MINISTRY OF ENVIRONMENT
PROVINCE OF BRITISH COLUMBIA

UPPER COLUMBIA RIVER AREA

COLUMBIA AND WINDERMERE LAKES SUB-BASIN WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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SECTION I

INTRODUCTION

Columbia and Windermere Lakes, the Columbia River between Columbia and Windermere Lakes, the Columbia River between Windermere Lake and Toby Creek, and Windermere Creek are 5 of 9 priority sub-basins in the Upper Columbia Planning Unit (Figure 1). These sub-basins have been selected for water quality assessment and the development of water quality objectives in this report.

The other priority sub-basins within the Upper Columbia River Basin are addressed in a separate report by Nijman (in prep.).

Several areas of water quality concern have been identified for Columbia Lake, Windermere Lake, the Columbia River to Toby Creek, and their watersheds. These are:

1. The possibility of future development on unstable soils or soils unsuitable for accepting sewage effluent. There is potential for input of nutrients, suspended sediments and fecal contaminants to the lakes. An integrated assessment of both soils and water quality has been conducted to assess this possibility.
2. The effects of the Kootenay Diversion on water quality of Columbia and Windermere Lakes, and the Columbia River between the lakes.

An overview of the data collected prior to August 1975, and between August 1975 and May 1978 was provided as part of the Kootenay Air and Water Quality Study (Ministry of Environment, 1976 and 1981b). This report combines the data prior to 1978, with the data up to May 1983.

SECTION 2
COLUMBIA AND WINDERMERE LAKES

2.1 INTRODUCTION

Columbia Lake, located just north of Canal Flats, is the headwaters of the Columbia River. The river then flows into Windermere Lake about 15 km further north.

The general morphological features of Columbia and Windermere Lake are summarized in Table 1, and the major topographic features of their watersheds are illustrated in Figure 1.

Both lakes are similar in many ways. They are high altitude, large, shallow lakes, oriented in the north south direction at the head of the Columbia River system. One major contrast is that Windermere Lake has a watershed area 7 times that of Columbia Lake. Both Windermere and Columbia Lakes were formed when the aggrading fans of Dutch and Toby Creeks dammed the Columbia River Valley. Lakes formed by this process are typically shallow.

Dutch Creek was not included in the Columbia Lake drainage as it enters the lake near the outlet, and is believed to have a small or negligible influence on the flushing rate and water quality (including nutrient loading of the lake). The influence of Dutch Creek will be restricted to the north end of the lake during freshet.

The bedrock geology of the area is typically metamorphosed sedimentary rock, with some volcanic intrusions. The sedimentary rock is composed of dolomite, limestone, and shales. The effect of the geology on water quality is important, and is discussed in Section 2.5.

The soils and surficial deposits are the dominant geologic feature in the valleys and lower slopes around the lakes. They are important with regard to water quality because of their ability to modify the groundwater quality, and absorb nutrients and pathogens from septic tank systems. These processes are described further in Section 2.4.2.

2.2 HYDROLOGY

Some insight into the hydrology of the area was obtained from the Water Survey of Canada (1977) stream flow gauge 08NA045 on the Columbia River. The station is located downstream from Fairmont Hot Springs between the two lakes, and data are available from 1945 to the present. The area of the watershed above the gauge is 890 km^2, and the mean annual runoff volume is 351 850 dam^3.

Dividing the annual runoff by the watershed area gives a watershed runoff ratio of 3.95 dam^3/ha. By multiplying the watershed runoff ratio by the area of each lake's watershed, the annual input of water to each lake can be roughly estimated (Table 2).

This method yields an average annual input of 73 100 and 523 000 dam^3 to Columbia and Windermere Lakes, respectively. Table 2 summarizes the most important hydrological variables for an average runoff year.

Dividing the calculated lake inflow by the lake volume gives the flushing rate. The water retention time is the inverse of the flushing rate.

2.3 WATER USE

The water licences for Windermere and Columbia Lakes are summarized in Tables 3 and 4. Location of the point of diversion on withdrawal of each water licence is illustrated in Figures 2 and 3.

2.3.1 DOMESTIC LICENCES

There are 26 domestic water licences on Windermere Lake (Table 3), 11 of which are held by waterworks which are, as a group, licenced to withdraw 4061 m^3/d. The remaining 15 domestic licences are for single family dwellings, which are each licenced to withdraw 2.3 m^3/d, or a total of 34.5 m^3/d.

Nineteen of the domestic and waterworks water licences are located on the east shore between Windermere Creek and Athalmer. The remaining seven domestic licences are located on the southwest shore of the lake (Figure 2).

There are fewer domestic licences on Columbia Lake (Table 4). There are three waterworks licences totalling 410 m^3/d, and one domestic water licence (2.3 m^3/d). The waterworks licences are in the name of Columere Waterworks Ltd., and have a single point of withdrawal located on the northwest shore. The remaining water licence is for a withdrawal on the west shore at mid-lake (Figure 3).

2.3.2 IRRIGATION LICENCES

There are 8 irrigation licences on Windermere Lake, licenced to withdraw 18.4 dam^3. Seven of these licences are grouped on the southwest shore (Figure 2). The remaining licence is further north on the south shore near Brady Creek.

There is only one irrigation licence on Columbia Lake. The point of withdrawal is located on the west shore near the midway point of the lake (Figure 3).

2.3.3 INDUSTRIAL LICENCES

There are four licences for industrial users (Table 3) located between Windermere and Athalmer on the east side of the lake (Figure 2). Three of the industrial licences are for lawn watering. The fourth is for a resort on the lake. There are no industrial licences on Columbia Lake.

2.3.4 LAND IMPROVEMENT

Only one licence for land improvement (Table 3) has been granted on Windermere Lake (Figure 2). The licencee, Land Logistics Western Limited, obtained the licence for marina and beach improvement. Construction included dyking, land filling and beach improvement.

2.3.5 BOAT LAUNCHES AND BEACHES

According to the Ministry of Lands, Parks and Housing, there is only one public boat launching ramp at the provincial park at the north end of Windermere Lake (Figure 4). Two boat launches are located at the south west and south east end of Columbia Lake (Figure 3).

The location of beaches around Windermere Lake was based on a Ministry of Health coliform bacteria survey. The locations of the 15 beaches are shown in Figure 4. It is not known if the 15 beaches represent all of the beaches on Windermere Lake. All known beaches are located at the north end of the lake between Windermere and Athalmer, or Invermere and Athalmer.

Future park development includes a 300-400 campsites park, day-use beach, picnicking, and boat launch near Invermere (Hanry, pers. comm.).

Only one beach has been located on Columbia Lake. Columere Beach is located at the northwest end of the Lake (Figure 3).

Turbidity, algal growth, temperature, aquatic plants, and coliform bacteria, which are important variables at beach areas, are considered in Section 2.5.

2.3.6 FISHERIES

A fish species list was compiled by the Inventory and Operations Unit of the Water Management Branch (Ministry of Environment, 1981a). The sport and commercial species found in each lake were burbot, Dolly Varden char, mountain whitefish, and rainbow trout. Pygmy whitefish and Yellowstone cutthroat trout are noted as probable, but unconfirmed, in the lakes.

Additional information regarding fishing pressure and spawning areas was obtained fron the Fish and Wildlife Branch office in Cranbrook (A. Martin, pers. comm.). Windermere Lake is subject to a fishing pressure of between 5 000 and 7 000 angler-days. Rainbow trout and Dolly Varden char are caught in the early spring. Kokanee (0.25 million) and trophy rainbow trout have recently been introduced to Windermere Lake to enhance the lake's fishery.

Columbia Lake is subject to a fishing pressure of between 3 000 and 4 000 angler-days. Some rainbow trout are caught in the early spring, but the majority of the fishing is for burbot at the mouth of Dutch Creek in the winter.

2.4 WASTE DISCHARGES

There are no point source discharges entering the lakes directly. Concern has been expressed for non-point inputs, two of which are considered below.

2.4.1 MOTOR BOATS

Effects of motor boats on lakes are difficult to assess, and no data directly related to the problem have been collected on Columbia or Windermere Lakes. Butcher (1982) reviewed the literature on the effects of motor boats and their emissions on the aquatic environment. Increased turbidity in shallow areas, and taste and odours caused by emissions can occur. Because of the size of both lakes, the effects of motor boats is expected to be minor. Heavy boating, however, around water intakes may result in problems for the water users.

Location of boat access and activities should be planned away from existing water intakes. Residents installing new water intakes near boating areas should be aware of the potential problems, and alternate sites should be considered.

2.4.2 SEWAGE DISPOSAL

The section on sewage disposal was divided into 4 subsections. Section 2.4.2a considered the present phosphorus contribution from sewage discharges That section was completed by Dr. J.H. Wiens of the Surveys and Resource Mapping Branch, Ministry of Environment in Victoria. The remaining sections (2.4.2b, c, and d) were completed by Ms. V. Hignett also of the Surveys and Resource Mapping Branch. These sections consider the phosphorus adsorption suitability of the soils for septic effluent around the lakes; the landscape suitability (instability potential of soils) around Windermere

Lake for septic tank tile field use; and the areas of development proposed by the East Kootenay Settlement Plan in relation to phosphorus adsorption suitability and potential instability problems caused by septic tank tile field use.

Agricultural impact on water quality was not identified as a problem in the report's terms of reference, and consequently it was not examined.

2.4.2a Septic Tank/Tile Field Sewage Discharges

Evaluation of nutrient loading from septic tank tile fields was a primary objective of this report. Dr. J.H. Wiens of the Surveys and Resource Mapping Branch assessed the phosphorus loading characteristics from existing septic tank sources and evaluated the phosphorus adsorption potential of the soils surrounding Windermere and Columbia Lakes. His report and assessment methodology is contained in Appendix 1 of this report. The following is a summary of this information.

The Invermere townsite has a sewage collection and treatment system with disposal to ground. The disposal area is outside the Windermere Lake watershed, in the Toby Creek watershed. The impact of this discharge on water quality is considered in the report by Nijman (in prep.).

The majority of the septic tanks located around Windermere Lake are between Athalmer on the north end, and Windermere at mid-lake. In 1975, within a 500 m zone around the lake there were 367 homes that either had individual septic tanks or a local collection system with discharge to ground. At present, there are two community collection systems with ground discharge of effluent. A third collection system, Calmere Holdings Ltd. (PE 2100) relies on evaporation of effluent rather than ground discharge. A brief description of the three permits and their history was completed by (Lawrence, 1984) and is summarized below.

Assuming homes serviced by Permits PE 1527 and PE 5173 have a similar impact as individual septic tank tile fields, an estimated 128 and 23 kg of total phosphorus enters Windermere and Columbia Lakes respectively each year from sewage disposal via septic tanks with tile fields. This represents 1.5% for Windermere and 1% for Columbia of the total annual phosphorus input to the lakes as summarized in Section 2.5. The impact of increased population on the annual phosphorus input is discussed in Section 2.5.5.

Terravista PE 1527

The disposal system at Terravista was installed in 1972, and consisted of a packaged extended-aeration treatment plant and two separate tile fields, each consisting of twelve 30.5 m lengths of perforated pipe. The tile field was designed to receive a discharge of 114 m^3 (25 000 gallons) per day and covered an area of approximately 1 600 m^2.

In the fall of 1978 problems associated with the tile field were noticed. At the request of Waste Management, Terravista engaged a consultant to investigate and report on the condition of the tile field. As a result of the report, some minor repairs were made to the tile field. In August 1979, effluent began surfacing near the tile field. Use of the tile field was prohibited and effluent was trucked to an alternate disposal site. The existing tile field was removed and a new field installed.

Discharge to the new tile field commenced on December 17, 1979. In August, 1981, the new tile became saturated due to the high effluent flows of 82 m^3 (18 000 gallons) per day. Once again it became necessary to truck sewage effluent to an alternate disposal site. In 1982 an additional tile field covering an area of 800 m^2 was constructed. During the 1983 summer season (peak effluent flow) the new tile field plus the new addition handled the sewage effluent with no problems.

The Waste Management Branch in Cranbrook is optimistic about the continued operations of the sewage disposal system. However, the potential does exist for problems with the tile field if high effluent flows occur for a sustained length of time.

Calmere Holdings Limited (PE 2100)

At the present time Calmere Holdings operates a 165 unit campground on the east side of Lake Windermere. The sewage effluent from the campground is discharged to two aerated lagoons. These lagoons are lined and there is no discharge to ground. The sewage effluent evaporates or is trucked to the Regional District of East Kootenay septic disposal site (PR 1475).

Originally Calmere Holdings had proposed a 40 unit motel and a 140 seat restaurant in addition to the campground. Sewage effluent from these facilities was to discharge to the aeration ponds and then into a lined 2.14 hectare evaporation basin. Final effluent disposal was to be via evaporation.

If Calmere proceeds with the proposed motel and restaurant, construction of the evaporation basin may be necessary. The Waste Management Branch in Cranbrook is concerned about odor, insects and possible health risks if the evaporation pond is constructed.

Land Logistics Western Limited (PE 5173)

Land Logistics Western Limited's permit authorizes the discharge of 162 m^3/day of typical septic tank effluent to ground via tile fields. To date there have been serious administrative problems with Land Logistics but the effluent treatment system has functioned properly with the exception of a minor odor problem at the sewage effluent pumping station.

It should also be noted that the treatment system has not experienced peak sewage flows.

2.4.2b Phosphorus Adsorption Potential

The rating of soils for their potential to transmit phosphorus from septic tank drainfields to the lake were based on soil characteristics, existing on-site waste disposal facilities, and distance to the lake. The evaluation of the soils for phosphorus adsorption is reviewed more specifically in Appendix 1 of this report.

Generally the soils surrounding Windermere and Columbia Lakes are excellent or good in their ability to adsorb phosphorus. This is due primarily to the calcareous nature and fine textures of the soils and surficial materials. Minor areas of low potential are associated with coarse textured fluvial materials.

2.4.2c Landscape Suitability for Septic Tank Adsorption Field Use on Areas Adjacent to Windermere Lake

In addition to the ability of the soil to adsorb phosphorus, many other terrain and soil factors are critical to the successful use of land for septic tank adsorption fields. When factors such as drainage, depth to bedrock or watertable, texture, slope, flooding hazards or geological hazards pose limitations to use they generally override the phosphorus adsorption capability of the soil.

The results of Sections 2.4.2c and 2.4.2d were presented to the Regional District on April 5. 1984. Following this presentation, a committee of Regional District personnel and representatives of the Ministries of Environment, Health, and Municipal Affairs was convened. The terms of reference were to investigate, on a site specific basis, soils that were identified to have poor characteristics for the renovation of septic tank effluent.

A map folio of landscape resources related to settlement suitability was prepared for the Windermere-Invermere area in 1978 by the Surveys and Resource Mapping Branch, Ministry of Environment (Howell-Jones et al., 1978). Factors such as soils, terrain, vegetation, aquatics, wildlife, recreation, visual analysis and agriculture were evaluated. The map and legend of landscape units adjacent to Windermere Lake (Figure 5 and Table 5) incorporates soils and terrain settlement suitability information from the above mentioned folio, and the phosphorus adsorption potential as outlined in Appendix 1 of this report.

As Figure 5 indicates, most areas adjacent to Windermere Lake are unsuitable for septic tank adsorption field use, although the overall settlement suitability rating is moderate for many of the same areas. The major and most common landscape limitations include soil perviousness, drainage, existing erosion processes, steep slopes, high watertable levels and groundwater contamination potential.

The fine textured lacustrine materials are slowly pervious and pose moderate constraints to use. Erosion hazards such as gullying, piping[1] or failing slopes associated with these materials pose severe limitations and preclude most development uses. In some areas (units 1, 2 and 11 on Figure 5) the lacustrine materials are overlain by sandy silty aeolian deposits. These areas are susceptible to seepage from septic tank discharges at the aeolian-lacustrine interface which may cause surface contamination problems. Units 1 and 11 are not currently experiencing erosion problems but may do so in the future should high density housing development occur, particularly if septic tank adsorption fields are used. Such development significantly increases the water regime of the materials through on-site wastewater disposal, storm run-off from buildings and roads, and lawn and garden watering.

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[1] Piping is a geological process whereby the landscape surface is modified by small hollows and channels which are commonly aligned along routes of subsurface drainage and results from the subsurface removal of particulate matter.

Units 3, 4, 6, 10, 16 and 17 (Figure 5) exhibit current flooding or geological erosion hazards and are unsuitable for most settlement uses. Development of land adjacent to steep slopes and to escarpments with failing slopes and gullies, requires an adequate setback allowance.

The coarse textured fluvial and fluvioglacial materials (Units 5, 7, 8, 9, 12, 13: Figure 5) are rapidly pervious and may be subject to groundwater contamination in the event of septic tank use.

Although settlement suitability is considered moderate for most of the areas evaluated in this study, the use of traditional septic tile fields for disposal of domestic wastewater is not expected to be successful. Alternate disposal methods will probably be required to protect the lakes water quality in the event of development. On the lacustrine terraces control of storm runoff from roads and buildings should also be considered. Lawn and garden locations adjacent to lacustrine escarpments should also be avoided as subsequent watering and irrigation could cause instability problems.

Existing septic tank tile field facilities around Windermere Lake, would appear to be located in areas rated as unsuitable for such use according to Figure 5. A program to inspect and assess these and all other existing septic tank tile fields immediately around the lake, would be adviseable. In addition to the inspection, a simultaneous scan of the lake shore between Windermere and Invermere with a fluorometer, designed to detect septic plumes, would be useful. The results of this study would assist in judging the present operation of septic tanks. The methodology for septic effluent detection has been used successfully in British Columbia, and is described by Suttie and Wiens (1981).

Interpretations related to settlement suitability uses are not available for Columbia Lake. Soils and terrain information is available for this area at a scale of 1:50 000 from the Surveys and Resource Mapping Branch, Ministry of Environment.

Generally much of the land adjacent to the lakeshore consists of fine textured lacustrine terraces on which active erosion is present in the form of gullies and piping. These areas present major limitations to high density development. Some areas of medium textured morainal and fluvial deposits exist further backshore that are better suited to settlement development. Soil and terrain interpretations for settlement suitability may be prepared at a future date upon request.

2.4.2d Proposed Development Areas

Seventeen areas of development have been proposed for various lands around Windermere Lake. Figure 6 shows the location of these areas. Table 6 lists the areas and describes the type of proposed development as well as the suitability of the land making up each proposal area for both septic tank tile field use and overall settlement development. The landscape map areas and suitability rating are taken from Figure 5. The specific characteristics and limitations of the land in the proposed development areas are described in Figure 5 and in the text following.

The landscape information presented in Figure 5 is based on a mapping scale of 1:20 000. These map units may contain areas of contrasting materials with different suitability ratings that are too small to be depicted on the map. Detailed site specific soil and terrain investigations are essential prior to development to determine more precisely the nature of the landscape limitations on the specific areas proposed for development.

As indicated in Table 5 most of the proposed areas are rated moderate for overall settlement suitability, and low for septic tank adsorption field use. In addition to the landscape limitations to septic tank use, portions of the proposed development areas numbered 2, 4, 9, 10, 13 and 14 (Figure 6) are adjacent to the lake or inflow creeks. Water quality problems may be expected in these areas from septic tank discharge.

The analysis of the soils information and the settlement plan in Figure 6 and Table 5 were not included to support or refute the need for a sewer system. The information was summarized to identify areas where water quality problems may develop following watershed development. In summary, the two main problems are with poor phosphorus adsorption characteristics of soils (the coarse textured gravels near Windermere), and soil instability problems in the lacustrine soils (slow adsorption of water causes soils to become saturated).

Septic tanks can cause the lacustrine soils to become saturated and unstable. The result is a failure of the septic tile field, and potential water quality problems in the adjacent lake or stream. Increased development with septic tanks may cause soil saturation and instability around existing septic tile fields, and result in contamination of ambient water quality.

Septic tile fields are not the only cause of soil saturation instability problems. High density development using sewers may create sufficient storm water runoff from homes and roads, or use sufficient irrigation water to saturate the soils causing instability. Should high density development on the lacustrine soils proceed, control of storm runoff and irrigation water is essential.

A detailed assessment of the soil suitability in the proposed areas of development outlined by the Short Term Plan of the Regional District of East Kootenay is considered by Coulton et al., (in prep.)

2.5 WATER QUALITY

The water quality monitoring stations used in this report are shown in Figure 7 for Windermere Lake and Figure 8 for Columbia Lake. All lake data are summarized in Tables 8 and 9.

2.5.1 INFLOW STREAMS

The water quality of a lake is largely determined by quality of the inflow streams. There are no data available for the inflow streams within the Columbia Lake watershed. However, sparse residential and industrial development within the watershed will not have caused water quality degradation. As a result, the water quality of the inflow streams, and the concomitant water quality of Columbia Lake are at or near natural levels.

Limited data are available on the streams around Windermere Lake. Windermere Creek and the Columbia River are the largest inflows. Their water uses, waste discharges and water quality are considered separately in Sections 3 and 5. A brief summary of their influence on Windermere Lake is presented below. Included in this section is a summary of the water quality data collected from several smaller inflow creeks.

2.5.1a Columbia River

The Columbia River enters Windermere Lake at the south end. It is the largest inflow to the lake contributing the majority of the total annual lake inflow. The water quality of the Columbia River between Columbia and Windermere Lakes is summarized in Section 3. Other than turbidity, there is little difference between the water quality of the river and Windermere Lake. The influence of the Columbia River's turbidity on Windermere Lake is discussed in Section 2.5.4.

The influence of the Kootenay River diversion on the water quality of the Columbia and Windermere Lakes would be much greater, if the diversion takes place. Temperature, turbidity and phosphorus loading would be the major concerns. The impacts of the diversion on the water quality of Columbia and Windermere Lakes is discussed in Sections 2.5.2, 2.5.4 and 2.5.5.

2.5.1b Windermere Creek

The water quality of Windermere Creek is summarized in Section 5. This section addresses the nutrient input from the creek to Windermere Lake.

Three samples have been collected at station 0200410 (Figure 7) on Windermere Creek in June, August, and September 1982. The average results were ammonia nitrogen: <0.005 mg/L; nitrate nitrogen: 0.14 mg/L; organic nitrogen: 0.16 mg/L; dissolved phosphorus: 0.005 mg/L; and total phosphorus: 0.009 mg/L. These results suggest that the nutrient loads from the septic tanks, permitted discharges (Section 5), and agriculture within the Windermere Creek watershed were not influencing the water quality of the creek. The nutrient loading from Windermere Creek to the lake is probably minimal because of the low nutrient content of the creek.

2.5.1c Other Inflow Creeks

Very little water quality information is available for the other small creeks (Figure 7) which drain into Windermere Lake. To evaluate their contribution to the lake, the Waste Management Branch sampled a number of these creeks in 1982 and 1983. The results (Table 7) show that in some creeks nitrogen and phosphorus concentrations were slightly higher than in the lake itself, but because of the very small flows, the effect on the lake would likely be slight. Intensive monitoring would be required to ascertain if significant nutrient loadings enter the lake with peak flows or storm events.

The groundwater entering the lake on the east shore of Windermere Lake was sampled once with a groundwater sampler. The sampler (using the design by Lee (1977)), was in place for three weeks in September-October 1982, (Figure 7) and the seepage collected was analysed for nutrients. The only high value was ammonia nitrogen (0.918 µg/L). Some additional sampling of this type should be considered if groundwater is suspected of causing a significant nutrient input to the lake.

2.5.2 TEMPERATURE AND DISSOLVED OXYGEN

Throughout the summer and fall, Columbia and Windermere Lakes did not develop any thermal stratification. This is the result of the relatively clear water, shallow water depth, and prevailing winds along the long axis of the lakes.

The temperature regime in both lakes was very similar during the summer. The water temperature reached 18°C in July/August, then temperatures decreased and the lakes froze by December. Winter stratification occurred below the ice with surface temperatures between 1-2° C, and bottom temperatures between 4-6° C.

B.C. Hydro has been investigating the feasibility of diverting a portion of the Kootenay River to Columbia Lake at Canal Flats. Preliminary estimates, given in the Phase II Kootenay Report (Ministry of Environment, 1981b) indicate that water temperatures at the south end of Columbia Lake may be lowered by 6-8°C, but at the north end of Columbia and in Windermere Lake, the main body of the lake may be lowered by only 1-2°C. B.C. Hydro is conducting further research into the effects of the Kootenay Diversion on the water temperatures of the beaches. These reports however have not been released to the public.

Dissolved oxygen concentrations were high due to the lack of stratification of the lake. During the isothermal conditions in the summer, oxygen was near saturation at all depths. Under the winter ice, dissolved oxygen concentrations ranged between 10 and 15 mg/L. Good water clarity (enabling some photosynthesis to occur), and the low organic content of lake sediments (5-15%) are the reasons for the low winter oxygen depletion rates.

2.5.3 HARDNESS AND ALKALINITY

Water quality summaries for Windermere and Columbia Lakes are shown in Tables 8 and 9. The locations of the water quality sites are shown in

Figures 7 and 8. The data indicate that the lakes had good water clarity, low colour, low nutrients (Section 2.5.5), low suspended solids, but were alkaline (pH~8.5), with moderate dissolved materials (alkalinity ~100 mg/L, and hardness ~125 mg/L). The geology of the area appears to have the greatest effect on the dissolved residue concentration. The metamorphosed sedimentary rock surrounding the lake is the source of this dissolved material.

The water quality of the Kootenay River is quite similar to that of Columbia and Windermere Lakes (Ministry of Environment, 1976). Consequently, no major change would be expected in the hardness or alkalinity summarized in Tables 8 and 9, should the Kootenay River be diverted to the Columbia River.

