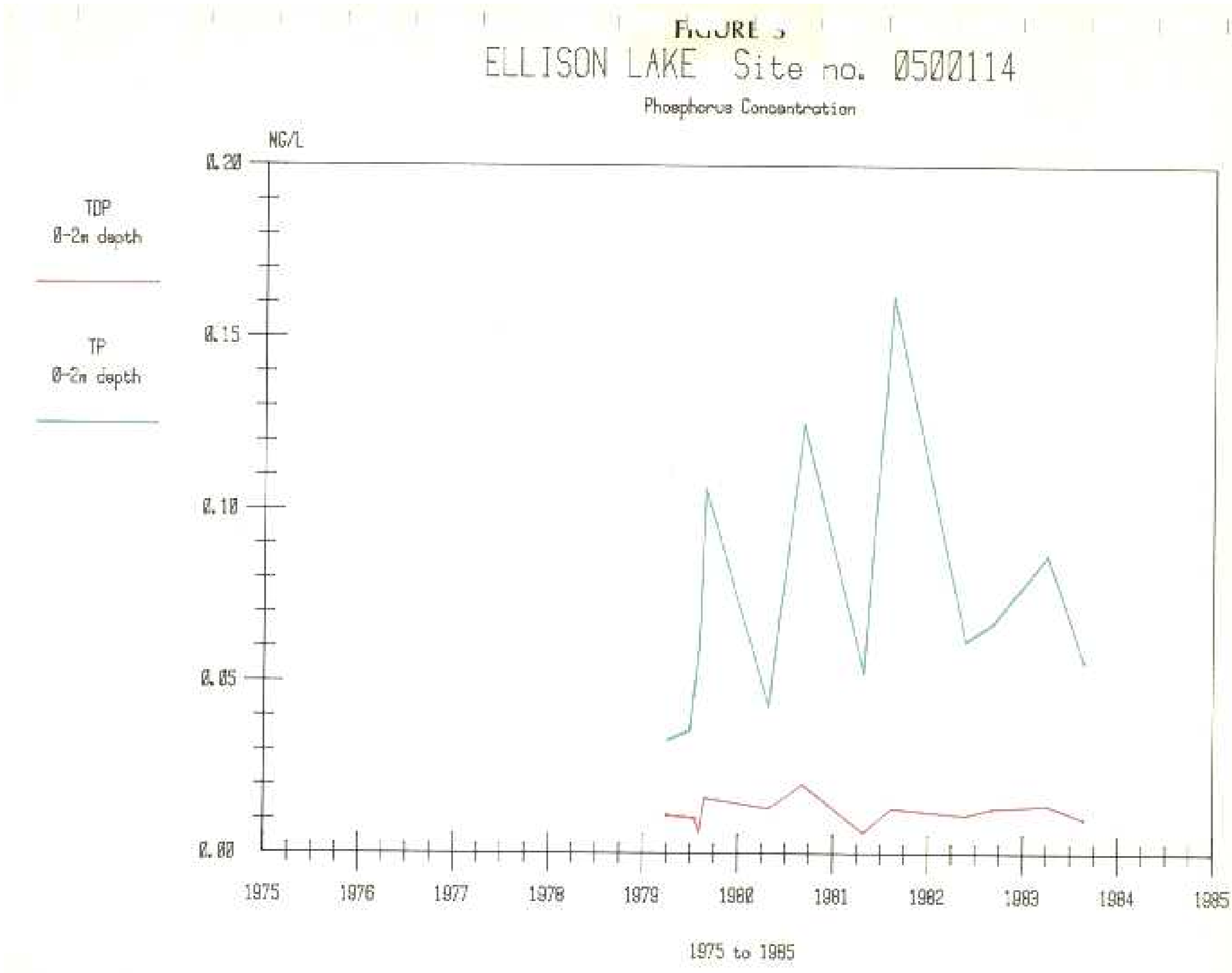


Figure 4. Phosphorus Concentrations, Wood Lake Site 0500245

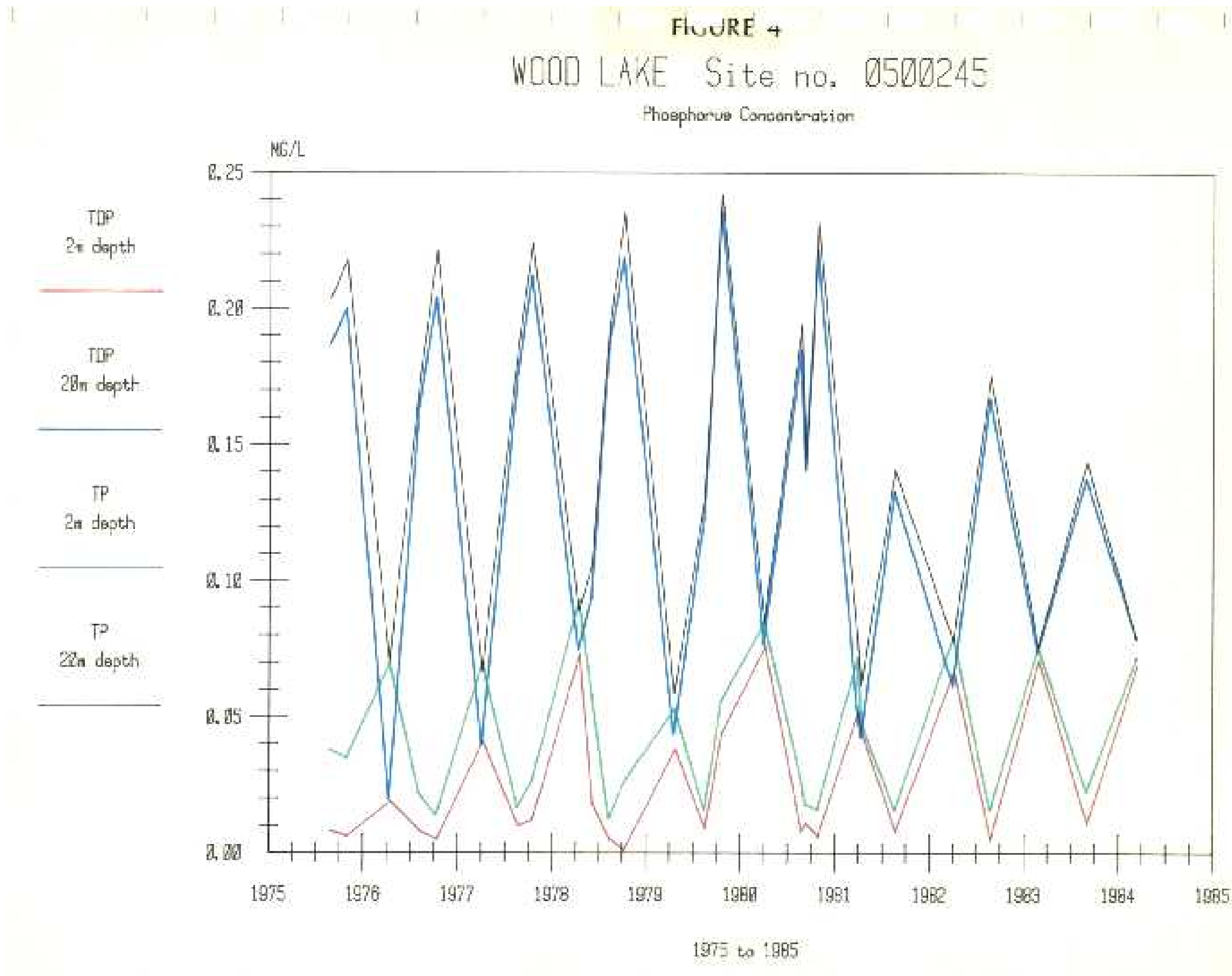


Figure 5. Phosphorus Concentrations, Kalamalka Lake Site 0500246

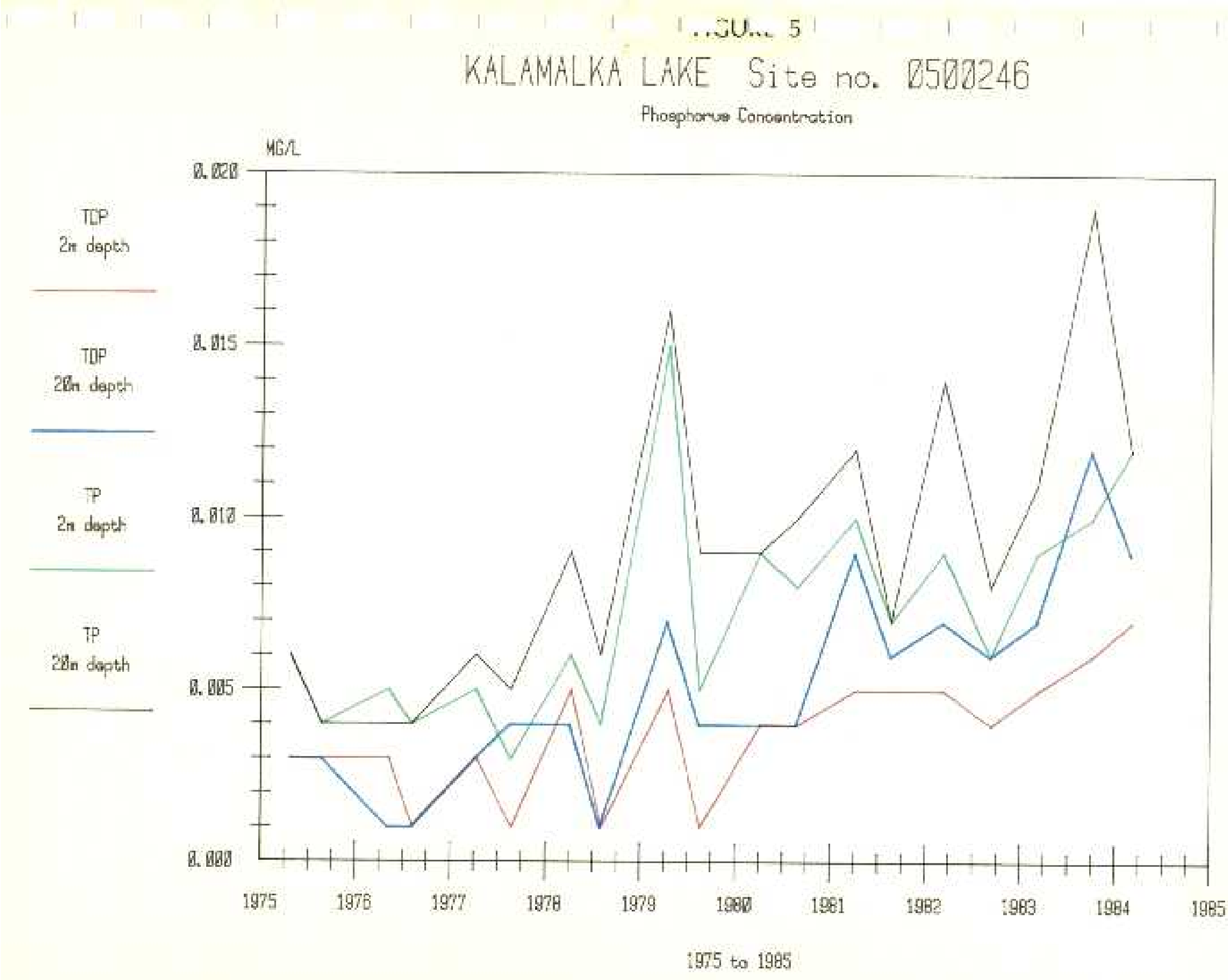


Figure 6a. Phosphorus Concentrations, Okanagan Lake Site 0500239

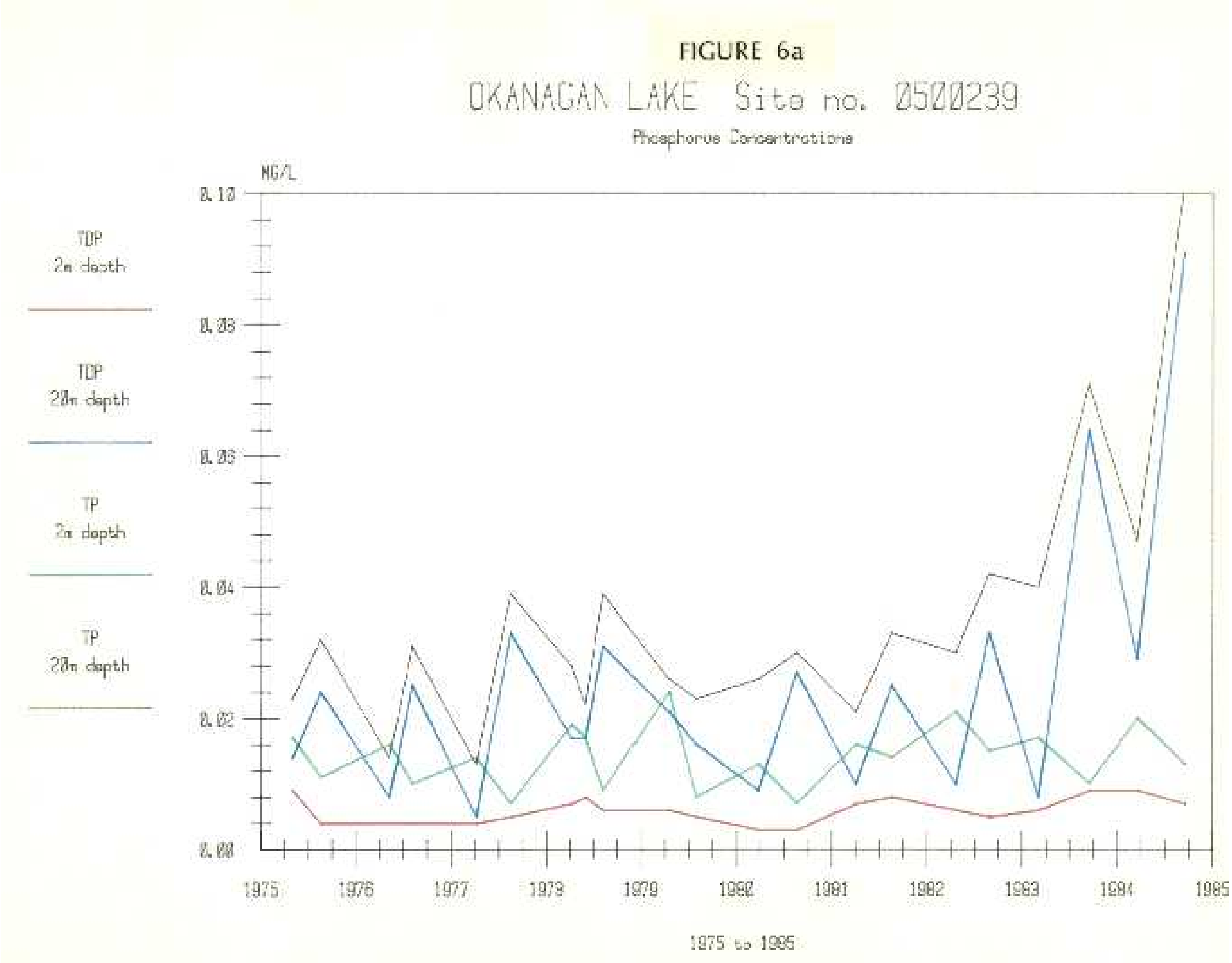


Figure 6b. Phosphorus Concentrations, Okanagan Lake Site 0500238

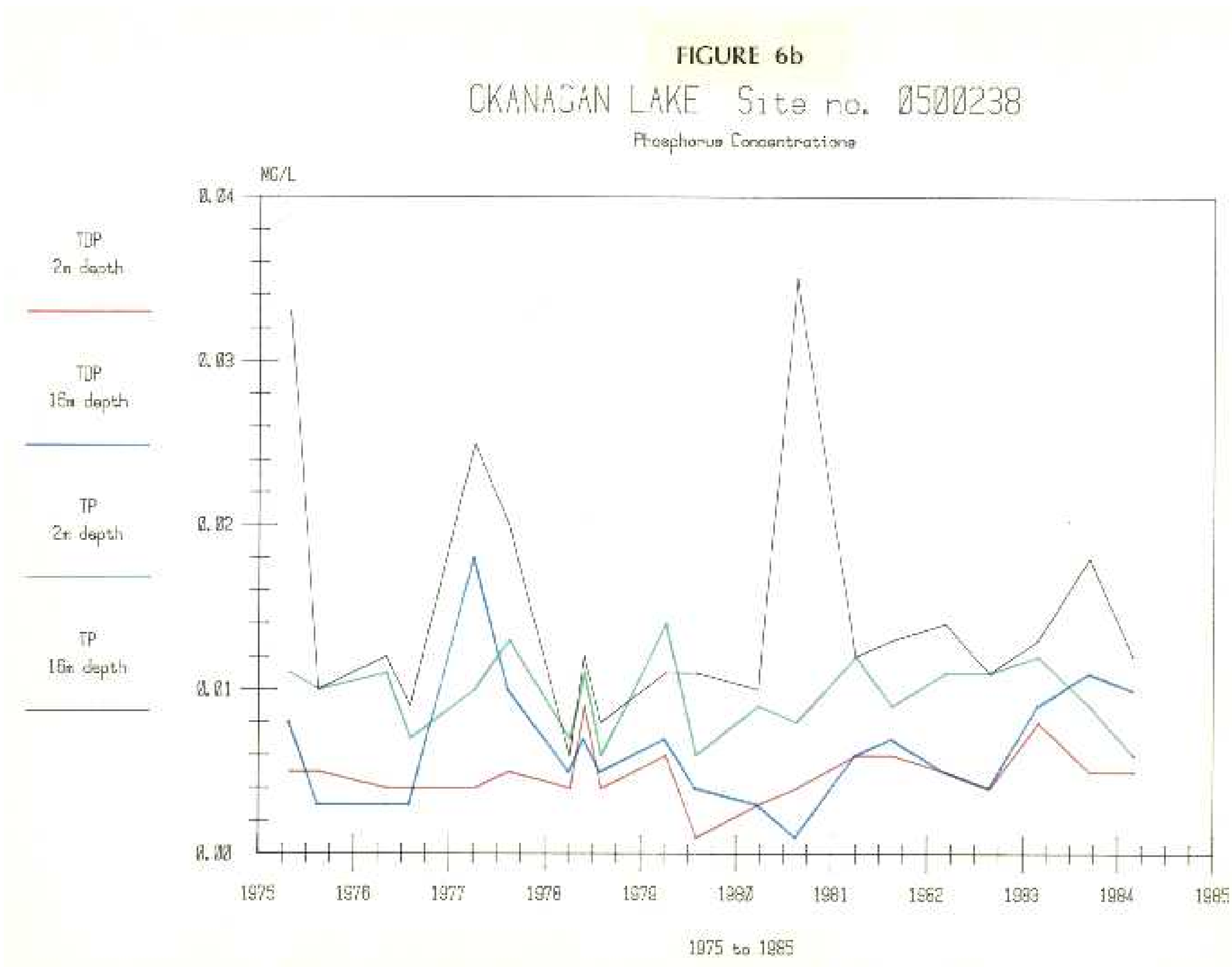


Figure 6c. Phosphorus Concentrations, Okanagan Lake Site 0500236

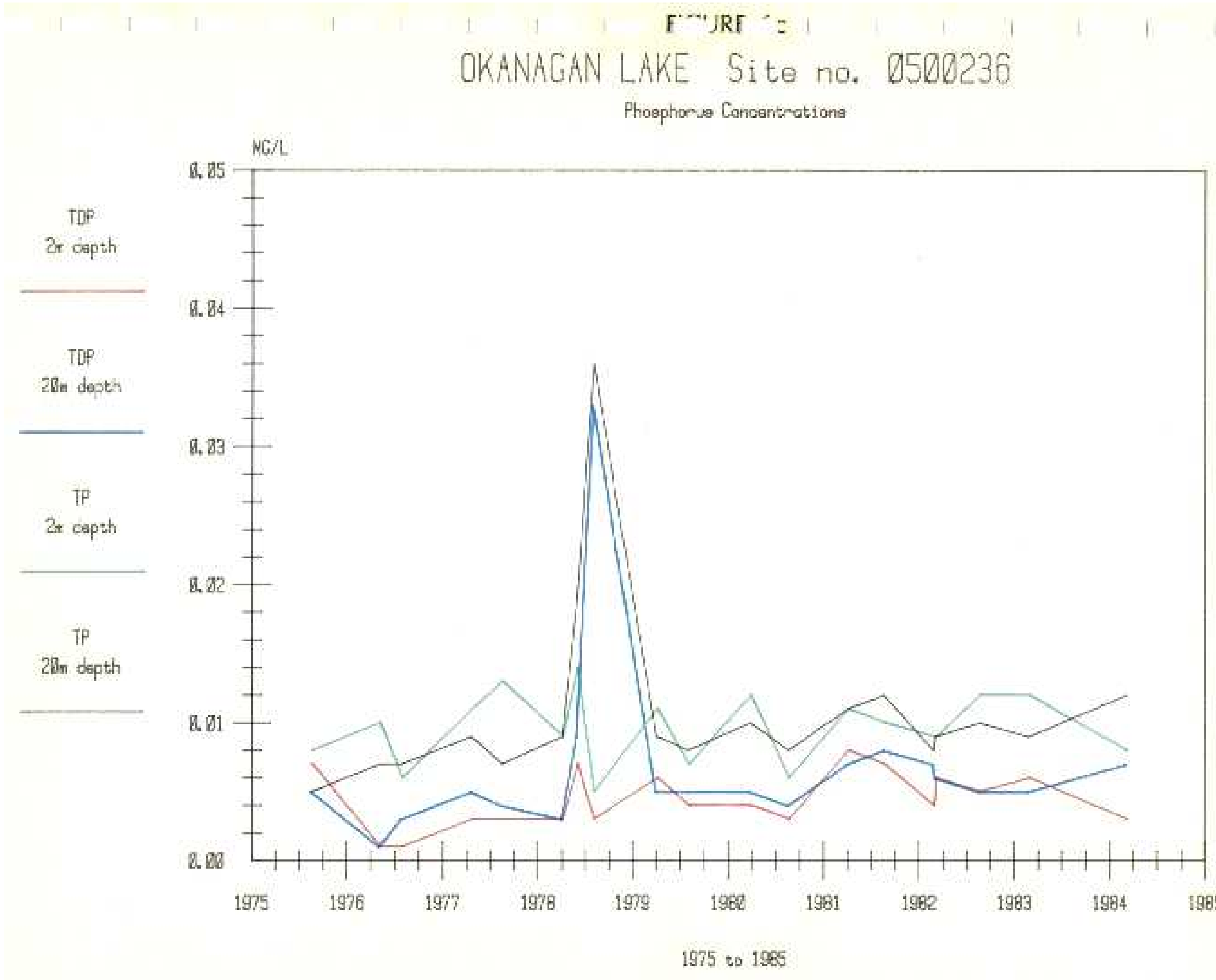


Figure 6d. Phosphorus Concentrations, Okanagan Lake Site 0500729

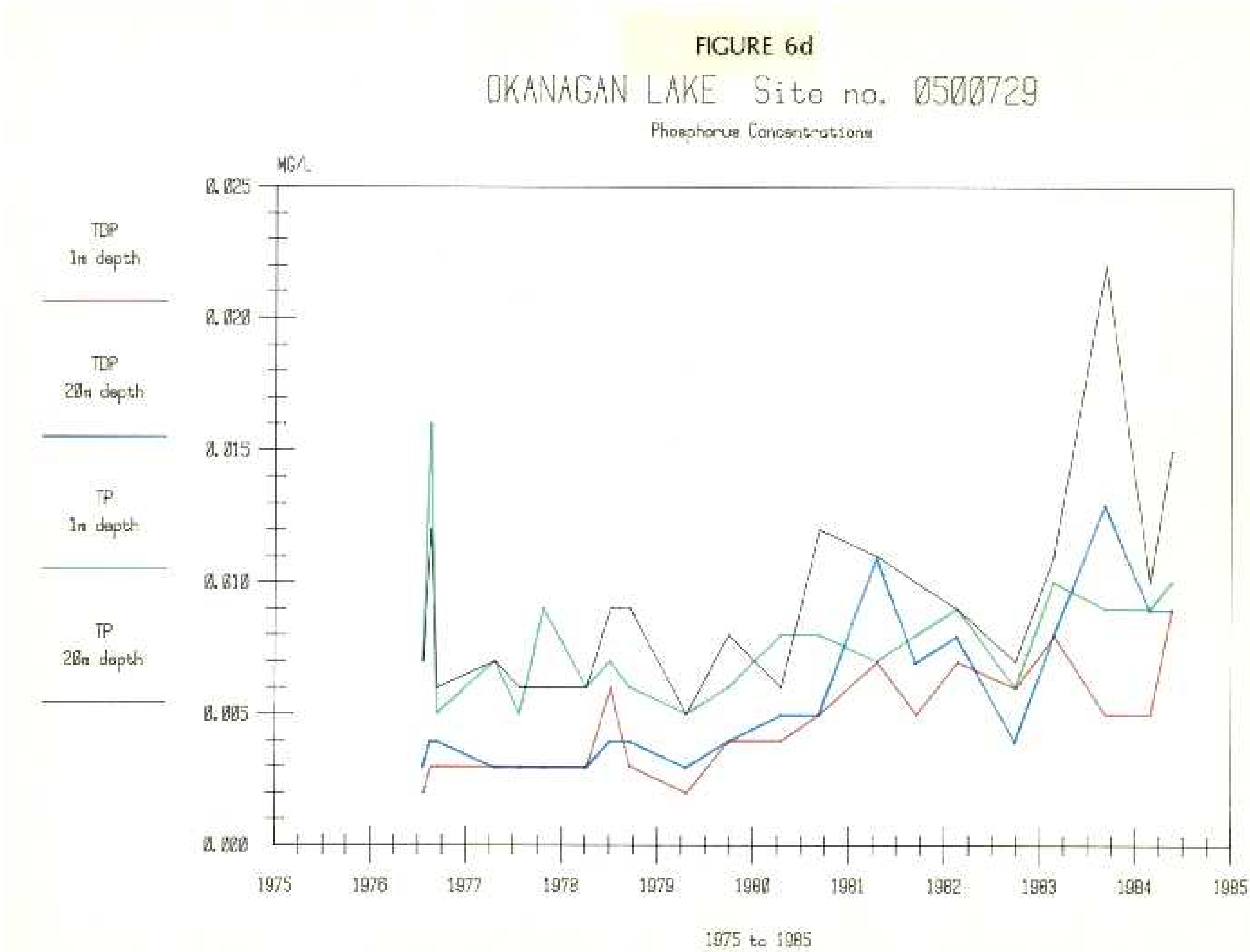


Figure 7a. Phosphorus Concentrations, Skaha Lake Site 0500453

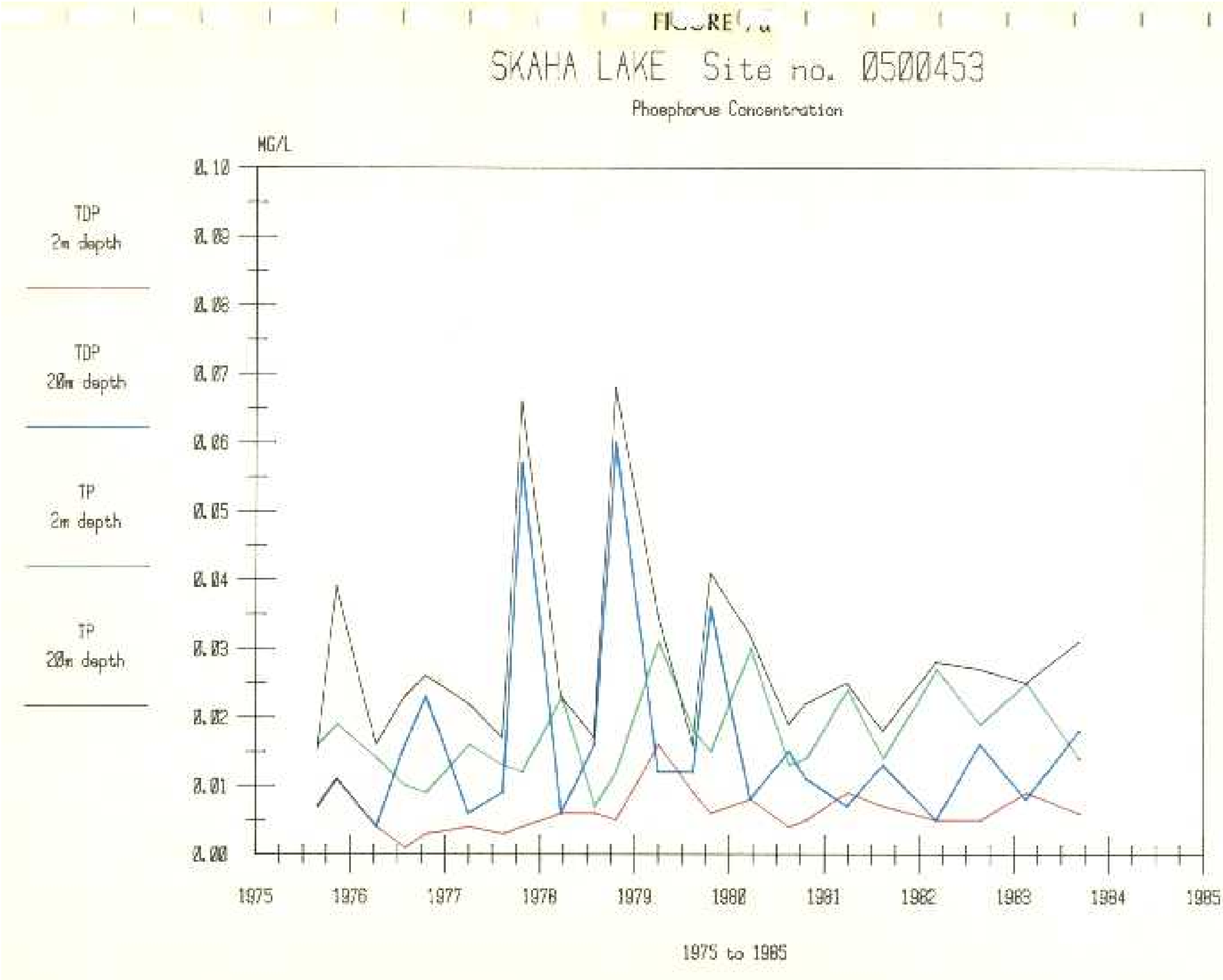


