Lake Desire Management Plan

April 1995

King County Surface Water Management
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Washington State Department of Ecology

KCM

Lake Desire
Management Plan

Final Plan

Grant No. TAX 91113

April 1995

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Lake Desire Management Plan
TABLE OF CONTENTS

Title | *Page No.*

LIST OF TABLES

No. *Title* *Page No.*

LIST OF FIGURES

EXECUTIVE SUMMARY

CONDITIONS SUMMARY

Lake Desire is located approximately 5 miles northwest of the Maple Valley area, Washington, in Metropolitan King County Council District Twelve. Access to the lake is via Petrovitsky Road which passes to the south of the lake. West Lake Desire Road, a minor road branching off of Petrovitsky Road, provides access to the public boat launch located on the northern shore of the lake.

Lake Desire is 80 acres in size, has a mean depth of 13 feet, maximum depth of 25 feet, and total lake volume of 921 acre-feet. The watershed encompasses 831 acres in southeastern King County.

Lake Desire is a very biologically productive or eutrophic lake characterized by frequent and intense algal blooms in the spring and fall which degrade the lake for recreational uses including swimming, boating, and fishing. The aesthetic appeal normally associated with the lake also dramatically decreases during the bloom periods. Existing water quality and associated lake productivity is unacceptable to the majority of residents who live on the lake and to many people from surrounding urban areas who utilize the lake for recreational purposes.

Based on the "historical" water quality data, the lake system has been characterized as a productive system since the early 1970's (Chapter 4). Examination of the sediment phosphorus profiles (Chapter 4) suggests that productivity in Lake Desire has increased recently (within the past 60 years). Two major watershed scale changes have occurred during this time period which may account for this shift in lake productivity. These watershed changes include: 1) the logging of the watershed and the beginning of shoreline development in the 1930's and 2) the beginning of peat excavation in Cedar River Wetland 14 in the 1960's.

For the study period (April 1993-April 1994), average in-lake epilimnetic total phosphorus (TP) concentration was 42 mg/L while summer epilimnetic concentrations averaged 34 mg/L. Summer chlorophyll *a* values averaged 15 mg/L with an annual Secchi depth of 2 meters. Peak chlorophyll *a* values of 44 mg/L and 63 mg/L were recorded in June, 1993 and April, 1994. A fall peak in chlorophyll *a* was not observed during the study year (most likely due to the unusually cool, wet summer of 1993) but has been documented for previous years (Metro, 1994).

Mesotrophic lakes or lakes of medium productivity, such as Lake Washington, have average total phosphorus concentrations of 10-20 mg/L, average chlorophyll *a* values of 4-10 mg/L, and Secchi depth values of 2-4 meters or greater. Lake Desire values for these parameters are indicative of a lake with a greater level of lake productivity.

The lake had low oxygen in the bottom waters (hypolimnetic oxygen depletion) and high surface water temperatures typical of a eutrophic lake. This restricted cold water fish habitat to the oxygenated, but warmer upper or epilimnetic waters for the summer months. In spite of this limitation of cold water habitat, the lake's fishery was generally healthy, with a mixed assemblage of warm-water fish species including bass and yellow perch. The microscopic plant and animal (planktonic) community included species typical of eutrophic lakes. The plant or phytoplankton community was dominated by the blue-green alga, *Aphanizomenon flos-aquae* while the animal or zooplankton community was comprised largely of rotifers.

Existing land use in the watershed is composed primarily of forested (49 percent) and low density residential uses (29 percent); the remaining land is classified as wetlands, streams, or lake. Phosphorus export from surface and subsurface flows associated with existing land use accounted for 58 percent (72 kg/year) of the current phosphorus loading to the lake. Internal phosphorus loading and precipitation accounted for 35 percent (43 kg TP per year) and 7 percent (9 kg TP per year), respectively, of the remaining annual phosphorus load to the lake under current conditions.

Because of Lake Desire's inclusion within the Urban Growth Boundary, much of the watershed immediately surrounding the lake is slated for urbanization. If the future land use zoning is realized, 63 percent of the watershed area will be developed for residential uses. Rural land use, in turn, will be reduced to 15 percent forest, 7 percent grass. The remaining watershed area will stay as wetland, stream or lake uses. For this modeled future scenario, external or watershed loading increased to 172 kg/year or 62 percent of the total while internal loading increased to 105 kg/year or 38 percent of the total phosphorus load.

MANAGEMENT APPROACH

It is unlikely that watershed loading levels can be restored to pre-logged conditions or prior to the peat excavation of Cedar River Wetland 14. However, a reasonable long-term management goal is to maintain lake productivity at a level between historical and existing trophic conditions. By focusing on maximizing external loading reductions in the watershed and minimizing existing internal loading and subsequent future increases in internal loading, the long-term management goal of improved trophic conditions can be achieved.

The management approach for the restoration of Lake Desire, then, is designed to address both watershed and in-lake sources of nutrients which contribute to the existing water quality problems. Restoration of Lake Desire will require a long-term commitment to reducing future watershed nutrient loading through source control best management practices, restoration of watershed wetlands, restoration of the existing wetland shoreline, retrofitting of existing stormwater facilities for pollutant removal, and the removal and management of non-native aquatic plants. In the near-term, in-lake water quality is proposed to be addressed using a combination of a buffered alum treatment and an in-lake aeration system to reduce internal nutrient cycling in the lake which contributes to eutrophic lake water quality. Watershed measures, which in the short-term, are not likely to result in an immediate improvement of lake water quality are nonetheless essential to reduce future watershed loading which would otherwise exacerbate current lake water quality conditions and reduce the effectiveness of in-lake measures under future conditions.

LAKE AND WATERSHED MANAGEMENT GOALS

Lake and watershed management goals were established by the Lake Desire community and were used in the restoration alternatives analysis and in the development of the subsequent management plan recommendations. The eight management plan goals are as follows:

- Improve Water Quality and Lake Trophic Status;
- Restore Watershed Wetlands;
- Protect Human Health;
- Protect Property Values;
- Maintain a Healthy Lake Fishery Habitat;
- Control Invasive, Nonnative Aquatic Plants;

- Educate and Involve Watershed Residents in Lake Restoration and Protection; and
- Work More Effectively with Government to Improve and Protect Lake Water Quality.

Improving lake water quality is the primary management goal for the lake. If lake water quality is improved, many of the remaining management goals, including protection of human health, lake property values, and the lake fisheries will also be met. Through in-lake aeration of the lake hypolimnion (LD-9) and the implementation of watershed measures, internal lake phosphorus loading should be reduced resulting in less frequent and severe algal blooms and improved lake water quality. Improving lake water quality will also reduce water quality related dermatitis and the risk of blue-green toxic algal bloom occurrence, thereby improving human health protection. Improved lake water quality resulting in swimmable, fishable, and boatable waters will also protect existing and future property values. In-lake aeration will also benefit the lake fisheries and general aquatic habitat by expanding the oxygenated area of the lake to include the currently oxygen depleted lake hypolimnion.

The remaining management goals of restoring watershed wetlands, controlling invasive nonnative aquatic plants, and education and involvement of the watershed residents are designed to be accomplished through the remaining management plan recommendations. To achieve these lake management plan goals, an effective working relationship with government and watershed residents will be needed. Without a combined long-term commitment and investment by watershed residents and government, the goal of improving lake water quality will likely remain unmet for Lake Desire.

RECOMMENDATIONS

The 14 recommendations for the lake management plan (Table ES-1) are divided into four groups: 1) watershed measures; 2) in-lake measures; 3) aquatic plant management; and 4) monitoring. Watershed recommendations address forest retention, wetland restoration, shoreline revegetation, stormwater treatment, ditch maintenance, homeowner source control best management practices, and sewers, and are designed to reduce existing and future external pollutant loading to the lake from watershed sources. Implementation of watershed measures is essential to the long-term restoration of Lake Desire water quality. In-lake restoration measures including buffered alum treatment and in-lake aeration will provide short-term lake water quality improvement. It is important to note, however, that long-term gains from in-lake measures will not be maintained unless watershed measures are successfully implemented.

PLAN IMPLEMENTATION

Management plan implementation is contingent on a variety of items including: (1) the availability of both public and private funding; (2) the successful award of public funding; and (3) the successful formation of a Lake Management District (LMD). A Washington State Department of Ecology Centennial Clean Water Fund grant application was submitted in February, 1995, for Phase II implementation of the *Lake Desire Management Plan*. Listed below is a preliminary schedule for management plan implementation which assumes that successful grant award will occur in 1995 and private-sector funding/LMD formation will be pursued for matching the CCWF grant revenues.

• Apply for CCWF Grant Funding	February 1995
• Final Management Plan	April 1995
• Transmittal of Management Plan to Metropolitan King County Council	May 1995
• Initiate Lake Management District (LMD)	July 1995
• Initiate Implementation	January 1996
• Complete LMD Formation	September 1996

Table ES-1: Lake and Watershed Recommendations

No.	Recommendations	Lead Implementor(s)[a]	Cost
	Watershed Measures		
LD-1	Subcatchment P-7 Forest Retention	King County	EP[b]
LD-2	Wetland Restoration	KCSWM	EP[b]
LD-3	Shoreline Wetland Revegetation	KCSWM/LDCC	$4,000
LD-4	Stormwater Treatment	King County	EP[b]
LD-5	Ditch Maintenance	Roads/KCSWM	EP[b]
LD-6	Homeowner BMPs	LDCC/KCSWM/SKCDPH	$3,000
LD-7	Sewering	SCWSD/LDCC	EC[c]
	In-Lake Measures		
LD-8	Buffered Alum Treatment	LDCC/KCSWM	$92,000
LD-9	Aeration (design and engineering)	LDCC/KCSWM	$100,000
	Aeration (SEPA)		$50,000
	Aeration (construction)		$340,000
	ongoing O/M $17,500/year[d]		
	Aquatic Plant Management		
LD-10	Milfoil Removal	LDCC/KCSWM	$20,000
LD-11	Purple Loosestrife Removal	LDCC/KCSWM	$5,000
LD-12	Lake Access through Hand Pulling	LDCC/KCSWM	EP[b]
	Monitoring		
LD-13	Lake, Fishery, and Watershed Monitoring	LDCC/KCSWM/WSDFW/ MIT	$70,000[d]
LD-14	Wetland Monitoring	KCSWM	$5,000
		Total	$689,000
		Total with 5-year O/M	$796,000[d]

[a]*KCSWM-King County Surface Water Management; LDCC-Lake Desire Community Club; MIT-Muckleshoot Indian Tribe; Roads-King County Roads Division; SKCDPH-Seattle King County Department of Public Health; SCWSD-Soos Creek Water and Sewer District; and WSDFW-Washington State Department of Fish and Wildlife.*

[b] *EP-existing programs are expected to cover costs.*

[c] *EC-the estimated cost for sewering lake properties is two million dollars but has not been included here.*

[d] *Four percent inflation factor assumed for O/M and monitoring costs.*

CHAPTER 1: INTRODUCTION

This document presents the findings of a Phase I lake diagnostic/restoration analysis performed for Lake Desire. Phase I lake projects typically focus on identifying the sources and causal effects of eutrophic lake water quality from which corrective management action to restore lake water quality are developed. The project was initiated in response to the decline of lake water quality as evident by the presence of severe blue-green algal blooms in Lake Desire during the spring and fall. The project commenced in April 1993 with the initiation of a one-year detailed limnological assessment of the lake and surrounding watershed. The management plan was developed for the lake during 1994 and was finalized in April 1995.

The project was funded through a Washington State Department of Ecology (WSDOE) Centennial Clean Water Fund grant with local grant match provided by the King County Department of Public Works, Surface Water Management Division and Department of Metropolitan Services (DMS), Environmental Laboratory Division. In-kind services to the project (including lake level monitoring, precipitation monitoring, groundwater monitoring, fisheries survey, boat use, and property access) were provided by the residents of Lake Desire.

BACKGROUND

Lake Location

Lake Desire is located in the Cedar River Basin approximately 5 miles northwest of Maple Valley (Figure 1-1). The lake is 80 acres in size with a watershed area of 831 acres. Access to the lake is via Petrovitsky Road, which passes to the south of the lake. Petrovitsky Road connects with 140th Way SE, a major roadway extending south from Highway 169 approximately 2 miles east of Interstate 405. West Lake Desire Road, a minor road branching off of Petrovitsky Road, provides access to the Washington State Department of Fish and Wildlife operated public boat launch, located on the northern shore of the lake, and the 400 acre open space tract along the southeastern side of the lake.

Lake Eutrophication

Lakes have been classically categorized and compared according to the level of biological productivity or trophic status. Lakes which are nutrient-poor and biologically unproductive are classified as oligotrophic. Washington's alpine lakes are classic examples of oligotrophic lakes. Lakes which are nutrient-rich and very biologically productive are called eutrophic. Lakes which exhibit characteristics between these two classes are called mesotrophic. Most of the lakes in King County are mesotrophic or eutrophic. Lake Desire and Cottage Lake (a 63-acre lake in the Bear Creek basin) are two examples of eutrophic lakes. Both have nutrient-rich waters and have frequent algal blooms. Lake Sammamish and Lake Washington are examples of mesotrophic lakes.

A lake's natural level of productivity is determined by a combination of factors including the watershed geology and size, lake depth, climate, and water sources entering and leaving the lake. Indeed, lakes may be naturally eutrophic based on their inherent character.

Increases in a lake's biological productivity over time or eutrophication is a process which occurs naturally in some lakes and may be accelerated in others by cultural factors. For many small lakes,

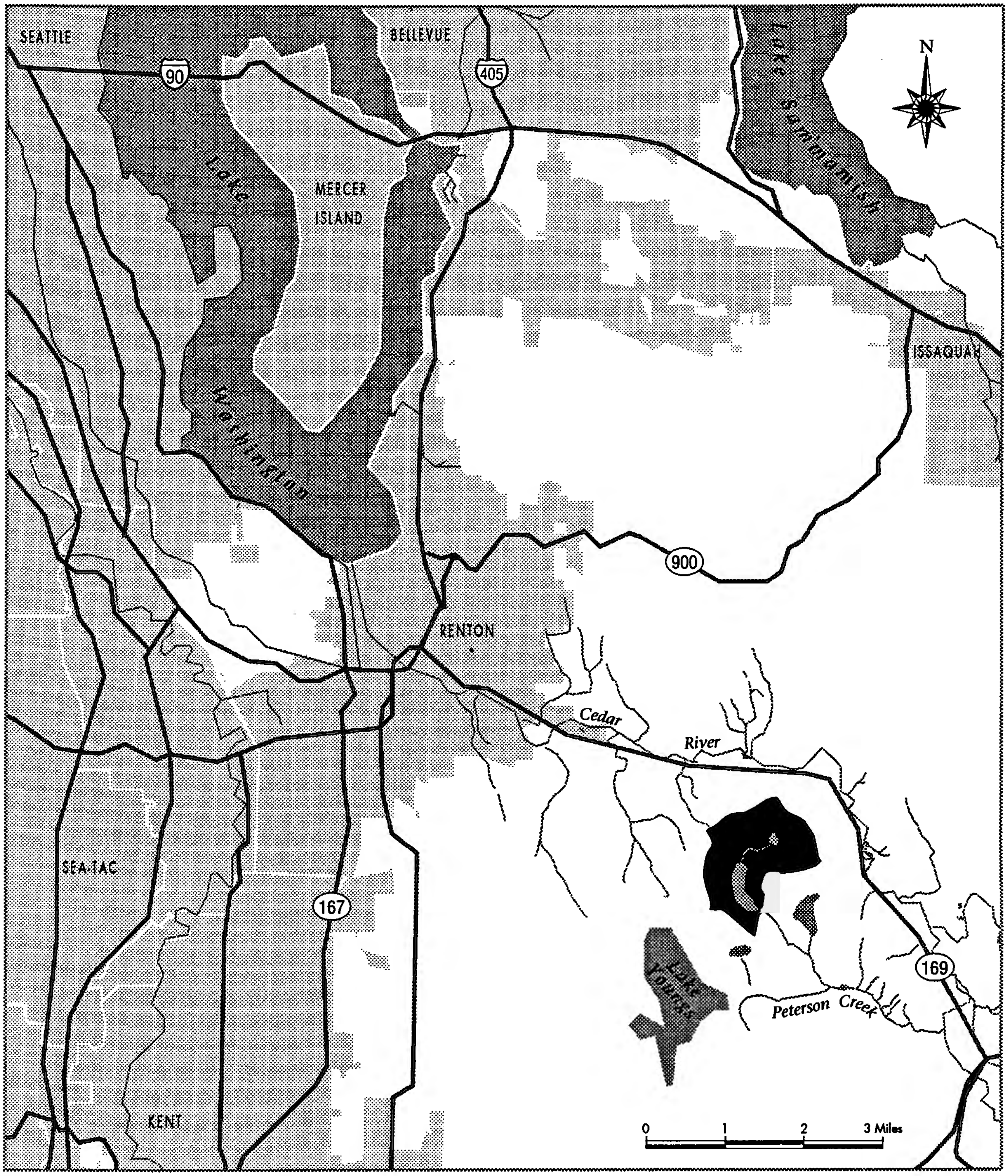

Figure 1-1: Lake Desire Watershed Location Map

Incorporated Area

Watershed Area

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natural eutrophication typically occurs on the time scale of hundreds to thousands of years and is not observable in a single lifetime. What we do witness in a single lifetime, however, is the human-induced or cultural eutrophication of lakes. Our land-based activities, including home-building, agriculture, forestry, resource extraction, landscaping, gardening, and animal-keeping, all contribute nutrients and sediment to surface waters which, in turn, contribute to increased lake productivity.

Increasing lake productivity levels and lake age are usually simply linked in the discussion of lakes; however, this usually represents an oversimplification of the eutrophication process. For example, many "old" lakes are oligotrophic and many "young" lakes can be "eutrophic." Both the alpine lakes of the Cascades and the Puget Sound lowland lakes are the same in age yet their productivity levels are very different. Both lake types are relatively old in the history of the region yet the alpine lakes remain unproductive. This is in part due to the difference in climate and geology for these lakes. On the other hand, reservoirs or other created lakes usually start in the mesotrophic or eutrophic range of lake productivity.

Frequency of algal blooms is often used as an indicator of lake trophic status and corresponding levels of nutrients in a lake system. Depending upon the timing, frequency, and duration of the algal blooms, the use of the lake for swimming, fishing, boating, and other uses may be severely restricted. Other water quality problems related to eutrophic conditions, including low dissolved oxygen levels, fish kills, algal toxicity, and excessive aquatic macrophyte or plant growth, may also threaten beneficial uses of a lake.

Typically, lake restoration involves reducing the cultural impacts to lake water quality, with the goal of decreasing biological productivity and improving water quality. A variety of tools, including in-lake and watershed restoration techniques, are used frequently to accomplish this goal.

Lake Desire Water Quality

Lake Desire has been extensively monitored by the King County DMS for the past 20 years. During this time, Lake Desire has been characterized by low summer water transparency, high nutrient levels, frequent algal blooms, and moderate shoreline aquatic plant growth including the nonnative, invasive species Eurasian watermilfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria*). The nutrient-rich water quality and associated biological productivity of Lake Desire reduces the beneficial uses of the lake including boating, fishing, swimming, aesthetic value, and possibly fish and wildlife habitat.

PROJECT OBJECTIVES

The purpose of this project was to develop a lake management plan for Lake Desire based on the Phase I lake restoration study process. As part of this process, education and involvement of the public is essential to meeting the project goals of improving current water quality and reducing future watershed impacts. In order to successfully complete this project, the following five project objectives were defined:

- Provide education and involvement opportunities for the public throughout the project to foster public ownership and commitment to the development and implementation of the lake management plan;
- Quantify and characterize the physical, chemical, and biological components of the lake and its surrounding watershed;

- Develop a nutrient and water budget which can be used as an analytical tool for the evaluation of restoration alternatives and development of a lake management plan;
- Identify existing sources of point and nonpoint pollution to estimate their importance in determining the trophic condition of Lake Desire; and
- Develop a comprehensive management plan for the improvement and protection of water quality in Lake Desire.

PROJECT MANAGEMENT

The project was managed by the King County Department of Public Works, SWM Division. Project tasks and associated activities were carried out by SWM staff with the assistance of KCM, Inc., the project consultant, and by members of the Lake Desire Community.

A technical advisory committee was formed which included representatives from Washington State Departments of Ecology and Fish and Wildlife; King County Parks, Surface Water Management, and Water Pollution Control Divisions; Soos Creek Water and Sewer District; Lake Desire Community Club; and major watershed landowners. The committee met throughout the project and participated in the development of the lake management plan.

UNITS

The units used throughout the report are based on the International System of Units (the SI, or metric, system) which is standard for most scientific work. The exceptions to the use of these units are found in Chapters 1 and 2 under the lake location description where English units were used. Also, in Chapter 2, the physical characteristics of the lake and watershed are reported in both metric and English units for reader convenience. Throughout the remainder of the document, metric values are consistently reported. A conversion table between the two systems is provided in Appendix A.

GLOSSARY AND ACRONYMS

For the preparation of this plan many terms specific to the study of lakes and watersheds were used in the development of this report. A glossary of these terms has been included in Appendix A for reader use. Acronyms were also used for the preparation of this plan and are defined in Appendix A as well.

CHAPTER 2: STUDY AREA DESCRIPTION

Background information on Lake Desire and its watershed was collected and assembled by the King County SWM Division. All reference materials which were developed for this project and used to develop this chapter and portions of the management plan were published in the Lake Desire Background and Technical Reports (King County, 1994a).