2.5.4 TURBIDITY AND SUSPENDED SOLIDS

The sedimentary rock of the entire basin is easily weathered and eroded. As a result, the rivers and streams contain a high sediment load which causes high turbidity. The best documentation of the relationship between stream flow and turbidity in the Columbia area, is the unpublished data for the Kootenay River at Canal Flats (site 0200020) (Figure 8). The turbidity of the rivers and streams strongly influences the water clarity of the lakes.

The Columbia River is the main inflow to Windermere Lake. The suspended sediment load of the river (Table 16) affects the turbidity values at the south end of the lake particularly during freshet. Turbidity values decreased from an average of 1.4 N.T.U. at the south end of Windermere Lake (site 0200050), to 0.54 at the north end (site 0200052, Table 8). Sedimentation, rather than dilution, is the most likely reason for the decrease.

The freshet suspended residue concentrations in Windermere Lake ranged between 6 to 40 mg/L. The variation from year to year is the result of differences in the amount of watershed runoff, and is also due to the periods of maximum turbidity not coinciding with the sampling dates in some years.

The turbidity data at all sites were collected infrequently. Field turbidity values during freshet ranged from 4 to 10 NTU. The field measurements were poorly correlated with the suspended residue results. Laboratory turbidity measurements during freshet were less frequent and little interpretation is possible. However the generalization can be made that all stations on Windermere Lake during freshet will be greater than 2 or 3 NTU, with peak values approaching 10 NTU in high runoff years.

The data base for turbidity and suspended residues for Columbia Lake is limited (Table 9). Average turbidity values were 1.3 NTU at the south end of the lake, 1.1 NTU (mid lake), and 0.7 NTU at the north end.

The low values at the north end of Columbia Lake do not reflect the influence of Dutch Creek during freshet. As Dutch Creek is the largest water input to the lake, it will influence the lake's turbidity most. However the influence should be restricted to the north end as the river enters the lake within 1 km of the outflow.

Based on limited data the freshet turbidity and suspended residue concentrations are expected to range between 1 to 3 NTU and 4 to 6 mg/L respectively. Areas affected by the turbidity of Dutch Creek will have much higher turbidity and suspended residue concentrations.

The Kootenay River Diversion Project would dramatically increase the suspended sediment load to Columbia Lake, and to a lesser extent Windermere Lake. The Ministry of Environment (1976) noted that B.C. Hydro, and their consultants are assessing the impact of the diverson on turbidity and suspended residues. The engineering and water quality impact assessment reports have not been published, consequently no interpretation or summary of the impact of the possible diversion is available at this time.

2.5.5 NUTRIENTS AND PHYTOPLANKTON

2.5.5a Nutrient Concentrations

The nutrient concentrations in Columbia and Windermere Lakes were briefly noted in the previous section and are summarized in Tables 8 and 9. Nutrients are important for lake productivity and will be affected by watershed development, and the possible Kootenay Diversion. Increases in nutrients would be manifested as increased algal growth, and could cause problems with water use (recreation, fisheries, drinking water supply).

Twelve samples from Columbia Lake indicate total phosphorus concentrations of approximately 4 to 9 µg/L and ortho-phosphorus less than 3 µg/L. Spring overturn total phosphorus in 1973 was estimated to be 6 µg/L. Nitrate nitrogen for the spring sample was less than 20 µg/L, ammonia nitrogen was 12 µg/L and organic nitrogen was 130 µg/L.

For Windermere Lake, total phosphorus was 7.3 µg/L (annual mean, all stations). Samples taken in April 1983 (spring overturn), showed total phosphorus to be 9.8 µg/L, and total dissolved phosphorus to be 5 µg/L, which appears to be higher than in previous years. This increase would be highly significant if it was part of a long term trend. It may, however, reflect annual variability. Several more years of spring overturn data will be required to assess any significant long term trends.

Nitrate nitrogen was always less than 20 µg/L, and ammonia nitrogen concentrations ranged from <5 to 8.3 µg/L. The organic nitrogen concentration was about 140 µg/L.

For evaluating the limiting effects of nutrients, the nitrogen to phosphorus weight ratio in the lake water is often used. The annual mean total N to total P ratio for Columbia Lake was 22:1, and for Windermere Lake was about 21:1. In both these cases, the ratios indicate that phosphorus would be the nutrient most likely to be limiting algal and non-rooted vascular plant growth.

2.5.5b Phosphorus Loading

Since phosphorus appears to be the primary factor controlling lake productivity, some estimates of present loading are necessary to judge the future effects of changes such as increased watershed development or the Kootenay diversion.

A model for estimating loading was described by Reckhow and Simpson (1980) and relates phosphorus loading to phosphorus concentration and water residence time as shown below.

ESTIMATION OF TOTAL PHOSPHORUS LOADING TO WINDERMERE AND COLUMBIA LAKES IN 1983

$$P = \frac{L}{11.6 + 1.2q_s} \quad \text{or}$$

$$L = P \times (11.6 + 1.2q_s)$$

L = phosphorus loading rate ($g/m^2/yr$)
P = spring overturn total phosphorus concentration (mg/L)
(0.006 mg/L for Columbia and 0.010 mg/L for Windermere)
q_s = areal water loading rate (Z/WRT)
(2.8 m/yr for Columbia, 29.2 m/yr for Windermere)
Z = mean depth
(2.9 m for Columbia, 3.6 m for Windermere)
WRT = water residence time
(1.02 yr for Columbia, 0.12 yr for Windermere)

By this method, approximate phosphorus loading rates for the two lakes are given below:

SUMMARY OF PHOSPHORUS LOADING TO WINDERMERE AND COLUMBIA LAKES

	Loading Rate ($g/m^2/yr$)	Loading(kg/yr)
Columbia Lake	0.09	2310
Windermere Lake	0.47	8540

Phosphorus loading rate is important in lake assessment studies as it provides the best measure of the lake's trophic state and annual phosphorus input.

The trophic state of each lake was estimated by its position on a curve developed by Vollenweider (1976). The results for Windermere and Columbia Lakes are graphed in Figure 9. The present (pre-diversion) trophic state of Columbia Lake is well within the oligotrophic zone. Windermere Lake is on the borderline between the oligotrophic and meso-trophic zones.

The impact of septic tank discharges, and the resulting input of phosphorus to each lake was discussed in Section 2.4.2 Based on the 1975 cultural information shown on 1:50 000 NTS topographic maps, 370 homes around Windermere Lake and 88 homes around Columbia Lake contributed 128 kg and 23 kg of total phosphorus to each lake annually. Based on the total phosphorus loading calculated above, the phosphorus input from septic tanks represents 1.5 and 1 percent of the loading to Windermere and Columbia Lakes, respectively.

2.5.5c Phytoplankton

There have been minimal phytoplankton data collected in Windermere Lake. Samples taken in August and September 1982 showed low biomass (all less than 600 cells/mL) and a diverse range of species. In August, the dominant species were two coccoid blue-greens (*Gomphosphaeria* and *Chroococcus*). In September, the most numerous taxa were *Gomphosphaeria*, *Dinobryon* (a chrysophyte), *Achnanthes* and *Meridion* (diatoms). Hawthorn (1973) noted no phytoplankton blooms on Windermere during the field visits in 1971-1972. The low phytoplankton standing crop reflects the low nutrient concentrations, and the general oligotrophic state of the lake.

The spring phytoplankton community collected by the Waste Management Branch in Cranbrook on April 6, 1983, was dominated by the diatoms *Synedra acus* and *Cyclotella glomerata*. This community is typical of oligotrophic lakes during the spring months (Wetzel, 1975).

Surface chlorophyll *a* (a measure of phytoplankton standing crop) was measured on June 3 and August 3, 1976 at three stations in Windermere Lake. Concentrations in June averaged 2.2 µg/L, and decreased to 0.9 µg/L in August. Extensive chlorophyll *a* sampling was completed in June, July, August and September 1982 at stations 0200051 and 0200052. These stations had mean summer chlorophyll *a* concentrations of 1.3 and 1.4 µg/L respectively. Based on the trophic state index for British Columbia lakes, these two stations clearly show Windermere Lake's oligotrophic state. Nordin and McKean (1984) developed a relationship between phosphorus and mean summer chlorophyll *a*. Normally the model uses spring overturn phosphorus to predict chlorophyll *a* content, but because Windermere Lake is shallow and well flushed the mean summer phosphorus concentration (7 µg/L) was used.

The model developed by Nordin and McKean (1984) predicts a mean summer chlorophyll a concentration of 1.5 µg/L (Figure 10). Windermere Lake has slightly less chlorophyll than predicted by the model (probably a function of the high flushing rate).

However, the relation between phosphorus and chlorophyll will be useful when predicting the effects of watershed development or the Kootenay Diversion (or other projects that will increase the supply of phosphorus to the lake) on the trophic state of the lake, and the mean summer algal biomass.

2.5.5d Effects of Future Watershed Development on Nutrient Levels

Population estimates were prepared for Windermere Lake by two methods. In the first method, 367 homes were counted from the 1:50 000 NTS topographic maps (1975 cultural information) for the phosphorus loading estimates prepared by Wiens (Appendix 1). In the second method, Brown (1983) estimated the population for 1976, 1981, 1986 and 1991 between Windermere and Athalmer for high, moderate and low growth scenario's (Appendix 2). Using the high growth scenarios, Brown (1983) estimates there were 275 dwellings (820 residents) and 415 non-resident households (1204 non-residents) in 1976. Note that a non-resident household does not refer to a dwelling. Non-resident households staying in the area for summer recreation, fall hunting, or winter skiing are thought to constitute the non-resident component of the estimates by Brown (1983).

It is important to estimate the number of non-resident dwellings, as the model developed by Wiens (1983) calculated phosphorus loadings based on the number of dwellings occupied on a year round basis. Some assumptions must be made about the length of stay by the non-residents, and the number of people in each non-resident household. In this report the average non-resident household is assumed to comprise 3 people and stay in the area for (1.5 months/yr). Using the high growth estimates by Brown (1983), the population around Windermere Lake is expected to increase to 365 permanent dwellings (1091 residents), and 333.3 non-resident households (9665 people) by 1991 (Appendix 2). Assuming each household stays 1.5 months (on average) per year, the non-resident households will require approximately 400 dwellings in 1991.

The Vollenweider (1976) model can also be used to predict the maximum volume of phosphorus that can be added to the lake. The present loading rate for Windermere Lake is 0.47 $g/m^2/yr$. This loading rate can be safely raised to 0.55 $g/m^2/yr$ without compromising the trophic state of the lake. This loading rate translates into an additional 1 500 kg of phosphorus per year. Should watershed development and recreational opportunities proceed around the Windermere area, the phosphorus loading should not exceed 750 kg from watershed development, and 750 kg from water based recreation.

The estimated phosphorus loading from septic tanks in 1991 will be the equivalent of 975 houses, (575 resident houses and 400 non-resident dwellings: assuming year round occupancy). The 975 houses is a 2.7 fold increase in housing units from 1975. Consequently, the phosphorus loading from septic tanks to the lake is expected to increase 2.7 times from the 1975 estimate calculated by Wiens (1983). The 1975 phosphorus loading rate was estimated at 1.5 percent of the annual phosphorus input to the lake. Assuming the high growth scenario outlined above, the phosphorus loading is expected to increase to 4.0 percent of the total phosphorus input by 1991.

The Wiens (1983) model assumes development will not proceed in areas where soil instability problems will occur. Using this assumption, the increased phosphorus loading from septic tanks by 1991 will be low. If development proceeds in areas where soil instability will occur, then failing septic tanks may have a serious effect on water quality.

2.5.5e Effects of the Kootenay Diversion on Nutrient Levels

The major effect of the Kootenay Diversion would be on phosphorus levels, and consequently on the biological production of the lakes. The impact can be estimated assuming that the diversion flow would be 1 850 000 dam^3. Using the mean total phosphorus concentration in the Kootenay River at Canal Flats (24 µg/L), the diversion would add an additional 44 000 kg/yr of total phosphorus to Columbia Lake. The Kootenay River at Canal Flats has a relatively heavy suspended sediment load (annual mean of 32 mg/L), containing particulate phosphorus and thus causing the total phosphorus load to be relatively high. With decreased water velocity in the lake, a significant portion of the suspended sediments and particulate phosphorus would settle from the water column. The total phosphorus input would cause the average lake concentration to rise from 6 to 18 µg/L . However, with the loss of the heavier particulate material, a more realistic post-diversion phosphorus concentration for Columbia Lake would be 9 to 10 µg/L. This estimate is based on an inflow concentration of 10-12 µg/L of biologically available dissolved phosphorus from the Kootenay River. This is a more realistic value than the high value of 24 µg/L, which includes many values (up to 670 µg/L) which reflect only the high suspended sediment load, and not the biologically available phosphorus. Columbia Lake would retain much of the Kootenay River phosphorus, through sedimentation, and only a small portion would be passed on to Windermere Lake. Using the Columbia Lake phosphorus concentrations following the diversion as input to Windermere Lake, the Windermere Lake concentrations would rise from the present 8-10 µg/L to 10-11 µg/L. The present and post diversion loadings, and their effects on trophic state are shown in Figure 9. Windermere Lake would remain on the borderline between oligotrophic and mesotrophic state, while Columbia Lake would move from oligotrophic to mesotrophic state (Figure 9).

Chlorophyll a and Secchi disc values in Table 10, were estimated using the formulae (below) developed for British Columbia lakes by Nordin and McKean (1984):

$$\log_{10} \text{Secchi(m)} = 0.8996 - 0.5521 \log_{10} \text{Chla}(\mu g/L)$$
$$\log_{10} \text{Chla}(\mu g/L) = -0.6231 + 0.9873 \log_{10} {}^{*}P(\mu g/L)$$

These formulae assume that phosphorus is the factor limiting algal growth, and that turbidity from inorganic suspended residue (solids) would have a negligible effect on water clarity. Consequently, little or no change in algal growth and water clarity (due to algal growth) would be expected in Columbia and Windermere Lakes due to the Kootenay Diversion.

No problems from taste and odour-causing algae or filter-clogging algae have been reported. Following a possible Kootenay Diversion the phosphorus concentrations could be expected to rise in Columbia and Windermere lakes to 9 and 11 µg/L, respectively. Figure 10 shows that the lakes (using the Vollenweider (1976) model) would not become eutrophic. A shift in the phytoplankton community, or an increase in chlorophyll a content would be unlikely.

2.5.6 SEDIMENTS

Very few data have been collected on lake sediment chemistry. Hawthorn (1973) collected sixty sediment samples from Windermere Lake and analysed them for percent organic carbon content. The results show a very low organic carbon content of 5-10 percent.

High sediment nutrient concentrations can be the cause of increased aquatic plant growth. Aquatic plant growth can also be affected by site suitability and light availability. It appears from the well established aquatic plant populations that both lakes are very suitable for the growth of aquatic plants.

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*Spring overturn total phosphorus concentration

2.5.7 AQUATIC MACROPHYTES

The distribution and density of aquatic plants was documented by Hawthorn (1973). A survey of residents regarding the nuisance areas of aquatic plants is also included in the report.

What becomes clear from the data is that aquatic plants have reached nuisance levels in Windermere and Columbia Lakes. Hawthorn (1973) notes that the nuisance populations were located in areas of silt deposits. Sandy and rocky areas did not have plant populations. Hawthorn's findings indicate that the plants were responding to substrate type rather than sediment nutrient concentrations. Freedman and Canale (1977) found similar results in White Lake, a eutrophic lake in Michigan, U.S.A. They concluded that the plants were restricted by light and space requirements. No evidence of phosphorus or nitrogen limitation was observed in White Lake. McKean and Nordin (in prep.) also concluded that *Nuphar polysepalum* was not limited by nitrogen or phosphorus in Brannen Lake, B.C. Their study involved the comparison of *N. polysepalum* in an area with increased nitrogen and phosphorus loading (the result of agriculture or septic tanks) with an undeveloped area. No difference in tissue nutrient content was observed between the two populations of *N. polysepalum*.

The conclusions are that the rooted aquatic plants in both Windermere and Columbia Lakes are not influenced by nutrient input (natural or from septic tanks), and that their density and growth is mainly restricted by the availability of light and suitable substrate.

Only one non-rooted aquatic plant was observed in Windermere Lake (Hawthorn, 1973). *Ceratophyllum demersum* was observed in low numbers. Because *C. demersum* obtains all of its nutrients required for growth from the water column, the low nutrient concentrations in the lake were believed responsible for its restricted growth.

Warrington and McKean (unpublished data) note that *C. demersum* may reach nuisance levels if the nutrient concentrations in the water column exceed 15 µg/L. The post-diversion nutrient concentrations in Windermere and Columbia Lakes would not be expected to exceed this threshold. It must be pointed out that should the lake phosphorus concentrations exceed 15 µg/L, *C. demersum* may not reach nuisance levels. *C. demersum* appears to grow best in shallow lakes that have low wind mixing, but Columbia and Windermere Lakes are well mixed by wind.

In areas where the plant growth becomes a nuisance, physical methods of weed control (harvesting), rather than nutrient starvation (i.e. removal of septic tanks) will be the most successful technique.

Because of the suitable growing habitat for aquatic plants, Newroth (1984) assessed the potential adverse affects of *Myriophyllum spicatum* (Eurasian water milfoil). Windermere Lake has been the subject of intensive study because:

a) there is a high diversity of aquatic plant species and there are extensive littoral areas that will support submerged and emergent aquatic macrophytes,

b) several species (notably *Potamogeton natans* and *Myriophyllum exalbescens*) form luxuriant, large populations, and

c) the growth of these species and other less dominant submerged aquatic plants has been a nuisance for many years and restricts multiple water use,

d) there is growing development along shoreline areas of Lake Windermere, particularly by Albertans (facilitates inter-provincial transport of aquatic plants).

The Water Management Branch initiated aquatic plant studies in Windermere Lake in 1971, and staff has visited this lake several times, including surveys for Eurasian water milfoil in 1971-74, 1977-1983. This species has not been found in either Columbia or Windermere Lakes. There have been numerous requests for assistance and complaints each year from residents of Windermere Lake concerned about nuisance aquatic weeds.

If Eurasian water milfoil were introduced to Columbia Lake, it would be most likely to become established and spread downstream into Windermere Lake and the Columbia River system. At this time, only that portion of the Columbia River system in the United States is known to be infested with Eurasian water milfoil. Columbia Lake is not highly utilized for water-based recreation, and because of the relatively low volume of boaters that visit this lake, it is unlikely that introduction of Eurasian water milfoil would occur as long as nearby lakes remain uninfested.

The heavy recreational use of Windermere Lake includes boating and water skiing which involves trailered boats. Most boating traffic occurs across the Alberta-British Columbia boundary, so Eurasian water milfoil is unlikely to be introduced from Alberta as long as this species does not grow there. However, the Ministry of Environment boat inspections (part of the Quarantine Project, 1978-1981) gathered data confirming that small numbers of boaters travelling from Eurasian water milfoil infested lakes in the Okanagan Valley had the potential to transport viable fragments to Windermere Lake. Also, if Eurasian water milfoil did become established in Windermere Lake, this lake could become the source of fragments that might be transported to Alberta waters. This could be expected to be a major concern to Alberta Environment officials because some of the most vulnerable Alberta recreational and irrigation waters are relatively near to Windermere lake (Calgary-Lethbridge area).

Introduction, establishment and spread of Eurasian water milfoil in Windermere Lake would be expected to produce in the following adverse impacts:

1) interference with water-based recreation, probably to a greater degree than native vegetation because of the more rapid and luxuriant vernal growth of Eurasian water milfoil,

2) fragmentation of Eurasian water milfoil leading to rapid downstream spread and infestation of marshy areas, perhaps displacing other aquatic plants with greater wildfowl food value, and threatening to spread to non- infested water bodies in the Kootenay area and Alberta. Also, since this lake is a migratory bird stopover, waterfowl may spread seeds/fragments.

3) dense growth of Eurasian water milfoil along the shallow weir upstream from the lake outlet and downstream in the oxbows and meandering Columbia River channel, interfering with water discharges. Eurasian water milfoil growth in the Okanagan River channel has interfered with water flow measurement and regulation, caused minor flooding and now requires an annual maintenance program.

2.5.8 FECAL CONTAMINATION

Concern has been expressed about fecal contamination of Windermere Lake because the lake is used as a drinking water supply and for water contact recreation. Tables 11 and 12 summarize the coliform bacteria data collected at beaches by the Ministry of Health from 1973 to 1981, and by the Waste Management Branch of the Ministry of Environment in 1982. The sampling locations for both surveys are shown in Figure 11.

Sixty-nine fecal coliform measurements were made from 1973 to 1982, ranging from 0 to 130 MPN/100 mL with a geometric mean of 3.3. Thirty-eight of the measurements were below detectable limits (<2 or <3 MPN/100 mL). Nine of the values exceeded 10 MPN/100 mL.

The Ministry of Health fecal coliform guideline for primary contact recreation waters (a fecal coliform running log mean of 200 MPN/100 mL, calculated from at least five weekly samples taken during the recreation season, and not more than 10 percent of samples during any 30-day period exceeding 400 MPN/100 mL; Richards, 1983) was never exceeded. The Ministry of Health guideline for the treatment of raw drinking water supplies (Ministry of Health, 1982) indicates that only disinfection is required if the 90th percentile of the fecal coliform values in any 30-day period is less than 10 MPN/100 mL. Not enough data were collected to determine if this guideline was met, but the data suggest that it was probably met. Consequently, disinfection is probably the only treatment required for raw drinking water supplies.

The relatively low fecal coliform values found in Windermere Lake in recent years indicate that a detailed study to identify sources of fecal contamination is not required at this time. However, regular monitoring similar to that conducted in 1982 by the Waste Management Branch should be conducted to provide warning of an increase in fecal contamination. Water quality objectives for fecal coliforms are outlined in Sections 2.5.10.

The total coliform data were more extensive and variable. Fifty percent of the results listed in Table 11 were below the detectable limit of 2 or 3 MPN/100 mL. The positive results ranged from 2 to >2400 MPN/100 mL. The total coliform results had a mean of 46±223* MPN/100 mL (n=123). Approximately 10 percent of the samples had coliform results greater than 100 MPN/100 mL.

The Canadian Drinking Water Standard for total coliform bacteria is:

1) no sample should contain more than 10 total coliform organisms per 100 mL; and

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*Standard deviation

2) not more than 10 percent of the samples taken in a 30-day period should show the presence of coliform organisms; and

3) not more than two consecutive samples from the same site should show the presence of coliform organisms; and

4) none of the coliform organisms detected should be fecal coliforms.

The results indicate disinfection of the raw water is required to meet the Canadian Drinking Water Standards.

2.5.9 PESTICIDES

Two applications for the use of pesticides within the study area, were filed in 1981 and 1982 with the Pesticide Control Branch, of the Ministry of Environment in Victoria. Both applications were for the control of noxious weeds with the pesticide Tordon 22 K. The information for both applications is summarized in Table 13.

The active component of Tordon 22 K is picloram, a water soluble herbicide. The permits set a maximum application rate of 1.1 kg picloram/ha and did not allow spraying within 30 m of water bodies. Of the two applications in Table 13, the 1981 application by the Ministry of Transportation and Highways would have had the potential for the most impact on the water of the lakes.

There are no data at this time to assessd the impact of these (relatively small) pesticide applications within the watershed.

2.5.10 WATER QUALITY OBJECTIVES

Provisional water quality objectives are proposed to ensure that the present and future water uses of Columbia and Windermere Lakes are protected. The important uses of the lake water are:

- drinking water supply
- primary-contact recreation (ie. swimming)
- cold water fishery
- irrigation
- stockwatering
- wildlife

It is recommended that these be adopted as the designated water uses to be protected in Windermere and Columbia Lakes. The first three uses are the most sensitive as far as coliform bacteria, nutrients, turbidity and temperature are concerned. Consequently the proposed water quality objectives are designed to protect the lake as a source of domestic water, and ensure no decrease in water based recreation or the cold water fishery.

Provisional water quality objectives are proposed only for those parameters that are or may be affected by present and future waste discharges or developments. The objectives recommended for each parameter are designed to protect the most sensitive water use. Provisional objectives have been recommended for fecal contamination, algal growth, turbidity and water temperature. Additional objectives may be added in the future if developments threaten other aspects of water quality.

2.5.10a Fecal Coliform Bacteria

Two water quality objectives are proposed for fecal coliform bacteria. The first is designed to ensure that no water treatment in addition to disinfection is required for drinking water. The second is to ensure safe contact recreation on the major beaches in the lakes.

The water quality objective for fecal coliform bacteria near or in water intakes is: Not more than 10 percent of at least 5 samples, from each site, in any 30-day period should have a fecal coliform density greater than 10 MPN/100 mL (i.e. the 90th percentile should be $<$10 MPN/100 mL). The objective for domestic intakes is based on the Ministry of Health's, B.C. Drinking Water Quality Standards (Ministry of Health, 1982).

The objective for samples taken at public beaches during the summer months is: not more than 10 percent of at least 5 samples from each beach in any 30 day period should have a fecal coliform density greater than 400 MPN/100 mL, nor shall the running log mean for 30 days be greater than 200 MPN/100 mL. The objective for primary contact recreation was based on the recommendations of Richards (1983).

The monitoring strategy is to sample the major public beaches and the waterworks. Sampling is recommmended to eight sites on Windermere Lake, and two sites on Columbia Lake. The sampling should be completed in July or August. The sample locations and sampling frequency are outlined in Section 2.5.11a.