Figure 7b. Phosphorus Concentrations, Skaha Lake Site 0500615

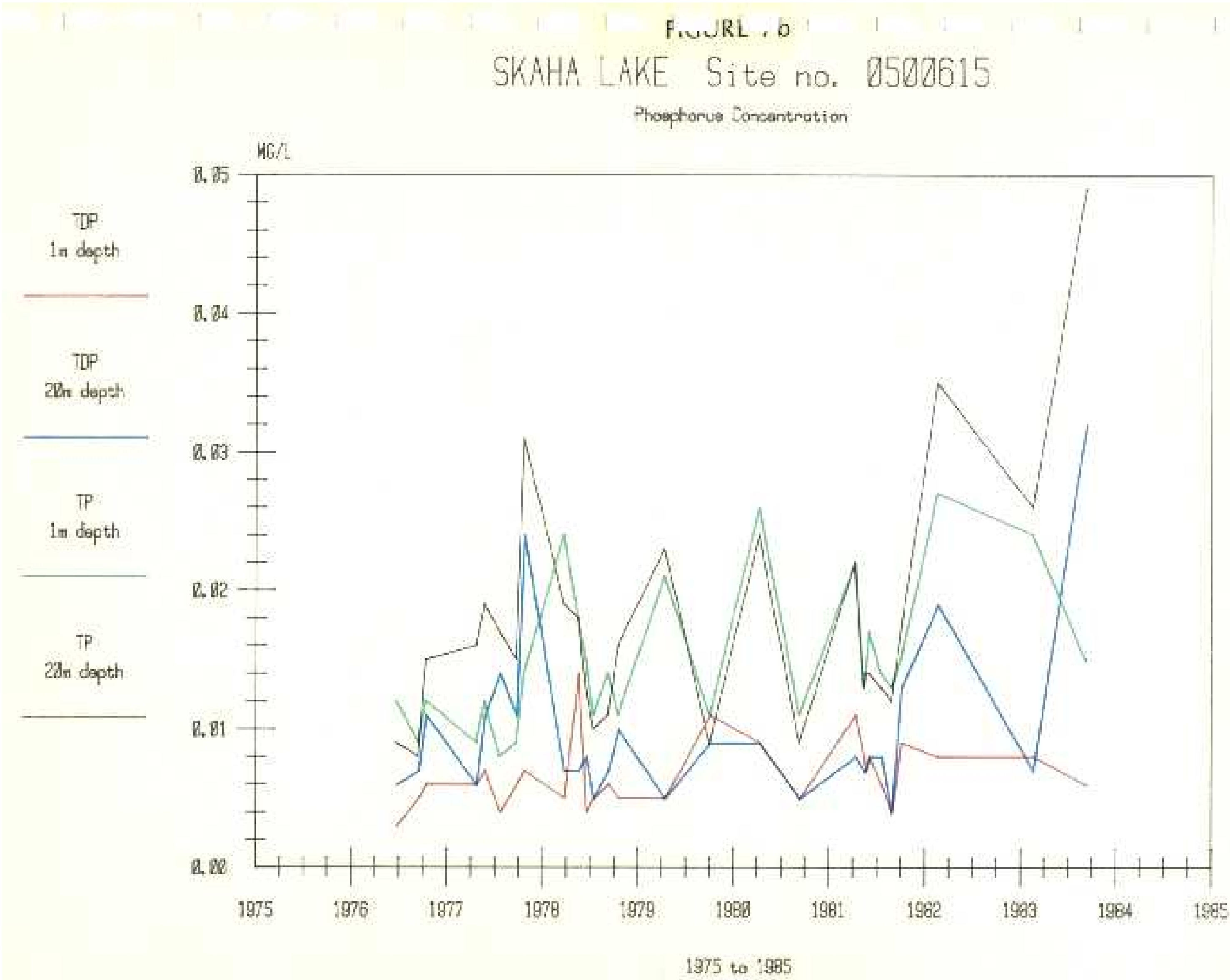


Figure 8a. Phosphorus Concentrations, Osoyoos Lake Site 0500249

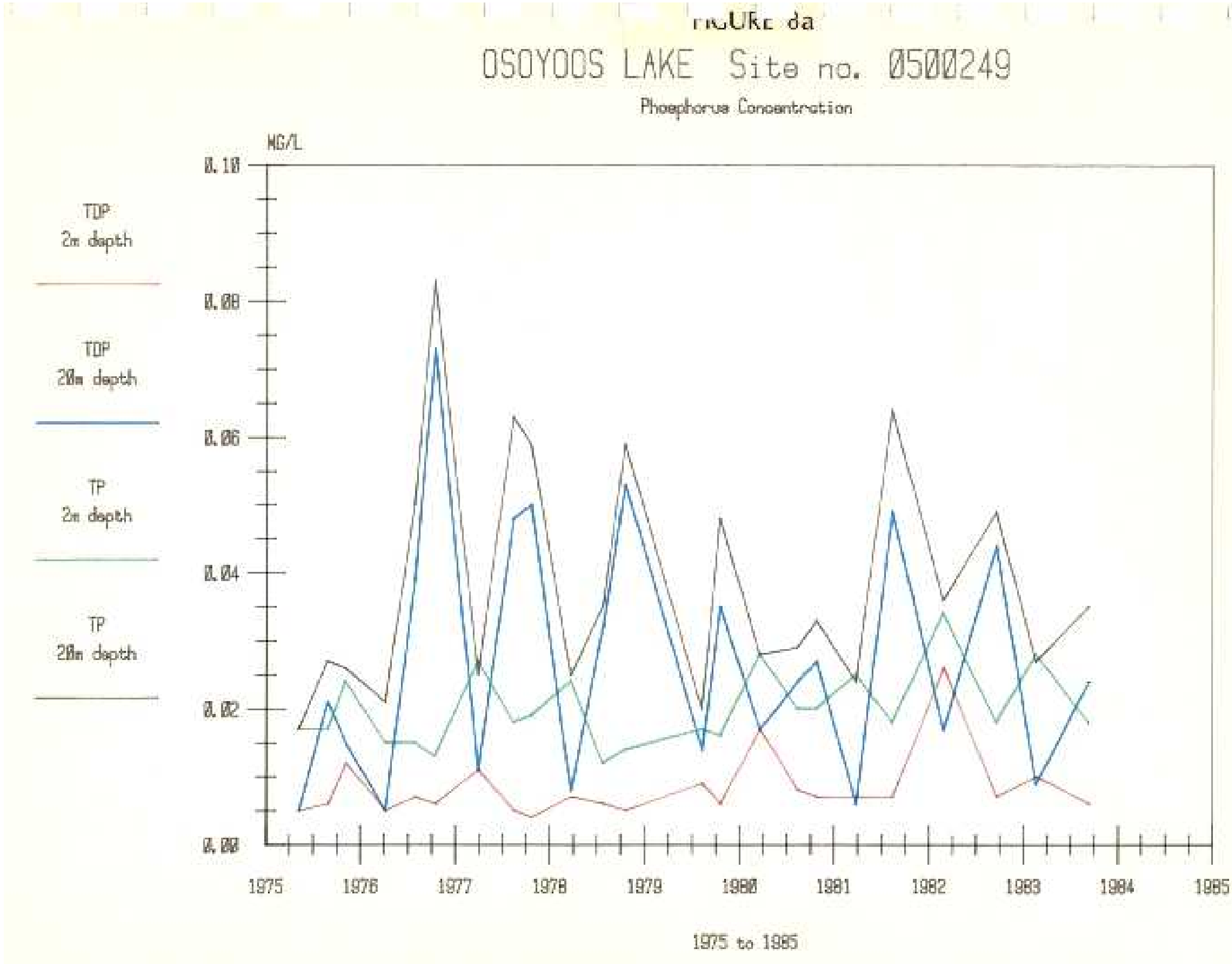


Figure 8b. Phosphorus Concentrations, Osoyoos Lake Site 0500248

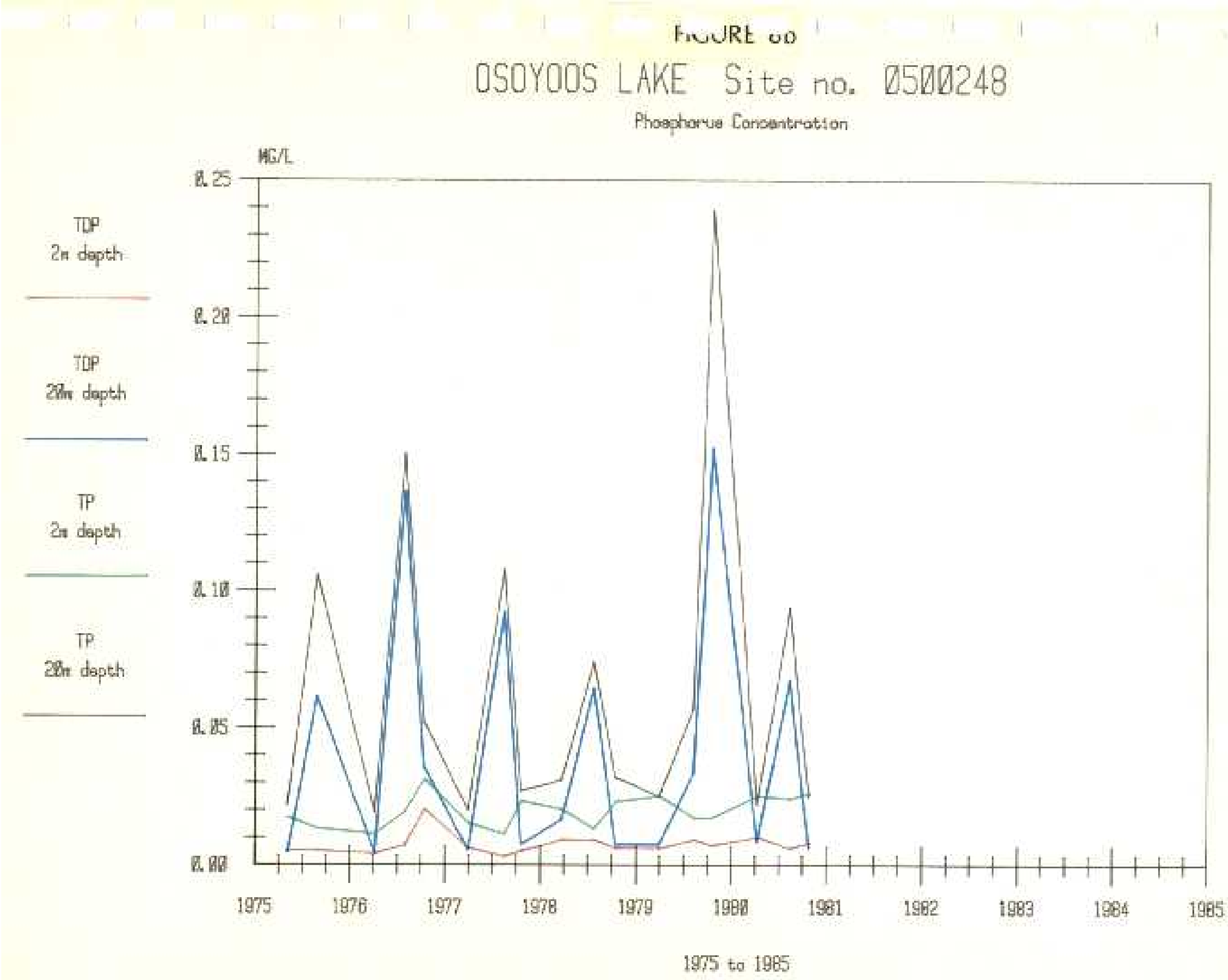


Figure 9. Location of Septic Tanks with Poor Phosphorus Removal Efficiency

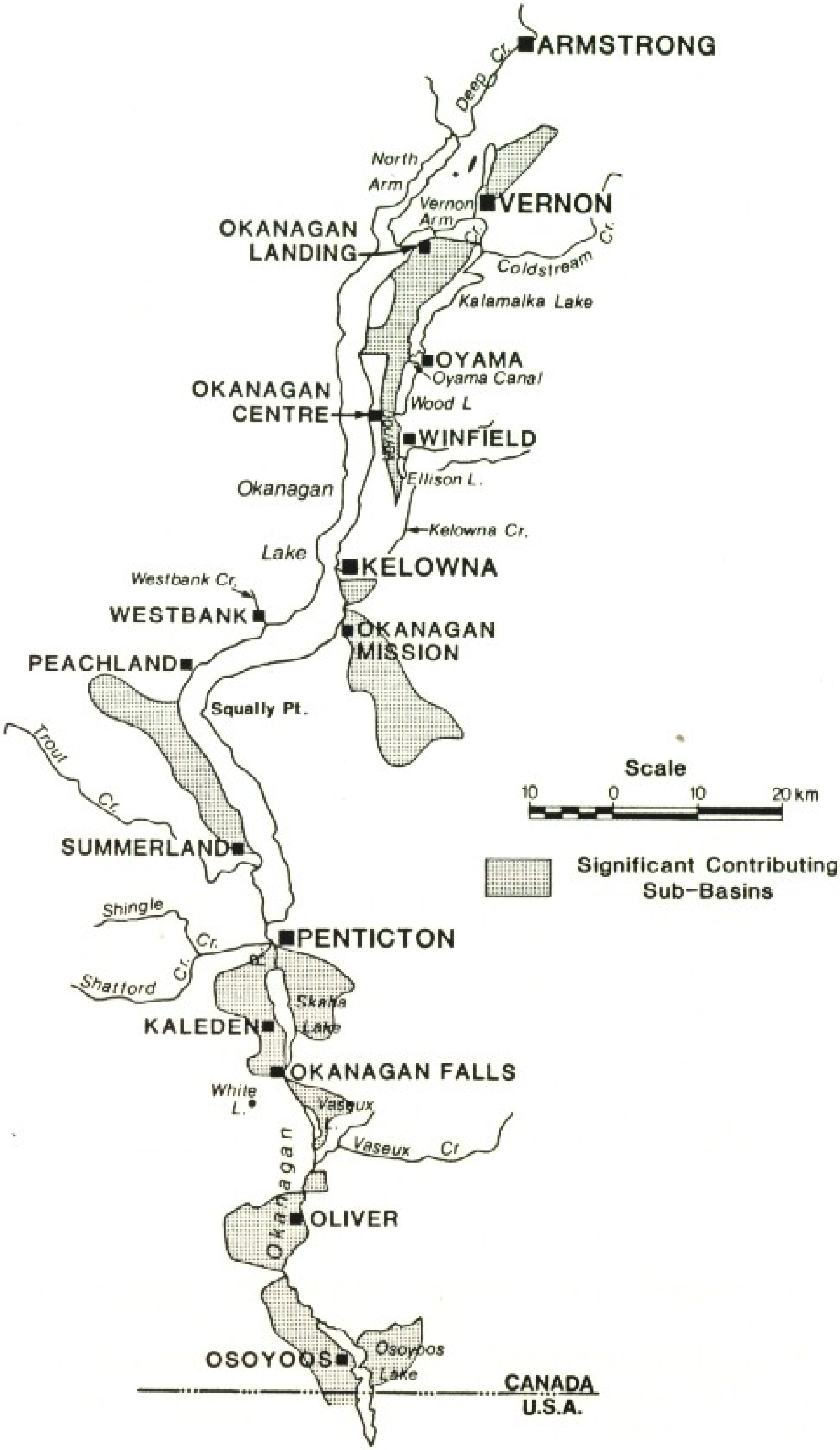


FIGURE 9 Location of Septic Tanks with poor Phosphorus Removal Efficiency.

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TABLES

Table 2-1. Morphometric Features of Six Okanagan Mainstem Lakes

LAKE	VOLUME $x10^6m^3$	AREA $x10^6m^2$	DEPTH mean-m	DEPTH maximum -m
Ellison (Duck)	5.4	2.1	2.5	5.0
Wood	200	9.3	22	34