LAKE AND WATERSHED DESCRIPTION

Lake Desire is located approximately 5 miles northwest of the Maple Valley area, Washington (Figure 1-1). Access to the lake is via Petrovitsky Road which passes to the south of the lake. West Lake Desire Road, a minor road branching off of Petrovitsky Road, provides access to the public boat launch located on the northern shore of the lake.

A lake's physical characteristics including size, mean depth, basin shape, and watershed geology influences how a lake will respond to alterations of the watershed and the corresponding changes in the lake's annual water and nutrient budget. Lake Desire is 80 acres in size, has a mean depth of 13 feet, maximum depth of 25 feet, and volume of 921 acre-feet. The watershed encompasses 831 acres in southeastern King County (Figure 2-1). Other physical characteristics of Lake Desire and its watershed are summarized in Table 2-1.

Table 2-1: Physical Characteristics of Lake Desire and Its Watershed

Characteristic	English	Units	Metric	Units
Watershed Area	831	acres	335	hectares
Surface Area	80	acres	32	hectares
Lake Altitude	490	feet	149	meters
Maximum Depth	25	feet	7.5	meters
Mean Depth	13	feet	4	meters
Lake Volume	921	acre-ft	1.14×10^6	cubic meters
Hypolimnetic Volume	120	acre-ft	1.48×10^5	cubic meters
Thermocline Depth	7-13	feet	2-4	meters
Shoreline length	84,480	feet	25,665	meters

Watershed topography ranges from 500 to 860 feet above mean sea level. The majority of the terrain is a mixture of gently sloping forested hills with several moderate sized wetlands in valleys. Immediately east of the lake, a steep hill rises 360 vertical feet in approximately 1000 horizontal feet. The King County Sensitive Areas Map Folio shows this hill slope to be an erosion and landslide hazard area (King County, 1990)

GEOLOGY

The entire east-central Puget Sound Basin Lowland is underlain by volcanic and sedimentary rocks formed during the Eocene, approximately 40 million years ago. These Eocene rocks are overlain regionally by younger glacial till and outwash deposits, locally by younger sedimentary rocks, and intruded locally by younger volcanic dike rocks. The oldest glacial sediments in Lake Desire's watershed were deposited from the Puget lobe of the Cordilleran continental ice sheet which advanced

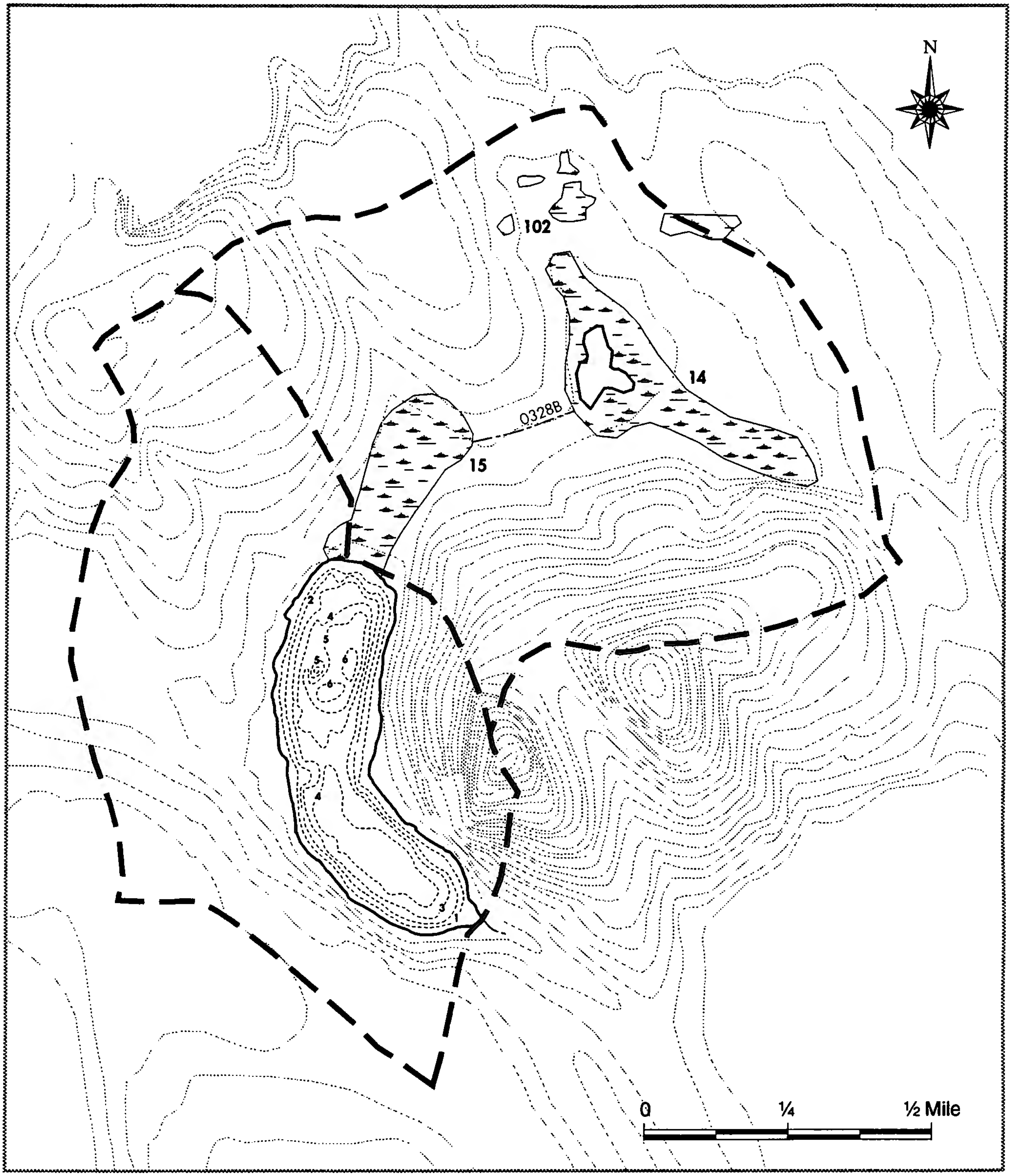

Figure 2-1: Lake Desire Water Features

Subcatchment Boundary
0328B Stream & Stream Number
4 Bathemetry (1 meter contours)
Contour Line (5 meter contours)
14 Wetland & Wetland Number
Lake

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into the Puget Sound Basin about 20,000 years ago. The geology of the Lake Desire watershed, however, is largely derived from the most recent glacial period, the Vashon stade of the Fraser glaciation. This period occurred approximately 15,000 years before the present and lasted roughly 2,000 years (Minard, 1985).

During the advance of the Vashon stade, coarser sediments were deposited close to the ice front and finer sediments farther away. As the glacier advanced, the coarse sediments were deposited over the finer sediments creating a coarsening-upwards and vertical succession of deposits. In addition, as the glacier advanced over the outwash and underlying material, it incorporated and mixed these materials to produce a nonsorted mass of clay, silt, sand, and gravel. Due to the extreme weight of the advancing glacier, this mixed material was compacted into a concrete like sediment called hardpan (Minard, 1985).

During the glacial recession, the meltwater from the ice left sediment on the till or eroded through the till. Lakes formed as meltwater filled depressions in the glacial deposits. Also during the glacial recession, fine sediments were deposited over coarser ones creating a fines upwards sequence. As a result of glacial recession, erosion and deposition have altered the land. Slopes are reduced by wasting and accumulation of colluvium, and steepened by undercutting and landsliding.

The Lake Desire watershed is dominated by glacial till deposited during the Vashon stade of the Fraser glaciation (Figure 2-2). This Vashon till consists of nonsorted mixtures of clay, silt, sand, pebbles, cobbles, and boulders. Water percolates readily through the upper one to two meters of loose, sandy, weathered material, but tends to pond and move laterally along the hardpan surface. Such conditions can result in wetlands in flat areas on uplands, and broad areas of saturated weathered till on hillsides during the winter and spring.

The Lake Desire watershed contains two differing types of glacial till. The upper northeastern section contains till composed of gray silty clay mixed with boulders and sand while the lower areas of the watershed largely consist of drumlinized ground moraine. Two large wetland areas along the headwaters of Peterson Creek are composed of peat and swamp deposits. These deposits are chiefly sedimentary, fibrous, mixed locally with sphagnum or woody peat and extraneous inorganic detritus. The steep hill slopes immediately to the east of the lake contain rocks of the Renton Formation as well as intrusive volcanic dikes. Rocks of the Renton Formation are feldspathic and arkosic micaceous sandstone, carbonaceous claystone, and coal. The thickness can range up to as much as 2,500 feet. The areas intruded by volcanic rock are largely composed of calcic andesite.

SOILS

Soils in the Lake Desire watershed were surveyed by the United States Department of Agriculture (USDA) Soil Conservation Service (USDA, 1973) and are shown in Figure 2-3.
Table 2-2 illustrates the soil types which are present in the watershed. The Alderwood series consists of moderately deep, moderately well-drained soils on till plains. These soils, which have a weakly consolidated to strongly consolidated substratum at a depth of 24 to 40 inches, formed in glacial till.

The Alderwood gravelly sandy loam (6 to 15 percent) soil type represents approximately 50 percent of the watershed, and is generally found on slopes ranging from 2 to 15 percent. This soil, formed in glacial till, is moderately well drained on till plains and moderately deep over a hardpan. Depth to the hardpan ranges from 20 to 40 inches. Permeability is moderately rapid above the hardpan and very slow through it. Available water capacity is low, runoff is slow, and the hazard of water erosion is slight. This soil type is located throughout the watershed. This soil type has limitations for home sites and septic tank

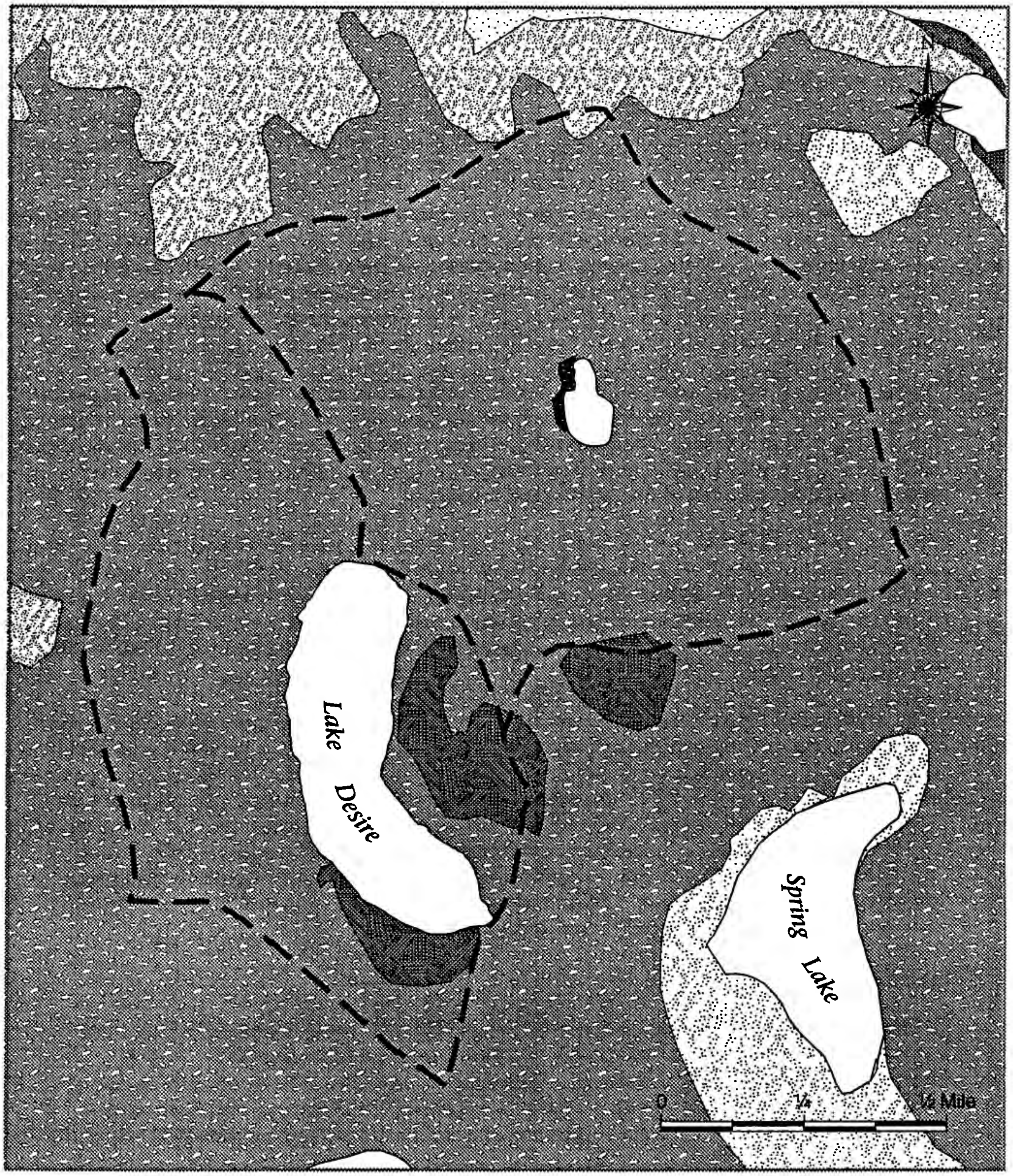

Figure 2-2: Lake Desire Geology

Subcatchment Boundary
Lake
Wetland (Qw)
Alluvium
Advance Outwash & Older Deposits (Qva, Qpf)
Recessional Outwash (Qvr)
Till (Qvf)
Bedrock (Ti, Ts, Tp, Br)

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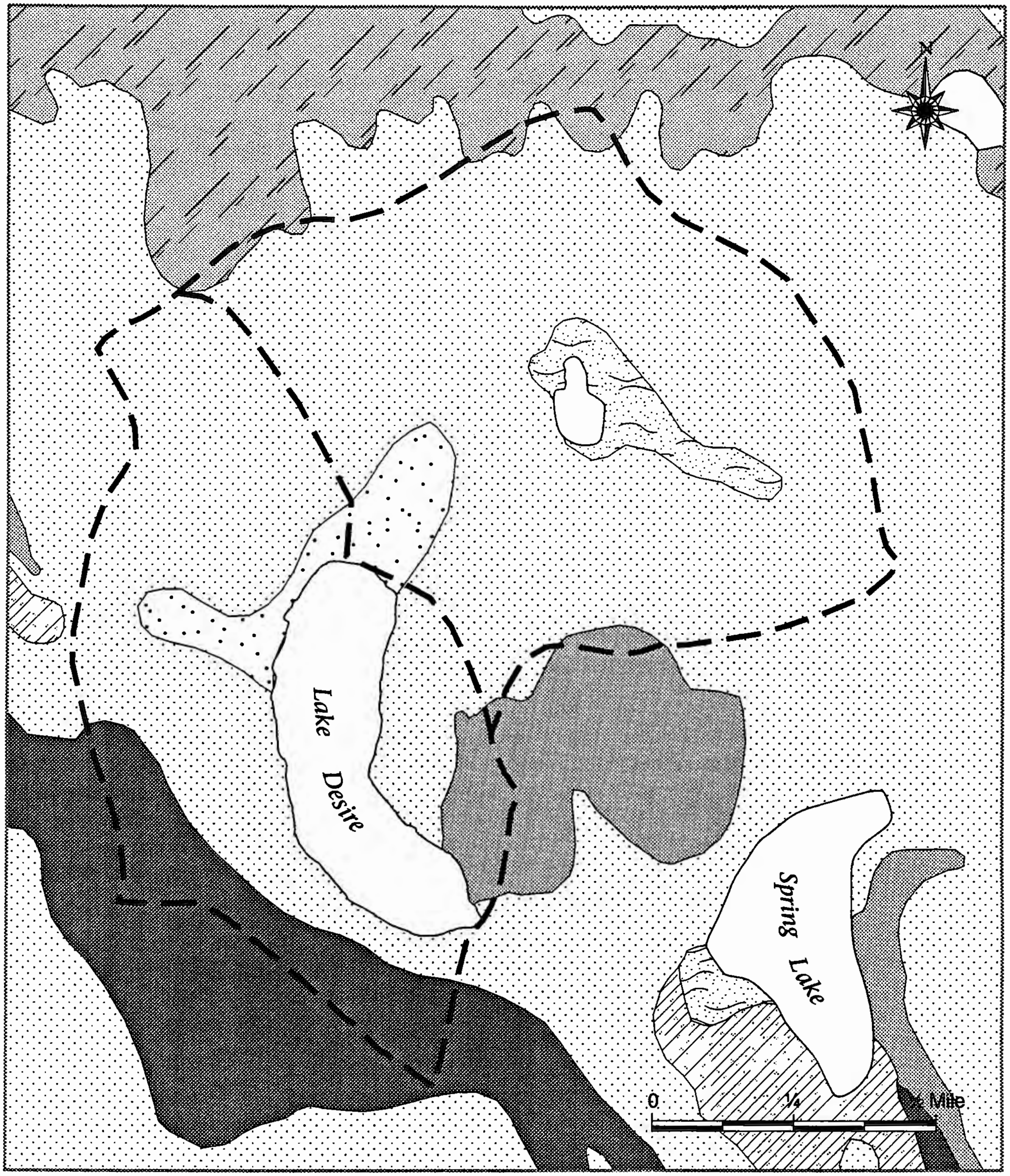

Figure 2-3: Lake Desire Soils

- Subcatchment Boundary
- Lake
- AgB—Alderwood Gravely/Sandy Loam (0-6%)
- AgC—Alderwood Gravely/Sandy Loam (6-15%)
- AgD—Alderwood Gravely/Sandy Loam (15-30%)
- Alderwood & Tukwila Soils
- Everett Gravely/Sandy Loam
- Orcas Peat
- Seattle Muck

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Table 2-2: Soil Types in the Watershed

Soil Type(slope)	Abbreviation	Occurrence in Watershed
Alderwood Gravelly Sandy Loam (0-6)	AgB	Moderate
Alderwood Gravelly Sandy Loam (6-15)	AgC	High
Alderwood Gravelly Sandy Loam (15-30)	AgD	Low
Alderwood and Tukwila		Low
Everett Gravelly Sandy Loam (6-15)	EvC	Low
Orcas Peat	Or	Low
Seattle Muck	Sk	Low

drainfields due to the shallow depth to the weakly cemented hardpan and wetness due to the seasonal high water table. Effluent from drainfields often flows laterally above the hardpan and can seep at the bottom of slopes.

The Alderwood gravelly sandy loam (0 to 6 percent) soil type represents approximately 20 percent of the watershed and is found on the slopes rising southwest from Lake Desire (Figure 2-3). This soil type is nearly level and often found in gently sloping or undulating terrain. The soil is very similar to the Alderwood gravelly sandy loam (6 to 15 percent), with moderate permeability above the hardpan, slow runoff potential, and a slight water erosion hazard. This soil type has limitations for home sites and septic tank drain fields due to the shallow depth to the weakly cemented hardpan and seasonal wetness. On-site wastewater septic systems often fail or do not function properly and possibly fail during periods of high rainfall.

The Alderwood gravelly sandy loam (15 to 30 percent) soil type represents approximately 10 percent of the watershed and is found on the steep hill slopes rising to the east of the lake (Figure 2-3). Permeability of this Alderwood soil type is moderately rapid above the hardpan and very slow through it. Available water capacity is low, runoff is medium, and the hazard of water erosion is moderate. This soil type has limitations for home sites and septic tank drainfields due to the depth to the weakly cemented hardpan and wetness due to the seasonal high water table. Effluent from absorption fields often flows laterally above the hardpan and can seep at the bottom of slopes.

The Everett gravelly sandy loam (6 to 15 percent) is a deep, excessively drained soil which formed in glacial outwash, and is found on terraces and outwash plains. Permeability of this soil is rapid and available water capacity is low. Runoff is slow and the hazard of water erosion is slight. This soil type represents approximately 10 percent of the watershed and is located in the immediate vicinity north of Lake Desire.

The Orcas peat soil type is a very deep, poorly drained soil formed in sphagnum moss and small amounts of Labrador tea and cranberry plants. This soil is generally located in basins and on undulating, rolling uplands. Permeability is rapid, available water capacity is high, runoff is ponded, and there is no erosion hazard. This soil type represents approximately 10 percent of the watershed and is located in the extensive wetland area that is located in the headwaters of Peterson Creek.

The Seattle muck soil type is a poorly drained soil that formed in material derived primarily from sedges. These soils are located in depressions and valleys on the glacial till plain. Permeability is moderate and there is a seasonal high water table at or near the surface. Runoff is ponded and there is little to no erosion hazard. This soil type represents approximately one percent of the watershed, and is located in a small wetland area east of the lake.

WATER SOURCES

The Puget Sound region receives moderate amounts of rainfall and maintains a mild year round climate due to its proximity to the Pacific Ocean and its location at approximately 47 degrees north latitude. Long-term rainfall records from two nearby weather stations (the City of Kent located ten miles southwest and Landsburg located seven miles southeast) together with precipitation isohyetals created by the U.S. Weather Bureau, suggest that rainfall averages approximately 50 inches per year in the watershed. King County SWM maintains a rain gauge (KCSWM 31W) at 19208 SE 196th, located approximately 2 miles southeast of Lake Desire. This gauge has been in service since 1989 and has provided a short term rainfall record in the watershed. Water enters Lake Desire via Peterson Creek Tributary 0328B, overland runoff from surrounding hill slopes, and groundwater seepage.