Should the water quality objectives for fecal coliform bacteria be exceeded, the source of contamination should be identified (if possible). This additional sampling should be under the direction of the Regional Health Inspector, Ministry of Health, and the Regional Waste Manager, Ministry of Environment.

2.5.10b Phosphorus and Algae

Nuisance algal growth is usually the result of excessive phosphorus in a lake. Algae can cause taste and odours in drinking water, aesthetic problems, poor water clarity, and hypolimnetic oxygen depletion which result in loss of fisheries habitat and possible winter or summer kill situations.

The most sensitive use for the lakes is the cold water fishery. Dillon and Rigler (1975) recommended a mean summer chlorophyll a concentration of 2 µg/L for lakes important for contact recreation and cold water fishery (trout). At this algal biomass level, no other water uses of the lakes will be compromised.

As mentioned earlier, the biomass of algae is controlled by the availability of phosphorus. To achieve a mean summer chlorophyll a concentration of 2 µg/L and maintain the lakes' present oligotrophic state under existing conditions, spring overturn phosphorus concentration must be approximately 8 and 10 µg/L for Columbia and Windermere Lakes respectively. Should the Kootenay diversion proceed, spring overturn phosphorus concentrations of 13 and 11 µg/L for Columbia and Windermere Lakes respectively should achieve the same level of chlorophyll a and trophic state.

Consequently, the water quality objectives for total phosphorus are a spring overturn concentration of 8 µg/L for Columbia Lake and 10 µg/L for Windermere Lake under present conditions, and 13 µg/L for Columbia Lake and 11 µg/L for Windermere Lake should the diversion proceed.

These objectives apply to the spring overturn mean of at least 3 samples collected at the surface, at mid-depth and above the bottom. The sampling locations are outlined inn Section 2.5.11d.

Should the phosphorus levels exceed the objectives, or algae become a problem, a limnological study should be initiated to identify the source of phosphorus, and water management programs should be designed to reduce the annual input of phosphorus.

2.5.10c Turbidity

Turbidity can be caused by algal growth, or suspended sediment resulting from erosion. Turbidity caused by algal growth will not be a problem unless the water quality objectives for phosphorus outlined above are exceeded. Inorganic residues from erosion or the Kootenay Diversion will be the major sources of turbidity in the lakes.

The water quality objective for turbidity is split into non-freshet and freshet periods. Because the timing of freshet is variable from year to year, the exact dates for the non-freshet turbidity objective can not be specified. Traditionally, freshet is defined as seasonal periods of snow melt causing high watershed runoff.

The non-freshet turbidity objective is based on the Ministry of Health (1982) objectives and standards for domestic water. The turbidity objective is an average level of less than 1 NTU, and a maximum level of 5 NTU. The objective is set to ensure the water quality is suitable for domestic water supply (the most sensitive use) with no water treatment in addition to disinfection (i.e. no removal of turbidity/suspended residues required). The average is calculated from at least 5 weekly samples taken in a period of 30 days. The maximum turbidity objective should apply to any grab sample (surface or bottom) collected anywhere in Columbia or Windermere Lake during non- freshet periods.

Because the freshet values are highly variable from year to year and frequently exceed the 5 NTU standard, no turbidity objective is proposed for domestic water use during freshet. Should the turbidity of the lake be caused by non-freshet events (anthropogenic causes suspected), it will be the obligation of the technician to sample adjacent streams, and the lake's major inflows. If the stream data show the turbidity was not above the 5 NTU maximum turbidity level and the stream flows were not elevated, then the streams are not considered to be in freshet and the water quality objective for turbidity will be in effect. Appropriate measures to identify and eliminate the non-freshet turbidity source should be initiated.

The turbidity objective can only apply to the pre-Kootenay diversion conditions. Should the diversion proceed, the turbidity objectives will need to be reassessed. Post diversion objectives are not proposed because the diverted flow regime, and the engineering studies have not been published by B.C. Hydro.

2.5.10d Water Temperature

Cool water (≤15°C) is desirable for drinking water (Ministry of Health, 1982), while warm water (25°C) is preferable for primary contact recreation.

The Kootenay Diversion is the only project proposed for the area that could change the natural water temperature in Columbia and Windermere Lakes. Thus an objective for temperature is not considered necessary at this time.

If the Kootenay Diversion proceeds, B.C. Hydro should obtain an adequate baseline of pre-diversion water temperatures to determine the range of summer monthly temperatures at various points in the lakes. The baseline data will serve as the basis for setting a water quality objective for temperature.

2.5.11 MONITORING RECOMMENDATIONS

2.5.11a Fecal Coliforms

The recommended fecal coliform monitoring locations for Windermere and Columbia Lakes are outlined in Table 14 and illustrated in Figures 12 and 13. Additional sampling is recommended at suspected sources of contamination, and the tap, if the objectives are exceeded (see Section 2.5.10a).

The monitoring program recommends the sampling of two major beaches on Windermere Lake (Athalmer, and Invermere Beaches), and 6 major waterworks intakes. These 6 intakes are also near 6 different beach areas on Windermere Lake (Table 14). The results from the waterworks intakes will also serve to assess the adjacent beaches for contact recreation. Although the sampling sites are not at each beach, they do serve as an indicator of potential problems on the adjacent beaches. Sampling of Columere beach and near the intake of Columere Waterworks is proposed for Columbia Lake.

The sampling frequency recommended is at least 5 times in July or August. Samples should be unconcentrated surface dip samples taken up to 3 m from the shore. The presence of people on the beaches should be noted during sampling.

Monitoring of the major water intakes can also be completed on the same day as the beaches are sampled. Only one sample either from the water intake (prior to chlorination) or a surface sample near the intake is adequate.

Collection of all bacteria samples on the same day will allow bulk shipment to the laboratory in Vancouver, while adequately monitoring the objectives for domestic water supply and primary contact recreation.

2.5.11b Temperature

Monitoring of water temperature will be required if the Kootenay Diversion project proceeds. The collection and interpretation of the summer temperature regimes would presumably be the responsibility of B.C. Hydro, as part of their environmental impact assessment.

2.5.11c Turbidity

The turbidity of Columbia and Windermere Lakes, during periods other than freshet, is within the Ministry of Health's (1982) objective for domestic water supplies (1 NTU). Freshet values, however, will exceed the 5 NTU maximum acceptable level for drinking water (Ministry of Health, 1982), and will vary dramatically from year to year, depending on the volume of watershed runoff.

The turbidity data at present do not serve as adequate baseline data for the Kootenay Diversion project. Should B.C. Hydro announce plans to start the Kootenay Diversion in the fall of 1984, 5 years of monitoring should be completed, monitoring should restart and continue through the construction and post-construction phases of the project. Monitoring should continue for an additional 5 years following the completion of the diversion. At that time the monitoring program should be re-evaluated.

The monitoring program recommends samples on Windermere and Columbia Lakes with the same sample locations and frequencies as the fecal monitoring program (beach samples plus surface samples near water intakes, Section 2.5.11a). Additional samples can be collected at the same time as the spring overturn nutrient concentrations are sampled on both Windermere and Columbia Lakes.

2.5.11d Phosphorus

Monitoring of nutrients must be conducted once a year at spring overturn of each year. Surface and above bottom samples should be collected at the following stations:

Station	Lake
0200050	Windermere Lake
0200051	Windermere Lake
0200052	Windermere Lake
1100645	Columbia Lake
1100643	Columbia Lake

The variables to be monitored are:

- ammonia nitrogen
- nitrate/nitrite nitrogen
- organic nitrogen
- total nitrogen
- ortho-phosphorus
- total dissolved phosphorus
- total phosphorus

2.5.11e Aquatic Plants

Because of the recreational importance of Columbia and Windermere Lakes, identification of an introduced population of *M. spicatum* would be advisable at an early date. An annual 2-day survey during July or August is recommended. Windermere Lake already has *M. exalbescens* and *M. verticillatum* so experienced personnel from the Water Management Branch in Victoria would be required.

2.5.11f Pesticides

Pesticide analysis of lake sediments near water intakes at the locations outlined in Table 14 during July or August is recommended. Surface sediment samples would be collected in a Eckman grab, and sent to the Environmental Laboratory for analysis of the water soluble herbicides 2,4-D, 2,4,5-T and picloram (Package N). Because herbicides are concentrated in lake sediments, their presence in the sediments will indicate whether they are or have been present in the water. The presence of herbicides in the lake sediments will indicate the need for additional sampling of lake water and possible herbicide sources.

2.5.11g Additional Monitoring

Data gaps have been described at various points throughout the report. The monitoring outlined in this section is not linked directly with the water quality objectives outlined in Section 2.5.10. Rather the proposed studies outlined below are designed to obtain more information about the processes occurring within the Upper Columbia River watershed.

i. Shoreline survey of Windermere Lake for septic contamination

Suttie and Wiens (1981) used a specially equipped fluorometer to detect septic plumes adjacent to septic tank tile fields. A similar survey of the west shore of Windermere Lake from Windermere to Athalmer, will be the best way to assess the present state of the existing septic tank tile fields.

ii. Groundwater monitoring near the two waste discharges (under permits PE 5173, PE 1527) on the west side of Windermere Lake.

Ideally ground water samples (designed by Lee, 1977) should be placed in areas where a possible septic plume has been detected. The recommended method of septic effluent detection is to use a specially equipped fluorometer, and to survey the shoreline in the developed areas. Suttie and Wiens (1981) have successfully used the equipment on several lakes in British Columbia.

The groundwater samples should be installed 0.3 - 0.5 m below the surface of the water, adjacent to where septic plumes have been detected. Samplers at two control sites where septic effluent was not a potential contaminant, should also be installed.

Samples should be collected every three weeks. The volume of the groundwater should be measured to give a flow, and then the sample analysed for the same nutrients outlined in Section 2.5.11d. Fecal coliform samples should also be collected.

iii. Section 2.5.7 noted that the effects of septic tank effluent on aquatic plants were not known. Limited data and literature were discussed in the section that indicated the growth of aquatic plants may be limited by light and substrate availability, not nutrients. Because Columbia and Windermere Lakes are very important for water based recreation, determination of the effects of septic tank discharges on aquatic plant populations may be desirable if septic tanks continue to be used around the lakes in the future.

The focus of the study should determine if the nitrogen and phosphorus from septic tile fields, filtering through the littoral zone of Windermere or Columbia Lakes will cause increased macrophyte growth. The monitoring program would include tissue, groundwater, and sediment sampling in areas influenced by septic effluent, and at several control sites.

Enhanced nutrient availability in areas influenced by septic effluent should be reflected in the tissue of the plants if nitrogen or phosphorus are limiting growth. If nutrients are not limiting aquatic plant growth (as suggested in Section 2.5.7) then no differences in their tissue content should be noted between the areas affected by septic effluent and the control areas.

The actual location of the sites should be determined following the results of the fluorometric studies outlined on the previous page. Three areas noted to have influence from septic tanks, and 3 control areas are recommended for the study. Six sites will be needed to observe differences within the sites, and differences between the sites.

The growing tips of *M. exalbescens* and *P. natans*, should be sampled at all sites every three weeks. Sediment and groundwater samples should be collected at the same frequency. Initially sediments should be analysed in each site on each sampling location. The metals package F should be used in the analysis of the surface sediments.

Groundwater samplers using the design of Lee (1977) should also be installed in the area. Water volumes would be collected and measured every three weeks and then analysed for the same nutrients as outlined by Section 2.5.11d.

SECTION 3

COLUMBIA RIVER BETWEEN COLUMBIA AND WINDERMERE LAKES

The Columbia River between Columbia and Windermere Lakes is the second priority sub-basin considered in this report (Figure 1). A detailed map of the sub-basin is shown in Figure 14. The river between the two lakes is the first riverine stretch of the Columbia River. It is 10 km long with a small shallow lake (Mud Lake) near Columbia Lake, and Tatley Slough downstream from Mud Lake. The sub-basin includes the Fairmont Creek watershed.

3.1 HYDROLOGY

Hydrologic records from 1945 to the present are available for the Columbia River from the stream flow gauge 08NA045, near Fairmont Hotsprings. The mean monthly discharge is summarized in Figure 15. The flow during freshet averages 36.5 m^3/s during June, and the average flow from December through April is 3.9 m^3/s. The monthly average low flows occurring once in 10 years have been calculated by Obedkoff (1983) at Radium Hot Springs. From these calculations, the 1 in 10 year monthly average low flow at Fairmont Hotsprings was estimated at 2.3 m^3/s.

The pre-diversion mean flow of the Columbia River near Fairmont Hot Springs is 11.6 m^3/s. The average flow of the Kootenay River water diverted (should the project be approved) would be 59 m^3/s. This is an increase of 500 percent of the mean stream flow. The impact on the Columbia River basin will be addressed by B.C. Hydro in an environmental impact assessment.

3.2 WATER USE

At present, there are no water licences on the Columbia River between the lakes. The river is typically slow moving with extensive marshy areas.

At present there are four water licences on Fairmont Creek (Table 15) The Fairmont Hot Springs Resort has two irrigation and two industrial licences. The industrial applications are lawn watering, golf course irrigation, and domestic use within the resort.

Licences C 41576, C 51577, and C 41163 all have a single point of withdrawal above the Hotsprings Resort. Licence C 40454 has a point of withdrawal above the other licences. Additional domestic water supplies for the Hotsprings Resort come from Galbraith Creek, a small creek south of Fairmont Creek.

A summary of the Fairmont Creek water quality, and the suitability of the water for industrial or irrigation uses is outlined in Section 3.4.

The wildlife found in the Columbia River and Fairmont Creek watersheds has been summarized by the Ministry of Environment (1982). The report notes that the area is important for water fowl (including trumpeter swans) and as an ungulate winter and summer range.

The most common recreational activities are hunting, canoeing, fishing and boating.* The weir near the outlet of Columbia Lake prevents boating traffic from travelling from Columbia Lake to Windermere Lake. Winter recreation includes downhill skiing near Fairmont Hotsprings. The river contains burbot, rainbow trout, Dolly Varden char, and mountain whitefish (Norris and Carswell, 1983). The extent of the fishery and the most important species are not known.

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* Information gathered from personnel of the Ministry of Lands, Parks and Housing, in Nelson and Cranbrook.

3.3 WASTE DISCHARGES

3.3.1 POLLUTION CONTROL PERMITS

There are no industrial discharges within the subbasin. Table 16 summarizes the permits issued by the Waste Management Branch. There are two sewage discharges, one municipal landfill, and the discharge from the hot-spring swimming pool at Fairmont Hotsprings Resort. The location of the waste discharges are shown in Figure 14. Previous reports (Ministry of Environment, 1976; and 1981b) have described the operations and their impact in detail (permits PE 1619, PE 2057, and PR 3484). This report will supply a quick summary of the previous reports' findings and incorporate new monitoring data (if they exist).

PE 1619

Effluent discharged under this permit has been diverted to the operation under PE 5467. The permit PE 1619 was for effluent discharged to ground on the east side of Columbia River in the Wycliffe soils. Section 2.4.2 considered these soils to be very suitable for the adsorption of phosphorus from septic tank effluent. The discharge was small, and the impact on the water quality of Fairmont Creek was expected to be minimal. Ministry of Environment (1981b), summarized the monitoring data, and the existing water quality data in Fairmont Creek from 1975-1978. It concluded that the impact of PE 1619 was minimal. No additional data have been collected since 1978 on any site in Fairmont Creek.

PE 2057

Ministry of Environment (1981b) described the impact of the hotsprings pool effluent (PE 2057) on the water quality of Fairmont Creek. Calcium, magnesium and specifically sulphate increased dramatically. Sulphate exceeded the criteria for taste (150 mg/L) and occasionally for health (500 mg/L) in drinking water (Health and Welfare, 1978). The change can be attributed to the natural minerals in the hotsprings discharge. The result is that Fairmont Creek below the hotsprings is not suitable for domestic water supplies, irrigation of sensitive crops, and some industrial purposes (Ministry of Environment 1981b). Six fecal coliform samples have been taken in the effluent since 1978, and all results were below detectable levels (<2 MPN/100 mL).

Ministry of Environment (1981b) noted toxic concentrations of residual chlorine from the discharge of PE 2057 may exist in Fairmont Creek during low flow. No data have been collected to provide confirmation of the report's hypothesis. Ministry of Environment (1981b) also noted the possibility of high arsenic concentrations in the hotsprings. Although recommended by Ministry of Environment (1981b), sampling for arsenic in the hotsprings and Fairmont Creek at low flow, has not been completed. Because of the steep gradient and lack of fisheries habitat, there are no fish immediately below the permitted discharge. Consequently, concern over toxic chlorine and arsenic concentrations is minimal.

The Ministry of Environment (1976 and 1981b) reports no significant impact of Fairmont Creek on the water quality of the Columbia River. The data presented in Table 16 agree with the previous findings.

PR 3484

The Ministry of Environment (1976) report outlines the operation of the municipal landfill described by PR 3484. The report concluded that the impact would be negligible because of the small volume of refuse deposited; the excess of evapotranspiration over precipitation; the considerable depth to the ground water table; the lack of surface runoff and flooding problems; and the great distance to surface waters and wells. No information is available to document the actual impact on the surrounding ground and surface water.

PE 5467

Sewage effluent discharged from the Fairmont Hotsprings Resort under PE 5467 is treated by aerated lagoons and then discharged into storage ponds. The storage ponds are used to store effluent during winter operation and allow a maximum of 60 days storage of effluent prior to irrigation.

The monitoring requirements of the permit are: 6 groundwater observation wells; inflow records; monthly total suspended solids levels (not to exceed 60 mg/L), and a standard 5-day biochemical oxygen demand test of the effluent (not to exceed 45 mg/L). The permit allows for 2760 m^3/d of discharge to the aeration lagoons in phase 1, expanding to 17 600 m^3/d in phase 2. Spray irrigation and/or exfiltration can proceed on an annual average of 3 500 m^3/d in phase 1, and 35 700 m^3/d in phase 2.

The Mericon Engineering Ltd (1979) annual report on PE 5467 noted that spray irrigation was initiated in May 1982, and 88 000 m^3 of effluent was disposed of in 1982. Two BOD values exceeded the permit level in April and June. High algal concentrations were the reasons given for the high levels. The average BOD for 1982 was within the 45 mg/L level allowable under the permit. All suspended solids results were within the 60 mg/L required by the permit.

The spray irrigation area is adjacent to the Columbia River (Figure 12). No monitoring of the nutrients or coliform bacteria was required under the permit. The water quality monitoring sites 0200049 and 0200125 on the Columbia River are upstream and downstream (respectively) from the confluence of Fairmont Creek (Figure 12). Both stations are within the zone of influence of the effluent. However, no water quality data have been collected on either site since the spray irrigation next to the Columbia River began in 1982. Consequently, no interpretation of the impact of the spray irrigation of effluent from PE 5467 is possible.

3.3.2 KOOTENAY DIVERSION

The background and description of the proposed Kootenay Diversion is described by the Ministry of Environment (1976). The report noted six possible impacts of the diversion on the area. Briefly the impacts are increased flooding, loss of land for other uses, destruction of habitats for aquatic and terrestrial wildlife, changes in water quality (turbidity), loss of fisheries habitat and spawning areas, and blockage of fish migration routes on the Kootenay River.

The extent of the impact can not be assessed until the engineering plans of the project are presented by B.C. Hydro and environmental impact studies are completed.

3.4 WATER QUALITY

Three water quality stations are located on the Columbia River between the lakes (Figure 14). The water quality data from 1973-1975 and 1975-1978 have been summarized by the Ministry of Environment (1976 amd 1981b). Table 16 summarizes all the data collected from 1973-1978. No new data have been collected since 1978.

Previous reports (Ministry of Environment, 1976 and 1981b) provide a good summary of the data presented in Table 16. These reports show that the Columbia River between Columbia and Windermere Lakes was found to be safe for fish and wildlife, and was a suitable source for domestic water (after disinfection) and irrigation water. During freshet turbidity values would exceed the Ministry of Health (1982) maximum acceptable level of 5 NTU for domestic water supplies.

Within this priority sub-basin only Fairmont Creek downstream from the discharge by the Fairmont Hotsprings would be considered unsuitable for domestic, industrial and irrigation purposes.

High concentrations of calcium, magnesium, sulphate, and the possibility of arsenic exceeding 50 µg/L during low flow, render Fairmont Creek downstream from the hotsprings unfit for domestic, irrigation or industrial use (Ministry of Environment 1976 and 1981b). The water licences in Fairmont Creek outlined in Section 3.2, have their point of withdrawal above the discharge points.

3.5 CONCLUSIONS

The only monitoring recommended for the Columbia River is for fecal coliform bacteria upstream and downstream from the spray irrigation operation on lots DL52 and DL290. The sampling locations should be left to the discretion of the regional office following an 'on site' inspection. Permanent sampling sites should be established, and monitored once per month during the periods of spray irrigation.

This water quality monitoring combined with the monitoring of the ground water wells (as required by the Permit) will assess the effectiveness of the spray irrigation system. No other water quality monitoring of the Columbia River is recommended, because of the lack of present and future water uses, and the generally good water quality.

The poor water quality in Fairmont Creek is caused by the natural discharge from the hotsprings. Consequently, no water quality objectives are proposed. Because of the poor water quality, the stream downstream from the hotsprings should be closed to domestic use. Applicants for water for irrigation or industrial use should be advised of poor water quality in the stream.

SECTION 4

COLUMBIA RIVER BETWEEN WINDERMERE LAKE AND TOBY CREEK

4.1 INTRODUCTION

The short stretch (2 km) of the Columbia River between the outlet of Windermere Lake and Toby Creek is the third priority sub-basin considered in this report. The sub-basin is outlined in Figure 14. Burnais Creek is the major inflow to the river, although the topographic maps (NTS 82 J12 and 82K 9) are unclear as to the exact point of entry to the Columbia River.

This stretch of the Columbia River meanders north through flat marshy areas, which is typical of the upper Columbia River.

4.2 HYDROLOGY

The gradient of this reach of the Columbia River is very low. Occasional flooding of Toby Creek when the lake level is low causes the river to reverse its flow.

The Athalmer area is very prone to flooding. A water level gauge is located on the Columbia River at Athalmer (08NA004). The winter low stage water levels are around 798.8 m above sea level. June water levels during freshet are as much as 1.7 m above the winter lows (Water Survey of Canada, 1982).

The partial diversion of the Kootenay River would have a large impact on the stream water levels near Athalmer. Because the engineering studies have not been published by B.C. Hydro, the impact on the Athalmer area has not been analyzed.

4.3 WATER USE

At present there are no water licences registered below the Athalmer Bridge (Figure 14). The water supply for the Athalmer area is from individual wells (Quin, pers. comm). An extension of the water supply from Invermere is presently being considered.

There is very little recreational (including fisheries) potential between Athalmer and Toby Creek. Recreational activities are centered around Athalmer beach. Future park and camping developments will be along the west shore of Windermere Lake (Section 2.3.5; Hanry, pers. comm.). There are no plans or proposals for park development between Athalmer Bridge and Toby Creek.

4.4 WASTE DISCHARGES

There are no pollution control permits within the sub-basin. The town of Invermere's sewage treatment plant is within the Toby Creek watershed. Nijman (in prep.) considers effects of the sewage treatment plant's effluent on the water quality of Toby and Columbia River in a separate report. Section 4.2 notes that the Columbia River can have reversed flow because of the flooding of Toby Creek. The discharge from the Invermere Sewage Treatment Facilities will influence the water quality of the river at Athalmer during periods of reversed flow. This impact on water quality has not been monitored, consequently, it is not known.

Septic tanks are the main form of sewage disposal, although there are some holding tanks and pits (Hamilton, pers. comm.). A serious problem will develop when the septic facilities become flooded during freshet. To alleviate this problem, an extension from the Invermere sewer system to the Athalmer area has been approved in principle by the Ministry of Municipal Affairs (Quin, pers. comm.).

4.5 WATER QUALTIY

4.5.1 GENERAL WATER QUALITY

Only one water quality site is located within the sub-basin (Figure 14). The Ministry of Environment (1976 and 1981) summarized the water quality data prior to April 1978. Since April 1978, six additional samples (mainly for nutrient analysis) have been collected (2 in 1978, and 4 in 1982). The water quality data from 1968 to 1982 are summarized in Table 17.

The results for alkalinity, hardness, specific conductance, calcium, magnesium, sulphate and dissolved solids, are typical of other sites in the Upper Columbia River. Waters used for domestic purposes are considered poor if the hardness is greater than 200 mg/L (Health and Welfare, 1978). The hardness of the Columbia River at Athalmer has been recorded as high as 225 mg/L, but the average is 165 mg/L.

The nutrient and turbidity results at station 020009 are strongly influenced by Windermere Lake. Total phosphorus concentrations do not fluctuate much throughout the year because of the low suspended sediment load (1-3 mg/L) in the river (even during freshet). Windermere Lake acts as a sediment trap causing the low sediment load and turbidity levels (3.4 NTU maximum, 1.3 NTU average; N=11). The average turbidity results are higher than the Ministry of Health (1982) objectives of 1 NTU, but well below the 5 NTU maximum acceptable level for domestic water supplies.

Metal concentrations were generally low, but periodically high concentrations of zinc, iron, lead and manganese would be recorded. The high concentration of manganese on March 3, 1970 was atypical, and thought to be an erroneous result. The above average results were however, within the recommended levels for domestic water supplies (Health and Welfare, 1978 and Ministry of Health, 1982). As there are no metal sources upstream from site 0200009, the metal concentrations are thought to represent natural background levels.

4.5.2 COLIFORM BACTERIA

There are three possible sources of fecal coliforms in the Athalmer Bridge area. They are Athalmer Beach, waterfowl, and mulfunctioniong septic facilities.