Kalamalka	1520	25.9	59	142
Okanagan-Vernon Arm	171	12	15	30
Okanagan-North Arm (Armstrong)	464	28	17	100
Okanagan-North Basin (south to Kelowna Bridge)	12171	126	97	230
Okanagan-Central Basin (south to Squally Point)	7085	96	74	205
Okanagan-South Basin (south to Penticton)	4753	89	54	150
Okanagan-Totals (mean)	24644	351	76	230
Skaha	558	20.1	26	57
Osoyoos-North Basin (north of highway bridge)	204.0	9.9	21	63
Osoyoos-Total (including US portion)	397.0	23.0	14	63

1. Ellison Lake data from Lake summary sheets, Fisheries Branch, Penticton
2. Wood, Kalamalka and Skaha Lakes data from Technical Supplement V to the Okanagan Basin Study, Limnology of the Major Lakes in the Okanagan Basin, March, 1974.
3. Okanagan Lake digitized from the Canadian Hrdrographic Service Chart No. 3052, Okanagan Lake, 1982
4. Osoyoos Lake data from Stockner, J. G. and T. G. Northcote. 1974. Recent Limnological Studies of Okanagan Basin Lakes and their Contribution to Comprehensive Water Resource Planning. J. Fish. Res. Board Can. 31: 955-976.

Table 2-2. Long-term Mean Flows for the Okanagan River and Major Tributaries

HYDROMETRIC STATION-NUMBER	long-term monthly mean flow m^3/s	RANGE m^3/s	PERIOD OF RECORD	long-term mean $dam^3/year$	RANGE $dam^3/year$
Vernon Creek-08NH162 inlet to Ellison Lake	0.644	0.284 to 0.925	1972 to 1974	20300	8950 to 29100
Vernon Creek-08NM182 outlet from Ellison Lake	0.548	0.186 to 0.796	1972 to 1974	17300	5860 to 25100
Vernon Creek-08NM009 inlet to Wood Lake	0.503	0.061 to 0.994	1970 to 1983	15900	19350 to 31500