Peterson Creek Tributary

Tributary 0328B forms the inlet and outlet for Lake Desire and eventually drains to the Peterson Creek system (0328) south of the outlet of nearby Spring Lake (Figure 2-1). The inlet to the lake drains approximately 430 acres or 52 percent of the total Lake Desire Watershed. The drainage area is a mixture of rolling forested hills and large wetland/peat bog areas.

This tributary (0328B) to Peterson Creek (Figure 2-1) originates approximately one mile northeast of the lake in a gently sloping forested area containing a large wetland (Cedar River Wetland 14). Peterson Creek Tributary 0328B flows southwest through relatively flat forested and wetland area (Cedar River Wetland 15) before passing through a culvert under West Lake Desire Road and entering the northern end of Lake Desire. Above Lake Desire, Peterson Creek Tributary 0328B has intermittent flow during the wet season and ceases to flow during the summer.

Peterson Creek is a first order, Class AA stream (WAC 173-201, WSDOE, 1992). Peterson Creek contains good to excellent salmonid habitat that is well buffered by an extensive lake and wetland network which has a mostly undeveloped riparian corridor throughout the majority of the watershed. Chinook and sockeye salmon utilize the main stem of Peterson Creek while coho salmon are known to migrate up Tributary 0328B to Lake Desire.

Wetlands

The 1990 King County Sensitive Areas Folio Map shows the location and identifying numbers for wetlands in the Lake Desire watershed identified by the 1990 King County wetland inventory (King County, 1990; King County, 1991a). Three wetlands, Cedar River Wetland 14, 15, and 102, were delineated by King County in the watershed. Detailed information on the vegetative classification, plant and animal species identified, and overall King County wetland ranking for each of these wetlands is presented in *Lake Desire Background and Technical Reports* (King County, 1994a). United States Fish and Wildlife Service (USFW) National Wetland Inventory maps (USFW, 1988) show similar wetlands delineation and vegetative classifications for the watershed wetlands.

Cedar River Wetland 14 is a 43 acre Class 1 system which lies in the extreme northeast portion of the headwaters to the Peterson Creek Tributary to Lake Desire. This wetland was the site of extensive peat mining from the early 1960's through the 1980's. Following mining, parts of the wetland were converted to open water ponds, using a series of channels. The wetland used to be dominated by typical bog species such as Labrador tea, cranberry, hemlock, and Sphagnum moss. Presently, only six out of the 43 acres remain in a pristine state. Current conditions show the mined sections to have exposed mineral soils, formerly covered by the peat deposits, that are being colonized by non bog species such as alder, cottonwood, hardhack, and a variety of emergent species. Cedar River Wetland 14 is bordered by large tracts of undisturbed forest land and linked to downstream wetland Cedar River Wetland 15 by a broad riparian corridor. Thus, the wetland is a valuable source of wildlife habitat in the region. Even though mining activities have significantly altered the natural state of the wetland, it still is a large complex wetland that provides significant plant and wildlife habitat and valuable stormwater runoff detention from the upper watershed areas.

Cedar River Wetland 15 is a 17 acre Class 1 wetland bordering the northern shore of Lake Desire and extending up Peterson Creek Tributary to the northeast for approximately 0.3 miles. This wetland is composed of forested, scrub-shrub, and emergent vegetative habitats. Additional information of plant and animal species detected in this wetland by King County (1990) is presented in *Lake Desire Background and Technical Reports* (King County, 1994a). Impacts to Cedar River Wetland 15 include logging, impoundment of flows behind West Lake Desire Road, and degradation of water chemistry and hydrology by road construction and runoff and new developments in the watershed.

PUBLIC ACCESS

A Washington State Department of Fish and Wildlife (WDFW) public boat launch on the northern shore and King County open-space park on the eastern shoreline provide direct public access to Lake Desire (Figure 2-4). The public boat launch area has one boat launch, a fishing pier, paved parking for thirty vehicles, handicapped access, pit toilets, and trash collection.

The forested 382 acre open-space park occupies an extensive area to the east of the lake including a hill which affords views of both Lake Desire and Spring Lake. The open-space park reaches the Lake Desire shoreline near the outlet at the southern end of the lake (Figure 2-4). Future plans for this forested park include the development of year-round public access to the lake through two miles of pedestrian/equestrian trails, formalized shoreline access, signage, picnic tables, and parking for 10 vehicles. The park trails can be accessed from W. Spring Lake Drive or W. Lake Desire Drive.

Less than a quarter of a mile from the lake is Petrovitsky Park (Figure 2-4), a 108 acre King County park facility operated year-round. The park currently has a baseball/softball field, a lighted soccer field, a children's play area, pedestrian trails, and parking for 100 vehicles. The park's Phase II development will include second baseball and soccer fields. The master plan for the park (Appendix B) shows a final design with 6 lighted tennis courts, two additional baseball fields, parking for another 100 vehicles, and foot trail access to W. Lake Desire Drive.

A complete public access inventory is included in Appendix B. The inventory follows the guidelines established by DOE for public access requirements for Phase II Centennial Clean Water Fund grant funding.

LAND USE

Surveys of the Lake Desire watershed in 1973 by the United States Geological Survey (USGS) estimated the land use in the basin to be 8 percent lake, 10 percent residential suburban, and 82 percent forest/wetland (USGS, 1976). Growth in the nearby Renton and Maple Valley areas has been

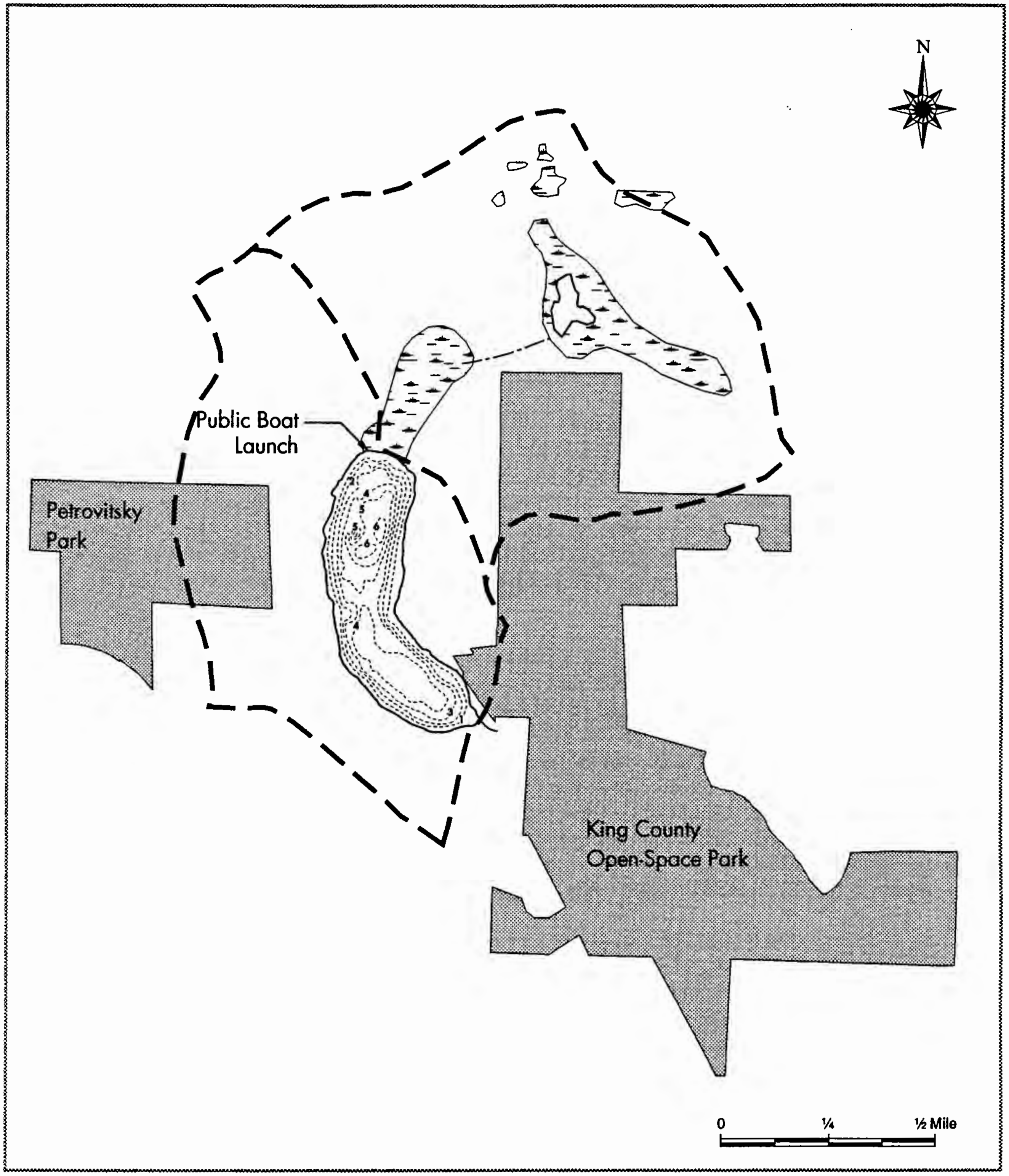

Figure 2-4: Lake Desire Public Access

Bathemetry (1 meter contours)
Subcatchment Boundary
Stream
Wetland
Lake

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considerable since the early 1970's, with a population increase from 60,100 in 1970 to 131,600 in 1991, an overall growth increase of approximately 115 percent (King County, 1986; King County, 1992).

The Lake Desire watershed is located entirely within the Soos Creek Community Planning Area. This area experienced the largest population gain of all King County planning areas during the 1980's with approximately 43,000 new residents. This was a 48 percent increase from 88,700 in 1980 to 131,600 in 1991. Continued growth in the area is expected, with a projected population of 158,300 in the year 2000 (King County, 1992).

Although the majority of the watershed has historically been forested, there are no known commercial timber harvesting operations in the watershed. The watershed does contain extensive coal and peat deposits (Rigg, 1958). Peat mining from the wetland areas at the headwaters of Peterson Creek occurred in the past (Rigg, 1958), but is no longer taking place. Coal mining occurred in the hills northwest of the lake from the 1950's through the 1980's at the now abandoned King Coal Mine.

Land use designations and zoning in the Lake Desire watershed are controlled by the Soos Creek Community Plan (King County, 1991b). This plan designated the immediate area around the lake and the area to the west of the lake to Petrovitsky Road to be in the urban growth boundary (UGB) with the rest of the watershed included in the rural area (Figure 2-5). Urban growth designation for the area around the lake means sewer service may be extended to this area in the future to meet urban public facility and service standard needs (King County, 1991b). Rural zoning of the remainder of the watershed means that development densities and service levels will remain low to preserve the undeveloped and pastoral character of the area.

Existing area zoning in the Lake Desire watershed is shown in Figure 2-5. The area of the watershed within the UGB has been designated by the community plan for Phase I urban development. The zoning associated with this phase is GR-5-P, RS-7200-P. The GR-5-P zoning expired December 31, 1994, putting in effect the RS-7200-P zoning. Under this new zoning, sewer and water services must be present to realize the density associated with the designation of RS-7200-P (six units per acre). Prior to the implementation of such services, new development lot size will be restricted to 12,500 square feet (3.5 units per acre), the minimum lot size required for on-site septic systems. The remainder of the watershed is designated as rural with zoning designations of AR-2.5-P (one unit per 2.5 acres) or AR-5-P (one unit per five acres). In all areas of the watershed, special development conditions are applied to new development as indicated by the "P" following all watershed zoning.

Current and future land use estimates by King County (1994b) are shown in Figures 2-6 and 2-7, respectively. Figure 2-8 shows total acreage in the watershed occupied by various land uses for historical, current, and future conditions (see Chapters 5 and 6 for additional land use discussion). It is apparent from these data that forest and wetland areas represent the major current land use in the watershed, with one unit or less per acre the next prevalent land use. Although wetland areas will be protected by forested buffers, the majority of the remaining forested areas will be converted to high or low density residential development under future build-out conditions.

Recently, the Metropolitan King County Council adopted a pilot project for the 4-1 program in Section 25, Township 23, Range 3, which lies partly within the Lake Desire watershed. The 4:1 program allows for rural property owners with properties contiguous to the Urban Growth Boundary Line to have the opportunity to obtain urban designation in exchange for dedicated open space. The program allows for the redesignation of one acre of property as urban for every four acres of property designated as permanent open space. This designation could allow for a major portion of the upper watershed to remain forested.

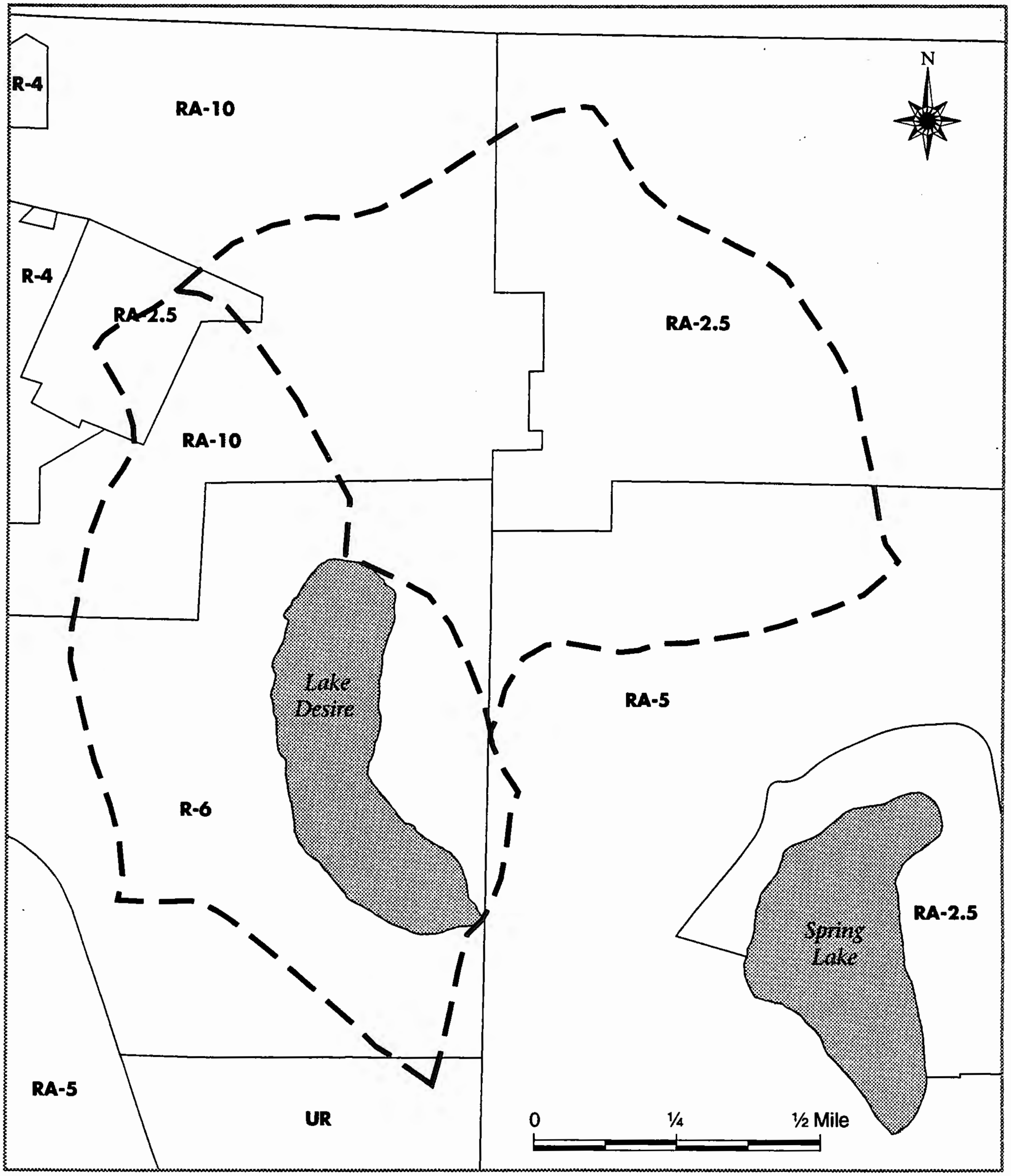

Figure 2-5: Lake Desire Zoning

Subcatchment Boundary

Lake

Zoning Designations

RA-10	Rural area, 1 unit/10 acres
RA-5	Rural area, 1 unit /5 acres
RA-2.5	Rural area, 1 unit /2.5 acres
UR	Urban Reserve, 1 unit/5 acres
R-4	Residential, 4 units/acre
R-6	Residential, 6 units/acre

Source: King County Zoning Atlas, Feb 2, 1995

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Figure 2-6: Lake Desire Current Land Use

- Subcatchment Boundary
- Wetland
- Lake
- Impervious
- Single Family High Density
- Single Family Low Density Grass
- Single Family Low Density Forest
- Grass
- Forest
- Quarry

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0 ¼ ½ Mile

Figure 2-7: Lake Desire Future Land Use

Subcatchment Boundary
Wetland
Lake
Impervious
Single Family High Density
Single Family Medium Density
Single Family Low Density
Grass
Forest

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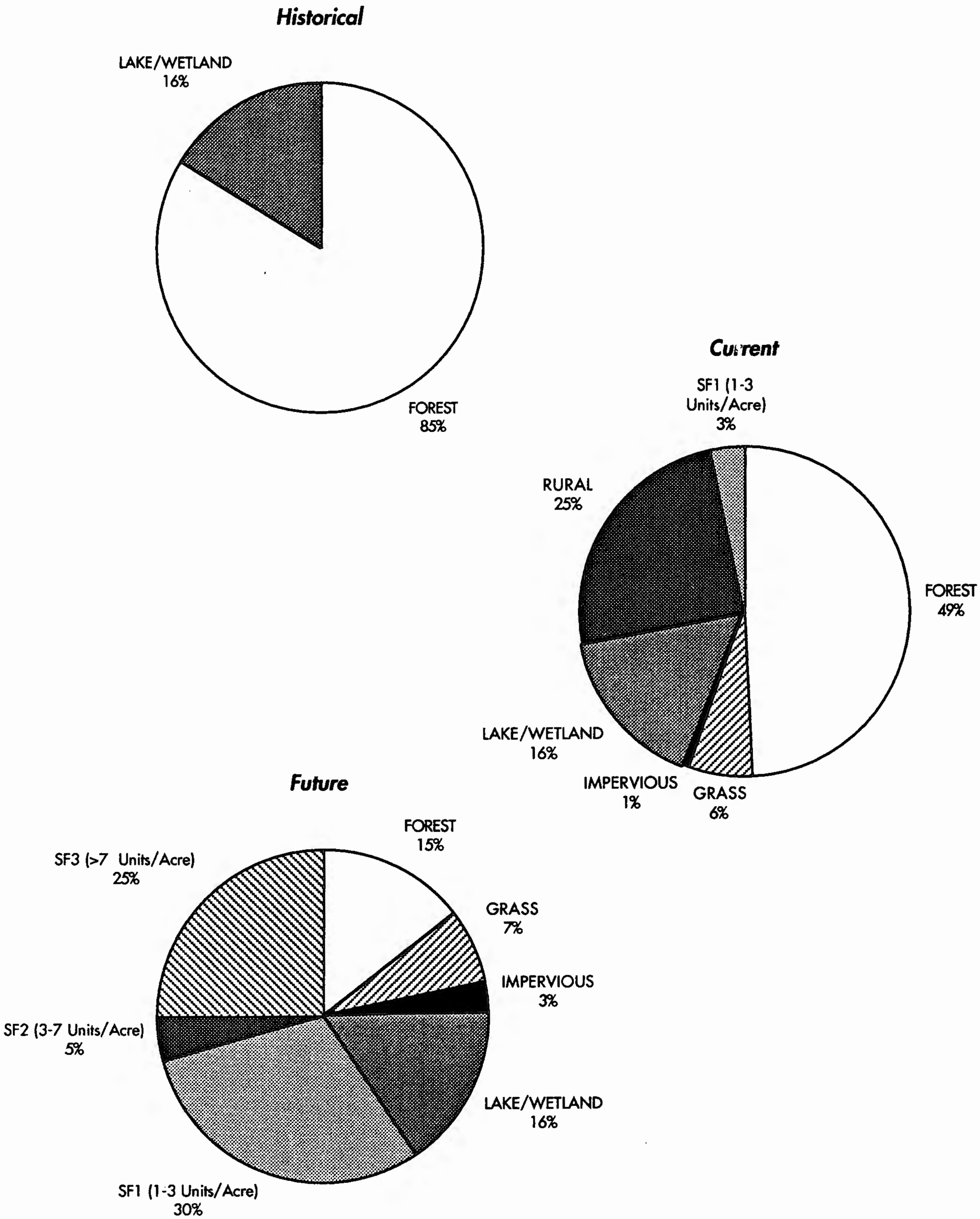
Figure 2–8 Lake Desire Historical, Current, and Future Land Use



CHAPTER 3: METHODS

The methods used to conduct the Phase I diagnostic/restoration analysis for Lake Desire are briefly described in this chapter. The hydrologic and routine lake and watershed monitoring program elements are described first, followed by the methods used for the special studies. Figure 3-1 illustrates the watershed sampling stations used during the study. Sampling station descriptions can be found in Appendix C. The quality assurance plan and full method descriptions for the project can be found in Lake Desire Background and Technical Reports (King County, 1994a).