Fecal coliform results collected at the Athalmer Bridge (Table 11) were generally low. Of the 13 samples collected, 3 samples were below the detectable level (2 MPN/100 mL) while the remaining samples ranged between 2 and 13 MPN/100 mL. Seventy percent of the samples with detectable levels were below 10 MPN/10 mL. The geometric mean of fecal coliform bacteria was 4.1 MPN/100 mL. Based on these fecal coliform levels, the Ministry of Health (1982) recommends domestic water be disinfected prior to use.

4.5.3 WATER QUALITY OBJECTIVES

No water quality objectives were set for the Columbia River between Athalmer and Toby Creek because there are no significant uses of the water. The water quality objectives set for Athalmer Beach are discussed in Section 2.5.10.

4.6 CONCLUSIONS

Two sampling strategies are recommended to determine the extent of the fecal coliform contamination at the Athalmer Bridge. The first is monitoring for fecal coliform bacteria at Athalmer Beach during the summer recreation season. This sampling schedule is outlined in Section 2.5.11a. Secondly, a June survey of the river's shoreline, and the flooded areas in Athalmer using the fluorometric technique developed by

Suttie and Wiens (1981) is recommended. This survey would locate and evaluate the efficiency of the septic facilities in the Athalmer area during flood conditions.

SECTION 5

WINDERMERE CREEK

5.1 INTRODUCTION

Windermere Creek is one of the five priority sub-basins in the Upper Columbia Planning Unit of British Columbia selected for water quality assessment. All priority sub-basins within this planning unit are shown in Figure 1. A detailed map of the Windermere Creek sub-basin is outlined in Figure 17.

5.2 HYDROLOGY

Windermere Creek drains about 84 km^2 on the western slopes of the Stanford Range. It flows into Windermere Lake at the community of Windermere (Figure 17). Flows have ranged from 2.9 m^3/s during freshet to 0.3 m^3/s in winter (Water Survey of Canada, 1977).

5.3 WATER USE

Licenced water withdrawals are concentrated in two reaches of Windermere Creek (Figure 17). There are 35 irrigation (0.37 m^3/s total), 5 domestic, and 1 industrial licenses. There are camping, picnicking and hiking opportunities in the headwaters, with recreation being classified as of moderate significance by Ministry of Environment surveys (Ministry of Environment, 1981a and 1982). There are small populations of cutthroat and eastern brook trout in the creek. The number of angler days is estimated to be between 100 and 200/year (Martin, pers. comm.).

5.4 WASTE DISCHARGES

Westrock Industries Ltd. (formerly Western Gypsum Ltd.) produces the only discharge within the Windermere Creek watershed. The quarry has been described by the Ministry of Environment (1981b). Surface runoff from the quarry is controlled by two settling ponds before entering Windermere Creek. There are no pollution control permits regulating the volume and quality of the runoff from the quarry.

5.5 WATER QUALITY

Data collected from the four sites on Windermere Creek (Table 19, Figure 17) showed water quality to be as reported in the Phase II Kootenay Study (Ministry of Environment, 1981b) (site 0200410 is a new site). There were relatively high calcium and sulphate levels due to the large gypsum (calcium sulphate) deposit in the basin. Table 19 shows that the sulphate levels were high along the entire length of the creek. The quarry elevated the creek's sulphate concentrations by 50 percent (calcium was not measured). Past data (Ministry of Environment, 1981b) showed similar proportional increases in calcium, sulphate, and hardness downstream from the quarry.

Consequently, the limited monitoring that has been completed shows that the calcium sulphate mineral deposit elevates the sulphate, calcium and hardness concentrations by 50 percent in Windermere Creek. It can not be determined from the existing data if the increase in dissolved minerals in the creek was a consequence of the mining operation, or a natural phenomenon associated with the mineral deposit.

Along the entire length of the creek the sulphate levels exceeded the drinking water criterion for taste (150 mg/L), and approached the criterion for health (500 mg/L) (Health and Welfare, 1978) at all sites downstream from the quarry. Dissolved solids measured at the most downstream site (0200410) was in the 700 mg/L range, which exceeded the drinking water criterion (500 mg/L) (Ministry of Health, 1982), and irrigation criteria for some salt sensitive crops (500-5 000 mg/L) (E.P.A., 1976). Although no data on hardness have been collected since the Phase II Kootenay Study (Ministry of Environment, 1981b), that report showed Windermere Creek water to be poor

(>200 mg/L) to unacceptable (>500 mg/L) for domestic purposes (Ministry of Health, 1982). Despite the poor water quality, Windermere Creek is not considered a health risk to domestic water use.

5.6 CONCLUSIONS

Present and potential water users should be advised that sulphate, hardness and dissolved solids render Windermere Creek water unsuitable or undesirable for domestic purposes, some industrial purposes, and for irrigation of salt-sensitive crops.

Because the effects of the mineral deposit on water quality is well documented in this and previous reports, no monitoring is required or recommended.

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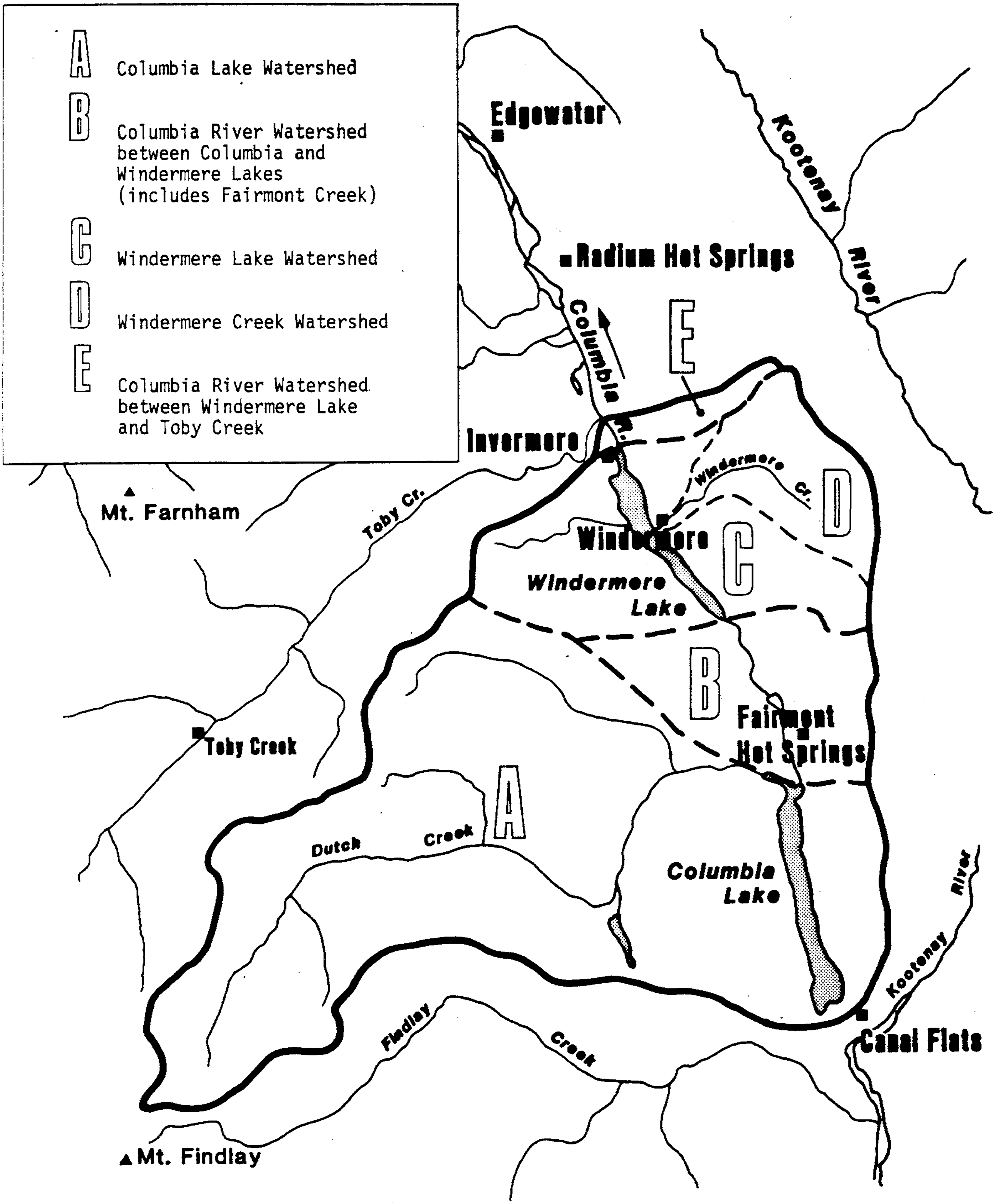

Figure 1: Upper Columbia River Sub-basins Discussed in Volume 1

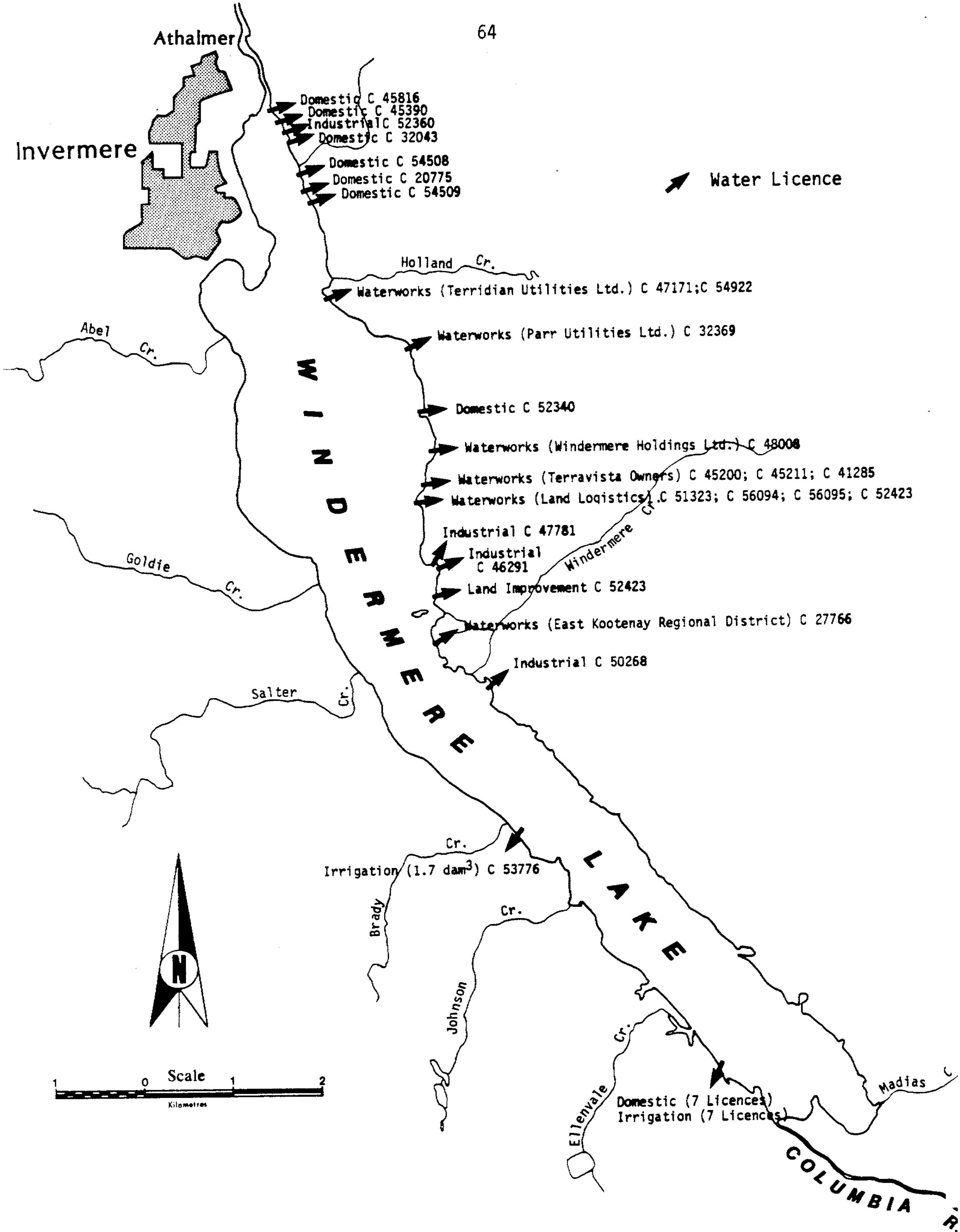

Figure 2: Location of Water Licences and Points of Diversion for Windermere Lake

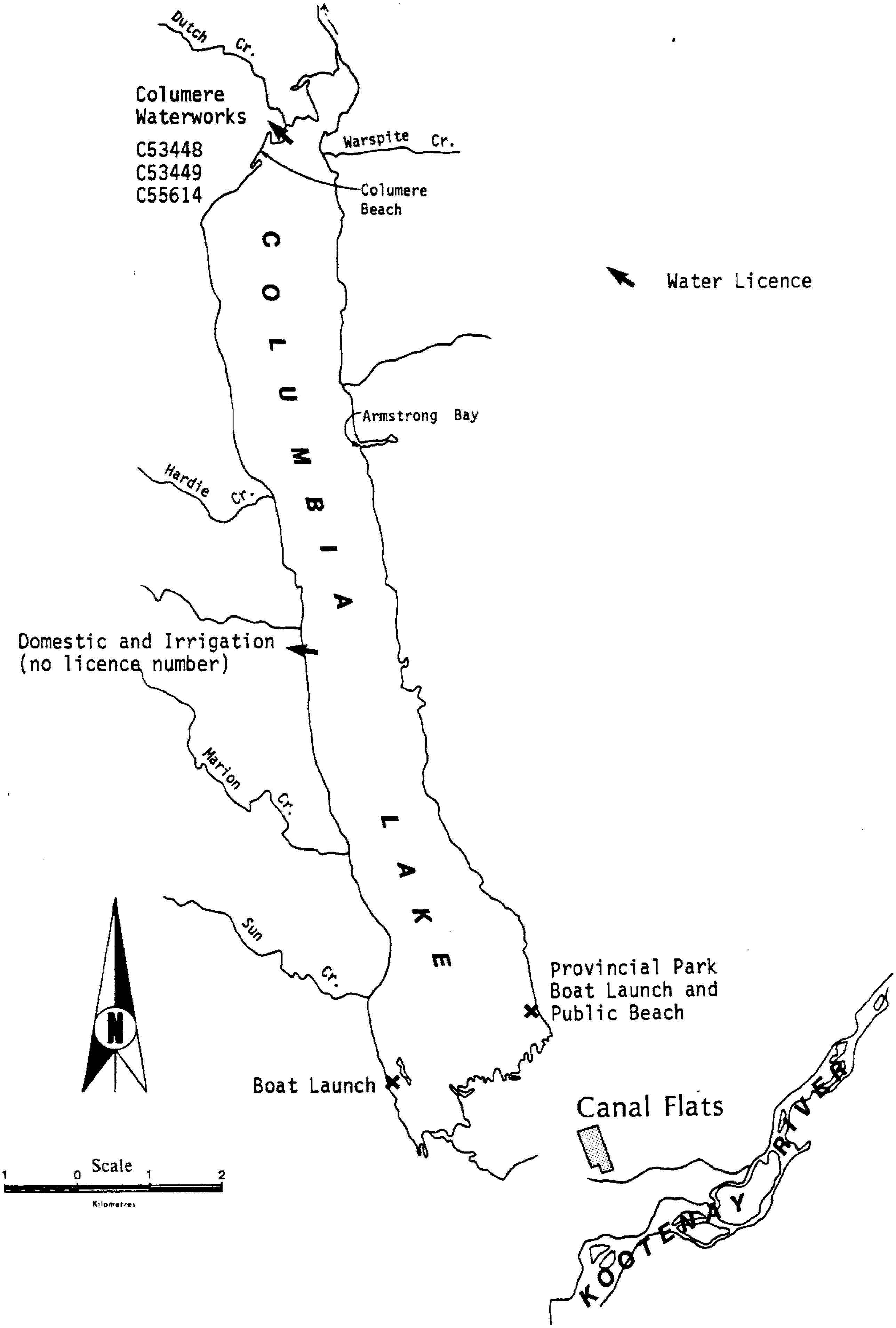

Figure 3: Location of Beach, Water Licences, and Point of Diversion for Columbia Lake