Oyama Canal-no gauge outlet from Wood Lake	.....	.....	.....	.....	.....
Oyama Creek-08NM048 above inlet to Kalamalka Lake	0.232	0.145 to 0.328	1970 to 1983	7318	4540 to 10400
Coldstream Creek-08NM179 above both Kalavista and the inlet to Kalamalka Lake	0.626	0.327 to 0.998	1970 to 1982	19800	10300 to 31500
Vernon Creek-08NM065 outlet from Kalamalka Lake	0.860	0.028 to 2.53	1972 to 1983	41500	4840 to 79800

Vernon Creek-08NM160 near mouth at Vernon Arm	1.57	0.431 to 3.42	1970 to 1982	49500	13600 to 108000
Deep Creek-08NM119 inflow to Okanagan Lake at Armstrong	0.214	0.074 to 0.395	1951 to 1982	6770	2340 to 12500
Deep Creek-08NM153 inflow to Okanagan Lake at the mouth	0.493	0.305 to 0.731	1970 to 1974	15500	9620 to 23100
Equesis Creek-08NM161 inflow to Okanagan Lake at mouth	0.649	0.285 to 1.13	1970 to 1982	20500	9010 to 35700
Whiteman Creek-08NM174 inflow to Okanagan Lake above Bouleau Creek	0.723	0.303 to 1.20	1971 to 1983	22800	9570 to 37900
Whiteman Creek-08NM180 inflow to Okanagan Lake at mouth	1.41	.....	1971	44500	.....
Shorts Creek-08NM151 inflow to Okanagan Lake at mouth	1.06	0.504 to 1.90	1969 to 1982	33500	15900 to 60100
Lambly Creek-08NM166 inflow to Okanagan Lake above mouth	1.49	0.635to 2.43	1970 to 1982	46900	20000 to 76600
Lambly Creek-08NM003 inflow to Okanagan Lake near mouth	1.55	0.64 to 2.630	1919 to 1975	49000	20200 to 83000
Powers Creek-08NM157 inflow to Okanagan Lake at mouth	0.731	0.294 to 1.50	1969 to 1981	23100	8620 to 47200
Trepanier Creek-08NM155 inflow to Okanagan Lake at mouth	1.06	0.38 to 2.280	1970 to 1981	33500	12000 to 71900