HYDROLOGIC MONITORING

Inflow

Inflow was monitored at site location LDIN1 (Figure 3-1) using monthly flow estimates for April through October, 1993 and a continuous stage recorder from November, 1993 through April, 1994. King County purchasing delays resulted in the lag between project start-up in April and stage monitoring equipment installation in November 1993.

The gauging station was maintained monthly by King County SWM during the study period. Stage was recorded in 15 minute increments. A discharge rating curve was not developed at this site because lake level frequently backwaters the site, preventing the accurate measurement of channel velocity. Therefore, the inflow record reflects stage only.

Outlet

Outflow was monitored at site location LDOUT (Figure 3-1) which is located upstream of the road culvert which crosses the lake outlet. Prior to November 1993 and the installation of gauging equipment, flow was estimated during monthly site visits. After November 1993, outlet stage was monitored using a continuous gauge. The station was maintained monthly by King County SWM during the study period.

Stage at LDOUT was recorded in 15 minute increments and a discharge rating curve was developed for the site using five flow measurements ranging from 0.02 to 4.33 cfs, and a 0.98 ft range in stage from the hydraulic control. It was necessary to project the curve to 10 cfs in order to accommodate the highest stage recording of 1.63 ft above the hydraulic control. The flow data collected throughout the period were generally good. Outflow gauging was terminated in April, 1994 due to vandalism of the gauging station.

Groundwater

Groundwater flow was measured by the project consultant at three locations from paired land-based (LD-1, LD-3, and LD-5) and lake based (LD-2, LD-4, and LD-6) drive points (Figure 3-1). A seepage meter was installed at each location. During the third quarter sampling period, site LD-2 was vandalized. No data was collected for this site during the third quarter. Site equipment was replace at LD-2 for the fourth quarter sampling period.

Hydraulic conductivity was evaluated at each of the three locations using slug test methodology (Hong West and Associates, Inc., 1994). A conceptual groundwater model of the site hydrostratigraphy and groundwater flow was developed using existing groundwater data and information collected during the

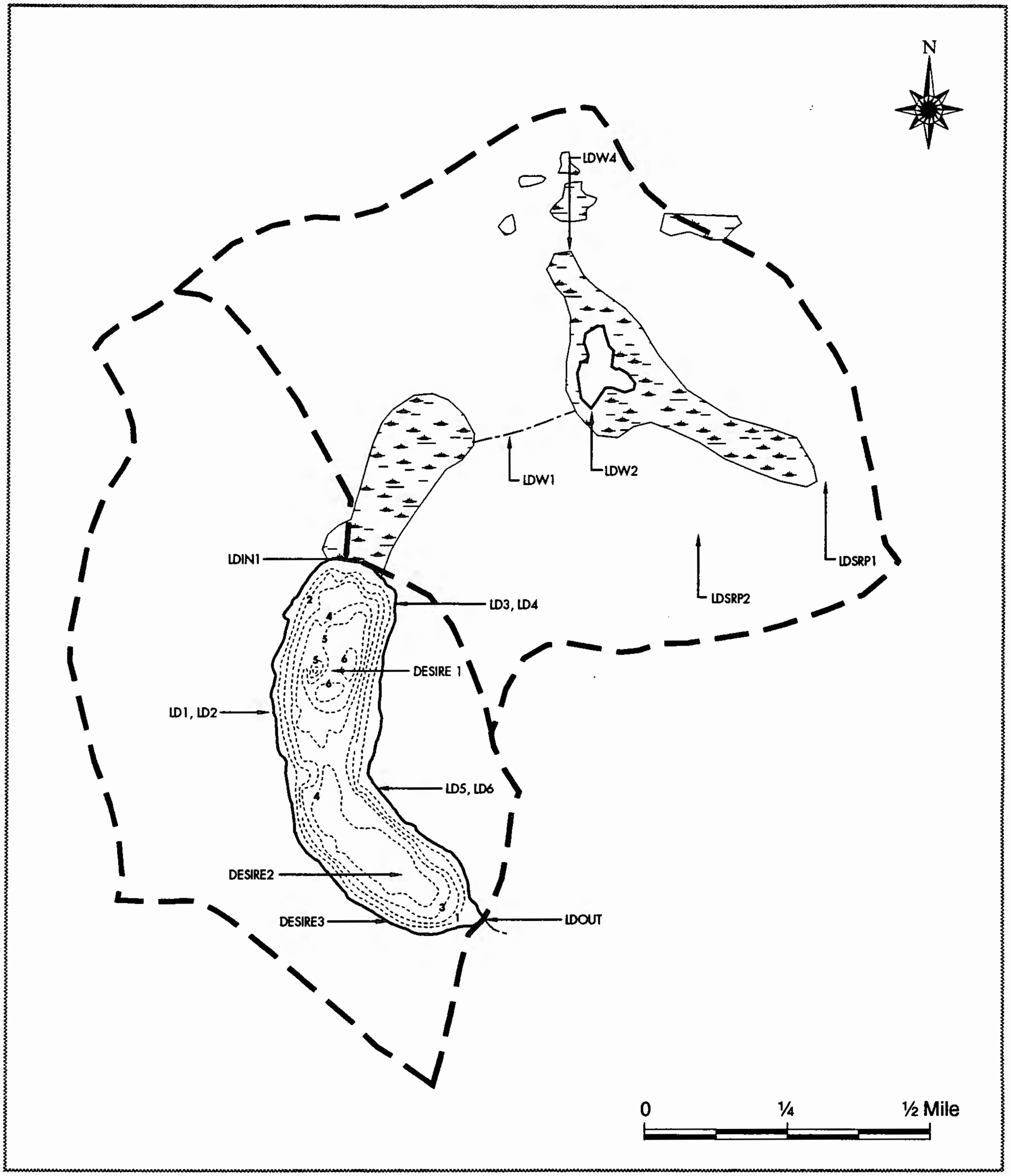


Figure 3-1: Lake Desire Monitoring Locations

Subcatchment Boundary
Stream
Bathemetry (1 meter contours)
Wetland
Lake
LD5 Monitoring Location Name

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study. Additional detail regarding groundwater monitoring methodology used for this project is provided in the *Lake Desire Background and Technical Reports* (King County, 1994a).

Lake Level

Lake level was measured daily by a resident volunteer from April 1992 through May 1994. This information was used in calibration of the Hydrologic Simulation Program-FORTRAN (HSPF) model which was used to develop the lake water budget.

Precipitation

Precipitation was measured daily by several resident volunteers at Lake Desire during the study period. Precipitation was also measured at the Layton King County SWM gauging station located near Spring Lake on SE 196th. The Layton station uses a tipping bucket gauge which records precipitation in 15 minute intervals. The Layton precipitation record, verified using locally collected data, was also used for HSPF model calibration.

WATER QUALITY MONITORING

Lake Desire water quality was measured through a combination of both field and laboratory methods which are fully described in the quality assurance plan for Lake Desire (King County, 1994a). Table 3-1 summarizes the monitoring program, sampling frequency, and targeted parameters for the water quality component of the project.

The water quality monitoring program was initiated in April, 1993 and was completed in April, 1994, except for groundwater which was completed in June, 1994. During April through September, in-lake water quality was monitored twice monthly, while inflow and outflow water quality were monitored monthly. During October through March, this pattern was reversed and in-lake water quality was monitored monthly, while inflow and outflow water quality were monitored twice monthly. This monitoring schedule allowed for an in-lake water quality focus during the growing season and a watershed loading emphasis during the wet season.

In-lake

All *in situ* measurements (dissolved oxygen, conductivity, pH, temperature, and Secchi depth) were made with calibrated equipment according to the recommended protocols or manufacturer's suggested calibration. Vertical profiles for dissolved oxygen, conductivity, pH, and temperature were developed for lake sites and recorded in the field notes.

Water samples were collected at two in-lake stations, DESIRE1 and DESIRE2 (Figure 3-1). Samples were collected at 1-meter intervals beginning at the surface using a vertical Alpha™ bottle (2.2 L Van Dorn bottle) water collection device. Water samples collected in the sampling bottle were transferred to prelabeled sample containers which were prepared according to the recommended quality assurance plan protocols (King County, 1994a). All samples were placed on ice until delivery to the analytical laboratory.

Total phosphorus concentrations from both stations were compared for the April through September sampling period. No significant difference was found in lake total phosphorus chemistry between stations and sample collection was subsequently discontinued at DESIRE2.

Table 3-1: Lake Desire Water Quality Monitoring Program

Component	Sampling Frequency	Stations	Parameters[a]
In-lake	Monthly: Oct-Mar Biweekly: April-Sept	2 stations, deep spots, each meter, duplicate TP at surface and bottom	Temp., pH, DO, Cond., TP, Ortho-P, NO2+NO3-N, NH3-N, TN, Turb., Alk., color
	Same	2 stations	Secchi depth
	Same	2 stations, compo-site (@0.5m, 1.5m, 2.5m, and 3.5m), triplicate chl a	Chl a, Phaeo, Phytoplankton species, biovolume, and identification
	Same	2 stations, vertical tow	Zooplankton species, enumeration, and identification
	monthly	2 stations, surface only	FC
	Quarterly	2 stations, deep spots, each meter	Ca, Mg, Na, K, Cl, Al, SO4, Fe, Total Soluble Phosphorus, DOC and TOC
Inlets/Outlets	Monthly: April-Sept Biweekly: Oct-Mar Four storm events	2 stations, triplicate TP at inflow 2 stations, composited over storm	Temp., pH, DO, Cond., TP, Ortho-P, NO2+NO3-N, NH3-N, TN, Alk., Cl., FC (inflow) Base flow parameters plus Turb., TSS, Oil/Grease, Hardness, Cu[b], Pb[b], and Zn[b]
Groundwater	Quarterly	6 sites	TP, Ortho-P, NO2+NO3-N, NH3-N, TN, Cl
Sediment characterization	Once	three depth strata (0-2m, 2-4m, and >4m) four cores from each stratum 0.5 m core, analyzed at 0-2 top and then 10 cm increments	TP, TN, % solids, Total Organic Carbon, and Fe
Sedimentation rate	Once	1 station, 2 cores/ station, 1-2m cores, 2 cm increments	% solids, Zn, and Pb
Precipitation	Monthly	2 stations, composited	TP, TN
Wetland	Three times	2 Stations	TP, Ortho-P, NO2+NO3-N, NH3-N, TN, TSS

[a]*Parameters are abbreviated as follows: Temp.-temperature, DO-dissolved oxygen, Cond.-conductivity, TP-total phosphorus, Ortho-P-orthophosphate, NO2+NO3-N-nitrite+nitrate-nitrogen, NH3-N-ammonia-nitrogen, TN-total nitrogen, Turb.-turbidity, Alk.-alkalinity, Chl a - chlorophyll a, Phaeo -pheophytin a, C-fecal coliform, Ca-calcium, Mg-magnesium, Na-sodium, K-potassium, Cl-chloride, Al-aluminum, SO4-sulfate, Fe-iron, DOC-dissolved organic carbon, TOC-total organic carbon, Cu-copper, Pb-lead, Zn-zinc, and TSS-total suspended solids.*

[b]*Total and dissolved.*

Nutrient Limitation Assessment

An *in situ* bioassay developed by Petersen (Petersen, R. October 1993, personal communication) was used to evaluate nitrogen and phosphorus limitation of phytoplankton production in Lake Desire. The exact methods are detailed in *Lake Desire Background and Technical Reports* (King County, 1994a) and are briefly described below.

The first bioassay was conducted in October, 1993, using eight 20-liter cubitainers (plastic carboys). Each carboy was filled with lake water and then received one of four possible nutrient additions: nitrogen only, phosphorus only, nitrogen and phosphorus, or no additions. Each treatment was replicated twice and the cubitainers were suspended at 0.75 m depth for five days.

After incubation was complete, carbon assimilation was measured by adding Carbon-14 (^{14}C) to three, 40 ml subsamples collected from each of the cubitainers. Following ^{14}C incubation, samples were evaluated for carbon assimilation (KCM, 1993b).

A second bioassay was conducted in August, 1994. The methods were the same as described above except each treatment was replicated three times and higher enrichment levels or nutrient additions were used (KCM, 1994b).

Sediment

The purpose of sediment sampling was twofold: 1) to estimate the rate of sedimentation; and 2) to quantify sediment nutrient content. To estimate the sedimentation rate, two 1 m cores (Figure 3-2, locations 13 and 14) were collected from the deep areas of the lake. Samples were collected using a piston-corer with 1 m x 34.5 mm inside diameter plastic core holders. The weighted coring device was dropped from the side of the boat and then retrieved. As the sampler was pulled to the surface, the bottom of the tube was capped and removed from the sampling device. Upon removal, the core was capped and stored in a bucket prior to delivery to the analytical laboratory. Cores for sedimentation rate analysis were sectioned into 2 cm

sections and analyzed for percent solids, lead and zinc concentrations. Surface (0-2 cm) sections were also analyzed for total phosphorus concentrations.

Sediment cores for nutrient characterization were stratified along three depth ranges, 0-2 m, 2-4 m, and >4m. Four 0.5 m cores were collected from each stratum (Figure 3-2, locations 1-12) as described above.

Cores for sediment nutrient content were sectioned into the top 2 cm and then 10 cm sections thereafter. Core sections were analyzed for percent solids, volatile solids, total phosphorus, total Kjeldahl nitrogen, and iron.

Stream

Inlet and outlet stations are shown in Figure 3-1. Site descriptions can be found in Appendix C. Manual grab sampling methods (USEPA, 1988a) were used to collect both base flow and storm flow inlet and outflow samples.

During stormwater sampling events, a combination of grab sampling methods and flow-compositing was used to sample two storm events (February 13-14 and April 9, 1994). Storm events, for the purpose of

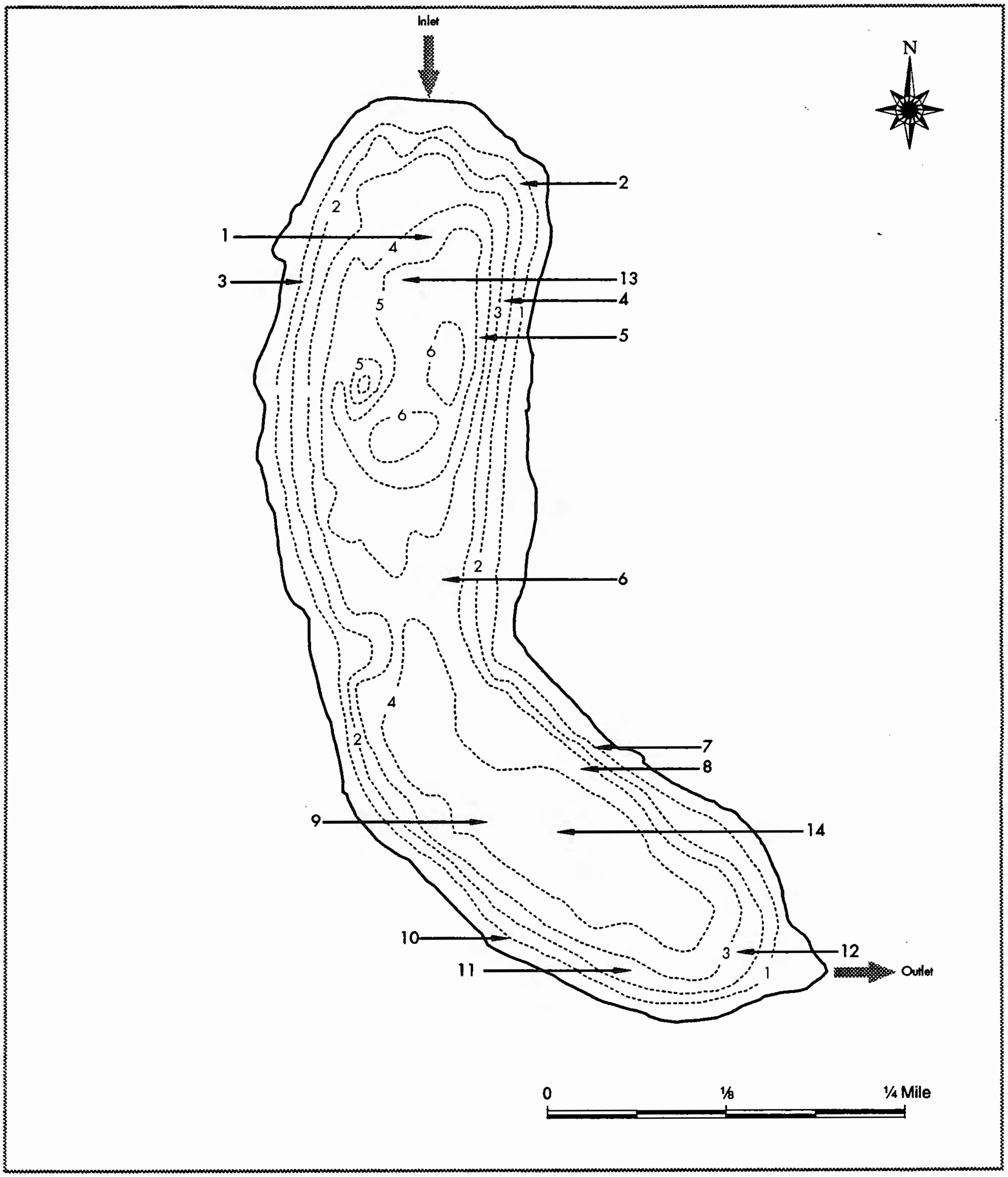

Figure 3-2: Lake Desire Sediment Sampling Locations

4 Bathemetry (1 meter contours)

11 Sampling Location Number

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this study, were defined as 0.5 inch of rainfall in a 6-hour period or 1.0 inch of rain in a 24-hour period preceded by 60 to 72 hours of dry conditions (less than 0.25 inch per day).

Precipitation

Precipitation was collected daily by two resident volunteers at Lake Desire during the study period. Volunteers recorded precipitation and collected rainfall in a sample bottle daily. Samples were stored in their freezer and picked up monthly. The protocols used by the volunteers are outlined in the quality assurance plan (King County, 1994a).

Groundwater

Groundwater was sampled quarterly during September 1993 through June 1994. Due to low permeability and well recharge rates, special well sampling procedures were used. The sampling procedures consisted of bailing the drive point dry, and installing the seepage meter bag on the first day of the sampling event. On the second day, the recovered water was sampled and seepage meters pulled. A 25.4 mm diameter stainless steel bailer was used to purge the wells the first day, and a peristaltic pump to sample the second day. Conductivity, pH, and temperature readings were taken in the field from the groundwater following sample collection.

Wetland

Wetland water quality sampling locations are shown in Figure 3-1. Manual grab sampling protocols, as described under stream monitoring, were used to sample wetland water quality. Wetland water quality was sampled three times between January and March when measurable flow was present in the upland stream/wetland system.

BIOLOGICAL MONITORING

Phytoplankton

Phytoplankton samples were collected from the surface from April to mid-June 1993, by submerging a sample bottle to 0.5 and filling. Beginning in mid-June, the phytoplankton sampling procedure was modified to collect a photic zone composite sample. This was accomplished by collecting vertical Alpha™ bottle (2.2 L Van Dorn bottle) samples from 0.5, 1.5, 2.5, and 3.5 m depths, and compositing them into a clean 22 L white bucket at the surface. The composite sample was hand-mixed and subsamples were collected for chlorophyll *a* and taxonomic analysis. Chlorophyll *a* samples were taken in triplicate in darkened one liter bottles, placed on ice, and taken to the lab for filtration and preservation. All taxonomic samples were preserved with Lugol's solution and stored in a cool, dark cabinet until delivery to the project consultant for taxonomic analysis. Phytoplankton enumeration, identification, and cell volume determination were made on preserved one liter samples. Phytoplankton taxonomic methods are detailed in Gibbons, 1994a.

Zooplankton

Zooplankton samples were collected with a 75 μm mesh, 25 mm inside diameter, vertical tow net. The net was lowered over the side of the boat to a depth of 0.5 m above the lake bottom for a tow depth of 4, 4.5, or 5 m depending upon lake level. Once in place, the net was pulled vertically through the water column. Haul depth and number of net tows were recorded in the field notes and used to calculate zooplankton densities.

Zooplankton samples were preserved, depending upon availability, using a 37 percent formaldehyde solution, a 70 percent isopropyl alcohol solution, or a blend of 400 ml formaldehyde, 200 ml isopropyl alcohol, 200 ml glycerin, 4 mg mercurous chloride, and a dash of magnesium carbonate diluted to a 2 liter volume with distilled water. Preservative was added to an approximate 10 percent concentration to each lake zooplankton sample. Samples were stored in a cool, dark cabinet until delivery for taxonomic analysis. Zooplankton identification, densities, and biomass determination were made on preserved samples. Zooplankton taxonomic analytical methods are detailed in Gibbons, 1994a.

Benthic Invertebrates

Benthic invertebrates were sampled in June, August, and October, 1993 at two in-lake stations, DESIRE1 (deep zone) and DESIRE3 (littoral zone). A single sediment sample was collected at each site using a 3,540 cm^3 Eckman dredge sampler. The collected sample was transferred from the sampler to a two liter, stainless steel pan and sieved into a 22L bucket through a 2 mm screen. The sample was sieved a second time using a 500 μm screen, placing the collected material in a sample jar and preserving with isopropyl alcohol. Population density and species composition were determined for each sample. Organisms were identified to genus except for chironomids and oligochaetes which were identified to family (Gibbons, 1994a).