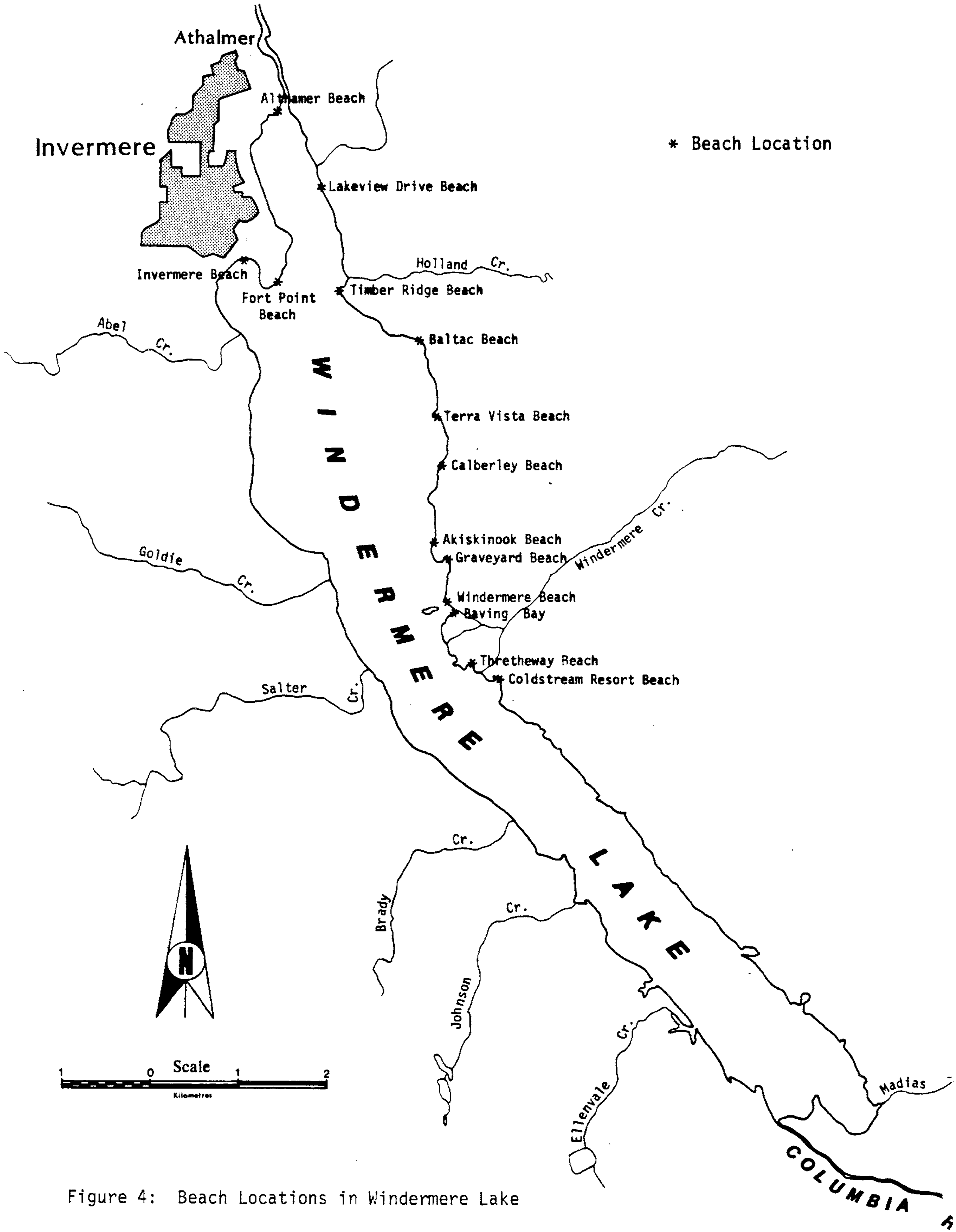

Figure 4: Beach Locations in Windermere Lake

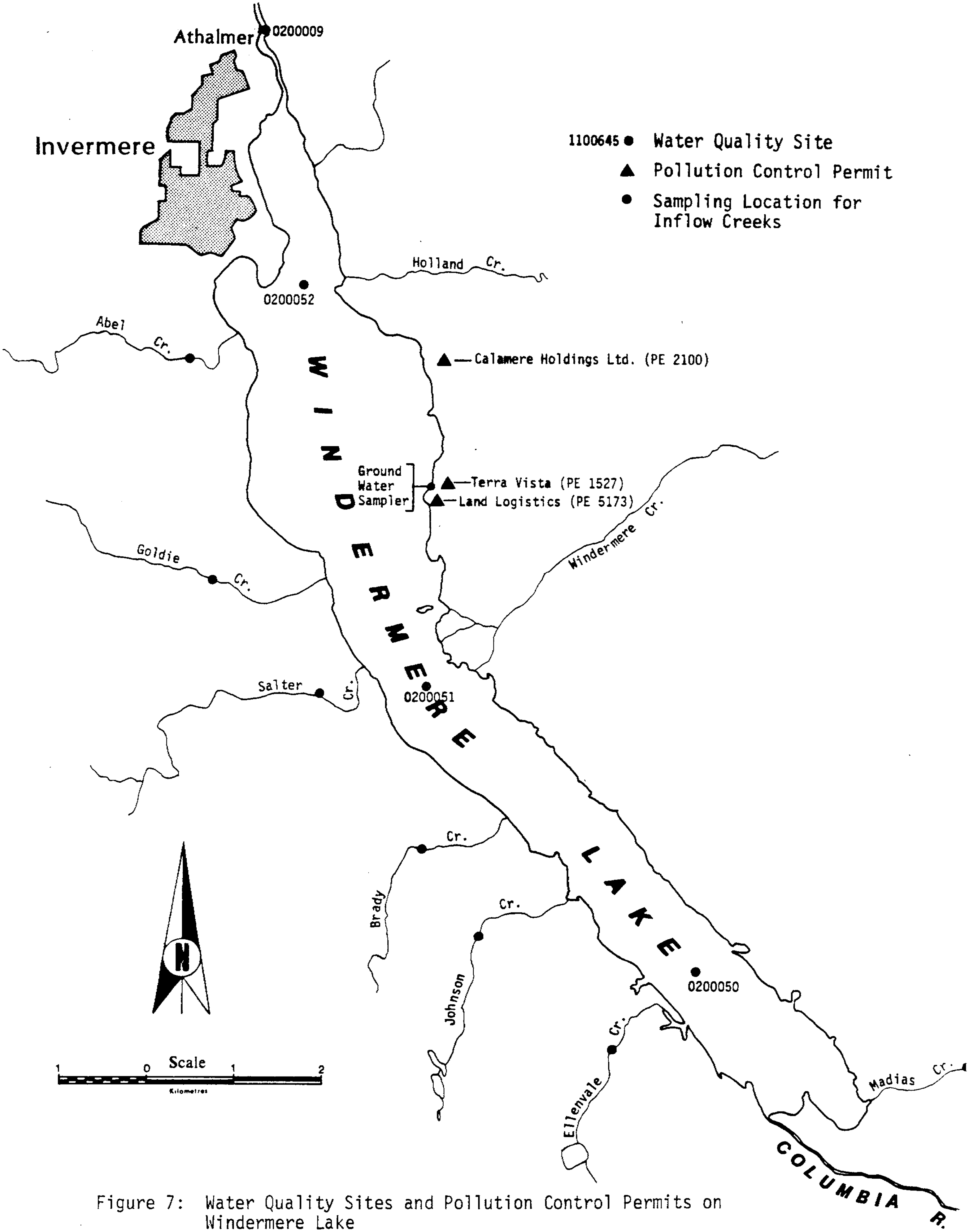

Figure 7: Water Quality Sites and Pollution Control Permits on Windermere Lake

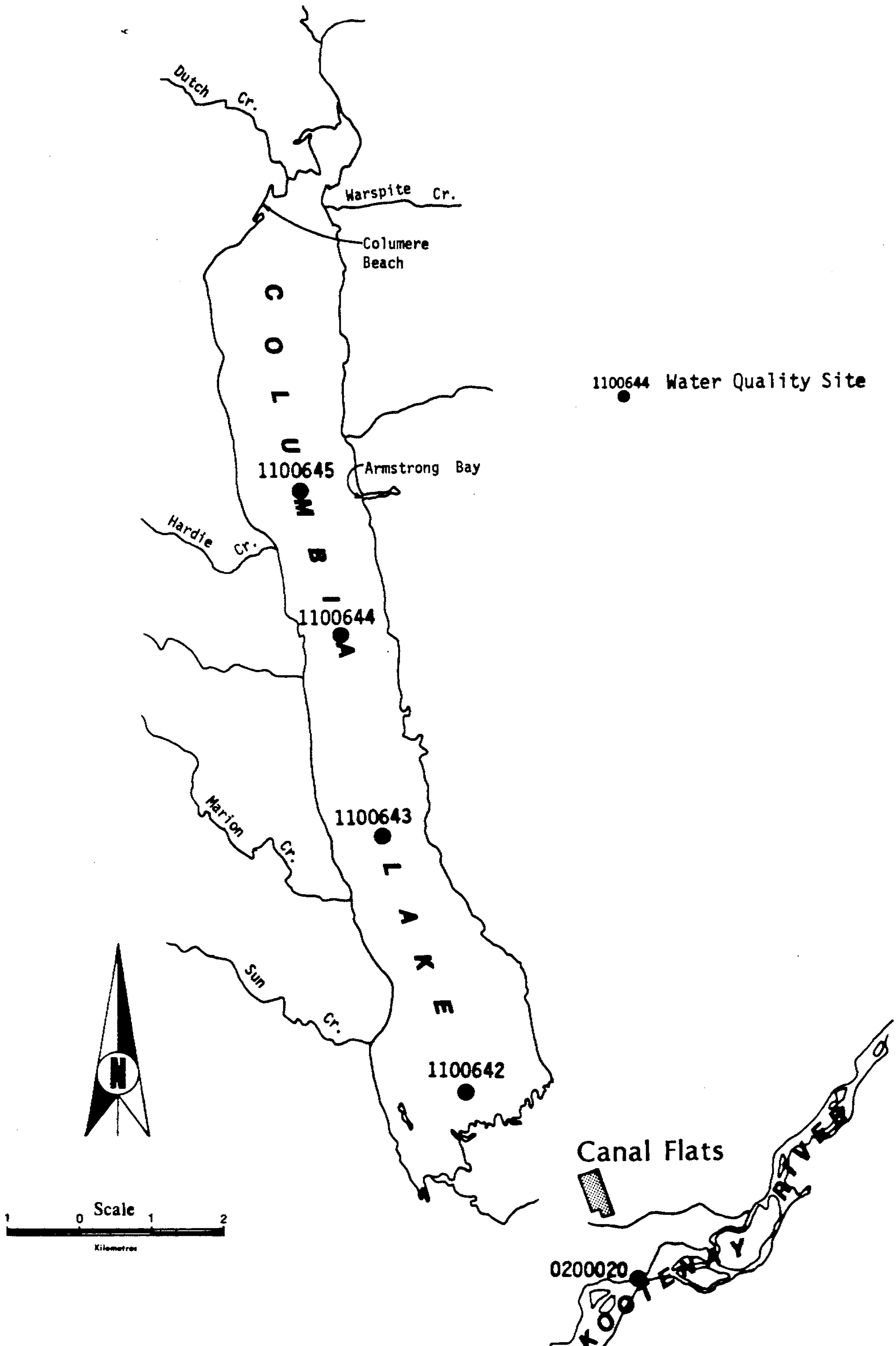

Figure 8: Water Quality Sites and Pollution Control Permits on Columbia Lake

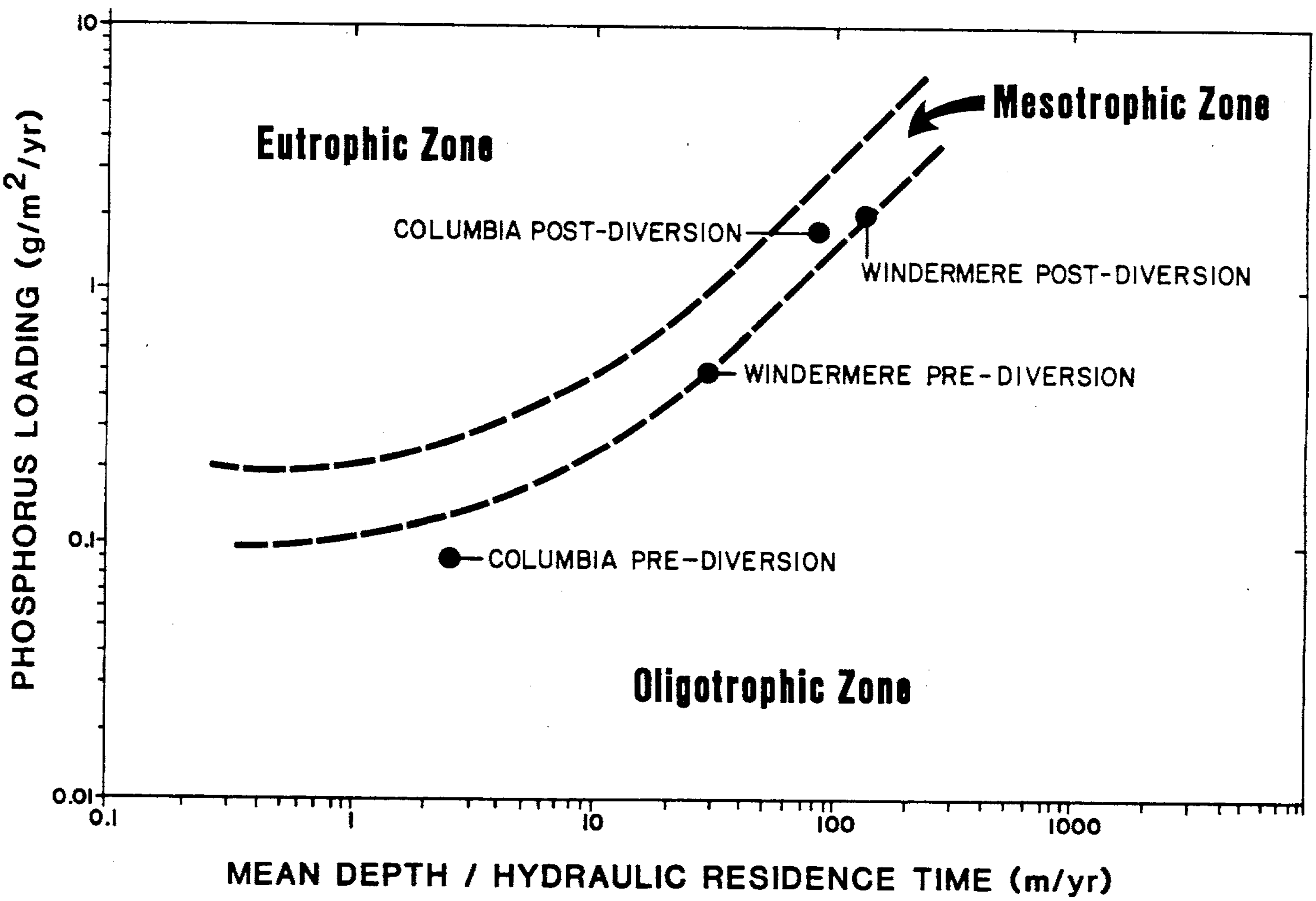

Figure 9: Trophic Status of Windermere and Columbia Lakes in 1983
Based on the Model Developed by Vollenweider (1976)

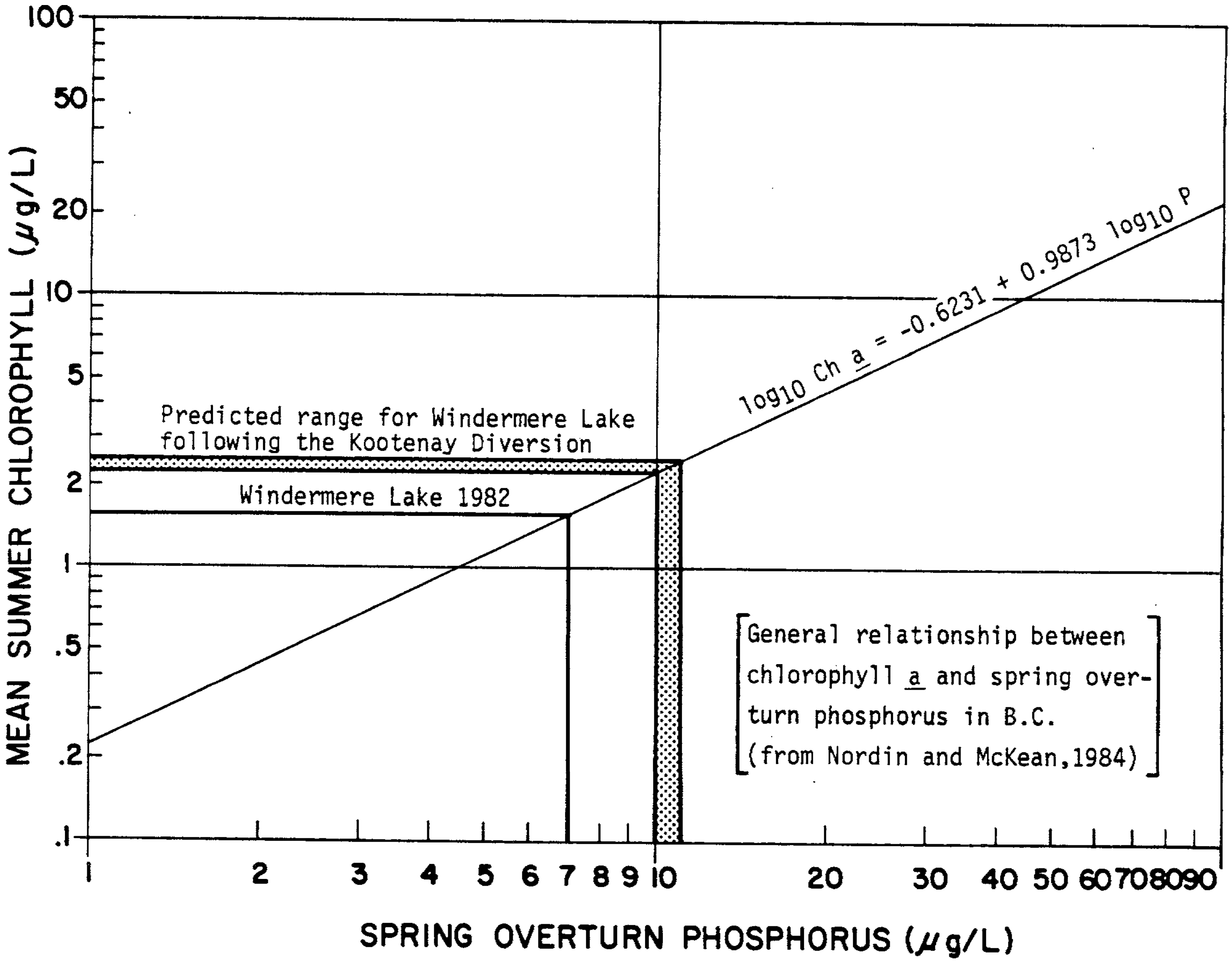

Figure 10: Mean Summer Chlorophyll a Content as a Function of Spring Overturn Phosphorus Concentration

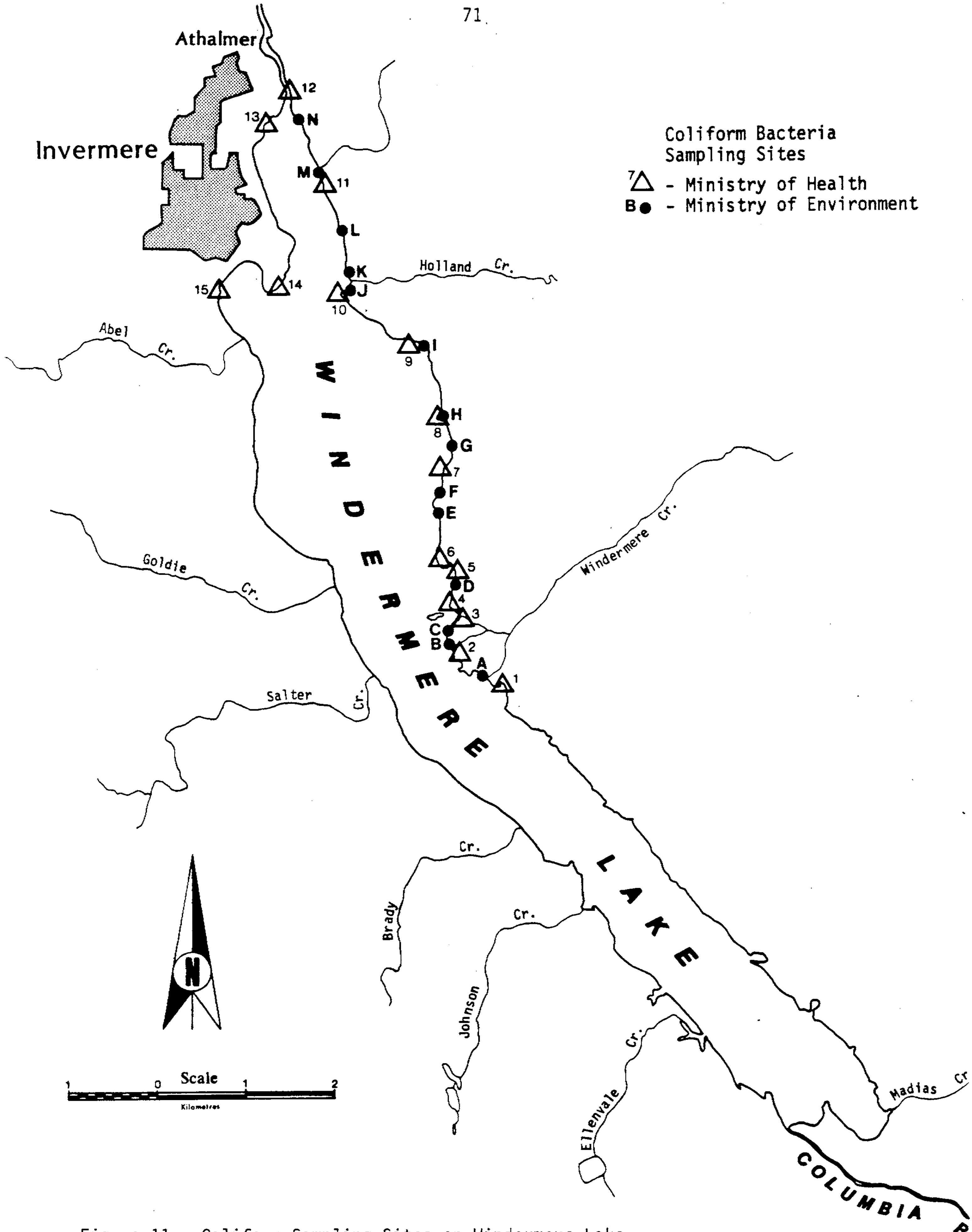

Figure 11: Coliform Sampling Sites on Windermere Lake

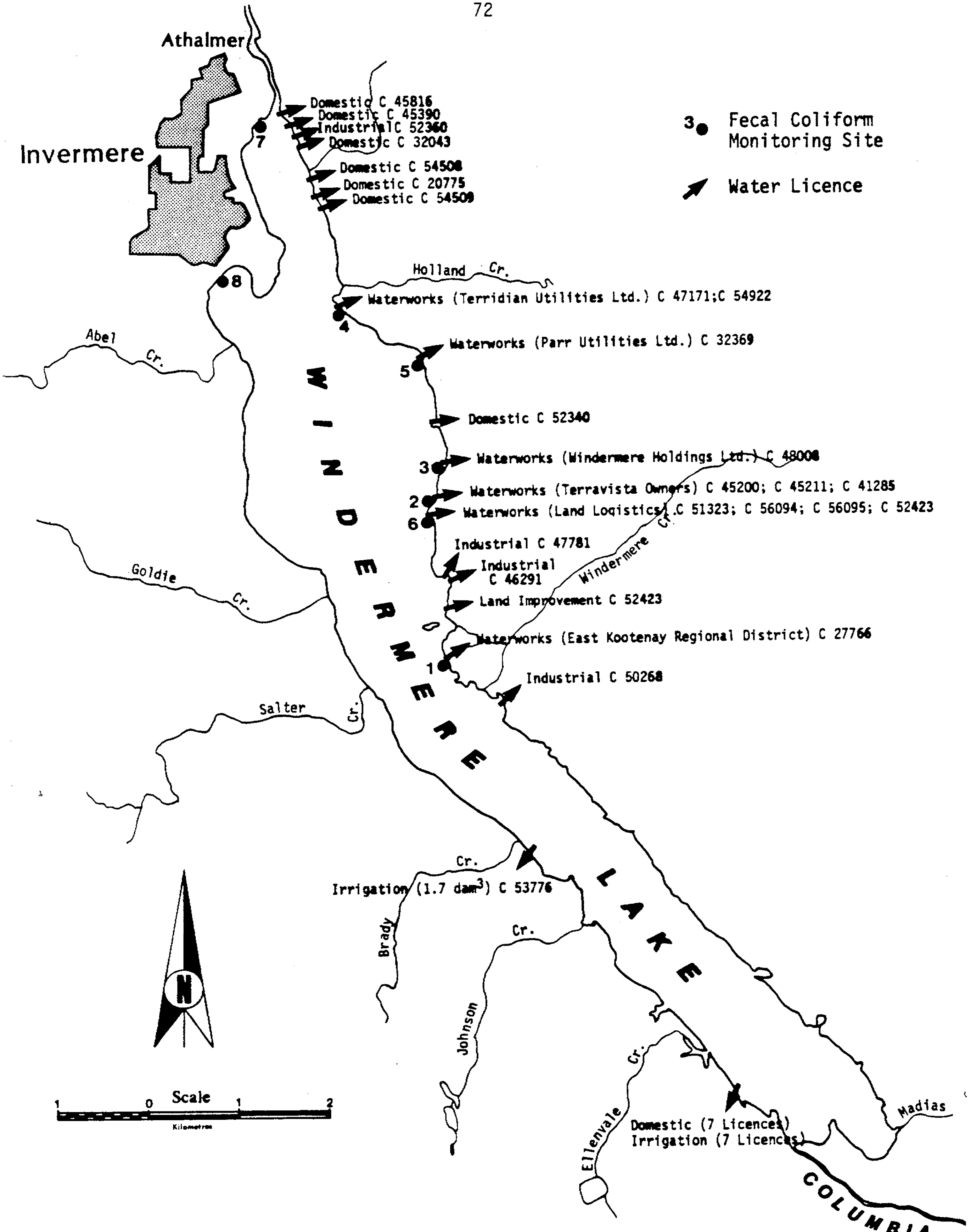

Figure 12: Fecal Coliform Monitoring Sites on Windermere Lake

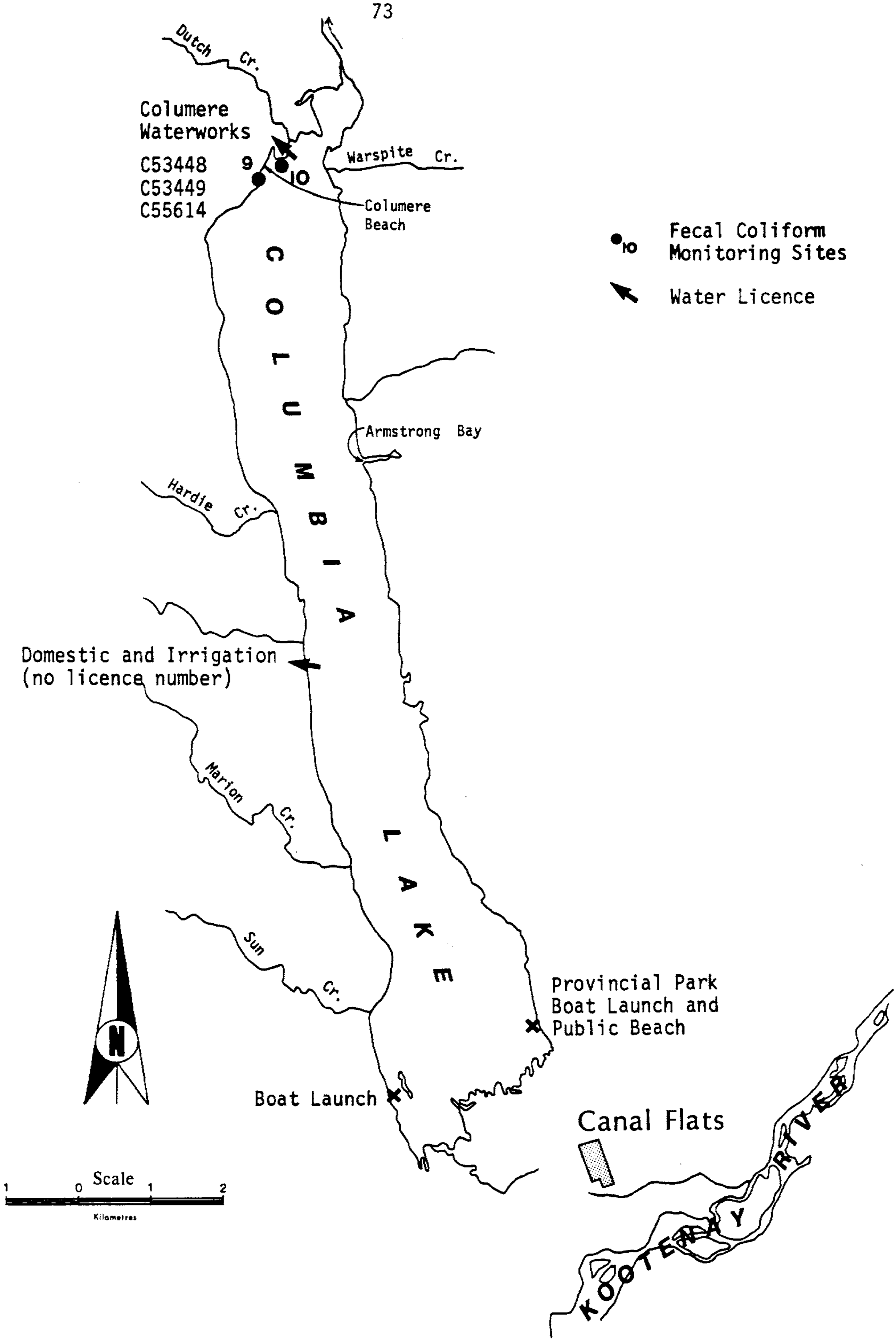

Figure 13: Fecal Coliform Monitoring Sites on Columbia Lake

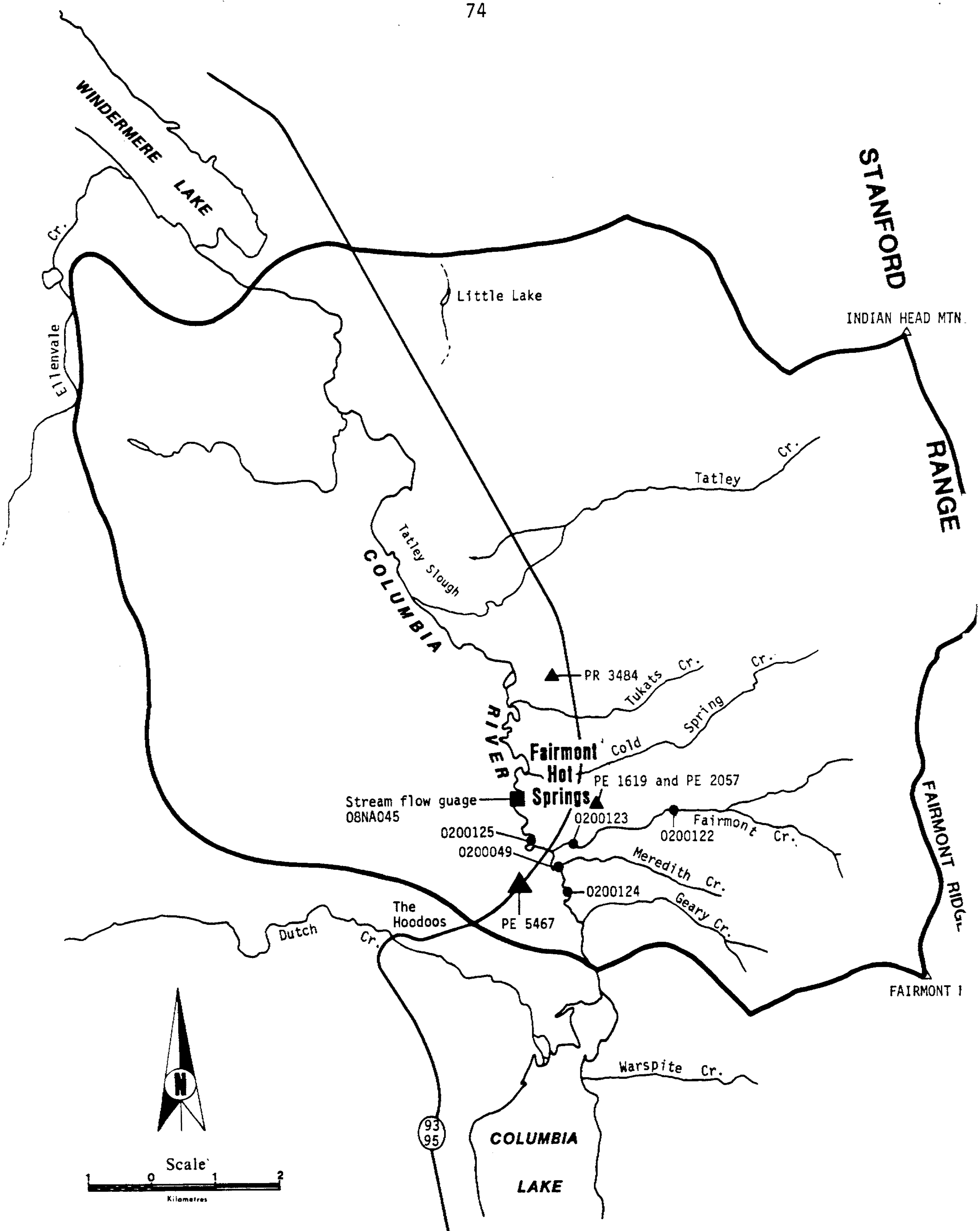

Figure 14: Pollution Control Permits and Water Quality Sites for the Columbia River between Columbia and Windermere Lakes