Peachland Creek-08NM159 inflow to Okanagan Lake at mouth	**0.395**	**0.156 to 0.958**	**1969 to 1982**	**12500**	**4920 to 30300**
Trout Creek-08NM158 inflow to Okanagan Lake at mouth	**2.15**	**0.345 to 5.42**	**1969 to 1982**	**68000**	**10900 to 171000**
KelownaCreek-08NM053 inflow to Okanagan Lake near Kelowna	**0.594**	**0.249 to 1.13**	**1922 to 1983**	**18700**	**7850 to 35500**
Mission Creek-08NM116 inflow to Okanagan Lake near East Kelowna	**6.29**	**2.84 to 9.12**	**1967 to 1983**	**199000**	**89400 to 289000**
Bellevue Creek-08NM035 inflow to Okanagan Lake near Okanagan Mission	**0.393**	**0.171 to 0.667**	**1969 to 1983**	**12500**	**5410 to 21100**
Penticton Creek-08NM118 inflow to Okanagan Lake at mouth	**0.651**	**0.221 to 1.08**	**1970 to 1972**	**20600**	**6960 to 34200**
Okanagan River-08NM050 outlet from Okanagan Lake at Penticton	**14.8**	**1.59 to 31.6**	**1922 to 1983**	**466700**	**50200 to 998000**
Shingle Creek-08NM150 inflow to Okanagan River at mouth	**0.385**	**0.149 to 0.638**	**1969 to 1980**	**12100**	**4690 to 20100**
Ellis Creek-08NM135 inflow to Okanagan Lake at Penticton	**0.422**	**0.130 to 0.843**	**1965 to 1979**	**13300**	**4100 to 26600**
Okanagan River-08NM002 at Okanagan Falls	**15.7**	**1.44 to 37.6**	**1915 to 1983**	**493900**	**45500 to 1190000**
Shuttleworth Creek-08NM149 inflow to Okanagan River at mouth	**0.133**	**0.062 to 0.203**	**1970 to 1971**	**4180**	**1950 to 6410**

Vaseaux Creek-08NM015 inflow to Okanagan River above Dutton Creek	1.41	0.56 to 2.41	1959 to 1982	44500	18900 to 64300
Okanagan River-08NM085 near Oliver	19.1	6.51 to 36.6	1944 to 1983	572000	205000 to 1150000
Testalinden Creek-08NM164 inflow to Okanagan River in canyon	0.029	0.007 to 0.080	1970 to 1983	900	301 to 2530
Okanagan River-08NM127 at Oroville, USA	19.4	6.95 to 39.6	1942 to 1983	614000	237000 to 1260000

Table 2-3. Mean Annual Discharge and Residence Times for Six Okanagan Lakes

LAKES	VOLUME $x10^6m^3$	MEAN ANNUAL OUTFLOW $x10^6m^3$	CALCULATED RESIDENCE TIME (YEARS)	OK BASIN STUDY-1974 RESIDENCE TIME (YEARS)
Ellison	5.4	17.3	0.3	.....
Wood	200	no gauge	.....	30.0 (14)
Kalamalka	1520	41.5	36.6	65.0 (45)
Okanagan	24644	466.7	52.8	60.0
Skaha	558	493.9	1.1	1.2
Osoyoos	397	614.0	0.6	0.7

1. volumes from table 2-1
2. outflows from table 2-2
3. calculated residence times are volume/mean annual outflow
4. (residence times) are after 1971 when cooling water pumped from Okanagan Lake to the Hiram Walker Distillery began discharging to Vernon Creek, assuming licenced flow rates

Table 3-1a. Comparisons of Past, Present and Projected Bioavailable Phosphorus Loadings to the Okanagan Main Valley Lakes-Wood Lake

SOURCE	Wood Lake basin-tonnes/year		
	1970	1980	1990
Controllable Point Sources			
Municipal	.....	.....	.....
Storm Sewers	.....	.....	.....
Industrial	.....	.....	.....
Controllable Non-Point Sources			
Agriculture-animals	0.4	0.5	0.5
Agriculture-fertilizer	0.1	0.1	0.1
Septic Tanks	0.4	0.8	1.8
Logging	n/a	0.5	0.5
Other Sources	0.1	0.1	0.1
Sub-total	1.0	2.0	3.0
Non-controllable			
Dustfall/Precipitation	0.1	0.1	0.1
Watershed Sources	1.7	1.2	1.2

Mainstem Loadings	.....	.....	.....
Sub-total	1.8	1.3	1.3
Total Loadings	2.8	3.3	4.3

Table 3-1b. Comparisons of Past, Present and Projected Bioavailable Phosphorus Loadings to the Okanagan Main Valley Lakes-Kalamalka Lake

SOURCE	Kalamalka Lake basin-tonnes/year		
	1970	1980	1990
Controllable Point Sources			
Municipal	.....	.....	.....
Storm Sewers	.....	.....	.....
Industrial	.....	.....	.....
Controllable Non-Point Sources			
Agriculture-animals	0.3	0.7	0.7
Agriculture-fertilizer	neg	neg	neg
Septic Tanks	0.4	0.3	0.4
Logging	n/a	0.1	0.1
Other Sources	neg	neg	neg
Sub-total	0.7	1.1	1.2
Non-controllable			
Dustfall/Precipitation	0.3	0.3	0.3
Watershed Sources	2.2	2.1	2.1
Mainstem Loadings	0.3	0.3	0.3

Sub-total	2.8	2.7	2.7
Total Loadings	3.5	3.8	3.8

Table 3-1c. Comparisons of Past, Present and Projected Bioavailable Phosphorus Loadings to the Okanagan Main Valley Lakes-Okanagan Lake

SOURCE	Okanagan Lake basin-tonnes/year		
	1970	1980	1990
Controllable Point Sources			
Municipal	37.5	17.0	8.5
Storm Sewers	0.3	0.5	0.7
Industrial	0.7	1.1	1.2
Controllable Non-Point Sources			
Agriculture-animals	2.2	8.8	8.9
Agriculture-fertilizer	0.3	0.4	0.4
Septic Tanks	3.8	6.6	8.3
Logging	n/a	6.0	6.0
Other Sources	0.2	1.3	0.3
Sub-total	45.0	41.7	34.3
Non-controllable			
Dustfall/Precipitation	8.9	8.9	8.9
Watershed Sources	24.5	18.5	18.5
Mainstem Loadings	0.1	0.1	0.1
Sub-total	33.5	27.5	27.5

Total Loadings	**78.5**	**69.2**	**61.8**

Table 3-1d. Comparisons of Past, Present and Projected Bioavailable Phosphorus Loadings to the Okanagan Main Valley Lakes-Skaha Lake

SOURCE	Skaha Lake basin-tonnes/year		
	1970	1980	1990
Controllable Point Sources			
Municipal	13.1	2.4	3.7
Storm Sewers	neg	neg	neg
Industrial	neg	.....	.....
Controllable Non-Point Sources			
Agriculture-animals	0.5	0.4	0.5
Agriculture-fertilizer	neg	neg	neg
Septic Tanks	0.6	1.8	2.3
Logging	n/a	0.9	0.9
Other Sources	neg	neg	neg
Sub-total	14.27	5.5	7.4
Non-controllable			
Dustfall/Precipitation	0.8	0.8	0.8
Watershed Sources	4.2	3.3	3.3
Mainstem Loadings	3.1	3.1	3.1
Sub-total	8.1	7.2	7.2
Total Loadings	22.3	12.7	14.6

Table 3-1e. Comparisons of Past, Present and Projected Bioavailable Phosphorus Loadings to the Okanagan Main Valley Lakes-Osoyoos Lake

SOURCE	Osoyoos Lake basin-tonnes/year		
	1970	1980	1990
Controllable Point Sources			
Municipal	2.7	0.9	.....
Storm Sewers	0.1	.....	.....
Industrial	.....	.....	.....
Controllable Non-Point Sources			
Agriculture-animals	0.3	0.5	0.6
Agriculture-fertilizer	0.4	0.5	0.5
Septic Tanks	2.8	2.0	2.5
Logging	n/a	0.9	0.9
Other Sources	0.1	0.1	0.1
Sub-total	6.4	4.9	4.6
Non-controllable			
Dustfall/Precipitation	0.5	0.5	0.5
Watershed Sources	7.1	6.2	6.2
Mainstem Loadings	8.9	8.9	8.9
Sub-total	16.5	15.6	15.6
Total Loadings	22.9	20.5	20.2

1. Controllable values assumes that all controllable sources of phosphorus are biologically available.
2. Dustfall and precipitation values assumes that all dustfall and precipitation sources of phosphorus are biologically available.
3. Biologically available loadings from watershed and mainstem sources were calculated as set out in Summary of Nitrogen and Phosphorus Loadings to the Okanagan Main Valley Lakes from Cultural and Natural Sources, by D. G. Alexander (unpublished as of July 1982)
4. Future loadings from municipal sources are uncertain due to the type of treatment to be employed and the possibility of sewering additional areas in addition to the growth for areas already sewered. Future loadings are estimated on the basis of population growth assuming that as a minimum objective, 90% of the phosphorus will be removed.
5. Loadings from non-controllable dustfall and precipitation sources are shown to be the same for all years since the data base was not sufficient to separate differences between present and previous loadings, nor to allow projections. However, changes in loadings to lakes may result in changes in loadings to downstream mainstem lakes.
n/a: not available
neg: negligible.