Fisheries

The lake fish population was surveyed in the fall (November, 1993) and spring (May, 1994). Electrofishing and fyke net traps were used to capture fish for assessment of the quality of the Lake Desire fish population. Electrofishing was performed using a Smith-Root GPP 5 electroshocking unit operated in a pulsed mode of DC with power outputs from 3-5 amps (KCM, 1994a).

The electrofishing effort was conducted between 6 and 10 p.m. on both sampling dates. During the course of the electrofishing period, the boat was maneuvered along the shoreline and the probes were pulsed on and off . Stunned fish were collected using dip nets and placed in a live well. At periodic intervals, the boat was stopped to measure fish length and weight before returning the revived fish to the water. Scale samples were removed from several fish for verification of fish age and several fish were retained for gut analysis.

The fyke nets were set prior to initiating the electroshocking activity. Fyke nets were secured by attaching the net to a shoreline point and running the length of the net perpendicular to the shore before dropping the weighted trap-end to the lake bottom. As fish encountered the net, they followed it to the deeper water and into the trap. The nets were removed the following morning and the fish in the traps were measured for weight and length and returned to the lake.

Aquatic Plants

Aquatic plant community composition, areal distribution, and phosphorus content were determined during peak abundance (August, 1993). Plant community composition and distribution were mapped by visually surveying the lake shoreline by boat and mapping the submersed, floating, and emergent plants. The lake shoreline was randomly divided into sections. Within each section, the community type (submersed, floating, or emergent), species present, and relative section cover (sparse, moderate, or dense) were determined. Sample locations and sections are shown in Figure 3-3.

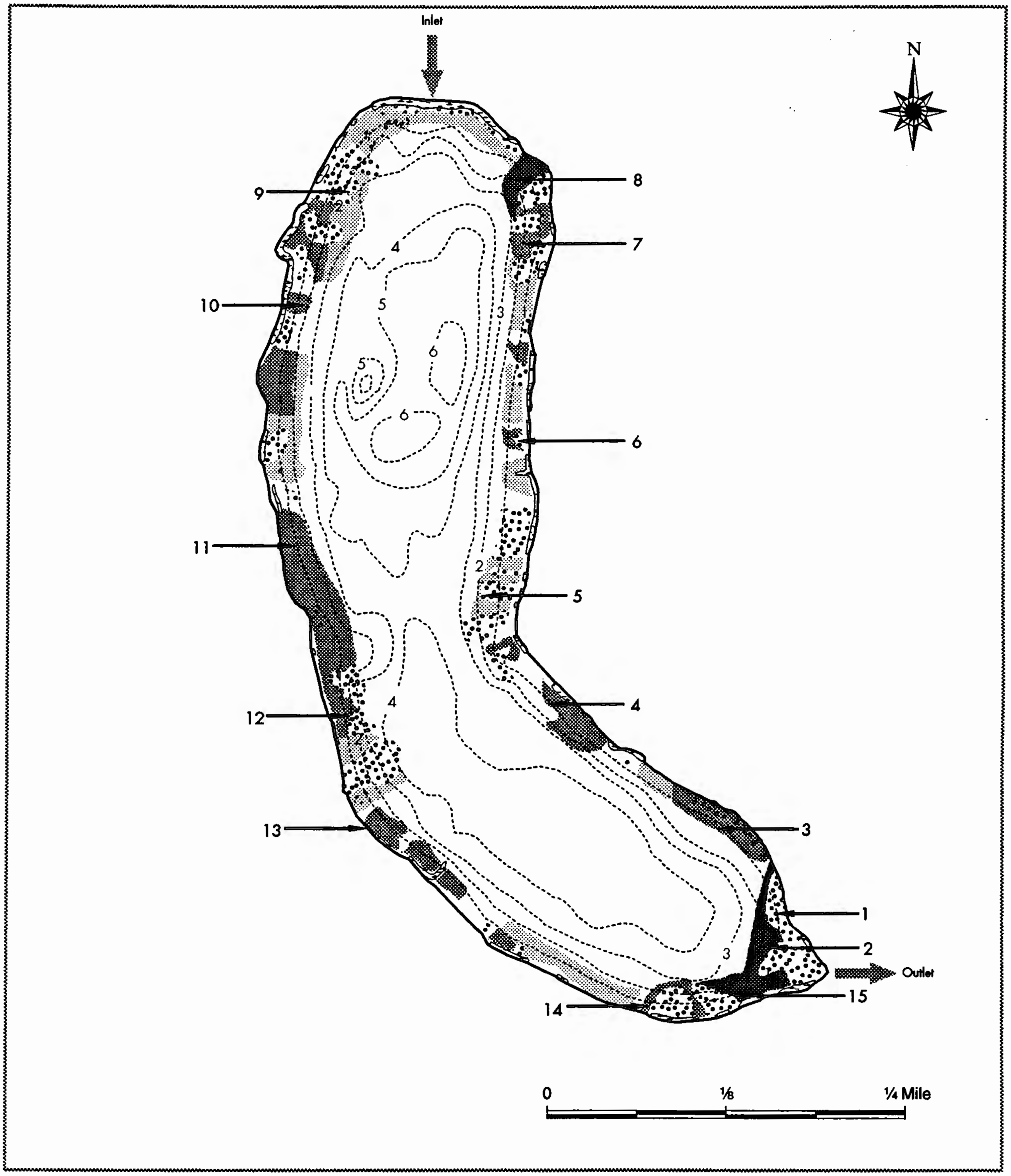


Figure 3-3: Lake Desire Macrophyte Sampling Locations

A rake sampler was used to facilitate the collection and identification of submersed macrophytes. Representative samples were placed in an iced cooler for pressing and positive identification back at the laboratory.

Plant biomass and phosphorus content were sampled by selecting 15 sites in the lake littoral zone and throwing a 0.25 m^2 sampling device and net into the macrophyte bed. The macrophytes were retrieved by scuba diver and were returned to the boat where the samples were rinsed, placed in a labeled bag, and iced until they could be processed in the office laboratory. At the office laboratory, plant samples were washed, weighed, sorted by species, and a representative subsample taken. Subsamples were delivered to the analytical laboratory for dry-weight and total phosphorus determination.

Bacteria

Fecal coliform samples were collected at the lake inflow (LDIN1) and at in-lake stations (DESIRE1 and DESIRE2) during routine monitoring (Table 3-1). Samples were collected as

described for other in-lake and stream samples; the only exceptions were: (1) the use of sterile bottles for sample collection and (2) the inversion of the bottle prior to filling.

WETLAND ASSESSMENT

Wetlands in the watershed were evaluated by the project consultant to characterize plant communities, wetland condition, inlet and outlet condition, and a functions and values assessment. Dominant plant species and subdominant species were recorded for each vegetation stratum (tree canopy, shrub layer, and herbaceous layer) present (Pentec Environmental Inc., 1994).

Soils were evaluated through review of US Soil Conservation Service (SCS) soil maps prior to site visits. Soils were analyzed for hydric indicators through on-site soil collection and compared using standard SCS protocols (Pentec Environmental Inc., 1994).

A wetland functional value assessment was performed to evaluate the benefits and roles of wetland functions. Functions assessed included groundwater exchange, hydrologic support, erosion prevention/shoreline protection, water quality improvement, food chain support, ecological support, and cultural/socioeconomic value. Additional detail regarding wetland monitoring methodology used for this project is provided in the *Lake Desire Background and Technical Reports* (King County, 1994a).

NONPOINT ASSESSMENT

Septic Survey

Aerial Shoreline Analysis (ASA) was used to assess the potential for on-site septic system contributions to lake phosphorus loading. Flights for the aerial imaging occurred in January, 1994. Aerial imaging provided a low-altitude, oblique view of lake shorelines and nearshore areas. Oblique imaging allowed the analyst to see beneath trees and shrubs to view both vertical banks and horizontal land surfaces at the same time. Both visible-color and modified-color infrared films were used at Lake Desire for each segment of shoreline examined for evidence of non-point pollution and nutrient loading problems (KCM, 1994d).

In conjunction with ASA analysis, field or shoreline surveys were conducted in October, 1993, and May, 1994, to establish a baseline prior to ASA, and secondly (May survey) to verify findings revealed during

ASA. The surveys consisted of visual observation of the shoreline area extending approximately 100 meters from the lake shore. Nearshore areas were observed for the presence of the following characteristics:

- Surfacing sewage or ponding over drainfield;
- Conspicuously lush vegetation in drainfield area;
- Dead vegetation in drainfield area;
- Soggy or odorous drainfields;
- Dark soil where excess organic matter has accumulated; and
- Excessive aquatic plant growth at the shoreline.

Particular attention was given to areas where septic system drainfields were likely to be located or where failures were suspected. This activity included verification of findings from the background resource materials and the ASA (KCM, 1994d).

The septic surveys were conducted from the water by boat. This allowed a view of drainfield areas near the lake while respecting private property. Conductivity was measured continuously from the moving boat during the October 1993 site visit using a Hydrolab™ water quality multiprobe instrument. Field notes and photographs were taken during both site visits to document locations where leachate intrusion or other conditions relevant to sources of lake water degradation were observed (KCM, 1994d).

TROPHIC STATUS

Lake trophic status was determined using Carlson's Trophic State Index (Carlson, 1977). Annual and summer epilimnetic mean values for total phosphorus, chlorophyll *a*, and Secchi depth were used to evaluate trophic status. Existing lake trophic status was also compared with historical Lake Desire data and with other small lakes in King County.

DATA REDUCTION

Mean, minimum, maximum, and standard deviation (STD) values were calculated for all in-lake (surface only), inflow, outflow, stormwater, wetland, groundwater, and precipitation water quality data. Summer mean, minimum, maximum, and standard deviation values were also calculated for in-lake (surface only) water quality data.

Weekly volume-weighted total phosphorus values were calculated from monthly and biweekly phosphorus concentration data by depth and the corresponding lake volume/depth curve value for the weekly time period. The lake volume/depth curve was developed from a revised lake bathymetry map which was created in May 1994 using depth soundings and corresponding longitude and latitude coordinates. Daily lake level data was used to establish maximum and minimum lake level from which corresponding weekly lake volumes were calculated. These lake volumes were, in turn, multiplied by corresponding lake phosphorus concentrations at one meter depth intervals (from the lake surface) to determine volume weighted lake phosphorus concentrations.

For weeks with no data, concentration values were interpolated between the previous and post sampling dates from the target week. For the stratified period, the epilimnion was defined as 0-2 m, the metalimnion as 2-4 meters, and the hypolimnion as 4-6 meters.

CHAPTER 4: LIMNOLOGICAL DESCRIPTION

The results of the one-year physical, chemical, and biological characterization of Lake Desire are described in this chapter. A description of nonpoint pollution survey results, discussion of historical water quality, and comparison of Lake Desire water quality with other local lakes, has also been included.

HISTORICAL WATER QUALITY

In-lake

The King County Department of Metropolitan Services (DMS), formerly the Municipality of Metropolitan Seattle (Metro) sampled Lake Desire from 1971 to 1973, 1979 to 1980, and from 1983 to the present. The measured chemical and biological parameters in the lake indicate a biologically productive lake system in a eutrophic stage. The density of phytoplankton growth, frequency of algal blooms, types of dominant algae, high phosphorus levels, and low transparency of the lake caused King County DMS to rate Lake Desire as having the third most productive water quality (Cottage Lake and Lake Ballinger had more productive water quality) out of 16 lakes surveyed between 1972 and 1974 (Metro, 1976a). Moreover, aesthetically Lake Desire ranked last among the 16 lakes studied due to phytoplankton blooms and bog seepage combining to give the lake a brown-green muddy appearance. Recently, King County DMS has consistently rated the water quality of Lake Desire as eutrophic based upon total phosphorus, chlorophyll *a*, and transparency data collected since 1983 (Metro, 1991).

Historical surface water quality data for Lake Desire are shown in Table 4-1. Nitrate and ammonia levels were moderate and similar to other lakes monitored in the Puget Sound region (Metro, 1976a). No fecal coliform samples exceeded the state lake water quality criteria of 100 organisms/ml, and yearly geometric means were well below the state lake criteria of 50 organisms/ml (WAC-173-201A; WSDOE, 1992). Alkalinity, pH, and conductivity levels were similar to other lakes in the region (Metro, 1976a), with measured pH levels above the state lake criteria of 8.5 only during the 1979 to 1980 sampling year. Review of dissolved oxygen profiles, where available in the historic data set, showed that anoxic conditions persisted near the lake bottom during the summer months. No historic data exists on metal or organic carbon concentrations in the lake.

Tributary Quality

Little historical water quality data exists on Peterson Creek or any of its tributaries. Although King County DMS monitors numerous streams throughout King County, there is no permanent sampling station established on Peterson Creek. Stormwater samples have been taken by King County SWM at the mouth of Peterson Creek at the Cedar River. Five storms were sampled during the fall and winter of 1989 to 1990. Although the data exceeded state water quality criteria a few times for fecal coliforms, copper, lead, and zinc levels, the overall water quality of the creek was determined to be good in comparison to other tributaries to the Cedar River (King County, 1993b). Pollutant level exceedances were not as extreme as in the more developed watersheds; this is likely due to the relatively undeveloped nature of a majority of the watershed. Of concern in the Peterson Creek watershed is the loss of riparian habitat to residential land use which in turn could reduce the quantity and quality of salmonid spawning and rearing habitats in the creek system.

Table 4-1: Summary of Historical Yearly Average Chemical Data for Lake Desire[a]

Constituent	1971-1973	1979-1980	1983-1993	1971-1993
pH				
Average	...	...	...	...
Maximum	7.7	8.8	8.2	8.8
Minimum	6.3	6.3	6.2	6.2
Conductivity (µS/cm)				
Average	79	62	65	73
Maximum	480	73	168	480
Minimum	46	52	40	40
Temperature (°C)				
Average	12.1	12.1	13.5	12.9
Maximum	25.8	24.2	26.7	26.7
Minimum	1.2	2.2	4.5	1.2
Conductivity (µS)				
Average	...	87	68	...
Maximum	...	...	...	...
Minimum	...	56	50	...
Alkalinity (mg/L as $CaCO_3$)				
Average	18	...	...	18
Maximum	28	...	...	28
Minimum	12	...	...	12
Transparency (m)				
Average	1.8	2.2	2	2
Maximum	2.8	3	4	4
Minimum	1	1	0.5	0.5
Dissolved Oxygen (mg/L)				
Average	8.8	8.2	10.1	9.2
Maximum	14.9	11.1	13	14.9
Minimum	0.1	2.2	0.8	0.1
Ammonia-N (µg/L)				
Average	79	...	...	79
Maximum	1220	...	...	1220
Minimum	10	...	...	10
NO3-N (µg/L)				
Average	156	...	...	156
Maximum	660	...	...	660
Minimum	10	...	...	10
Total Phosphorus (µg/L)				
Average	40[b]	34	30	31
Maximum	410[b]	60	86	86
Minimum	10[b]	22	4	4

Table 4-1 (continued): Summary of Historical Yearly Average Chemical Data for Lake Desire

Constituent	1971-1973	1979-1980	1983-1993	1971-1993
Chlorophyll *a* (µg/L)				
Average	17.2	14.4	9.8	11.8
Maximum	74.3	46.7	57.5	74.3
Minimum	2	3.1	0.01	0.01
Fecal Coliform (Organisms/100 ml)				
Geometric Mean	21.9	16.1	...	20.7
Maximum	61	65	...	65
Minimum	20	10	...	10

[a] *Data sources Metro, 1976a; Metro, 1988; Metro,1989; Metro, 1990; and Metro, 1991; averages are for surface water samples only.*

[b] *Total hydrolyzable phosphorus*

Groundwater Quality

Currently, little detailed information is available on the groundwater quality in the Lake Desire watershed. Although substantial amounts of regional groundwater information are included in the King County Groundwater Management Plan for South King County (King County, 1991c), there is little information on the Lake Desire watershed region. Wells near Lake Desire are being monitored by the Seattle-King County Department of Public Health; however, water quality data is currently unavailable. A general overview of the groundwater geology is provided in both the King County Groundwater Management Plan for South King County (King County, 1991c), and the Cedar River Current and Future Conditions Report (King County, 1993b).

Groundwater quality is generally good in the vicinity of Lake Desire. Water quality surveys of both shallow (less than 200 feet) and deep (greater than 200 feet) groundwater have been conducted since the early 1970's. Well surveys of the North Covington Upland area show that concentrations of iron exceeded the state secondary maximum contaminant level of 300 µg/L in 9 out of 44 shallow wells sampled. No exceedances occurred in 3 deep wells surveyed. Concentrations of manganese exceeded the state standard of 50 µg/L in 16 out of 44 shallow wells sampled and 3 out of 3 deep wells sampled. Of the wells sampled that had exceedances, only 1 is located in the Lake Desire Watershed (King County, 1991c). Nitrate levels in the shallowest aquifer, well depth < 200 feet (based on 65 samples collected between 1977 and 1987) were low, with mean and maximum concentrations of 0.68 mg/L and 4.5 mg/L, respectively. These shallow well nitrate concentrations are below the maximum state level of 10 mg/L (WAC 173-200). Nitrate levels for the deeper aquifer, well depth > 200 feet, were not reported by King County (1991c). Additional groundwater quality data is expected to be available from the Seattle-King County Department of Public Health in the near future.

Phytoplankton

Lake Desire was sampled for phytoplankton in 1971, 1973, and 1974 by King County DMS (Metro, 1973; Metro 1976a). No single genera of algae dominated the lake; rather a variety of algae dominated ranging from blue-greens to greens to diatoms. Studies by King County DMS (Metro, 1973) showed diatoms to dominate during the spring, and a combination of diatoms, greens, and blue-greens to dominate in the summer and fall. During 1973 to 1974 Lake Desire had consistently high chlorophyll *a* concentrations (average concentration of 19.7 µg/L) and phytoplankton densities (average biovolume of 7.3 cm^3/m^3), indicating a very productive phytoplankton population existed in the lake. Indeed, the lake had one of the top four mean chlorophyll *a* values and phytoplankton densities out of 16 lakes sampled by King County DMS in King County between 1973 and 1974 (Metro, 1976a).

Macrophytes

Macrophyte surveys were conducted on Lake Desire in 1976, 1978 and 1980 by King County DMS (Metro, 1976b; Metro, 1978; Metro, 1980). Between 1976 and 1980, macrophyte aerial coverage varied due to natural yearly fluctuations in plant growth. However, the dominant species remained the same with *Potamogeton berchtoldii* (pondweed), *Nymphaea odorata* (Fragrant white water lily), *Nuphar variegatum* (Yellow water lily), and *Elodea canadensis* (Waterweed) the most common aquatic plants. Metro (1980) rated the plant density as light to moderate with macrophyte coverage in the lake ranging from 10 to 21 acres between 1976 and 1980. Of particular importance was the presence of the exotic species *Myriophyllum spicatum* (Eurasian watermilfoil), detected for the first time in the lake in 1979.

CURRENT PHYSICAL CONDITIONS

Temperature

Water is at its densest at 4°C. This unique property of water allows ice to float and form at the surface of lakes at 0°C or less and thermal stratification to occur during the warmer, summer weather. As lakes transition from winter, when the water column is completely mixed, light energy from the sun heats the upper surface water layer, eventually resulting in the upper water layer or epilimnion becoming isolated (from mixing) from the lower layer or hypolimnion (Figure 4-1). The layers are separated by the middle layer or metalimnion where large temperature changes occur with changes in lake depth.

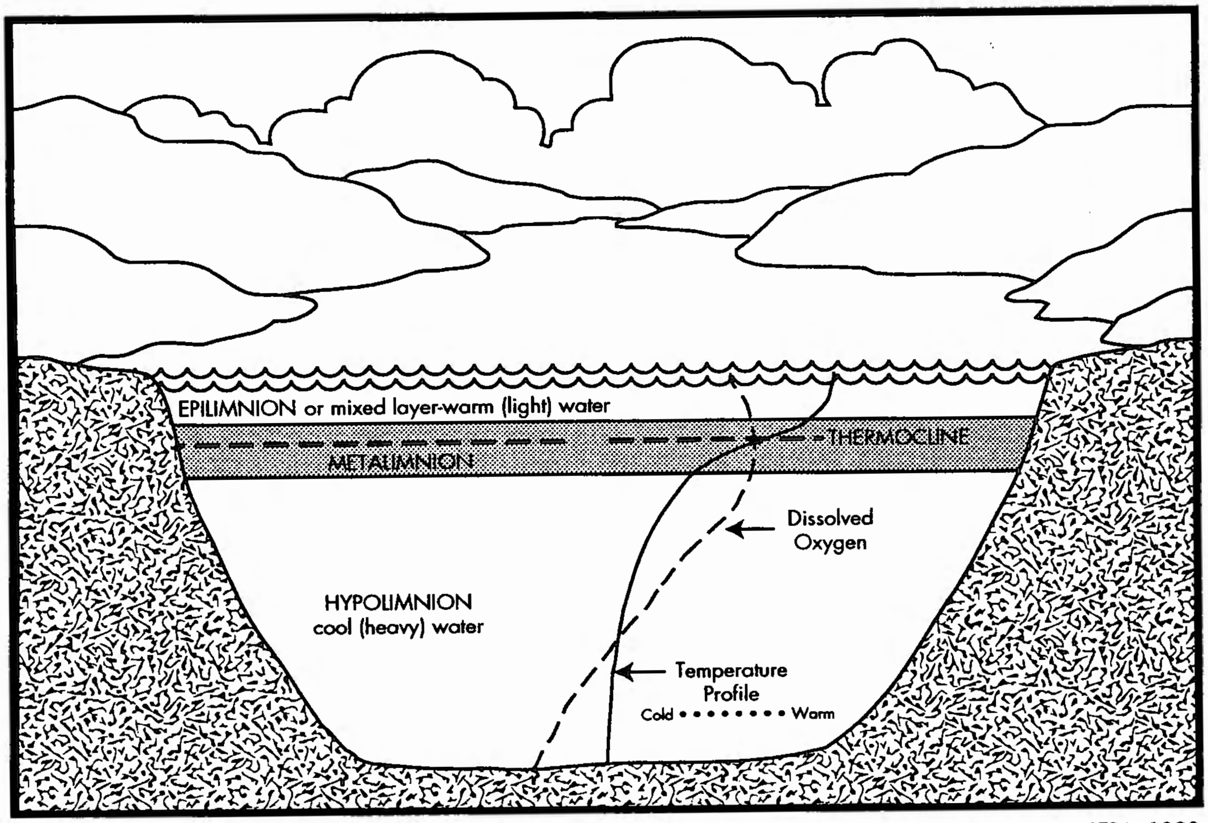
Figure 4-2 illustrates five representative temperature profiles for Lake Desire during the study period. The difference between surface temperatures in the spring (May 25, 1993) and summer profiles (August 31, 1993) is unusually small due to the cool summer of 1993. A summary of selected water quality variables, including temperature, is shown in Table 4-2. Lake surface temperatures averaged 15°C with a summer mean value of 20°C. Lake turnover occurred in November, 1993, as evident by the uniform water column temperature (Figure 4-2). The lowest water column temperature was recorded in February, 1994, at 4.4°C.