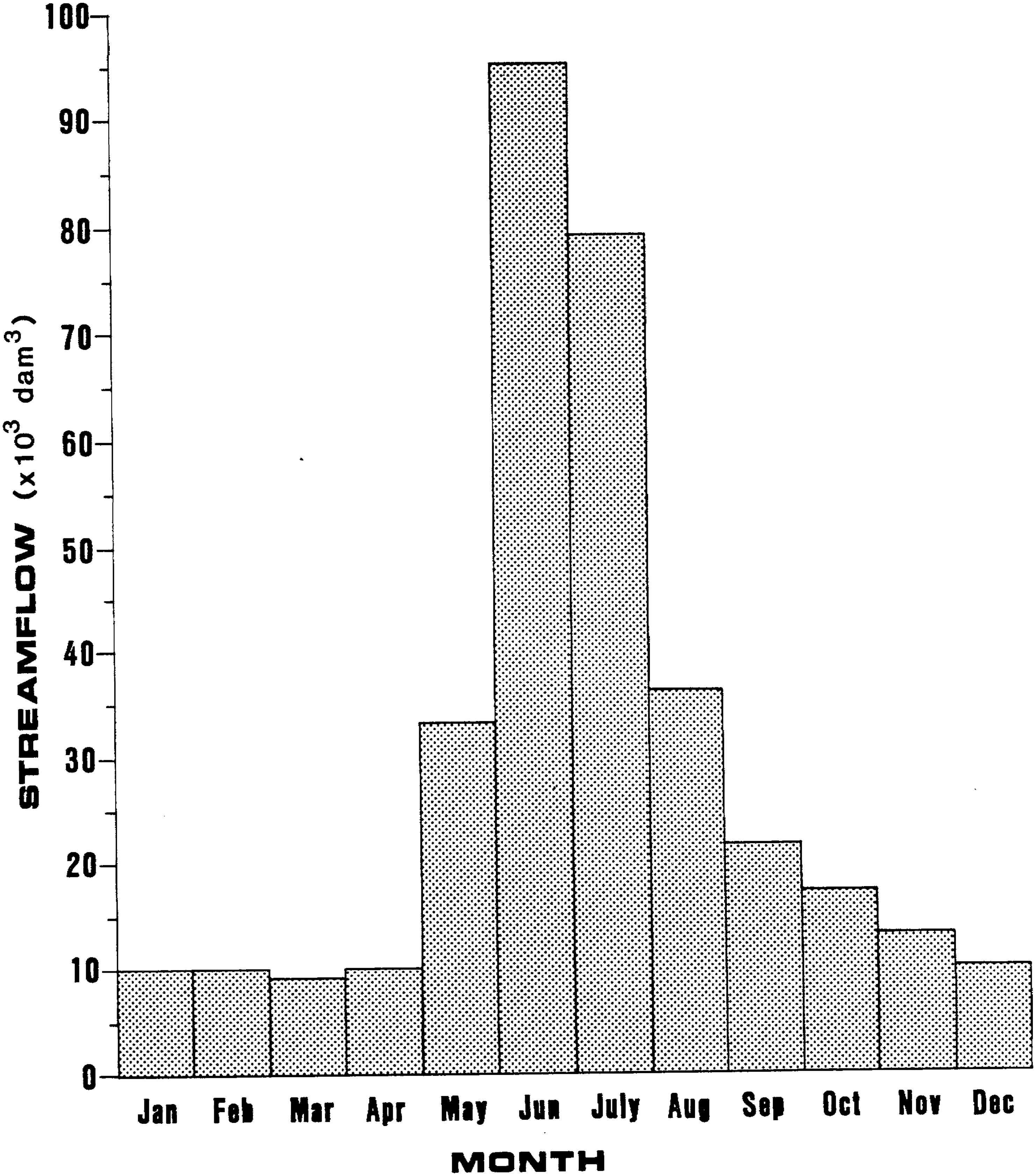

Figure 15: Hydrograph for Mean Flow of Columbia River at Fairmont Hot Springs

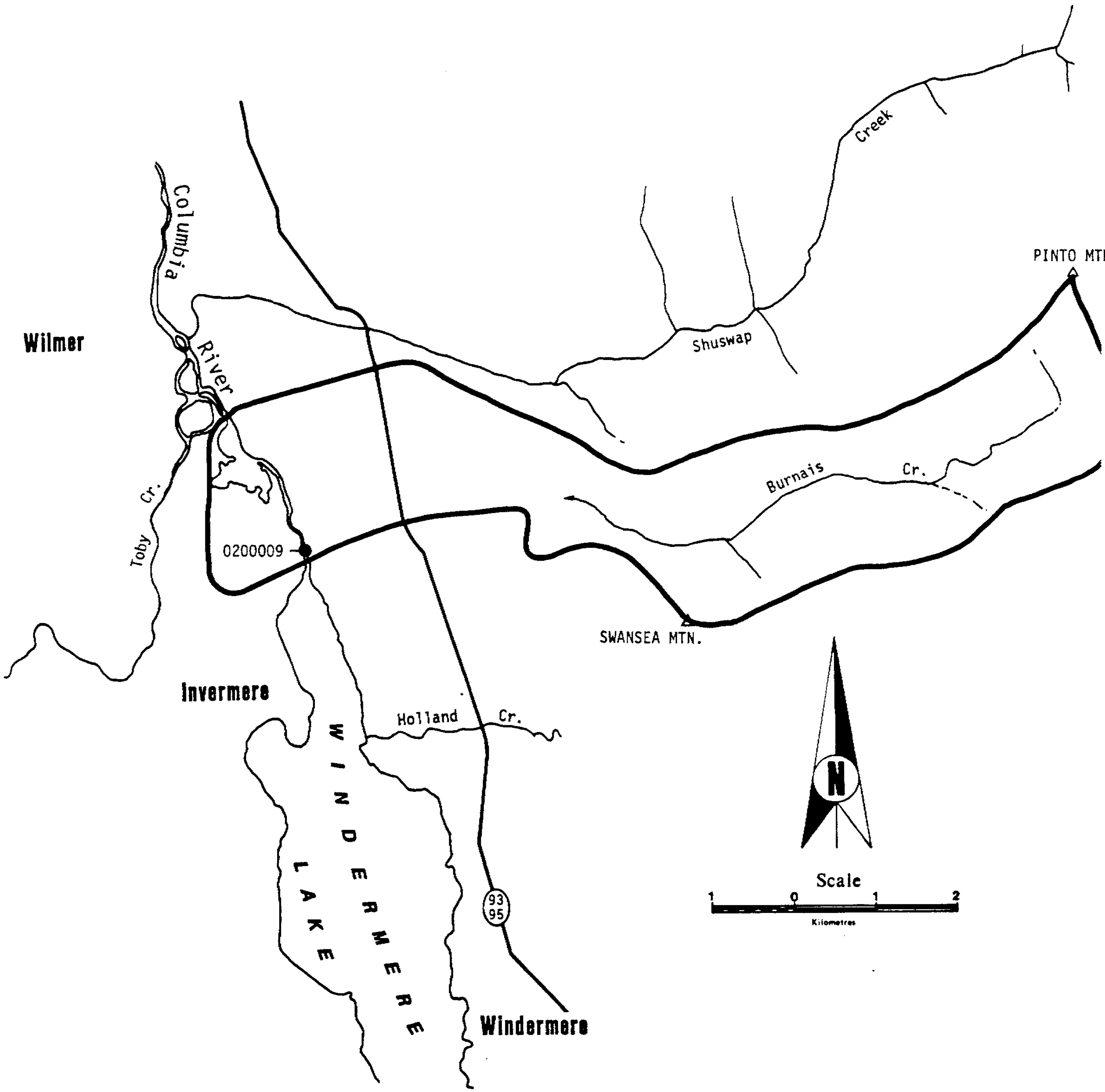

Figure 16: Water Licences and Water Quality Sites for the Columbia River Between Windermere Lake and Toby Creek

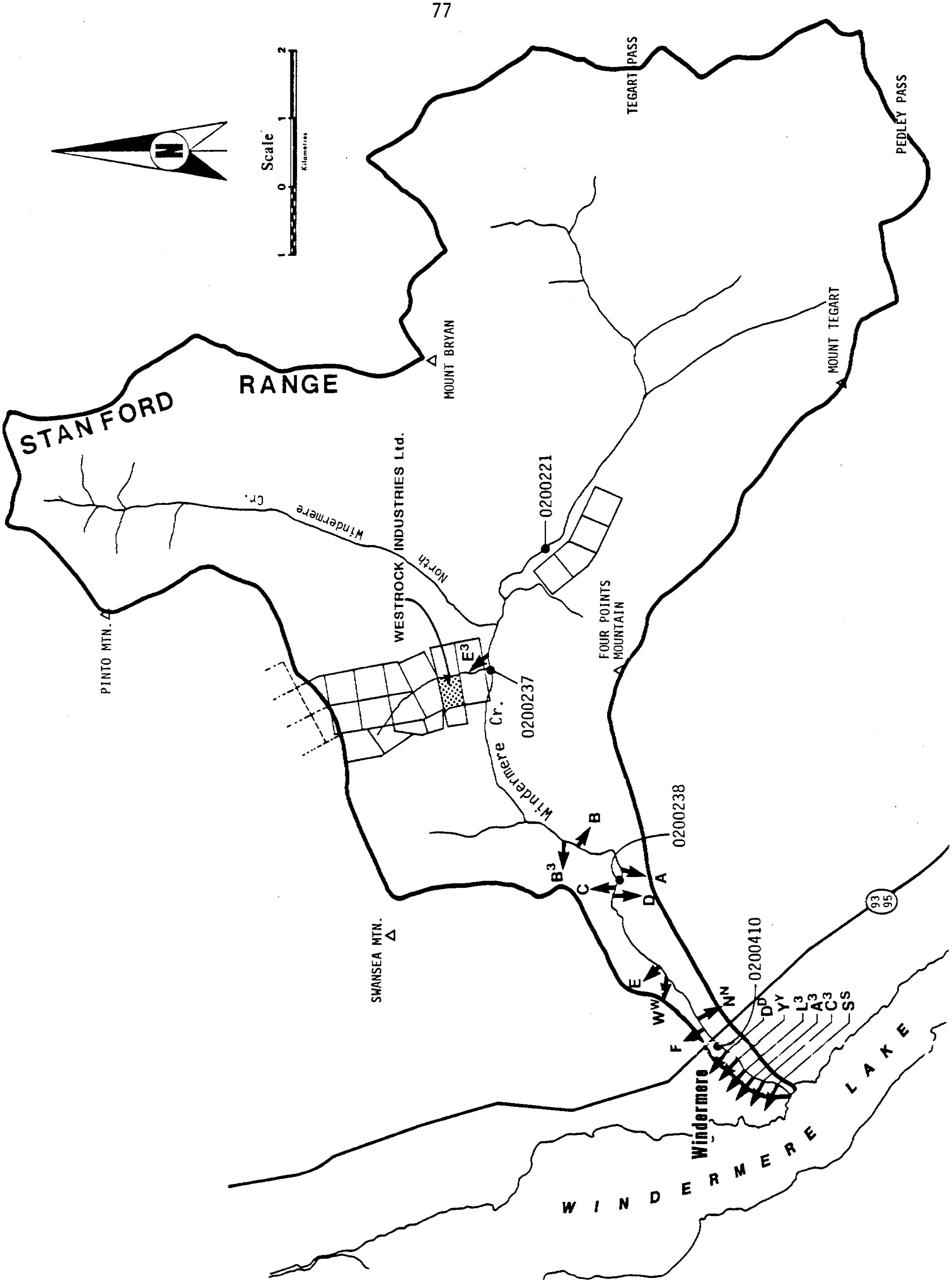

Figure 17: Water Licences and Water Quality Sites for Windermere Creek

TABLE 1

MORPHOLOGY OF COLUMBIA AND WINDERMERE LAKES

VARIABLE	COLUMBIA LAKE	WINDERMERE LAKE
Latitude, Longitude:	50°15',115°50'	50°30',116°0'
Elevation:	809 m	800 m
Surface Area:	2574 ha	1817 ha
Watershed Area	185 km^2	1325 km^2
Maximum Depth:	5.2 m	7.3 m
Mean Depth:	2.9 m	3.6 m
Volume:	74.87 X 10^6 m^3	64.50 X 10^6 m^3
Shoreline Perimeter:	42 184 m	46 330 m
Length:	13.6 km	13.3 km
Average Width:	1.7 km	1.1 km

Source: Fish and Wildlife Br., Lake Survey, August 28, 1958.

TABLE 2

HYDROLOGY ESTIMATES FOR COLUMBIA AND WINDERMERE LAKES

LAKE	WATERSHED RUNOFF RATIO (dam^3/ha/yr)	WATERSHED SIZE (ha)	INFLOW (dam^3/yr)	FLUSHING RATE (yr^{-1})	WATER RETENTION TIME (yr)
Columbia	3.95	18 500	73 100*	1.0*	1.0
Windermere	3.95	132 500	523 000	8.1	0.13

* The inflow from Dutch Creek is not included in this estimate.

TABLE 3
WINDERMERE LAKE WATER LICENCES

DOMESTIC

Priority Date	Licence Number	Quantity (m^3/d)	Location	Licencee
1958.09.02	F 20775	2.3	L 27 of L 4347 Kootenay Dist Plan 2886	Gemeroy Clifford H
1958.11.27	F 46291	2.3	L 3,4,5 of L 8 Kootenay Dist Plan	MacDonald A Webster
1962.04.13	C 27766	455	Land in Bdy Windermere Imp Dist	East Kootenay Regional District
1966.03.01	F 45816	2.3	L 1 of L 4347 Kootenay Dist Plan 4007	Rempal Dean & Shirley
1971.11.03	F 52340	2.3	L 17 of Blk D of L 704 Kootenay Dist Plan 2038	Sparks Terry
1971.11.09	C 41285	205	Undertaking of licencee within part L 3 of L 704 Kootenay Dist Plan 2554 lying W of Rd on plan 2554 exc plan 2960 ref plan 624411 of L 704	Terravista - Owners of Strata Plan N-9
1974.07.15	C 48008	16	L 2 of L 704 Kootenay Dist Plan 2737	Windermere Holdings Ltd.
1975.02.21	C 45200	35	Undertaking of licensee C of PC & N OIC 2155/1973 & any amendment or substitution	Terravista - Owners of Strata Plan N-9
1975.02.21	C 45211	48	Undertaking of licensee	Terravista - Owners of Strata Plan N-9
1975.03.17	C 47171	435	Undertaking of licensee C of PC & N 143/1976 & any amendment or substitution	Terridian Utilities Ltd.
1965.12.21	C 32043	2.3	L 76 of L 4347 Kootenay Dist Plan 2886	Dixon Lloyd
1966.03.10	F 45390	2.3	L 72 of L 4347 Kootenay Dist Plan 2886	Nelson Marjorie E
1966.04.06	C 32369	2275	As set out in CPC & N	Parr Utilities Ltd.

TABLE 3 (Continued)

DOMESTIC WATER LICENCES

Priority Date	Licence Number	Quantity (m^3/d)	Location	Licencee
1979.04.18	C 56095	92	Undertaking of licensee within CPCN #489/1983	Land Logistics Western Ltd.
1977.11.18	C 51323	225	Undertaking of licensee C of PC & N #489/1983	Land Logistics
1977.12.06	C 54922	198	Undertaking of Licensee C of PC & N 143/1976	Terridian Utilities Ltd.
1978.09.28	C 54508	2.3	L 30 of L 4347 Kootenay Dist Plan 2886	Carbury Joseph & Rose C
1978.09.28	C 54509	2.3	L 21 of L 4347 Kootenay Dist Plan 2886	Brisske Alfred
1980.08.07	C 56094	77	Undertaking of licensee within CPCN #489/1983	Land Logistics Western Ltd.
1980.08.01	C 56178	2.3	1 AC of L 42 of L 346 Kootenay Dist Plan 5332	Lamb WC
1980.08.04	C 56515	2.3	0.5 AC of L 43 of L 346 Kootenay Dist Plan 5332	Obermeyer Rudolf C Winnifred R
1980.11.19	C 56277	2.3	0.8 AC of L 19 of L 346 Kootenay Dist Plan 5322	Reed R
1980.12.02	C 56093	2.3	1 AC of L 41 of L 346 Kootenay Dist Plan 5332	Lamb F
1981.07.21	-	2.3	0.5 AC of L 15 of L 346 Kootenay Dist Plan 5332	Garrett J.R.
1981.09.14	-	2.3	L 27 of L 346 Kootenay Dist Plan Dist 5332	Brandsgard A & B
1982.04.22	-	2.3	0.75 AC of L 16 of L 346 Kootenay Dist Plan 5332	Burke R/M

TABLE 3 (Continued)

IRRIGATION WATER LICENCES

Priority Date	Licence Number	Quantity (dam^3)	Location	Licencee
1978.11.06	C 53776	1.7	0.4 AC of L 9 of L 21 Kootenay Dist Plan 6751	Christie Natt T & Martha M
1980.06.11	C 56721	2.5	0.8 AC of L 14 of L 346 Kootenay Dist Plan 5332	Boutilier Harold A
1980.08.01	C 56178	3.1	1 AC of L 42 of L 346 Kootenay Dist Plan 5332	Lamb WC
1980.08.04	C 56515	1.5	0.5 AC of L 43 of L 346 Kootenay Dist Plan 5332	Obermeyer Rudolf C Winnifred R
1980.11.19	C 56277	2.5	0.8 AC of L 19 of L 346 Kootenay Dist Plan 5322	Reed R
1980.12.02	C 56093	3.1	1 AC of L 41 of L 346 Kootenay Dist Plan 5332	Lamb F
1981.07.21	-	1.5	0.5 AC of L 15 of L 346 Kootenay Dist Plan 5332	Garrett JR
1982.04.22	-	2.5	0.75 acre of L 16 of L 346 Kootenay Dist Plan 5332	Burnke R/M

INDUSTRIAL WATER LICENCES

1958.11.27	F 46291	4.23/dam^3	L 3,4,5, of L 8 Kootenay Dist Plan 1080	MacDonald A Webster JR
1976.04.30	C 49781	16 m^3	L 3 & 4 of L 8 Kootenay Dist Plan 1080	MacDonald A Webster JR
1976.03.01	C 50268	3.1/dam^3	L 91 & 92 of L 8 Kootenay Dist Plan 1080	Dubois William D & Georgina N
1977.07.28	C 52360	0.8/dam^3	L 74 of L 4347 Kootenay Dist Plan 2886	Balfour Robert F

LAND IMPROVEMENT

1978.08.24	C 52423	0.0	Lot A of L 20 Kootenay Dist Plan 11231 & UF/S & land held under lands File 0337989	Land Logistics Western Ltd.

TABLE 4
WATER LICENCES FOR COLUMBIA LAKE

DOMESTIC

Priority Date	Licence Number	Quantity (m^3/d)	Location	Licencee
1974.08.06	C 53448	245	Undertaking of licensee within CPC & N 290/1979	Columere Waterworks Ltd.
1978.12.04	C 53449	150	Undertaking of licensee within CPC & N 290/1979	Columere Waterworks Ltd.
1981.01.14	C 55614	16	Undertaking licensee as set out in CNC & N 365/1981	Columere Waterworks Ltd.
1981.04.23	-	2.3	20 AC of that part of SL 105 of L 4596 Kootenay Dist Plan X32 lying W of Hwy #95 (Plan R-345)	Reinarz, Frans A

IRRIGATION

Priority Date	Licence Number	Quantity	Location	Licencee
1981.04.23	-	50 dam^3	20 AC of that part of SL 105 of L 4596 Kootenay Dist Plan X32 lying W of Hwy #95 (Plan R-345)	Reinarz, Frans A

TABLE 5

Windermere Lake Soil and Terrain Interpretations for Settlement Suitability

MAP UNIT NO.	LANDSCAPE DESCRIPTION	SUITABILITY AND LIMITATIONS TO USE							
		Septic Tank Absorption Fields	Phosphorus Adsorption Potential	Landscape Stability	Dwellings with Basements	Dwellings without Basements	Local Roads and Streets	Soils as Roadfill Sources	Overall Settlement Suitability
1.	thin, fine textured aeolian (wind-blown) deposits overlying silty lacustrine materials; well drained with a 0.5 to 10% slope range;	M^{3}	E	M	$M_{5,8}$	$M_{5,8}$	$M_{5,8}$	M_{8}	M
2.	identical materials to unit no. 1 on steeper slopes ranging from 9 to 30%	$L^{3,5}$	G	M	M^{5}_{8}	M^{5}_{8}	M^{5}_{8}	M^{5}_{6}	M
3.	complex of fine textured lacustrine and coarse, textured colluvial and fluvial materials on steep slopes and escarpments; slopes range from 30 to 100+%; active erosion includes gullying, failing slopes and piping	$L^{3,5,25}$	G-E	L	$L^{5,14,25}_{8}$	$L^{5,14,25}_{8}$	$L^{3,5,25}_{8}$	$L^{5,13,25}_{8}$	L
4.	present shoreline areas of lacustrine materials ranging in texture from silts to gravels with slopes less than 5%; very poorly drained and subject to floods	$L^{1,4}$	G-E	M	$L^{1,2,4}$	$L^{1,2,4}$	$L^{1,2,3,4}_{8}$	$L^{1,2,3,4}_{8}$	L
5.	thin, fine textured aeolian deposits overlying sandy gravelly fluvioglacide terraces and fans; well drained with a slope range of 0.5 to 9%	$L^{3,12}$	G-E	H	H	H	H	H	M-H
6.	very steep (45 to 100%) coarse textured fluvial escarpments; active gullying present	$L^{3,5,12,25}$	G-E	L	$L^{5,25}$	$L^{5,25}$	$L^{5,25}_{6}$	M^{5}	L
7.	thin fine textured aeolian deposits overlying fluvio-glacial terraces which are underlain by silty lacustrine deposits; slopes range from 0.5-9%	$L^{3,12}$	E	M	H	H	H	H	M
8.	thin, fine textured aeolian deposits overlying gravelly fluvial terraces and moraine; well-drained with a slope range of 6 to 15%	$L^{3,12}_{5}$	E	H	M_{5}-H	M_{5}-H	M_{5}-H	H	M-H
9.	gravelly fluvial terraces and fans that are well to imperfectly drained on less than 5% slopes	$L^{3,12}$	P	H	M^{2}_{1}	M^{2}_{1}	H	H	M
10.	complex of sandy floodplain deposits and organic materials overlying fluvial fans; very poorly drained and subject to flooding	$L^{1,2,4,17}$	P	M	$L^{1,2,4,17}$	$L^{1,2,4,7}$	$L^{1,2,4,7}_{8}$	$L^{4,17}_{8}$	L
11.	sandy aeolian deposits overlying silty lacustrine terraces that are well drained and have a 2 to 3% slope range	$M^{3}_{5,12}$	G-E	M	M_{5}-H	M_{5}-H	M_{5}-H	M_{5}-H	M
12.	sandy aeolian deposits overlying gravelly fluvial and fluvioglacial terraces; well drained with a 2 to 15% slope range	$L^{3,12}_{5}$	G	H	M_{5}-H	M_{5}-H	M_{5}-H	M_{5}-H	M-H
13.	similar materials and slopes to unit no. 12 but with imperfect to poor drainage	$L^{1,12}_{4,5}$	G-E	M	$M^{4}_{1,5}$	M^{4}_{5}	M^{5}_{4}	M^{4}_{5}	M
14.	sandy and silty gravelly morainal deposits that are well drained on slopes ranging from 6 to 30%	$M_{3,5}$	G	H	M_{5}	M_{5}	$M_{5,8}$	$M_{5,8}$	M
15.	silty aeolian deposits overlying silty gravelly morainal deposits on well drained slopes ranging from 6 to 45%	M^{5}_{3}	E	M	M^{5}	M^{5}	M^{5}_{8}	M^{5}_{6}	M
16.	fine and medium textured colluvial deposits at the base of escarpments; well to imperfectly drained on slopes raning frokm 10 to 100+%; active erosion in the form on piping and failing slopes	$L^{5,25}_{3}$	G-E	L	$L^{5,13,25}_{8}$	$L^{5,13,25}_{8}$	$L^{5,13,25}_{8}$	$L^{5,13,25}_{8}$	L
17.	sandy gravelly colluvial deposits that are well drained and range in slopes from 10 to 30%	$L^{3,5}_{12}$	G	M	M^{5}_{14}	M^{5}_{14}	$L^{5}_{10,14}$	M^{5}	L-M

N.B. See Figure 5 for complete explanation of symbols

TABLE 6
PROPOSED DEVELOPMENT AREAS AND THEIR SUITABILITY FOR SEPTIC TANK ABSORPTION FIELDS AND OVERALL SETTLEMENT DEVELOPMENT

AREA	PROPOSED LAND USE		LANDSCAPE MAP UNIT NUMBER/S *	SEPTIC TANK ADSORPTION FIELD SUITABILITY *	OVERALL SETTLEMENT SUITABILITY *
	SHORT TERM	LONG TERM			
1	Small Holdings	Comprehensive Resort	7	L	M
2	Rural	Comprehensive Resort	3,5,7,8,14	L,L,L,L,M	L,M-H,M,M,M
3	Rural	Tourist, Highway or Mixed Commercial	5	L	M-H
4	Small Holdings 2	Small Holdings 1	2,14,16	L,M,L	M,M,L
5	Small Holdings 2	Single Family Residential	1,3,5	M,L,L	M,L,M-H
6	Small Holdings 1	Single Family Residential	11,13	M,L	M,M
7	Small Holdings 2	Single Family Residential	2,11,12	L,M,L	M,M,M-H
8	Rural	Tourist or Highway Commercial	12,16	L,L	M-H,L
9	Rural	Resort Commercial	5,6	L,L	M-H,L
10	Small Holdings 2	Single Family Residential	5,6	L,L	M-H,L
11	Small Holdings 1	Single Family Residential	5,6	L,L	M-H,L
12	Small Holdings 1	Multiple Family 1 and Single Family Residential	5	L	M-H
13	Small Holdings 2	Mobile Home	5,6	L,L	M-H,L
14	Small Holdings 2	Single Family Residential and open space	5,6	L,L	M-H,L
15	Small Holdings 2	Single Family Residential and open space	5,6,10	L,L,L	M-H,L,L
16	Small Holdings 2	Mobile Home	12,13	L,L	M-H,M
17	Small Holdings 2	Mobile Home	5	L	M-H

The landscape map units and the high-moderate-low ratings are taken directly from Figure 5. The specific limitations to each use are given in Figure 5 and are elaborated upon in the tex following that figure.