Table 3-2. Permitted Discharges to Watercourses

Name	Permit Number	Receiving water body	Treatment provided	permit discharge volume m^3/day	Phosphorus loading tons/year
Hiram Walker Distillery	PE 268	Ellison Lake via Vernon Creek	Cooling towers	22730	.....
City of Armstrong	PE 75	Okanagan Lake via Deep Creek	secondary: 2 aerated ponds, 2 aerated waste stabilization ponds	1950	2.4 (1984) 2.6 (1983)
Fraser Valley Milk Producers	PE 310	Okanagan Lake via Deep Creek	none-cooling water	91	.....

City of Vernon	PE 167	Okanagan Lake via Vernon Creek or by land runoff	tertiary: trickling filters, alum addition, settling basins or trickling filters, reservoir, spray irrigation	102280	0.38 (1984) 0.00 (1983)
Hydra Estates	PE 2478	Okanagan Lake via Girrard Creek	none-cooling water	100	.....
City of Kelowna (industrial)	PE 1434	Okanagan Lake via Brandts Creek	secondary: flow equalization, aeration basin, clarifiers, centrifuge	2650	1.4 (1984) 0.49 (1983)
City of Kelowna	PE 5724	Okanagan Lake	tertiary: clarifiers, Bardenpho activated sludge, dual media filtration	22730	6.74 (1984) 4.02 (1983)
Westbank	PE 1592	Okanagan Lake via Westbank Creek	secondary: aerated lagoons	1092	0.83 (1984) 0.44 (1983)
Lake Area Growers Cooperative	PE 2050	Okanagan Lake	none-cooling water	136.3	.....
City of Penticton	PE 69	Skaha Lake via Okanagan River	tertiary: activated sludge, flocculation, coagulation	8183	2.54 (1984) 3.54 (1983)
BC Ministry of Environment	PE 5801	Skaha Lake	fish hatchery flow-through water	3250	.....
Oliver-Osoyoos Cooperative Growers Association	PE 2217	Osoyoos Lake	none-cooling water	970	.....
Monashee Cooperative Growers Association	PE 2120	Osoyoos Lake	none-cooling water	1130	.....

Summerland Trout Hatchery	PE 1585	Okanagan Lake	none	4550	0.2 (1983/1984)
Total phosphorus loadings in 1984 to Okanagan Lake					12
Total phosphorus loadings in 1984 to all lakes					14.5

Table 4-1. Number of Licenced Withdrawals and Volume Withdrawn from the Okanagan Main Valley Lakes

LAKE	IRRIGATION m^3/year	DOMESTIC m^3/d	INDUSTRIAL m^3/d	WATERWORKS m^3/d
Ellison	2 licences 1,332,160	.....	.....	.....
Wood	9 licences 363,075	4 licences 9	1 licence 20	2 licences 341
Kalamalka	21 licences 1,798,454	36 licences 205	2 licence 141	12 licences 22,941
Okanagan	206 licences 14,265,159	338 licences 2117	27 licence 85,435	96 licences 2340
Skaha	42 licences 5,305,575	61 licences 857	1 licence 9	8 licences 3241
Osoyoos	70 licences 4,711,765	17 licences 59	2 licence 1827	2 licences 227

Table 4-2a. Fish Species and Relative Fishing Effort and Fish Harvest in the Okanagan Mainstem Lakes

lake	# of fish species	dominant fish species	% salmonids
Okanagan	15	kokanee, peamouth chub, mountain whitefish	49% salmonids
Kalamalka	14	kokanee, rainbow trout	49% salmonids
Skaha	15	squawfish, peamouth chub	33% salmonids

Osoyoos	20	kokanee, mountain whitefish	42% salmonids
Wood	10	squawfish, peamouth chub	12% salmonids
Ellison	N/A	coarse fish	.....

Table 4-2b. Fish Species and Relative Fishing Effort and Fish Harvest in the Okanagan Mainstem Lakes

lakes	1980 angler effort days	1980 harvest, # of fish		1991 projected angler effort days
		rainbow trout	kokanee	
Okanagan	52000	13109	222867	74000
Kalamalka	4600	791	15597	6623
Skaha	1600	554	831	2144
Osoyoos	2000	N/A	N/A	N/A
Wood	not heavily fished	N/A	N/A	N/A
Ellison	50	.....	.....	N/A

1. The fish species data is from: Anon. 1974. Technical Supplement V to the Final Report, The Limnology of the Major Okanagan Basin Lakes.
2. The angler effort days and harvest data is from: Anon. 1982. Report on the Okanagan Basin Implementation Agreement, Okanagan Basin Implementation Board.
3. The Osoyoos 1980 angler effort days data is from: The Fisheries Branch lake summary sheets, Penticton.
4. The wood lake 1980 angler effort days data is from: Fisheries Management Plan for Okanagan Main Valley Lakes, Fisheries Staff Okanagan Region, March 1980.
N/A is not available.

Table 4-3. Selected Shoreline Development in the Okanagan Mainstem Lakes, 1980

Lake	Shoreline total length in km	The % of the total shoreline developed for:				
		1 Recreation	2 Commercial	1 + 2	3 Residential	1 + 2 + 3
Okanagan	270	6.1	3.0	9.1	25.1	34.2
Kalamalka	44	3.7	3.8	7.5	17.2	24.7
Skaha	29	6.7	5.2	11.9	19.8	31.7
Osoyoos	34	12.2	6.5	18.7	19.7	38.4
Wood	17	0	9	9	6	15
Ellison	7	.....	.....	.....	.....	.....

from: Phipps and James, 1980

Table 4-4. The Contribution of the Okanagan Main Valley Lakes to the Total Beach-Oriented Recreation

Area and Lake	% total participation in beach-oriented recreation	# of beach-oriented public recreation sites
Vernon area: Kalamalka Lake	.....	2 (3)
Vernon area: Wood Lake	.....	0
Vernon area: Okanagan Lake-north	.....	3
Vernon area: total	25	5 (6)
Kelownan area: Okanagana Lake-central	35	14
Penticton area: Okanagan Lake-south	.....	11

Penticton area: Skahaa Lake	.....	3
Penticton area: total	30	14
Vernon area: Osoyoos Lake	greater than 10	2

1. The number of beach-oriented public recreation sites is taken from Provincial and Municipal Parks, 1974.
2. (values) include Kalamalka Lake Park which is an undeveloped Crown Park Reserve but use to some extent by the public.
3. The Osoyoos % participation includes use of Tugulnuit Lake, a small lake not otherwise discussed in this report.

Table 4-5. Projection of Demands, Water-Based Recreation, Okanagan Main Valley Lakes

YEAR	VISITORS		BEACH DAYS		
	NUMBER	VISITOR DAYS	RESIDENTS	VISITORS	TOTAL
1970	0.48	3.10	2.20	1.70	3.90
1980	1.05	6.28	3.68	3.47	7.15
1990	1.20	7.18	5.06	3.97	9.03
2000	1.35	8.09	5.92	4.48	10.400
2010	1.53	9.21	7.00	5.10	12.10
2020	1.72	10.33	8.08	5.72	13.80

from: Anon. 1982. Okanagan Basin Implementation Board. Report on the Okanagan Basin Implementation Agreement.
1. The values in the table are in millions of visitors or beach-days

Table 9-1. Summary of Estimated Costs to Improve Municipal Treatment, Including Phosphorus Control, Over the Next Ten Years

Municipality	Plant upgrading (lowest cost scheme)			Spray irrigation (after plant upgrading)		
	Improvment Required	Cost ($millions)	% phos removal	Equipment cost ($millions)	Land cost ($millions)	% phos removal
Armstrong	.....	.....	.....	$3.3	.....	99%
Vernon	outfall, filtration	$11.9	$95%	$16	$36	99%
Kelowna	outfall, repair	$0.5	$95%	$20	$53	99%
Westbank	new plant	$1.8	$95%	.....	.....	.....
Penticton	clarification, sludge thickening, filtrationr	$5.0	$95%	$32	$8.0	99%
Okanagan Falls	.....	.....	$99%	.....	.....	.....
Oliver	.....	.....	$99%	.....	.....	.....
Osoyoos	alum addition	$0.05	$98%	.....	.....	.....
Totals	.....	$19.25	.....	$71.3	$97	.....
Total for 99% phos removal	.....	$187.55				

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