Transparency (Clarity)

Water clarity determines the quality and quantity of light in the water column. Light is needed for algae and aquatic plants to grow. Light and temperature often limit plant growth. A variety of factors influence lake clarity including natural color, algae, and turbidity from sediments or other suspended matter.

Secchi depth is a common measure of lake clarity and is one of the indices used to determine a lake's trophic status. Over the course of the study period, Secchi depth transparency in Lake Desire varied between 0.5 and 2.5 meters with an average value of two meters (Figure 4-3). This average Secchi depth value for Lake Desire is low compared to most other King County lakes. This low number, however, must be considered in the context of other factors which affect transparency values including color and algae.

Figure 4–1 Thermal Stratification



USEPA, 1990

A cross-sectional view of a thermally stratified lake in mid-summer. The water temperature profile illustrates how rapidly the the temperature decreases in the metalimnion compared to the nearly uniform temperatures in the epilimnion and hypolimnion. The metalimnetric density gradient associated with this region of rapid temperature change provides a strong, effective barrier to water column mixing.

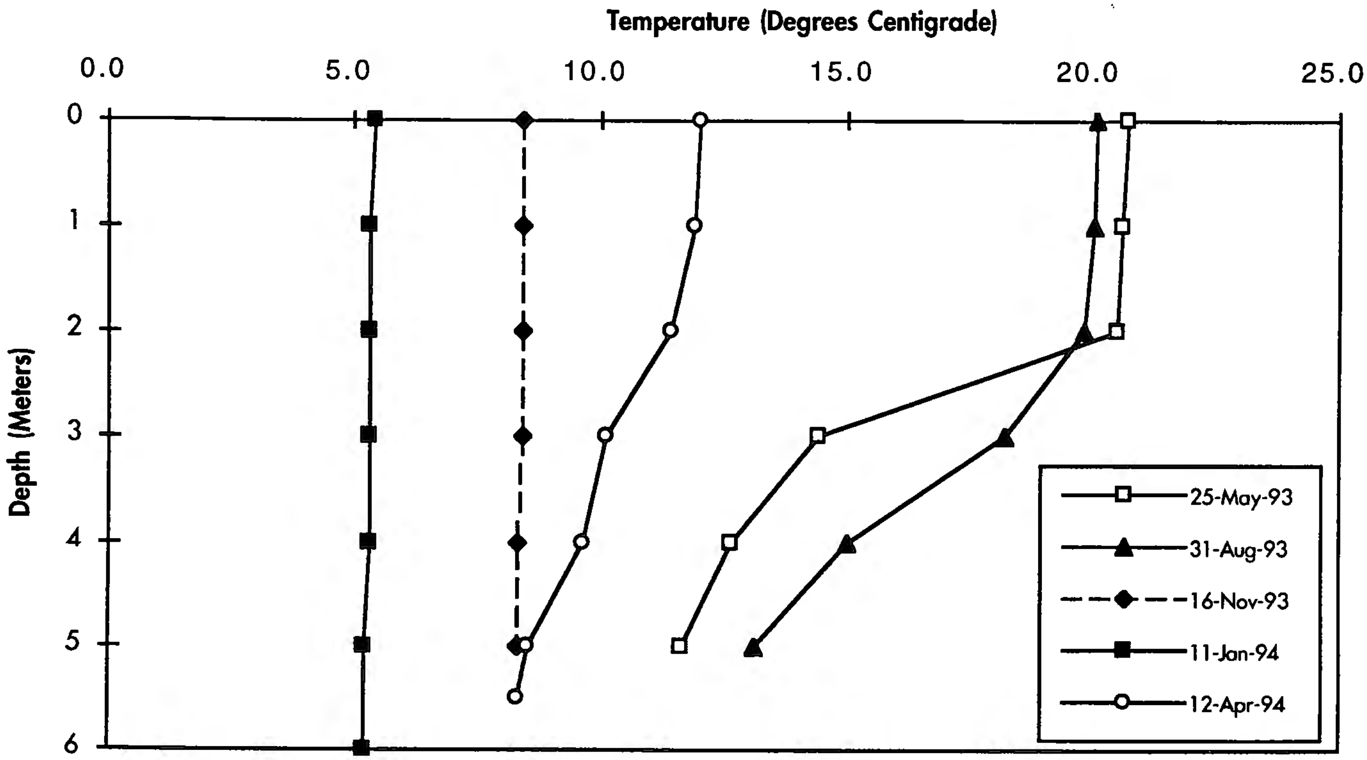
Lake Desire's transparency is naturally influenced by its wetland inflows which are high in organic acids, giving the lake its natural tea color. Figure 4-4 illustrates the inter-relationships between Secchi depth, color, and chlorophyll *a* (a measure of algal biomass) in the lake. Color concentration averaged 59 units in Lake Desire and is inversely related to Secchi depth (Figure 4-4). The relationship between chlorophyll *a* and Secchi depth is less pronounced. During periods of algal blooms, however, Secchi depth or water column transparency is obviously influenced by chlorophyll *a* (Figure 4-4). During most of the year, however, the low transparency values observed in Lake Desire can be attributed to color alone. This is evidenced by the low transparency values observed during the winter months when chlorophyll *a* values are low and color remains consistently between 60-70 units (Figure 4-4).

CURRENT CHEMICAL CONDITIONS

Dissolved Oxygen

Oxygen concentrations are important in lakes for regulating chemical processes and in determining the amount of available habitat and types of organisms that can exist. When the oxygen concentration drops to zero in the lake hypolimnion, the anoxic (no oxygen) condition affects the phosphorus chemistry at the

Figure 4-2 Lake Desire Temperature Profiles



water-sediment interface. During anoxic conditions, phosphorus is released from the sediments to the hypolimnetic water.

Oxygen is added to the water column from the atmosphere and by plants as they photosynthesize during the day. Oxygen is removed through respiration of aquatic organisms and plants.

Surface dissolved oxygen concentrations averaged 9 mg/L during the study period, with a minimum value of 5 mg/L (August 13, 1993) and a maximum value of 12 mg/L (March 15, 1994). As shown in Figure 4-5, dissolved oxygen profiles for Lake Desire are fairly typical for a shallow stratified lake. Dissolved oxygen concentrations in the hypolimnion were 2 mg/L or less from May through September. This oxygen concentration in the hypolimnion is generally too low to support most animal life. Thus, most animal activity is restricted to the upper water layers which are sufficiently oxygenated during the stratified period. The cold-water fishery, however, may be restricted to a narrow band within the metalimnion of preferred oxygen and temperature conditions.

Conductivity

Conductivity is a measure of a solution's ability to conduct electricity and is used as an indicator of the amount of dissolved ions present. Conductivity of a solution increases with increasing ion concentration. Surface water conductivity of Lake Desire averaged 65 µmho/cm and ranged from 50 to 85 µmho/cm. Conductivity in most freshwater systems ranges between 10 to 1,000 µmho/cm. In King

Table 4-2: Summary of Select Water Quality Variables for In-lake Sampling Stations Collected April 1993 through April 1994

Parameter	Units	DESIRE1 n=18			DESIRE2[a] n=11		
		Mean[b]	Min	Max	Mean[b]	Min	Max
Temperature	(°C)	14.8	4.5	20.7	18.9	12.2	22.2
Dissolved Oxygen	(mg/L)	8.7	5.1	12.1	7.9	4.4	10.6
pH	(units)	7.4	6.5	7.9	8.1	6.8	9.0
Conductivity	(µS/cm)	65.1	50.0	85.0	65.5	58.0	70.0
Total Phosphorus	(µg/L)	39.3	19.0	70.0	33.1	22.0	54.0
Ortho-Phosphorus	(µg/L)	14.1	2.0	50.0	8.2	2.0	28.0
Total Nitrogen	(µg/L)	726.3	290.0	1500.0	667.3	410.0	1300.0
Nitrate-Nitrogen	(µg/L)	149.3	6.0	570.0	51.5	6.0	220.0
Ammonia-Nitrogen	(µg/L)	51.4	7.0	170.0	52.2	7.0	180.0
Alkalinity	(mg CaCO3)	21.5	18.0	27.0	20.1	16.0	25.0
Turbidity	(NTU)	1.7	0.5	9.1	1.8	0.6	7.8
Color	(units)	58.5	40.0	75.0	55.5	20.0	70.0
Fecal Coliforms	(CFU/100 ml)	3.8	1.0	9.0	2.4	1.0	4.0
Transparency	(M)	1.8	0.5	2.3	1.8	0.8	2.7
Chlorophyll *a*	(µg/L)	12.9	1	63	14.4	2.1	61.0
Pheophytin	(µg/L)	11.5	0.9	72	11.2	8.8	1.5

[a] *Data was collected from April 27, 1993 to September 28, 1993 only at the second in-lake location.*

[b]*Arithmetic mean values are given for surface concentrations (0.5 m) only, logarithmic means were calculated for pH values and geometric means for fecal coliform values.*

County conductivity values are generally low in most streams and lakes, averaging less than 100 µmho/cm during non-storm flows.

Alkalinity and pH

Alkalinity of water generally refers to the quantity and kinds of compounds present which buffer changes in pH. The property of alkalinity is usually imparted by the presence of bicarbonates, carbonates, and hydroxides (Wetzel, 1983).

Lake Desire surface water alkalinity averaged 22 mg calcium carbonate($CaCO_3$)/L and did not vary greatly with lake depth. Generally alkalinity values of 75 mg $CaCO_3$/L or less are found in low alkalinity waters. The alkalinity values observed in Lake Desire are consistent with those found in western Washington which are generally low due to the lack of sedimentary carbonate (Carroll and Pelletier, 1991).

Figure 4–3 Lake Desire Secchi Depth

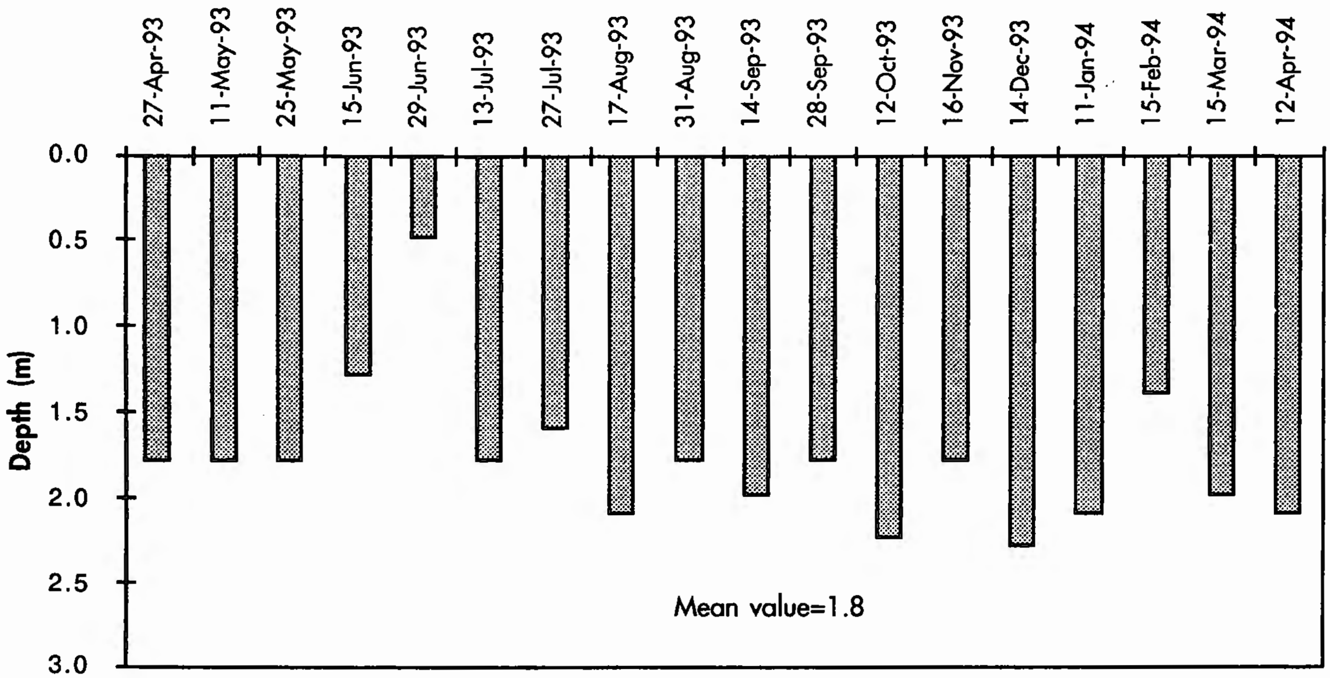


Figure 4–4 Lake Desire Chlorophyll *a*, Color, Secchi Depth Interrelationship

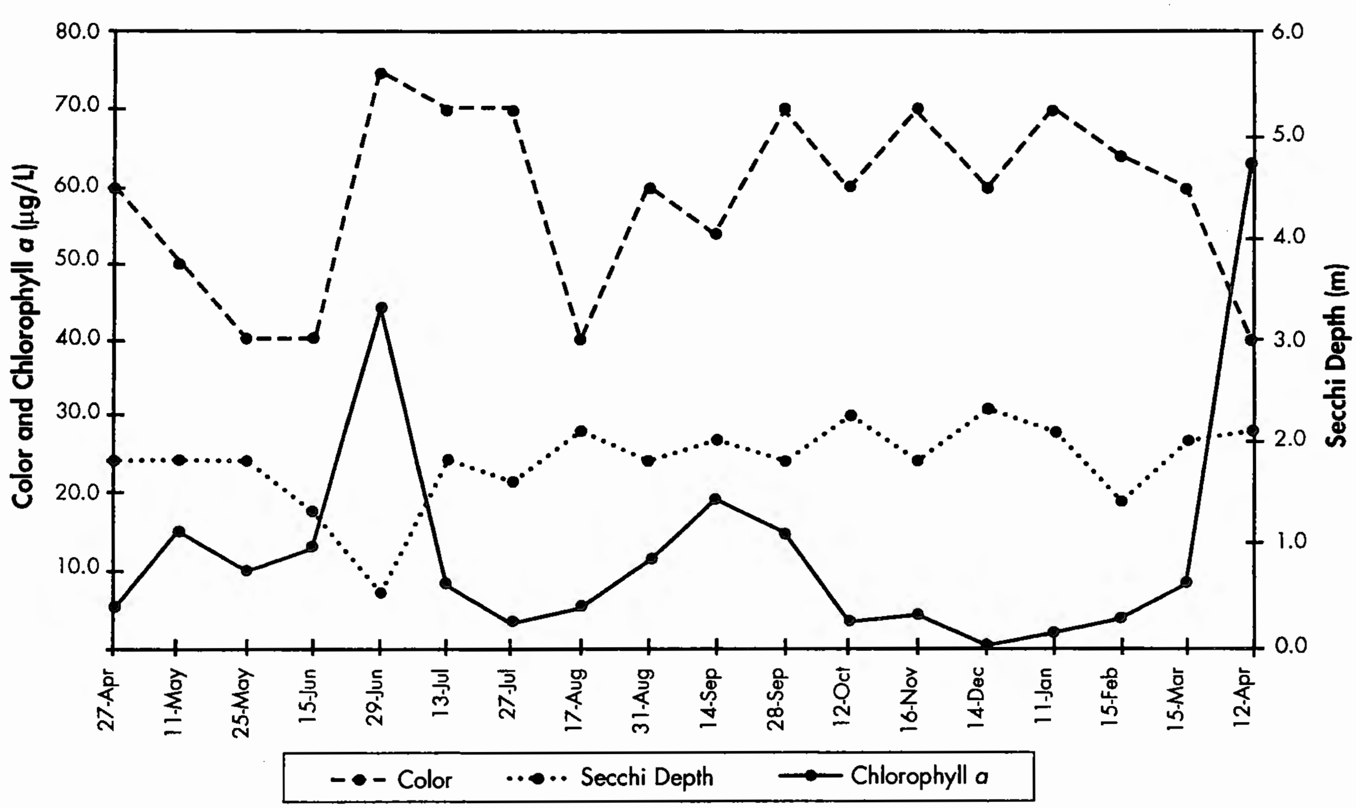
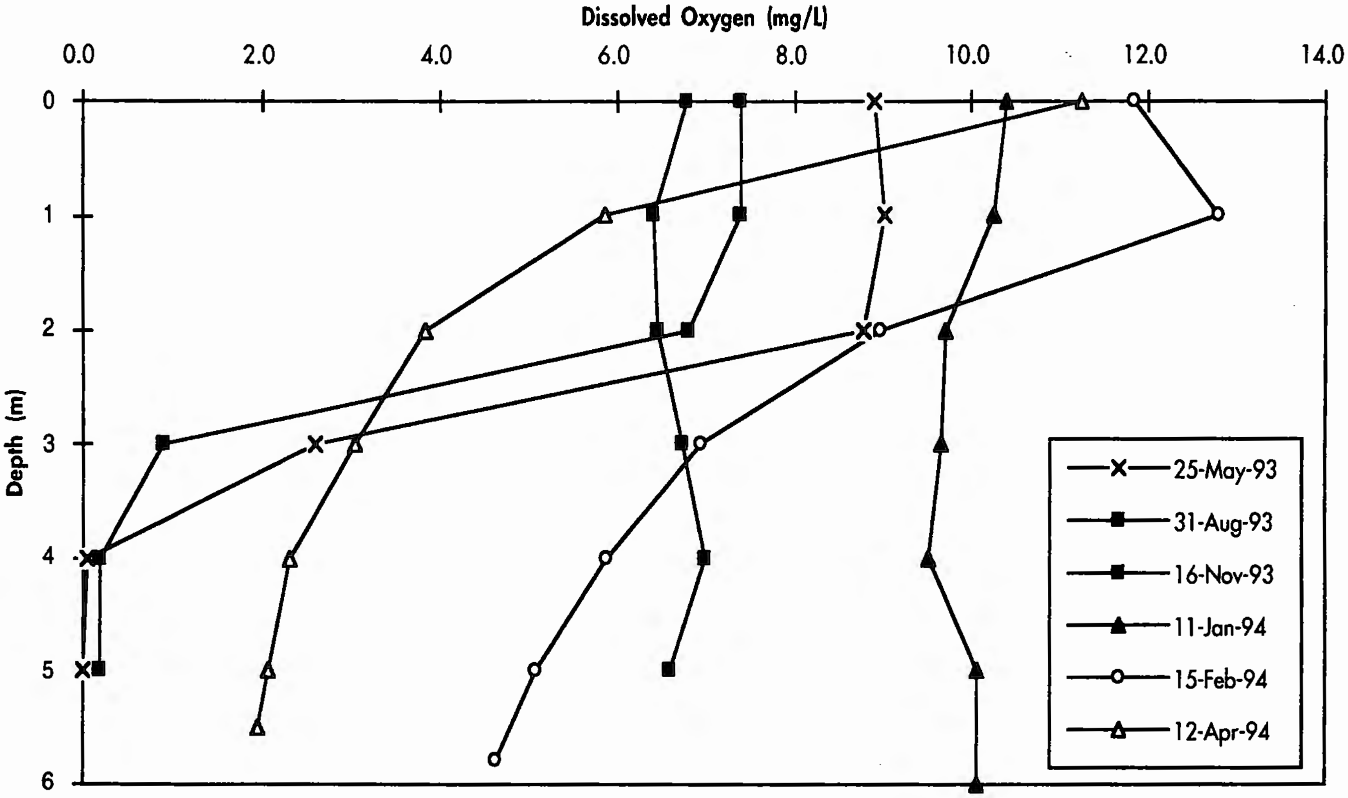


Figure 4–5 Lake Desire Dissolved Oxygen Profiles



The pH or hydrogen ion activity is a measure of acidity. Lake pH showed a similar pattern to alkalinity with depth. Average surface pH was 7.4 and ranged from 6.5 to 7.9. Elevated surface pH values were noted on several occasions and were attributed to photosynthetic activity of algae in the lake epilimnion. In general, most surface water pHs fall within the range of 6.0 to 8.5. The lower lake pH which was observed during the study period is likely to be influence by the humic and fulvic acid inputs from upstream wetlands.