TABLE 7
NUTRIENT CONCENTRATIONS OF INFLOW STREAMS TO WINDERMERE LAKE

June 8, 1982 (n = 1)	Flow (m^3/s)	Ammonia Nitrogen (µg/L)	Nitrate Nitrogen (µg/L)	Organic Nitrogen (µg/L)	Ortho Phos- phorus (µg/L)	Dissolved Phosphorus (µg/L)	Total Phos- phorus (µg/L)
Abel Cr.	0.148	<5	90	140	<3	4	13
Brady Cr.	0.092	<5	<20	160	<3	4	12
Ellenvale Cr	0.015	<5	<20	670	3	13	23
Goldie Cr.	0.159	<5	130	80	<3	3	21
Madias Cr.	0.012	<5	20	200	4	8	10
Salter Cr.	0.062	<5	<20	210	3	4	7

April 7, 1983
(n = 1)

Abel Cr.	0.0546	5	100	60	<3	4	7
Brady Cr.	0.0365	<5	50	60	<3	3	6
Ellenvale Cr.	0.0021	19	<20	310	<3	7	13
Goldie Cr.	0.0297	10	220	70	9	12	16
Johnston Cr.	0.0017	15	70	140	3	6	11
Salter Cr.	0.0379	5	20	90	<3	3	8

TABLE 8

WINDERMERE LAKE WATER QUALITY, JANUARY 1973 - MAY 1983

SAMPLING SITE		SOUTH END MID LAKE, 0200050				MID LENGTH MID LAKE, 0200051				NORTH END MID LAKE, 0200052			
Parameter		Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N
Alkalinity, Total	mg/L	135	52	99	20	119	51	96	20	124	96	103	18
Carbon, Total Organic	mg/L	8	<1	3	19	8	<1	3.5	19	8	<1	3.7	19
Chlorophyll a	µg/L	1.7	<0.5	1.0	3	3.3	0.7	1.3	17	2.2	0.6	1.4	22
Coliforms, Fecal	MPN/100 mL	<2	<2	<2	4	<2	<2	<2	4	<2	<2	<2	4
Color, TAC	T.A.C.	8	2	5.2	5	6	1	4	5	6	2	4	4
True	Color Units	10	<5	5.2	18	10	<5	5.8	18	10	5	5.3	17
Copper, Dissolved	µg/L	70	<1	6	19	4	<1	2	20	<10	<10	<10	19
Total	µg/L	4	1	1.5	2	<10	<10	<10	8	<10	<10	<10	8
Depth, Extinction	m	4.5	1	2.5	12	4.8	<2	3.6	17	6.1	1.2	4.2	17
Hardness, Total	mg/L	191	99	125	25	209	95	134	25	210	111	133	23
Iron, Dissolved	mg/L	<0.1	<0.1	<0.1	19	<0.1	<0.1	<0.1	20	<0.1	<0.1	<0.1	19
Total	mg/L	--	--	--	-	<0.1	<0.1	<0.1	8	0.04	<0.01	0.04	8
Lead, Dissolved	µg/L	4	<1	1.6	19	<1	<1	<1	20	4	<1	1.7	19
Total	µg/L	<1	<1	<1	2	<100	<100	<100	8	<100	<100	<100	8
Manganese, Dissolved	µg/L	<20	<20	<20	15	<20	<20	<20	16	<20	<20	<20	15
Magnesium, Dissolved	mg/L	17	11	13.6	20	18.5	10.6	14.6	20	18	11.7	14.7	19
Nitrogen, Ammonia	µg/L	19	5	10.6	15	22	<5	9.8	23	26	<5	13	22
Nitrite/Nitrate	mg/L	<0.02	<0.02	<0.02	7	<0.02	<0.02	<0.02	15	<0.02	<0.02	<0.02	14
Organic	mg/L	0.53	0.03	0.16	24	0.27	0.01	0.14	32	0.31	0.07	0.15	30
Oxygen, Dissolved	mg/L	11.8	8.8	10.2	23	12.9	8.3	10.2	57	11.4	7.7	9.5	66
% Saturation		134	85	110	8	137	98.9	114.3	35	114.1	88	106.4	51
pH	pH Units	8.8	7.6	8.4	21	8.8	8.2	8.45	33	8.6	8.1	8.4	31
Phosphorus, Dissolved	µg/L	--	--	--	-	7	3	4	8	9	<3	4	8
Total	µg/L	29	<3	8	25	44	4	9.2	33	156	3	11.5	31
Solids, Dissolved	mg/L	220	112	144	23	258	110	162	31	260	107	162	29
Suspended	mg/L	<1	<1	--	2	3	<1	1.5	10	2	<1	1.2	10
Specific Conductivity	µS/cm	380	160	240	21	333	189	250	23	400	217	260	22
Temperature	°C	22.5	4	14.5	27	23	2	15.6	61	22.5	5	16.2	70
Turbidity (Lab analysis)	NTU	7.8	0.4	1.4	10	1.1	0.4	0.7	17	0.9	0.4	0.54	16
Turbidity (Field data)	NTU	10.0	0.5	2.9	17	7.1	0.4	2.0	10	7.3	0.3	1.6	13
Zinc, Dissolved	µg/L	30	<5	9	18	20	<5	5.9	20	20	<5	5.7	19
Total	µg/L	<5	<5	<5	2	<10	<10	<10	8	<10	<10	<10	8

Data are from Ministry of Environment's Data Bank, EQUIS.
N = number of values.
* = geometric mean.

TABLE 9

COLUMBIA LAKE WATER QUALITY, JANUARY 1973 - MAY 1983

SAMPLING SITE	SOUTH END, MIDLAKE 1100642				SOUTH THIRD, MIDLAKE 1100643				MIDLENGTH, MIDLAKE 1100644				NORTH THIRD, MIDLAKE 1100645			
Parameter	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N
Alkalinity mg/L	136	126	132	3	132	113	123	3			102	1	106	98	102	2
Carbon, Total Organic mg/L	2	1	1.3	3	3	<1	1.7	3			<1	1	5	2	3.5	2
Color, TAC	1	1	1	1	1	1	1	1			--	-	--	--	1	1
True	5	<5	5	3	5	<5	5	3			<5	1	--	--	5	1
Depth, Extinction m	3.6	1.4	2.1	4	4.5	2.7	3.6	3					4.7	3.7	4.2	2
Hardness, Total mg/L	160	138	149	4	154	123	136	4			103	1	129	105	117	3
Nitrogen, Ammonia mg/L	0.012	0.009	0.011	4	0.011	0.008	0.009	4			0.006	1	0.021	0.01	0.016	2
Nitrite/Nitrate mg/L	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3			0.02	1	<0.02	<0.02	<0.02	2
Organic mg/L	0.2	0.13	0.16	4	0.16	0.13	0.15	4			0.03	1	0.15	0.11	0.13	3
Total mg/L	--	--	--	-	--	--	--	1			--	-	--	--	--	-
Oxygen, Dissolved mg/L	11.6	9	10.5	4	12	8.5	10.4	4			11.4	1	12	8.8	10.4	2
pH	8.5	8.2	8.3	4	8.5	8.2	8.3	4			8.2	1	8.5	8.3	8.4	3
Phosphorus, Dissolved µg/L	<3	<3	<3	4	<3	<3	<3	4			<3	1	<3	<3	<3	2
Phosphorus, Total µg/L	9	4	6	4	8	4	6	4			4	1	6	4	4.5	3
Specific Conductance µS/cm	320	282	304	4	309	253	278	4			215	1	257	211	234	3
Solids, Dissolved mg/L	188	162	178	4	180	150	162	4			124	1	148	122	135	2
Solids, Suspended mg/L	2	2	2	1	1	1	1	1			1	1	--	--	--	-
Temperature °C	16	6.5	12.3	4	16.5	6	12.3	4			13	1	16.5	6.5	12.1	3
Turbidity NTU	1.6	0.7	1.1	4	2.6	0.7	1.3	4			1	1	0.9	0.6	0.7	3

Data are from Ministry of Environment's Data Bank, EQUIS

TABLE 10
SUMMARY OF IMPORTANT LIMNOLOGICAL VARIABLES
BEFORE AND AFTER THE KOOTENAY DIVERSION

	Areal Water Loading Rate qs (m/yr)	Phosphorus Loading Rate L ($g/m^2/yr$)	Mean Total Phosphorus (μg/L)	Chlorophyll *a* (μg/L)	Water Clarity (Secchi) (m)
Columbia Lake					
present	2.8	0.09	6	1.4	6.6
post diversion	70.5	0.88	9	2.1	5.3
Windermere Lake					
present	29.2	0.47	10	2.3	5.0
post diversion	132	1.87	11	2.5	4.8

TABLE 11
WINDERMERE LAKE BEACH SAMPLING, TOTAL AND FECAL COLIFORMS
1973-1981 (MINISTRY OF HEALTH)
MPN/100 mL

No.	Sampling Location	1973	1974	1977	1978	1979	1980	1981
1	Coldstream Resort Beach	<3 15		<2 <3	<3	13 2		
2	Threteway Beach	31 5 13	79/31 180/5 13/14	<2 <2		5 <2		
3	Bavins Bay			8 <2		<2 <2		
4	Windermere Beach	<3 <3	≥16		23 <2		<3 9	<3 <3
5	Graveyard Bay	<3 <3		<2 <2	5 5	2 2		
6	Akiskinook	<3 <3		<2 <2		<2 <2	<2	
7	Calberley Beach	<3 4		<2 <2		<2 <2		
8	Terra Vista	<3 <3	23/23 0 >2400 11 27	<2 <2	2 9 <2	5 <2		<3F <3F
9	Baltac Beach	<3 <3	<2	<2 <2	<3 <2	7 2		<3 <3
10	Timber Ridge Beach	4 <3		2 2	0 0	2 2		<3
11	Lakeview Drive	<3 <3 <3 <3		2 <2	33 13	<2 <2 2 2	2	
12	Athalmer Bridge at Midstream	<3 4		49 110 33 23	170 79 33 <2 350 79	5 <2		
13	Athalmer Beach	<3 <3	11 23 8 31 130 9	23 240 <2 4 11 0	<3 49 <3	7 2	3	3 <3

Fecal coliform results are underlined

TABLE 11 (Continued)

No.	Sampling Location	1973	1974	1977	1978	1979	1980	1981
14	Fort Point Beach	<3 <3	<2 <2	<2 <2	<2 <2 2 <u>2</u>			
15	Invermere Beach	4 <3	350 240 180 110 8	240 33 <u>130</u> <u>13</u>	<u>4</u> <u>3</u>			<<u>3</u>

NOTE: Fecal Coliform results are underlined
< = Less Than
> = More Than
* See Figure 11 for sampling locations.

TABLE 12
MINISTRY OF ENVIRONMENT FECAL COLIFORM RESULTS FOR WINDERMERE LAKE BEACHES
MPN/100 mL

Station Location*	19 May 1982	8 June 1982	21 July 1982	26 July 1982	25 August 1982	22 September 1982
A	-	2	-	-	-	-
B	-	13	4	-	-	-
C	<2	-	<2	-	-	-
D	-	5	<2	-	-	-
E	-	<2	-	<2	<2	-
F	-	-	<2	-	-	-
G	<2	-	<2	-	-	-
H	-	-	-	-	-	<2
I	<2	14	<2	2	<2	<2
J	-	-	-	-	-	2
K	-	2	-	-	-	-
L	-	-	-	-	<2	<2
M	-	<2	-	<2	-	<2
N	-	-	-	<2	33	2

* See Figure 11 for station locations.

TABLE 13
PESTICIDE PERMIT SUMMARY FOR COLUMBIA-WINDERMERE AREA
FROM 1980 TO PRESENT

AGENCY	DATE	AREA	LOCATION
Ministry of Transportation and Highways	81/02/16	100 ha	Route 93/95 from Radium south to Golden Highway District Boundary.
Ministry of Forests	82/04/15	30 ha	Within the Invermere Forest District, Invermere area

TABLE 14

FECAL COLIFORM MONITORING PROGRAM FOR WINDERMERE AND COLUMBIA LAKES

LAKE	SITE (FIGURE 12 and 13)	SITE DESCRIPTION	RATIONALE
Windermere	1	Inline sample prior to Chlorination	monitor waterworks licence C27766 and Threteway Beach
Windermere	2	Inline sample prior to Chlorination	monitor waterworks licences C41285, C45200, C45211 and south end of Calberley Beach
Windermere	3	Inline sample prior to Chlorination	monitor waterworks licence C48008 and north end of Calberley Beach
Windermere	4	Inline sample prior to Chlorination	monitor waterworks licence C47171, C54922 and Timber Ridge Beach
Windermere	5	Inline sample prior to Chlorination	monitor waterworks licence C32369 and Baltac Beach
Windermere	6	Inline sample prior to Chlorination	monitor waterworks licences C56095, C51323, C56094, C52423 and Terra Vista area
Windermere	7	Athalmer Beach 1-3 m from shore	monitor for nearby water licences and beach area
Windermere	8	Invermere Beach 1-3 m from shore	monitor beach area
Columbia	9	Columere Beach 1-3 m from shore	monitor beach area
Columbia	10	Inline sample prior to Chlorination	monitor waterworks licences C53449, C53449, C55614

TABLE 15
WATER LICENCES ON FAIRMONT CREEK

PRIORITY DATE	LICENCE NUMBER	QUANTITY	LICENCE TYPE	LOCATION	LICENCEE	FILE
1889.12.27	C 41576	9.25dam³	IRR	3 AC of L 4084 & part of L 46 Kootenay Dist Lying W of old Hwy (plan 8377) Exc Hwy 93 & 95 (Plan R320)	Fairmont Hot Springs Resort Ltd.	0242290
1889.12.27	C 51577	84 dam³	IRR	3 AC of L 4084 & part of L 46 Kootenay Dist lying W of old Hwy (Plan 8377) Exc Hwy 93 & 95 (Plan R320)	Fairmont Hot Springs Resort Ltd.	0242292
1959.08.18	C 40454	45 m³/d	IND	4 AC of L 18 Kootenay Dist	Fairmont Hot Springs Resort Ltd.	0227180
1973.01.12	F 41163	185 dam³	IND	Part of L 46 & 47 Lying E of Plan 8377; & L 40 Exc Plan 8377 Kootenay Dist	Fairmont Hot Springs Resort Ltd.	0316272

TABLE 16

POLLUTION CONTROL PERMITS FOR COLUMBIA RIVER BETWEEN COLUMBIA AND WINDERMERE LAKES (INCLUDES FAIRMONT CREEK)

PERMITTEE	PERMIT NUMBER	DISCHARGED TO	QUANTITY m^3/d	TYPE OF WASTE DISCHARGE
Fairmont Hotsprings Resort Ltd.	PE 1619	ground	136	septic tank/sauna bath effluent
	PE 2057	Fairmont Creek	1 410	hot springs pool effluent
	PE 5467	ground	17 600 Phase 1 35 700 Phase 2	sewage effluent sewage effluent
Regional District of East Kootenay	PR 3484	ground	-	refuse, landfill

TABLE 17

COLUMBIA RIVER WATER QUALITY, BETWEEN COLUMBIA AND WINDERMERE LAKES, 1973-1978

SAMPLING SITE	COLUMBIA R. UPSTREAM FAIRMONT CK. 0200124				COLUMBIA R. DOWNSTREAM FAIRMONT CK. 0200049				COLUMBIA R. DOWNSTREAM FAIRMONT CK. 0200125			
Parameter	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N
Alkalinity, Total mg/L	153	96	124	10	130	86	98	4	152	96	125	18
Cadmium, Dissolved µg/L	1	<1	1	2	2.4	0.1	1.1	3	1	<1	<1	20
Carbon, Total Organic mg/L	22	<1	--	14	1	<1	1	3	20	<1	3.7	23
Coliforms, Fecal MPN/100 mL	5	<2	2.5	11	--	--	7	1	70	<2	6.7	20
Color, T.A.C. Colour Units	5	1	2.5	4	--	--	1	1	3	<1	1.5	10
TRUE Colour Units	--	--	--	-	<5	<5	<5	3	5	<5	5	21
Copper, Dissolved µg/L	--	--	--	-	7.2	<1	1	5	5	<1	1.3	20
Hardness, Total mg/L	176	97	134	14	162	92	125	10	198	111	151	22
Iron, Dissolved mg/L	--	--	--	-	0.08	0.02	0.05	4	<0.1	<0.04	<0.1	20
Lead, Dissolved µg/L	--	--	--	-	12	<3	5	5	1	<1	1	20
Manganese, Dissolved µg/L	--	--	--	-	<10	<10	<10	5	30	<10	17	20
Nitrogen, Ammonia µg/L	39	5	16	4	15	7	10	5	39	<5	12	21
Nitrite/Nitrate mg/L	0.05	<0.02	0.04	9	0.12	0.02	0.05	4	0.06	0.02	0.042	11
Organic mg/L	0.15	0.10	0.13	4	0.23	0.01	0.084	10	0.23	<0.01	0.08	28
Total mg/L	0.25	0.04	0.15	4	--	--	--		0.16	0.08	0.118	5
Oxygen, Dissolved mg/L	12.6	12.6	12.6	1	12.2	9.4	10.5	9	12.6	8.3	10.4	17
pH pH Units	8.6	8.3	8.3	16	8.3	7.8	8.0	10	8.4	7.9	8.1	28
Phosphorus, Dissolved µg/L	<3	<3	<3	4	3	<3	3	5	<3	<3	<3	28
Total µg/L	17	5	8.3	16	31	4	10	9	15	3	7.5	28
Solids, Dissolved mg/L	196	114	155	14	196	102	142	10	230	126	178	23
Suspended mg/L	7	4	5.5	2	9	9	9	1	9	3	6	2
Temperature °C	15	0	6.8	14	13	1	6.7	9	13	1	6.7	22
Turbidity N.T.U.	8.4	1.4	3.5	4	10	1.8	4.4	5	5.4	1.1	2.9	7
Zinc, Dissolved µg/L	--	--	--		40	<5	17	5	10	<5	5.2	20

Data are from Ministry of Environment's Data Bank, EQUIS.
N = number of values.

TABLE 18
WATER LICENCES ON WINDERMERE CREEK

PRIORITY DATE	LICENCE NUMBER	POINT OF DIVERSION	LICENCE VOLUME	USE	LICENCE DESCRIPTION	LICENCEE
1883.09.19	F 18134	E	3.2 dam^3	IRR	2.58 AC OF BLK 58 OF L 8 KOOTENAY DIST PLAN 1080	CROSSMAN JOHN W
1883.09.19	F 18135	E	1.2 dam^3	IRR	0.40 AC OF U 12-15 of BLK OF L 8 KOOTENAY DIST PLAN 686	SMITH FRANK F & PHYLLIS K
1883.09.19	F 18136	E	58.6 dam^3	IRR	19.01 AC OF BLK 53,59,60,61,66,67 & PART OF BLK 69 OF L 8 KOOTENAY DIST PLAN 1080 LYING SW OF KOOT-COL HWY	TAYLOR JOSEPH E
1883.09.19	F 18140	E F	20.7 dam^3	IRR	6.72 AC OF BLK 39,51,52 OF L 8 KOOTENAY DIST PLAN 1080	ANDERSON CHARLES D
1881.09.19	F 18143	E	6.1 dam^3	IRR	1.98 AC OF BLK 55 OF L 8 KOOTENAY DIST PLAN 1080	MILLER TED & PATSY
1883.09.19	D 18144	E	5.6 dam^3	IRR	1.81 AC OF THAT PART OF BLK 65 OF L 8 KOOTENAY DIST PLAN 1080 EXC KOOT-COL HWY R/W	LESCANEC MIRKO & DOROTHY
1883.04.09	C 39257	D	26.8 dam^3	IRR	8.7 AC OF THAT PART OF L 19 KOOTENAY DIST EXC PLAN 263021 EXC PLAN 5506	HANEN INVESTMENTS LTD
1883.04.09	C 39259	D	4.0 dam^3	IRR	1.3 AC OF THAT PART OF L 19 KOOTENAY DIST EXC PLAN 263021 INCLUDED ON PLAN 5506	WHETHAM DONALD O & AUDREY O
1883.04.09	C 39260	A	2.9 dam^3	IRR	1.5 AC OF THAT PART OF PCL 1 REF PLAN 65821 OF L 19 KOOTENAY DIST INCLUDED IN PLAN 5506	WETHAN DONALD O & AUDREY O
1883.04.09	C 52954	A	126 dam^3	IRR	65.0 AC L B OF L 19,4596,4619, 7154 KOOTENAY DIST PLAN 6208 EXC PLAN 9359	RAVEN HERMAN E & ANNE M
1883.04.09	C 52955	A	6.8 dam^3	IRR	3.5 AC L 1 OF L 19,4596, 7154 KOOTENAY DIST PLAN 9359	PETERSON MICHAEL & GRETCHEN
1883.04.09	F 44499	C	4.6 dam^3	IRR	1.5 AC OF L 19 KOOTENAY DIST EXC REF PLAN 65821 & PLAN 4997	HANEN INVESTMENTS LTD
1883.09.19	F 18145	E	4.4 dam^3	IRR	1.44 AC OF L A OF L 8 KOOTENAY DIST PLAN 6573	HIDDEN VALLEY DEVELOP-MENTS LTD.