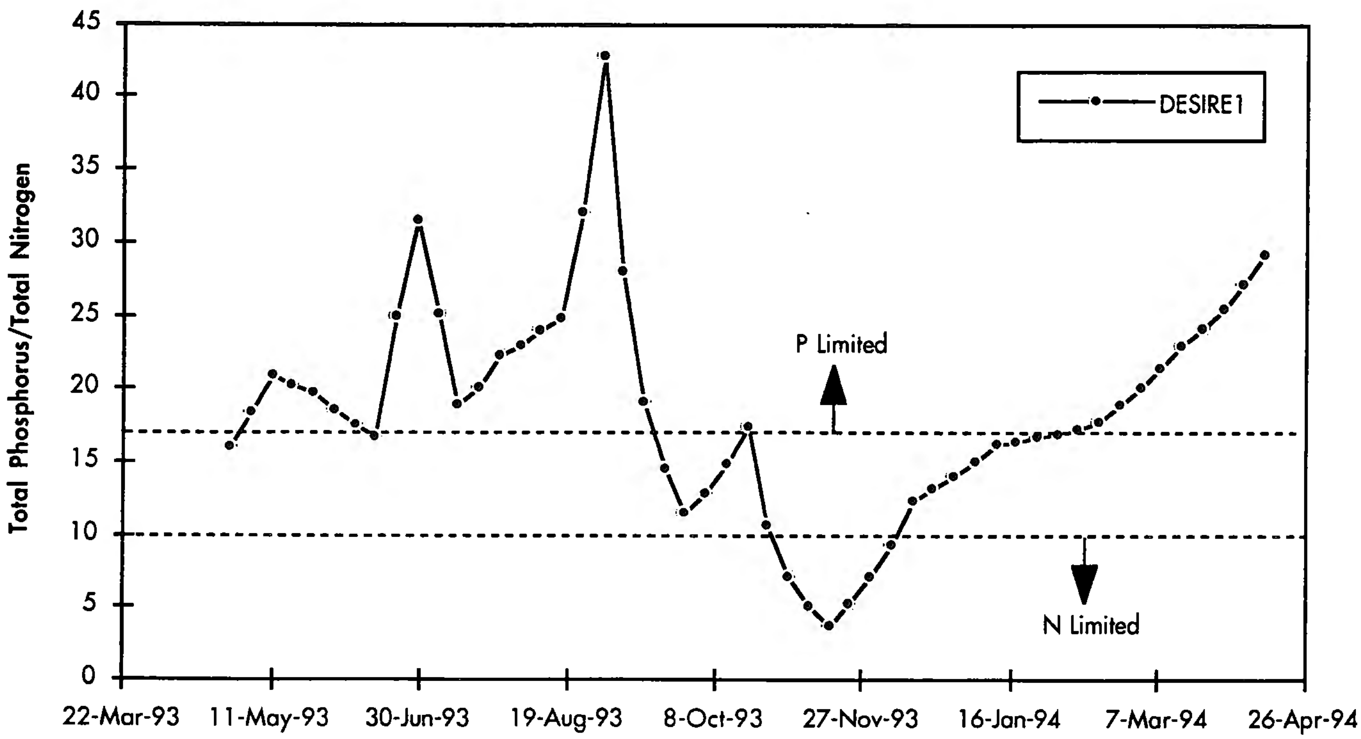
Nutrient Limitation

Most lake water quality problems are associated with an overabundance of plant nutrients, which results in excessive plant growth. In managing such water quality problems, it is important to assess what nutrient or nutrients limit plant growth. Nitrogen and phosphorus usually are the major nutrients that limit algal growth. In freshwater, phosphorus is often the nutrient in shortest supply. Therefore, most lake management strategies focus on reducing phosphorus loading.

Epilimnetic nitrogen to phosphorus ratios greater than 17:1 generally suggest that phosphorus limits phytoplankton or algal growth (Carroll and Pelletier, 1991). During much of the growing season, Lake Desire appears to be phosphorus limited (Figure 4-6). During September nitrogen to phosphorus ratios dropped below 17:1 suggesting nitrogen limited algal growth during the fall season.

Nutrient limitation in Lake Desire was also evaluated using an in-lake algal fertilization technique. The first bioassay results from October 1993, suggested that both nitrogen and phosphorus were important in controlling algal biomass (KCM, 1993b). The second bioassay, conducted in August 1994, showed

Figure 4–6 Lake Desire Weekly Volume-weighted Total Phosphorus/Total Nitrogen Ratio



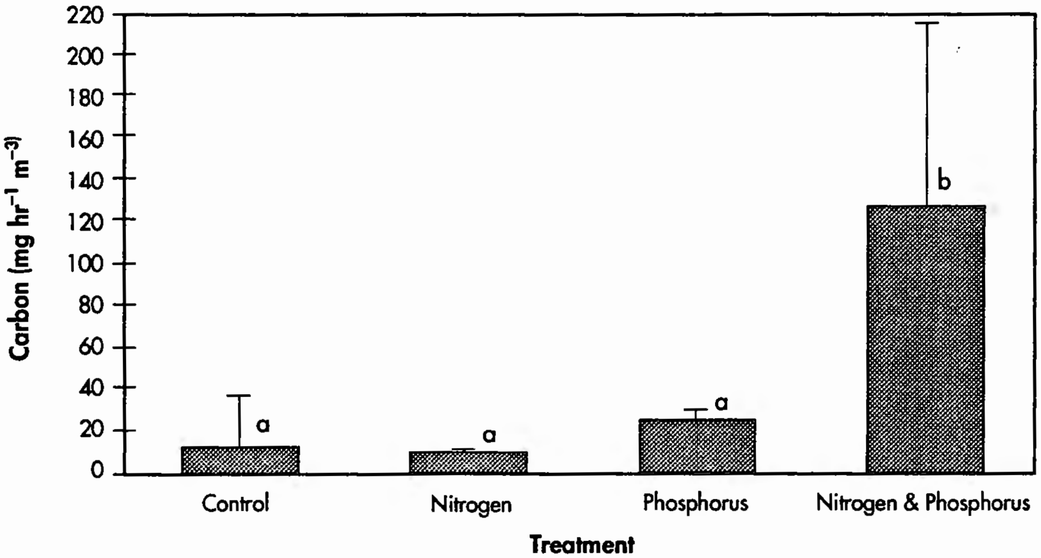
conclusively that both phosphorus and nitrogen limited algal growth during the in-lake experiment (KCM, 1994b). Phytoplankton enrichment response, measured as mg carbon hr^{-1} m^{-3} showed a threefold increase with the addition of both phosphorus and nitrogen (Figure 4-7). The results from both bioassays are generally consistent with the seasonal patterns of epilimnetic nitrogen to phosphorus ratios in the lake seen during the study period (Figure 4-6).

Phosphorus

Phosphorus is a common element in the environment. It is naturally occurring both in soil and rock and can be found in plant and animal tissue as well as in the atmosphere. The importance of phosphorus in algal growth, as described above, is that its concentration often limits productivity in freshwater systems. That is, every other element needed for growth is present in excessive amounts. It is only when phosphorus or some physical factor (i.e., light or temperature) becomes limiting that algal growth is significantly reduced.

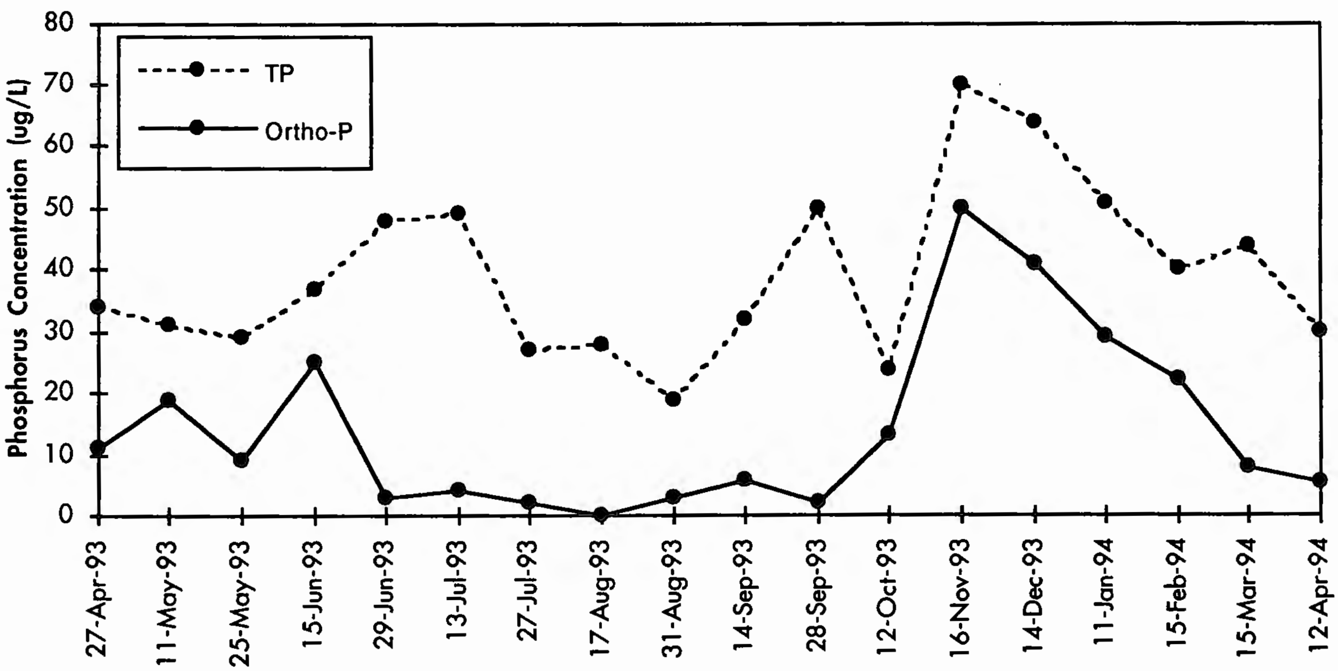
Phosphorus was measured as both total phosphorus (TP) and ortho-phosphorus (ortho-P) during the study period. Total phosphorus represents both organic and inorganic forms of phosphorus. Ortho-P generally represents the portion (dissolved) of phosphorus that is available for algal growth. Annual TP and ortho-P surface concentrations are shown in Figure 4-8. Ortho-P concentrations followed expected seasonal patterns with lowest concentrations during the summer months when much of the soluble phosphorus is being utilized by phytoplankton. Maximum differences between TP and ortho-P concentrations were also present during the summer when phytoplankton biomass was consistently high.

Figure 4–7 Mean Response of Phytoplankton in Lake Desire to Nutrient Enrichment



Columns with the same letter are not significantly different (α = 0.05, n = 3).
95% confidence limits shown.

Figure 4–8 Lake Desire Annual Total Phosphorus and Orthophosphorus Concentration



Surface concentrations for TP averaged 39 µg/L and for ortho-P, 14 µg/L. Summer concentrations averaged 34 µg/L for TP and 3 µg/L for ortho-P. Total phosphorus concentrations for Lake Desire are high and fall in the eutrophic range for lakes.

Total phosphorus concentrations were volume-weighted for calculation of whole-lake, epilimnetic, and hypolimnetic TP concentrations. Weekly volume-weighted, whole-lake total phosphorus concentrations were used in the development of the lake phosphorus model. Annual and summer volume-weighted epilimnetic, hypolimnetic, and whole-lake TP concentrations are summarized in Table 4-3.

Table 4-3: Volume-weighted Total Phosphorus Summary

Period	Epilimnetic	Hypolimnetic	Whole-lake
Annual	42 µg/L	101 µg/L	49 µg/L
Summer (Jun-Sept)	34 µg/L	165 µg/L	49 µg/L

Nitrogen

Nitrogen exists in several forms in aquatic systems including nitrite+nitrate-nitrogen, nitrate-nitrogen, ammonia-nitrogen, organic nitrogen, and elemental nitrogen. The dissolved forms of nitrogen, including ammonia-nitrogen and nitrate-nitrogen, are the most common forms of nitrogen used by algae and aquatic plants for growth.

For this study, total nitrogen, nitrite+nitrate-nitrogen, and ammonia nitrogen were measured. Total nitrogen, nitrite+nitrate-nitrogen, and ammonia nitrogen concentrations at the surface averaged 726 µg/L, 190 µg/L, and 53 µg/L, respectively.

Ammonia-nitrogen concentrations typically increased in the hypolimnion once the lake stratifies. High levels of un-ionized ammonia can be toxic to aquatic animals, especially in alkaline pH lakes. Average ammonia-nitrogen concentration in the hypolimnion during the stratified period was 834 µg/L. A maximum value of 1800 µg/L was observed at five meters in the hypolimnion on September 14, 1993.

Quarterly Parameters

As described in Table 3-1, a variety of parameters of interest to lake water quality management were monitored on a quarterly basis. Aluminum, calcium, magnesium, and iron concentrations are particularly important when considering phosphorus inactivation or sediment oxidation as a restoration alternative.

Calcium and magnesium concentrations at the surface were 5925 µg/L and 2350 µg/L, respectively. Magnesium concentration only slightly increased in concentration with depth (2525 µg/L at 5 m), while calcium showed greater variation with depth (7325 µg/L at 5 m). Sodium and chloride concentrations at the surface were 4175 µg/L and 2900 µg/L, respectively, and showed a similar to that of magnesium with increasing depth. Both potassium and aluminum were less than the method detection limits.

Sulfate concentrations averaged 4525 µg/L at the surface only showed an appreciable decrease in concentration during lake stratification below the thermocline (average value of 3500 µg/L at 5 m;

minimum value of 100 µg/L, at 5 m, September, 1993). Iron concentrations averaged 470 µg/L at the lake surface and through much of the water column with increasing depth. At five meters, the iron concentration increased to an average value of 2898 µg/L with a September, 1993, maximum of 8300 µg/L.

Total organic carbon and dissolved organic carbon concentration were typically less than 10 µg/L. Total soluble phosphorus concentration ranged from 8 to 600 µg/L. The highest value was recorded at 5 m during September, 1993.

Sediment Quality

Sediment type and chemistry plays a significant role in nutrient cycling in most lakes. In particular, the capacity of sediments to release or retain phosphorus to/from the lake hypolimnion is dependent upon the ability of sediments to bind phosphorus and the length of the anoxic period during lake stratification.

Table 4-4 summarizes the quality of sediment in Lake Desire for three depth ranges in the lake: 0-2 m, 2-4 m, and >4 m. Sediment total phosphorus concentrations in the upper 0-2 cm fractions increased with core sampling depth. Cores taken from a depth of >4 m averaged 1911 mg/kg total phosphorus in the upper 0-2 cm fraction while those taken from a depth range of 0-2 meters averaged 1025 mg/kg total phosphorus. This general relationship for total phosphorus concentration between core sampling depth and core fractional depth was consistent for the four core sections sampled (Figure 4-9). Total iron to total phosphorus ratios were generally low for all three depth strata and were greatest (12:1) in the cores from the 0-2 m depth range (Table 4-4).

Average sediment zinc and lead concentrations are shown in Figure 4-10 for two 0.5 meter cores. Below the 10-12 cm mark, lead and zinc concentrations dramatically decreased in the sediment profile. This point most likely represents the maximum use of leaded gasoline in the United States prior to the introduction of unleaded gasoline. In the upper 8 cm, lead concentrations showed a decreasing trend which most likely represents the reduction of leaded gasoline use. The first increase in lead concentration is noted at the 24-26 cm depth.

The use of leaded gasoline began in 1930 and decreased again around 1972 (Cooke et al., 1993a). Using this information, it is estimated that the sedimentation rate in Lake Desire was 0.33 cm/yr between 1930 and 1972 and 0.45 cm/yr between 1972 and 1994.

Tributary Water Quality

Tributary water quality was evaluated during base flow and high (storm) flow conditions. Tributary water quality is used to assess the significance of watershed or external nutrient loading to the lake. Much of the external nutrient loading to lakes enters lakes during the wet portions of the year (typically October through April). In Lake Desire, the inflow to the lake is intermittent and usually only flows significantly during the months of December through May.

The base flow water quality, which is summarized in Table 4-5, is fairly reflective of the forested/wetland conditions of the inflow tributary area. The inflow water quality is heavily influenced by the tributary wetlands which result in lower dissolved oxygen concentration (5 mg/L on average) and pH values (6.0), and higher nutrient concentrations (Table 4-5) due to the cycling of organic material within the wetlands.

Table 4-4: Sediment Quality for Lake Desire by Sediment Core Fractional Depth and Lake Depth Strata

Parameter	Units	0-2 cm	2-12 cm	12-22 cm	22-32 cm
Core Sampling Depth 0-2 m					
n		4	4	4	-
% Solids	%	6.3	8.0	8.8	-
% Volatile Solids	%	50.8	53.3	52.3	-
Total Phosphorus	mg/kg	1025	691	623	-
Total Kjeldahl Nitrogen	mg/kg	15196	13407	16809	-
Iron	mg/kg	12433	12589	6724	-
Total Iron/Total Phosphorus		12:1			
Core Sampling Depth 2-4 m					
n		4	4	4	2
% Solids	%	5.7	7.0	7.7	7.7
% Volatile Solids	%	37.2	35.9	35.4	32.9
Total Phosphorus	mg/kg	1352	1243	1106	1048
Total Kjeldahl Nitrogen	mg/kg	12934	11990	12698	12608
Iron	mg/kg	13419	7962	19310	4692
Total Iron/Total Phosphorus		10:1			
Core Sampling Depth >4 m					
n		6[a]	4	4	3
% Solids	%	5.1	6.6	7.9	7.6
% Volatile Solids	%	37.1	35.2	35.8	38.2
Total Phosphorus	mg/kg	1911	1287	1721	1538
Total Kjeldahl Nitrogen	mg/kg	14816	11333	13098	15323
Iron	mg/kg	16159	11878	11676	6647
Total Iron/Total Phosphorus		8:1			

[a] *n=6 for % solids, TP, and TKN only. n=4 for remaining parameters.*

During storm flow, total phosphorus concentrations were elevated averaging 88 µg/L for the four dates measured. Much of the elevated concentration is attributed to a 24-hour composited sample taken on February 14, 1994, which had a total phosphorus concentration of 210 µg/L (precipitation total for February 13 and 14 was 1.04 inches). For the other three events sampled, total phosphorus concentrations were similar to base flow values. This suggests that with the exception of large storm events, the concentrations in the outlet of Cedar River Wetland 15 are consistent during the wet season. Total nitrogen concentrations were also, on average, elevated during high flow events, but elevated concentrations were less obviously correlated with flow.

Upland Water Quality

Upland water quality was evaluated during the wet season on a monthly basis. Inflow and outflow water quality to Cedar River Wetland 14 are summarized in Table 4-6. Samples were taken on routine sampling dates to allow for greater data comparability with wetland outflow data from Cedar River Wetland 15.