TABLE 18 (Continued)
WATER LICENCES ON WINDERMERE CREEK

PRIORITY DATE	LICENCE NUMBER	POINT OF DIVERSION	LICENCE VOLUME	USE	LICENCE DESCRIPTION	LICENCEE
1883.09.19	F 18152	E	8.4 dam^3	IRR	2.73 AC OF BLK 28 & 29 OF L 8 KOOTENAY DIST PLAN 1080	SCHOOL DISTRICT NO 04 WINDERMERE
1883.09.19	F 18158	F	26.5 dam^3	IRR	8.58 AC OF BLK 36,37,38 & PART OF BLK 35 LYING S OF LINE PARALLEL TO & 93 FT FROM SLY BDY OF BLK 35 OF L 8 KOOTENAY DIST PLAN 1080	ANDERSON CHARLES D
1883.10.31	C 39764	D	2.3 m^3/d	DOM IRR	200.8 AC OF BLK B & C OF L 108 KOOTENAY DIST PLAN 1386	HANEN INVESTMENTS LTD
1886.05.15	C 55054	C	74 dam^3	IRR	24 AC OF L 1093 KOOTENAY DIST EXC REF PLAN 1026811 & PLAN 2828, 6442,7131,11986	DELESALLE PHILLIPPE E SWANSEA RANCH
1886.05.15	C 55055	C	277 dam^3	IRR	90 AC OF SL 35 of L 4596 KOOTENAY DIST PLAN X32 & U A OF L 2846 & 1093 KOOTENAY DIST PLAN 11986	MAURER E FRITZ & SHIRLEY E
1890.09.12	C 32730	C	7.4 dam^3	IRR	2.4 AC OF L 2 OF L 218 KOOTENAY DIST PLAN 4997 LYING SW OF RD	REID WILLIAM E & PHYLLIS K
1890.09.12	F 44309	C	82 dam^3	IRR	26.6 AC OF L 218 KOOTENAY DIST EXC PLAN 4997 REF PLAN 928251 EXP PLAN 263021	HANEN INVESTMENTS LTD
1895.03.04	F 03996	C	2.3 m^3/d 154 dam^3	DOM IRR	50 AC OF L 2561 KOOTENAY DIST	DELESALLE PHILIPPE
1896.09.23	F 09093	A	9.1 m^3/d 410 dam^3	DOM IRR	133 AC OF N PART OF LOWER COLUMBIA LK IR KOOTENAY DIST	INDIAN AGENCY-COLUMBIA LAKE BAND
1900.10.08	C 39761	B	2.3 m^3/d 215 dam^3	DOM IRR	70 AC OF L 7155 KOOTENAY DIST	HANEN INVESTMENTS LTD
1908.09.01	C 55056	C	111 dam^3	IRR	36 AC OF L 1093 KOOTENAY DIST EXC REF PLAN 1026811 & PLAN 2828,6442 7131,11986	DELESALLE PHILLIPE E SWANSEA RANCH
1883.04.09	C 32479	C	1.25 AF 1.5 dam^3	IRR	0.5 AC OF L 1 & 2 OF L 19 KOOTENAY DIST PLAN 4997	REID WILLIAM E & PHYLLIS K
1909.02.13	C 42244	D	120 dam^3	IRR	39 AC OF L 41 KOOTENAY DIST EXP PLAN 263021	HANEN INVESTMENTS LTD

TABLE 18 (Continued)
WATER LICENCES ON WINDERMERE CREEK

PRIORITY DATE	LICENCE NUMBER	POINT OF DIVERSION	LICENCE VOLUME	USE	LICENCE DESCRIPTION	LICENCEE
1911.06.02	C 39762	B	21.6 dam^3	IRR	7 AC OF SL 2 OF L 4596 KOOTENAY DIST	HANEN INVESTMENTS LTD
1911.07.18	C 38878	A	7.7 dam^3	IRR	2.5 AC OF L 7154 KOOTENAY DIST EXC PLAN 5506 & 6208	HARRIS ROBERT B
1911.07.18	C 38879	A	4.6 dam^3	IRR	PART OF L 1 PLAN 5506 LYING IN L 7154 KOOTENAY DIST	WETHAM DONALD O & AUDREY O
1950.04.18	C56992	D	2.3 m^3/d 45 dam^3	DOM IRR	14.70 AC OF L A OF L 108 KOOTENAY DIST PLAN 1386 EXC R PLAN 102682-I & HWY 93 & 95 (PLAN 289)	WENGER SEPP & JOAN
1956.03.19	F 17116	DD	0.86 dam^3	IRR	0.27 AC OF L 11-13 OF BLK 17 OF L 8 KOOTENAY DIST PLAN 686	CONKLIN RODNEY C
1956.03.19	F 17117	DD	1.9 dam^3	IRR	0.64 AC OF L 14-20 OF BLK 17 PART OF L 8 KOOTENAY DIST PLAN 686	ELDSTROM PATRICK O & HELEN M
1966.12.01	C 33464	WW	308 dam^3	IRR	100 AC PART OF L 2 LYING E OF KOOT-COL HWY(PLN R289) EXC REF PLAN 93841& PLAN 2349; L 775 EXC REF PLAN 570151 & PLAN 4548; L 2562 EXC REF PLAN 570151 ALL KOOTENAY DIST	KIMPTON FRANCES M
1973.08.10	C 49135	L3	2.3 m^3/d	DOM	L 4 of L 8 KOOTENAY DIST PLN 5513	HAM CATHERINE T
1973.08.28	C 49136	A3	2.3 m^3/d	DOM	L 17 oF L 8 KOOTENAY DIST PLAN 5278	NORALINE HOLDINGS LTD IREDALE NORMAN R
1973.09.04	C 49137	YY	2.3 m^3/d	DOM	L 9 of L 8 KOOTENAY DIST PLAN 5513	LLOYD KENNETH W & IRENE L
1974.04.22	C 49138	YY	2.3 m^3/d	DOM	L 3 of L 8 KOOTENAY DIST PLN 5513	BARTEL HENRY
1976.03.01	C 50268	C3	3.0 dam^3	IND	L 91 & 92 OF L 8 KOOTENAY DIST PLAN 1080	DUBOIS WILLIAM D & GEORGINA N
1977.07.22	C 52665	B	37 dam^3	IRR	12 AC OF L 5107 KOOTENAY DIST	TEGART NANCY L

TABLE 19

WINDERMERE CREEK WATER QUALITY, APRIL 1978 TO NOVEMBER 1982

Sampling Site			0200221 Upstream Gypsum Quarry				0200237 Downstream Gypsum Quarry				0200238 3 km Downstream Quarry				0200410 Hwy. Bridge in Windermere			
Parameter	Type of Value		Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N
Calcium	Dissolved	mg/L	121	118	119.5	2	199	140	169.5	2	-	-	-	-	-	-	-	-
Nitrogen	Ammonia	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<5	<5	-	3
	NO_2/NO_3	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.14	0.10	0.12	3
	Organic	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.16	0.06	0.10	3
Solids	Dissolved	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	700	678	691	3
	Suspended	mg/L	2	<1	-	4	6	1	2.8	4	11	3	7	2	-	-	-	-
Phosphorus	Dissolved	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	5	4	4.7	3
	Total	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	14	5	9	3
Sulphate	Dissolved	mg/L	268	244	256	2	459	319	389	2	454	314	384	1	339	318	326	3
Turbidity		NTU	0.3	0.2	0.28	4	1.8	0.4	0.9	4	4.1	1.1	2.6	2	-	-	-	-
pH			8.2	8.1	8.15	4	8.3	8.2	8.28	4	8.3	8.2	8.25	2	8.4	8.2	8.3	3

Data are from Ministry of Environment's data bank, EQUIS

N = number of values

APPENDIX 1*
PHOSPHORUS LOADINGS FROM SEPTIC TANKS

Phosphorus loadings from septic tank sources to Windermere and Columbia Lakes were estimated using several sources of information, certain assumptions, and some literature values.

Initially, a count was made of the number of homes in the 0-50, 50-100 and 100-500 metre distance zones from the lakes. This was done by reference to cultural information on the recently updated 1:50 000 topograhic maps of the area, supplemented by use of aerial photos where necessary. The number of homes on each soil mapping unit (as delineated on 1:50 000 maps) was also determined.

Two basic assumptions were made regarding the homes enumerated as above. First, it was assumed that the homes were permanent (i.e. they are occupied year-round). Second, it was assumed that on average each home has three residents. These assumptions are necessary to allow application of per capita phosphorus loadings for wastewater.

Map and legend information for soils of the area was reviewed. (Pertinent information is summarized in Tables 1 and 5 for Windermere and Columbia Lakes, respectively). Based on this information and considering factors such as type of parent material, soil depth, soil texture, calcareousness, etc., soil associations and soil mapping units were ranked in order of their probable potential for transmitting phosphorus from septic tank drainfields to the lake (rank 1 having the lowest potential). Tables 2 and 6 present the rankings for soil mapping units in the Windermere and Columbia Lake areas, respectively.

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* prepared by J.H. Wiens, Surveys and Resource Mapping Branch, B.C. Ministry of Environment

Based on limited literature information and professional judgement, tables of phosphorus transmission coefficients by rank (soil mapping unit) and distance to the lake were prepared. Tables 3 and 7 present these coefficients for the Windermere Lake and Columbia Lake areas, respectively.

Potential phosphorus loadings were calculated by distance zone and soil mapping unit in two steps. First, the number of homes was multiplied by three, the assumed number of residents per home. Second, the total number of residents was multiplied by 1.46 kg/yr; the selected literature value for per capita phosphorus loading in a typical household wastewater stream. Tables 4 and 8 present both number of homes and potential phosphorus loadings for Windermere and Columbia Lake areas, respectively.

Estimates of actual phosphorus loadings were calculated by applying the appropriate phosphorus transmission coefficients (Tables 3 and 7) to the potential loadings (Tables 4 and 8). Thus, the attenuation of phosphorus passing through soils and surficial deposits is accounted for, albeit in a simplified fashion. Estimates of phosphorus entering the lakes are also presented in Tables 4 and 8. The estimated phosphorus loadings from septic tank systems are 128 and 23 kg/yr for Windermere and Columbia Lakes, respectively.

TABLE 1

SOIL ASSOCIATIONS IN THE WINDERMERE LAKE AREA AND INFORMATION ON SOIL AND PARENT MATERIAL CHARACTERISTICS

SOIL ASSOCIATION	SOIL DEVELOPMENT[1]	LANDFORM & PARENT MATERIAL CHARACTERISTICS	GENERALIZED BEDROCK	CALCAREOUSNESS OF PARENT MATERIAL	COMMENTS
Fireweed	FF_1 CU.R calcareous phase FF_3 CU.R calcareous phase - GL.CUR calcareous phase FF_{10}CU.R calcareous phase - R.G calcareous phase, R.HG calcareous phase FF_{11}R.G calcareous phase, R.HG calcareous phase - CU.R calcareous phase	- deep medium to coarse texture (cl-gls) floodplain deposits	mostly limestone & colomite gravels	strongly calcareous	3200-4000 feet elevation
Kayook	KY_1 O.EB KY_2 O.EB - O.DB, CA.DB, O.MB, drier O.EB KY_4 O.EB - O.GL, BR.GL KY_9 O.EB - O.EB calcareous phase	- fine to medium texture (si-s) aeolian veneer (>30 cm.) over gravelly (gsl-gs) fluvial or morainal deposits	mostly limestone & dolomite gravels	strongly calcareous	2300-3500 feet elevation
Keeney	KE_1 O.EB KE_2 O.EB - O.DB, CA.DB, O.MB, O.EB calcareous phase, drier O.EB KE_3 O. EB - O.DYB, wetter O.EB KE_4 O.EB - BR.GL, O.GL KE_7 O.EB - O.R calcareous phase, O.R calcareous phase,	- deep medium to coarse texture (gsl-gs) fluvial deposits, may have a shallow veneer of sandy (s-si) fluvial or aeolian materials.	mostly limestone, dolomite gravels	strongly calcareous	3100-4300 feet elevation
Mayook	MY_1 O.EB MY_2 O.EB - O.DB, CA.DB, O.EB calcareous phase, drier O.EB MY_4 O.EB - O.GL, BR.GL MY_{10} O.EB - O.DB saline phase	- deep, fine texture (c-fsl) lacustrine deposits	various bedrocks	generally strongly calcareous	2400-3000 feet elevation
Marmalade	MD_1 O.EB MD_2 O.EB - O.DB, CA.DB, O.MB, O.EB calcareous phase, drier O.EB MD_3 O.EB - O.DYB, wetter O.EB MD_4 O.EB - O.GL, BR.GL MD_5 O.EB - O.EB lithic phase MD_7 O.EB - O.R calcareous phase MD_8 O.EB - CU.HR calcareous phase, O.R calcareous phase, O.MB	- deep medium to fine texture (gl-gcl) moraine	mostly limestone & dolomite	strongly calcareous	3000-4500 feet elevation

TABLE 1 (Continued)

SOIL ASSOCIATION	SOIL DEVELOPMENT[1]	LANDFORM & PARENT MATERIAL CHARACTERISTICS	GENERALIZED BEDROCK	CALCAREOUSNESS OF PARENT MATERIAL	COMMENTS
Ryanier	RY_1 O.EB RY_2 O.EB - O.MB, O.DB RY_3 O.EB - O.DYB, O.HFP RY_4 O.EB - BR.GL, O.GL RY_5 O.EB - O.EB lithic phase RY_6 O.EB lithic phase - RO RY_7 O.EB - O.R RY_8 O.EB - CU.R, O.R, O.MB	- shallow medium texture (gl-gsl) colluvium (generally < 1 m)	argillite, siltstone, mudstone	generally non-calcareous	3000-4500 feet elevation
Wycliffe	WY_1 O.EB WY_2 O.EB - O.DB, CA.DB, O.MB, drier O.EB WY_4 O.EB - O.GL, BR.GL WY_5 O.EB - O.EB shallow phase WY_7 O.EB - O.R calcareous phase	- deep medium to fine texture (sl-cl) moraine	limestone, dolomite	strongly calcareous	2300-3500 feet elevation

[1]See Soils Legend for the East Kootenay Map Area for Explanation and Abbreviations

TABLE 2

RANKING OF SOIL MAPPING UNITS IN THE WINDERMERE LAKE AREA ACCORDING TO THEIR ESTIMATED POTENTIAL FOR PHOSPHORUS ABSORPTION

DOMINANT SOIL ASSOCIATION NAME/SYMBOL	MAPPING UNIT	RANK
1. Fireweed	$\frac{FF_3}{BA}$	10
2. Keeney (KE)	$\frac{KE_2}{Ce}$	9
	$\frac{KE_2}{B}$	8
	$KE_4^7-WY_3^3$	6
	$\frac{KE_4^7-MY_1^3}{df}$	7
3. Mayook (MY)	$\frac{MY_1}{de}$	1
	$\frac{MY_2}{Dg}$	2
	$\frac{MY_2}{Eg}$	3
	$\frac{MY_1^7-KE_4^3}{de}$	5
	$\frac{MY_2^6-KY_2^4}{ef}$	4

TABLE 3

ESTIMATED PHOSPHORUS TRANSMISSION COEFFICIENTS FOR MAPPING UNITS IN THE WINDERMERE LAKE AREA

Rank	Distance to the Lake		
	0 - 50 m	50 - 100 m	100 - 500 m
1	0.015	0.010	0.005
2	0.015	0.010	0.005
3	0.025	0.02	0.01
4	0.030	0.025	0.013
5	0.085	0.07	0.035
6	0.15	0.12	0.06
7	0.15	0.12	0.06
8	0.20	0.16	0.08
9	0.20	0.16	0.08
10	0.25	0.20	0.10

TABLE 4
ESTIMATED NUMBER OF HOMES AND ASSOCIATED PHOSPHORUS LOADING TO WINDERMERE LAKE BY SOIL MAPPING UNIT AND DISTANCE

Soil Mapping Unit	Distance to the Lake[1]		
	0 - 50 m	50 - 100 m	100 - 500 m
$\frac{FF_3}{BA}$	2 8.76 2.19	6 26.28 5.26	31 135.75 13.58
$\frac{KE_2}{Ce}$	- - -	- - -	35 153.3 12.26
$\frac{KE_2}{B}$	- - -	- - -	24 105.12 8.41
$\frac{KE_4^7 - WY_3^3}{de}$	24 105.12 15.77	10 45.26 5.43	61 267.18 16.03
$\frac{KE_4^7 - MY_1^3}{df}$	30 131.4 19.71	6 26.28 3.15	- - -
$\frac{MY_1}{de}$	5 21.9 0.33	- - -	3 13.14 0.07
$\frac{MY_2}{Dg}$	- - -	- - -	2 8.76 0.04
$\frac{MY_2}{Eg}$	2 8.76 0.22	3 13.14 0.26	8 35.04 0.35
$\frac{MY_1^7 - KE_4^3}{de}$	22 96.36 8.19	20 87.6 6.13	21 91.98 3.22
$\frac{MY_2^6 - KY_2^4}{ef}$	25 109.5 3.29	20 87.6 2.19	7 30.66 0.40
Totals			
Est. No. of Homes	110	65	192
Est. Potential P Loading	481.80	286.16	840.96
Est. Actual P Loading	49.70	22.42	54.36
Est. Total Actual P Loading		128.48	

[1] First value is estimated number of homes (assumed to be permanent); second value is estimated potential loading (kg/yr) based on per capital loading; third value is estimated actual loading (kg/yr).

TABLE 5
SOIL ASSOCIATIONS IN THE COLUMBIA LAKE AREA AND INFORMATION ON SOIL AND PARENT MATERIAL CHARACTERISTICS

SOIL ASSOCIATION	SOIL DEVELOPMENT[1]	LANDFORM & PARENT MATERIAL CHARACTERISTICS	GENERALIZED BEDROCK	CALCAREOUSNESS OF PARENT MATERIAL	COMMENTS
Colin Creek	COL_1 O.EB COL_2 O.EB - O.DB, O.EB calcareous phase, drier O.EB COL_4 O.EB - O.GL COL_7 O.EB - O.R calcareous phase	- deep medium to coarse texture (gl-gs) colluvium	limestone, dolomite	strongly calcareous	2300-4000 feet elevation
Elko	E_1 O.EB E_2 O.EB - O.DB, CA.DB, O.MB, drier O.EB E_4 O.EB - O.GL, BR.GL E_9 O.EB - O.EB calcareous phase	- fine to medium texture (si-s) aeolian veneer (gsl-gs) fluvial deposits	mostly limestone & dolomite gravels	strongly calcareous	2300-3500 feet elevation
Fishertown	FX_1 O.EB FX_2 O.EB - O.DB, CA.DB, O.MB, drier O.EB FX_9 O.EB - O.EB calcareous phase	- deep medium to coarse texture (gsl-gs) fluvial deposits	mostly limestone & dolomite gravels	strongly calcareous	2300-3500 feet elevation
Flagstone	F_1 O.EB F_2 O.EB - O.DB, CA.DB, O.MB, drier O.EB F_9 O.EB - O.EB calcareous phase	- deep sandy (fsl-s) fluvial deposits	calcareous sands	strongly calcareous	2300-3500 feet elevation
Glen Cairn	GN_1 O.EBB GN_2 O.EB - O.MB, O.DB GN_3 O.EB - O.DYB, O.HFP GN_4 O.EB - BR.GL, O.GL GN_{10}O.EB - CU.R, GLCU.R	- deep gravelly (gsl-gs) fluvial deposits	various bedrocks	generally noncalcareous	3000-4500 feet elevation
Kayook	KY_1 O.EB KY_2 O.EB - O.DB, CA.DB, O.MB, drier O.EB KY_4 O.EB - O.GL, Br.GL KY_9 O.EB - O.EB calcareous phase	- fine to medium texture (si-s) aeolian veneer (>30 cm.) over gravelly (gsl-g) fluvial or morainal deposits	mostly limestone & dolomite gravels	strongly calcareous	2300-3500 feet elevation
Lakit	L_1 O.EB L_2 O.EB - O.DB, CA.DB L_3 O.EB - O.DYB L_{10}O.EB - GLCU.R, CU.R L_{11}R.G, R.HG - O.EB	- moderately to fine texture (s-si) veneer (<30 cm.) over gravelly (gsl-gs) lower terraces and floodplains	mostly medium to coarse grained, non-calcareous gravels	non to weakly calcareous	- mapped on the E. flanks of the Purcells only 2500-2800 feet elevation

TABLE 5 (Continued)

SOIL ASSOCIATIONS IN THE COLUMBIA LAKE AREA AND INFORMATION ON SOIL AND PARENT MATERIAL CHARACTERISTICS

SOIL ASSOCIATION	SOIL DEVELOPMENT[1]	LANDFORM & PARENT MATERIAL CHARACTERISTICS	GENERALIZED BEDROCK	CALCAREOUSNESS OF PARENT MATERIAL	COMMENTS
Mayook	M_1 O.EB M_2 O.EB - O.DB, CA.DB, O.EB calcareous phase, drier O.EB M_4 O.EB - O.GL, BR.GL M_{10}O.EB - O.DB saline phase	- deep fine texture (c-fsl) <u>lacustrine</u> deposits	various bedrooms	generally strongly calcareous	2400-3000 feet elevation
Rockbluff	RB_1 O.EB RB_2 O.EB - O.DB, CA.DB, O.EB calcareous phase, drier O.EB RB_4 O.EB - O.GL RB_5 O.EB - O.EB lithic phase RB_6 O.EB lithic phase - RO RB_7 O.EB - O.R calcareous phase	- shallow medium to coarse texture (gl-gs) <u>colluvium</u>	limestone, dolomite	strongly calcareous	2300-4000 feet elevation
Wycliffe	WY_1 O.EB WY_2 O.EB - O.DB, CA.DB, O.MB, drier O.EB WY_4 O.EB - O.GL, BR.GL WY_5 O.EB - O.EB shallow phase WY_7 O.EB - O.R calcareous phase	- deep medium to fine texture (sl-cl) <u>moraine</u>	limestone, dolomite	strongly calcareous	2300-3500 feet elevation

1 See Soil Legend for the East Kootenay Map Area for Explanation and Abbreviation

TABLE 6

RANKING OF SOIL MAPPING UNITS IN THE COLUMBIA LAKE AREA ACCORDING TO THEIR ESTIMATED POTENTIAL PHOSPHORUS

DOMINANT SOIL ASSOCIATION NAME/SYMBOL	MAPPING UNIT	RANK
1. Colin Creek (COL)	$\frac{COL_7}{EG}$	9
	$\frac{COL_2^6\text{-}FX_9^4}{D}$	8
2. Elko (E)	$\frac{E_2^6\text{-}MY_2^4}{f}$	5
	$\frac{E_9^6\text{-}F_1^4}{fg}$	6
3. Glen Cairn (GN)	$\frac{GN_1^5\text{-}L_{10}^5}{DB}$	7
4. Kayook (KY)	$\frac{KY_{10}}{BC}$	4
5. Mayook (MY)	$\frac{MY_2}{dg}$	2
	$\frac{MY_2^8\text{-}E_2^2}{Eg}$	3
6. Wycliffe (WY)	$\frac{WY_1^8\text{-}FX_1^2}{cd}$	1

TABLE 7

ESTIMATED PHOSPHORUS TRANSMISSION COEFFICIENTS FOR MAPPING UNITS IN THE COLUMBIA LAKE AREA

Rank	Distance to the Lake		
	0 - 50 m	50 - 100 m	100 - 500 m
1	0.015	0.010	0.005
2	0.030	0.025	0.013
3	0.085	0.07	0.035
4	0.085	0.07	0.035
5	0.085	0.07	0.035
6	0.10	0.08	0.04
7	0.20	0.16	0.08
8	0.25	0.20	0.10
9	0.30	0.24	0.12

TABLE 8
ESTIMATED NUMBER OF HOMES AND ASSOCIATED PHOSPHORUS LOADING
TO COLUMBIA LAKE BY SOIL MAPPING UNIT AND DISTANCE

Soil Mapping Unit	Distance to the Lake[1]		
	0 - 50 m	50 - 100 m	100 - 500 m
$\frac{COL_7}{EG}$	-	-	4
	-	-	17.52
	-	-	1.75
$\frac{COL_2^6 - FX_9^4}{D}$	-	-	4
	-	-	17.52
	-	-	1.40
$\frac{E_2^6 - MY_2^4}{f}$	3	2	3
	13.14	8.76	13.14
	1.17	0.61	0.46
$\frac{E_2^6 - F_1^4}{fg}$	-	-	2
	-	-	8.76
	-	-	0.35
$\frac{GN_1^5 - L_{10}^5}{DB}$	-	-	9
	-	-	39.42
	-	-	4.73
$\frac{KY_{10}}{BC}$	7	9	26
	30.66	39.42	113.88
	2.61	2.76	3.99
$\frac{MY_2}{dg}$	3	-	-
	13.14	-	-
	0.20	-	-
$\frac{MY_2^8 - E_2^2}{Eg}$	1	1	13
	4.38	4.38	56.94
	0.37	0.31	1.99
$\frac{WY_1^8 - FX_1^2}{cd}$	-	-	1
	-	-	4.38
	-	-	0.057
Totals			
Est. No. of Homes	14	12	62
Est. Potential P Loading	61.32	52.56	271.56
Est. Actual P Loading	4.35	3.68	14.72
Est. Total Actual P Loading		22.76	

[1] First value is estimated number of homes (assumed to be permanent); second value is estimated potential loading (kg/yr) based on per capita loadings; third value is estimated actual loading (kg/yr).

APPENDIX 2

POPULATION PROJECTIONS FOR THE NORTH END OF WINDERMERE LAKE

Study Area Boundary

The settlement planning area covered by the North End of Windermere Lake Official Settlement Plan, excluding the Wilmer sub-area. This leaves the area east of Windermere Lake between the Columbia and Shuswap Indian reserves (Figure 1).

High, Moderate and Low Growth Scenarios

Three growth scenarios are presented for future population in the area. The moderate and high growth scenarios are those found in the official settlement plan, excluding the resident population of Wilmer. No adjustment was made to non-resident population estimates, since the current and projected non-resident component of Wilmer's population is considered to be minor relative to the total non-resident population for the study area (Tony Quin, pers. comm.)

The low growth scenario is based on MOE's resident population projection for the immediate and surrounding area, and a lower non-resident growth rate compared to the high or moderate growth projections in the official settlement plan (OSP).

Population projections and supporting notes from the OSP are shown in Table 1. Table 2 shows the adjusted moderate and high growth projections, and the low growth projection with supporting calculations.

Interpretation of Projections

The three population projections give some indication of the range of future scenarios which could occur in the study area, given the assumptions noted. The high growth scenario reflects continued rapid expansion of the tourism industry at the same rate as occurred in the 1976-1981 period.

Given recent trends, it seems unlikely that this rate of expansion will continue. The moderate growth scenario takes account of longer-term economic slowdown but still projects a doubling of the non-resident population by 1991. This may not be unrealistic if development pressures from within the study area continue. The low growth scenario projects a 40% increase in non-resident population by 1991 which may occur if the recent economic trend continues.

All projections should be treated with caution as any major new development or expansion of an existing industry could significantly change population projections. Additional uncertainty stems from the fact that the major source of difference among the three scenarios comes from the non-resident component for which estimation of even current populaton can prove to be difficult. Future population growth of non-residents will directly depend on general economic conditions and available services both within and outside the study area.

(i) High Growth Scenario

Year	Residents	Non-Residents[4]	Total
1976	820[1]	1 204	2 024
1981	902[2]	2 410	3 312
1986	992[3]	4 826	5 818
1991	1 091[3]	9 665	10 756

Notes:

1. 1020 - 200 (1976 population of Wilmer).
2. 2% growth rate per year ffrom 1976-1981 assumed, as in the North End of Windermere Lake Official Settlement Plan.

   Census data for 1981 indicates that Wilmer grew at a significantly faster rate than Windermere so that a 2% growth rate for the study area may be slightly high. The 2% growth rate is still used since the population for the study area is not readily available from 1981 census results, and a lower growth rate for the resident population will have an insignifiant impact on total future projections.
3. 4% growth rate per year from 1986-1991 assumed, as in the OSP.
4. Taken directly from the OSP.

(ii) Moderate Growth Scenario

Year	Residents	Non-Residents[4]	Total
1976	820[1]	1 204	2 024
1981	902[2]	2 409	3 311
1986	929[5]	3 614	4 543
1991	957[5]	4 819	5 776

Notes:
5. 3% growth rate per year assumed, as in the OSP.

(iii) Low Growth Scenario

Year	Residents	Non-Residents	Total
1976	820[1]	1 204[4]	2 024
1981	902[2]	2 409[4]	3 311
1986	923[6]	3 011[8]	3 934
1991	950[7]	3 387[9]	4 337

Notes:
6. 2.3% growth rate per year from 1981-1986 assumed.
7. 2.9% growth rate per year from 1986-1991 assumed.
8. 5% growth rate per year from 1981-1986 assumed, representing 50% of the moderate growth rate which is in turn 50% of the high growth rate.
9. 2.5% growth rate per year from 1981-1986 assumed, representing 35% of the moderate growth rate which in turn is 35% of the high growth rate.