Figure 4–9 Lake Desire Sediment Total Phosphorus Content for Three Depth Strata

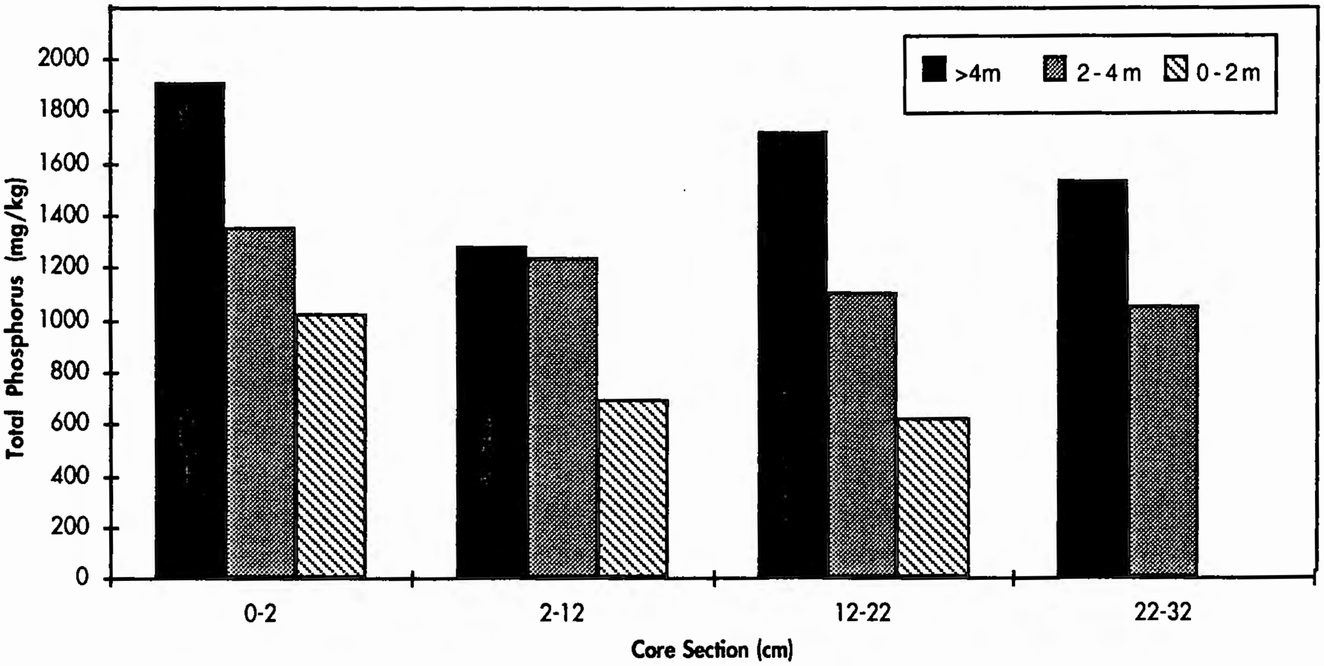


Figure 4–10 Lake Desire Lead and Zinc Sediment Profile

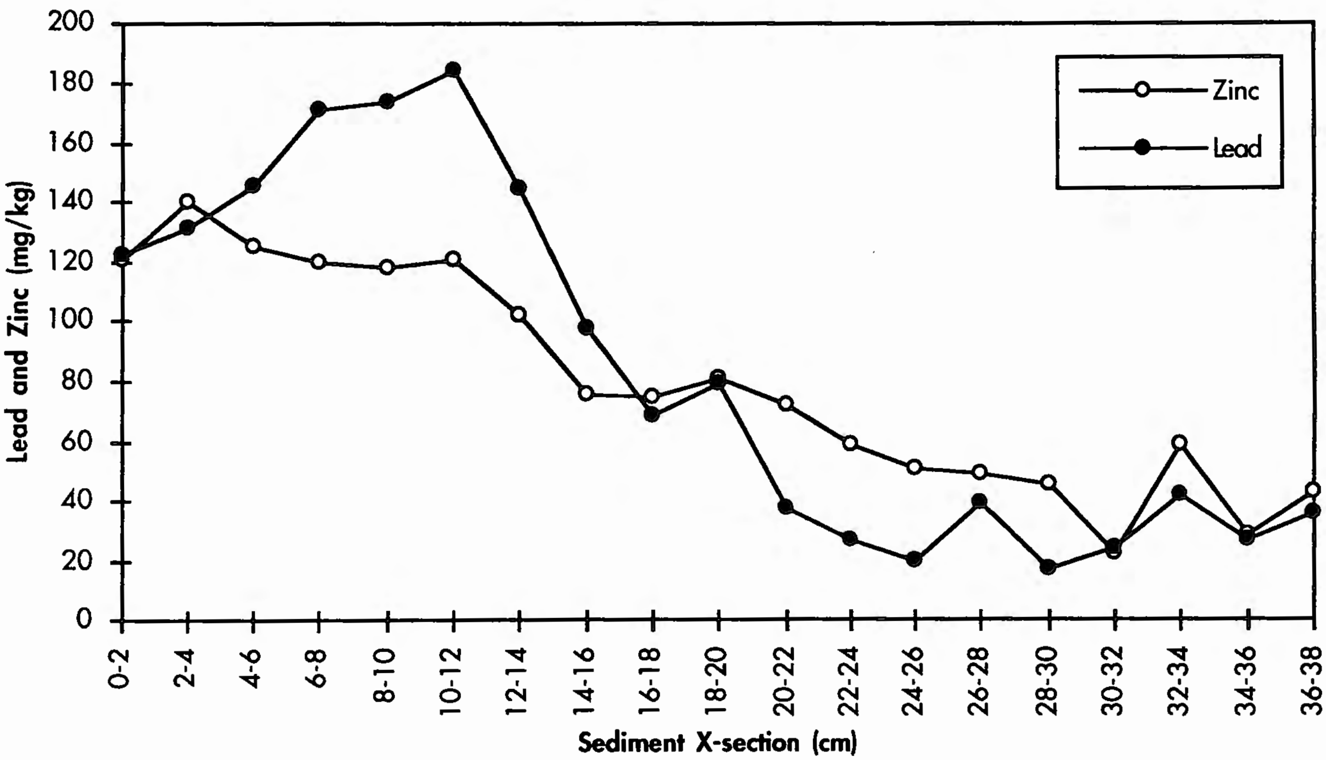


Table 4-5: Inflow and Outlet Water Quality

Parameter	Units	LDIN1 (Inflow), n=12			LDOUT (Outflow), n=15			LDIN1 (Storm flow), n=4[a]		
		Mean[b]	Min	Max	Mean[b]	Min	Max	Mean[b]	Min	Max
Temperature	(°C)	7.8	0.4	14.3	11.4	4.9	19.7	5.3	---	---
Dissolved Oxygen	(mg/L)	5.1	1.4	7.3	9.0	2.5	12.0	7.3	---	---
pH	pH	6.3	5.3	6.6	7.1	6.1	7.8	6.5	---	---
Conductivity	(µmhos/cm)	49.0	45.0	52.0	79.2	65.0	98.0	---	---	---
Total Phosphorus	(µg/L)	52.4	31.0	82.0	41.2	5.3	67.0	87.8	210.0	40
Ortho-Phosphorus	(µg/L)	19.1	8.0	41.0	21.0	11.0	39.0	23.8	14.0	35.0
Total Nitrogen	(µg/L)	1745.8	60.0	3000.0	885.0	300.0	2200.0	2325.0	1800.0	2600.0
Nitrite+nitrate-Nitrogen	(µg/L)	1186.6	63.0	2500.0	278.3	10.0	580.0	1830.0	1300.0	2400.0
Ammonia-Nitrogen	(µg/L)	79.9	7.0	260.0	109.8	9.0	450.0	95.8	56.0	140.0
Chloride	(µg/L)	3215.8	2100.0	7700.0	3027.1	2600.0	3900.0	---	---	---
Alkalinity	(mg CaCO3/L)	12.0	6.6	31.0	22.6	18.0	34.0	---	---	---
Fecal Coliform	(CFU/ 100 ml)	35.4	4.0	240.0	---	---	---	---	---	---

[a]n=1 for temperature, dissolved oxygen, and pH.

[b]Arithmetic mean values are given for surface concentrations [0.5 m] only, logarithmic means were calculated for pH values and geometric means for fecal coliform values.

Elevated concentrations of total phosphorus, total nitrogen, and nitrite+nitrate-nitrogen (Table 4-6) were recorded from the outflows of two residential stormwater detention ponds (LDSRP1 and LDSRP2) which inflow to Cedar River Wetland 14. Elevated nitrogen concentrations were also recorded at site LDW2 which is a channelized ditch running along the southern border of Cedar River Wetland 14 (Table 4-6). This ditch collects much of the drainage from sites LDSRP1 and LDSRP2. At the outlet of Cedar River Wetland 14, nitrogen and phosphorus concentrations (Table 4-6) were lower and comparable to those of the outlet of Cedar River Wetland 15 (Table 4-5).

Groundwater

Several quality trends were noted in the limited groundwater data collected for Lake Desire. Nitrite+nitrate-nitrogen was undetected in all but two samples. Total nitrogen and ammonia-nitrogen concentrations were notably higher in the West and East sites than at the North site (Table 4-7).

The west and east sites are both within well developed residential areas, while the north site is within a large undeveloped area. The above trends indicate that the developed area may be providing a source of nitrogen to the lake, possibly from septic systems, fertilizers or other unknown sources (Hong West and Associates Inc., 1994).

Table 4-6: Upland Water Quality

		LDW1 (Wetland 14 outflow1) n=3			LDW2 (Wetland 14 outflow2) n=3			LDW4 (Wetland 14 inflow1) n=3		
Parameter	Units	Mean[a]	Min	Max	Mean[a]	Min	Max	Mean[a]	Min	Max
Temperature	(°C)	8.0	7.4	9.1	7.4	6.8	7.9	8.6	7.5	10.7
Dissolved Oxygen	(mg/L)	10.3	8.4	11.7	9.2	7.6	10.8	11.2	10.8	11.7
pH	pH	6.8	6.4	7.3	6.4	6.3	6.5	6.6	6.5	6.8
Conductivity	(µmhos/cm)	122.6	48	270	55.5	53	58	40.6	35	45
Total Phosphorus	(µg/L)	27.7	24.0	32.0	24.7	22.0	26.0	27.0	24.0	30.0
Ortho-Phosphorus	(µg/L)	4.0	8.0	6.2	11.0	10.0	12.0	6.4	3.0	8.1
Total Nitrogen	(µg/L)	1883.3	1700.0	2100.0	3233.3	2300.0	3700.0	1346.7	940.0	1700.0
Nitrite+nitrate-Nitrogen	(µg/L)	1433.3	1300.0	1700.0	2633.3	1800.0	3200.0	990.0	570.0	1300.0
Ammonia-Nitrogen	(µg/L)	<20.0	---	---	<20.0	---	---	<20.0	---	---
TSS	(mg/L)	2.9	1.0	5.5	1.8	1.2	2.3	3.3	1.4	5.4

		LDSRP1 (R/D Pond1) n=3			LDSRP2 (R/D Pond2) n=3		
Parameter	Units	Mean[a]	Min	Max	Mean[a]	Min	Max
Temperature	(°C)	9.7	7.9	13.0	10.3	8.4	13.5
Dissolved Oxygen	(mg/L)	11.3	10.4	12.2	13.1	12.2	13.9
pH	pH	7.2	7.1	7.3	7.0	6.9	7.3
Conductivity	(µmhos/cm)	113.7	108	125	121.0	115	130
Total Phosphorus	(µg/L)	90.3	31.0	130.0	37.0	11.0	64.0
Ortho-Phosphorus	(µg/L)	85.9	7.8	150.0	4.8	2.0	6.3
Total Nitrogen	(µg/L)	2433.3	300.0	3700.0	3866.7	3600.0	4300.0
Nitrite+nitrate-Nitrogen	(µg/L)	2180.0	240.0	3200.0	3633.3	3400.0	3800.0
Ammonia-Nitrogen	(µg/L)	83.3	20.0	130.0	<20.0	---	---
TSS	(mg/L	45.0	2.2	130.0	2.9	1.7	4.5

[a]Arithmetic mean values are given parameters except pH where logarithmic means were calculated.

Table 4-7: Groundwater Quality

Parameter	Units	West (LD-1 & LD-2) n=4			North (LD-3 & LD-4) n=4			East (LD-5 & LD-6) n=4		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Total Nitrogen	(µg/L)	2110	180	4580	870	230	1700	1610	230	3900
Ammonia-Nitrogen	(µg/L)	2040	75	4980	660	470	1150	2100	350	5030

CURRENT BIOLOGICAL CONDITIONS

Phytoplankton

Phytoplankton or algae are the microscopic plants found in the lake water column. There are many different types of algae including free-floating, swimming, filamentous, colonial, and single-celled. Algae are easily carried by wind-generated currents and often will accumulate in windward areas of the lake forming surface scums and nuisance conditions. Algae can also become a nuisance when populations rapidly increase forming high concentrations in the water column or even surface accumulations known as algal blooms.

Multiple algal species can usually be found in the lake any time during the year. Algal blooms are usually the result of one or more species dominating for a short time period. A variety of environmental factors including light, temperature, nutrient levels, and zooplankton densities affect phytoplankton production and the occurrence of algal blooms. Most Puget Sound region lakes are monomictic, mixing completely once in the fall, increasing the nutrient content of the upper lake waters. Nutrient concentrations remain elevated throughout the winter, and are available in the spring for phytoplankton growth. During the spring, light is not at its summer maximum and water temperatures remain cool, creating optimal growing conditions for diatoms which have an ability to grow under these conditions. During the summer, increased water temperature and available light as well as shifts in micronutrient availability, create conditions that favor green or blue-green algae. As the green or blue-green algae grow during the summer, they utilize the available nutrients and will tend to decline in numbers as the nutrients are used up. In the fall, turnover allows for the release of nutrients from the hypolimnion, creating nutrient-rich conditions for algae to once again grow.

Algae is another index used to evaluate the water quality conditions of a lake. The two most important aspects of algal or phytoplankton surveys are productivity/biomass and dominant species composition. By measuring chlorophyll *a* (an indicator of algal biomass) and examining species type, the lake trophic state can be estimated. Blue-green algae or cyanobacteria can form blooms and are most frequently associated with eutrophic conditions. Blue-green algae are particularly problematic because they will float to the surface, forming scums which affect the recreational use and aesthetic qualities of the lake.

Algal numbers are most abundant during the spring and summer when light and temperature conditions are most optimal. As the summer proceeds, a drop in algal numbers is often noticed as nutrient supplies are exhausted. As summer turns to fall, nutrient supplies which have been held in the hypolimnion become available as thermal stratification breaks down. This in turn, frequently results in increasing algal numbers in the fall, often to bloom conditions in eutrophic lakes.

In Lake Desire, phytoplankton populations are dominated by blue-green or Cyanophyta algae through most of the year except during mid-August to September, where Chrysophyta or golden-brown algae begin to dominate. Blue-greens comprise 73 percent and golden browns 16 percent of the total cell numbers/ml during the study period.

Figure 4-11 illustrates total phytoplankton volume during the study period. Peak volumes were seen in June, 1993, and April 1994. In terms of total volume, blue-green algae (37 percent) were still dominant through much of the year, with golden-browns the next largest component (29 percent).

Aphanizomenon flos-aquae was the dominant blue-green algal species present. Other blue-green species present included *Anabaena sp., Coelosphaerium naegelianum, Oscillatoria sp.,* and *Spirulina. Asterionella formosa, Dinobryon sp., Fragilaria crotonesis, Melosira sp., Synedra cyclopum,* and *Synura sp.* were the typical Chrysophyta species or genera found in the samples.

Chlorophyll *a* was also measured throughout the study to assess algal concentrations. Figure 4-12 shows the average chlorophyll *a* concentrations in the lake during the study period. Peaks in algal total volume (Figure 4-11) correspond well with peaks in chlorophyll *a* concentrations. Chlorophyll *a* concentrations averaged 14 µg/L during the course of the study. Peak values of 44 µg/L and 63 µg/L were recorded in June 1993 and April 1994. The April 1994, value was taken at the beginning of an intense blue-green algal bloom which continued through May prior to dissipating in June.

Zooplankton

Zooplankton are the tiny animals found in the lake water column. They are visible to the naked eye upon close inspection of a glass of lake water. Zooplankton are an important element in lake trophic structure because they consume algae and, in turn, are consumed by small fish. The types and number of zooplankton present are a good indicator of lake water quality. Generally, the presence of large grazing species such as *Daphnia* usually improve water quality (by eating algae) while the presence of rotifers and other smaller zooplankton are typically found in more nutrient-rich waters.

Zooplankton density ranged from 8,840 to 198,960 organisms/m3. Average density was 96,500 organisms/m^3. Rotifers (71 percent) were the dominant zooplankton group throughout much of the study year (Figure 4-13). The remaining zooplankton community was dominated by Cladocerans (12 percent) and Nauplii. (12 percent). As total dry weight biomass, Cladocerans and Dipterans were the most dominant component (Figure 4-14).

Benthic Invertebrates

Benthic macroinvertebrate organisms are found in the sediment of lakes and streams. The species found in a given area are usually representative of the surrounding water quality. Some organism, like mayflies, are intolerant of low dissolved oxygen conditions while other organisms like oligochaetes and chironomids are more tolerant of low dissolved oxygen conditions and are frequently used as pollution indicators. The overall proportion of pollution tolerant versus intolerant species is often used to evaluate overlying water quality.

The greatest density and diversity of benthic organisms is usually found in the littoral zone of the lake where ample vegetation and oxygen are present. Here, habitat and food resources can be found to support benthic communities. The benthic communities, in turn, provide food for fish and other larger animals.

Figure 4–11 Lake Desire Phytoplankton Total Volume

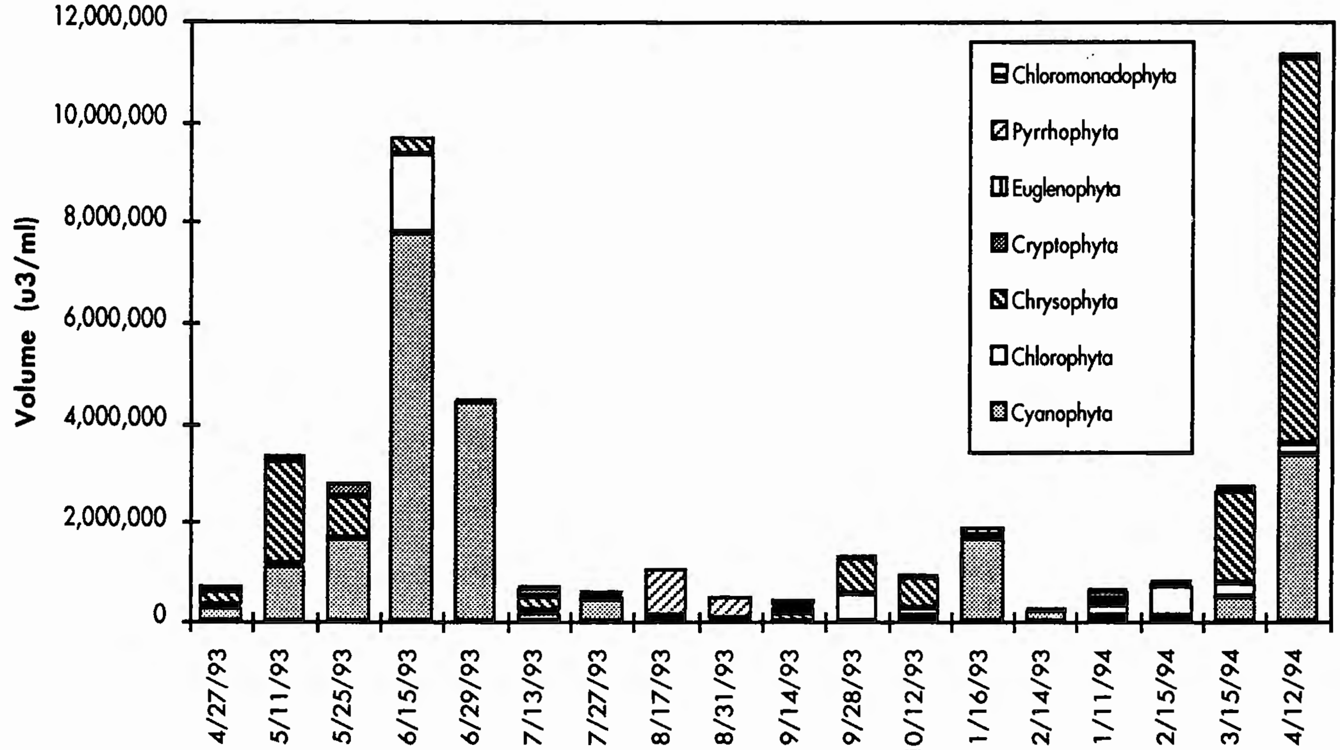


Figure 4–12 Lake Desire Chlorophyll *a* Concentrations

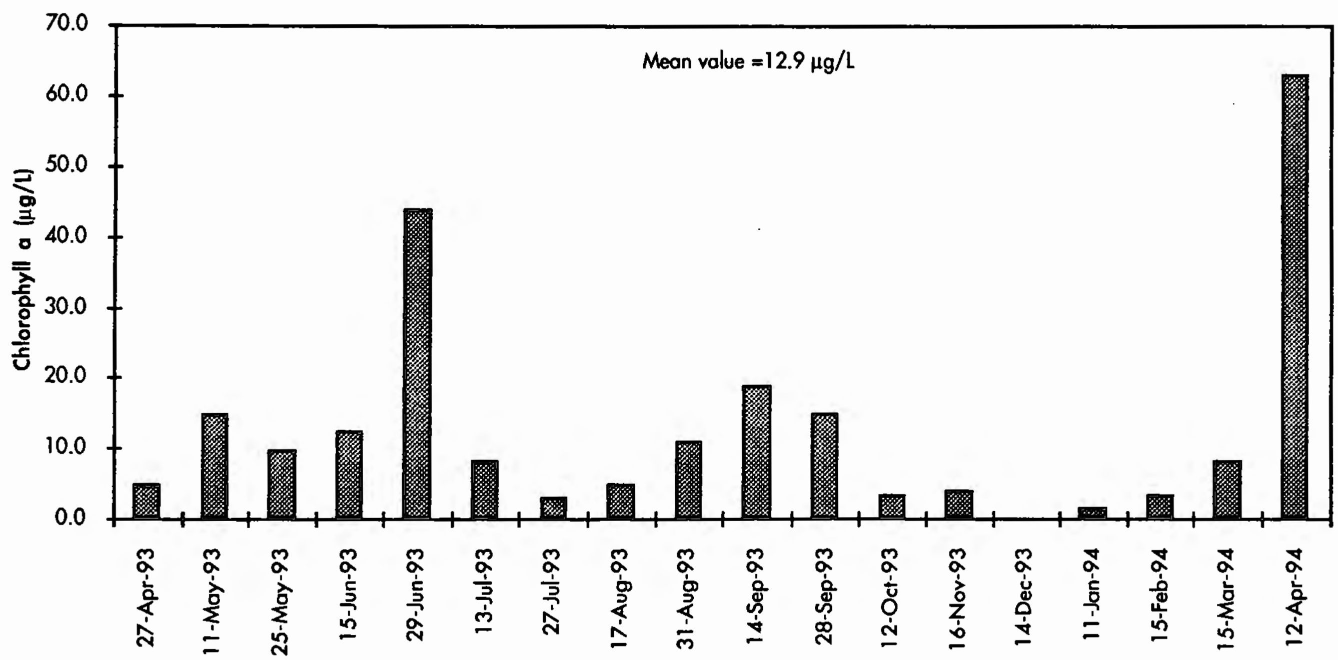


Figure 4–13 Lake Desire Zooplankton Densities

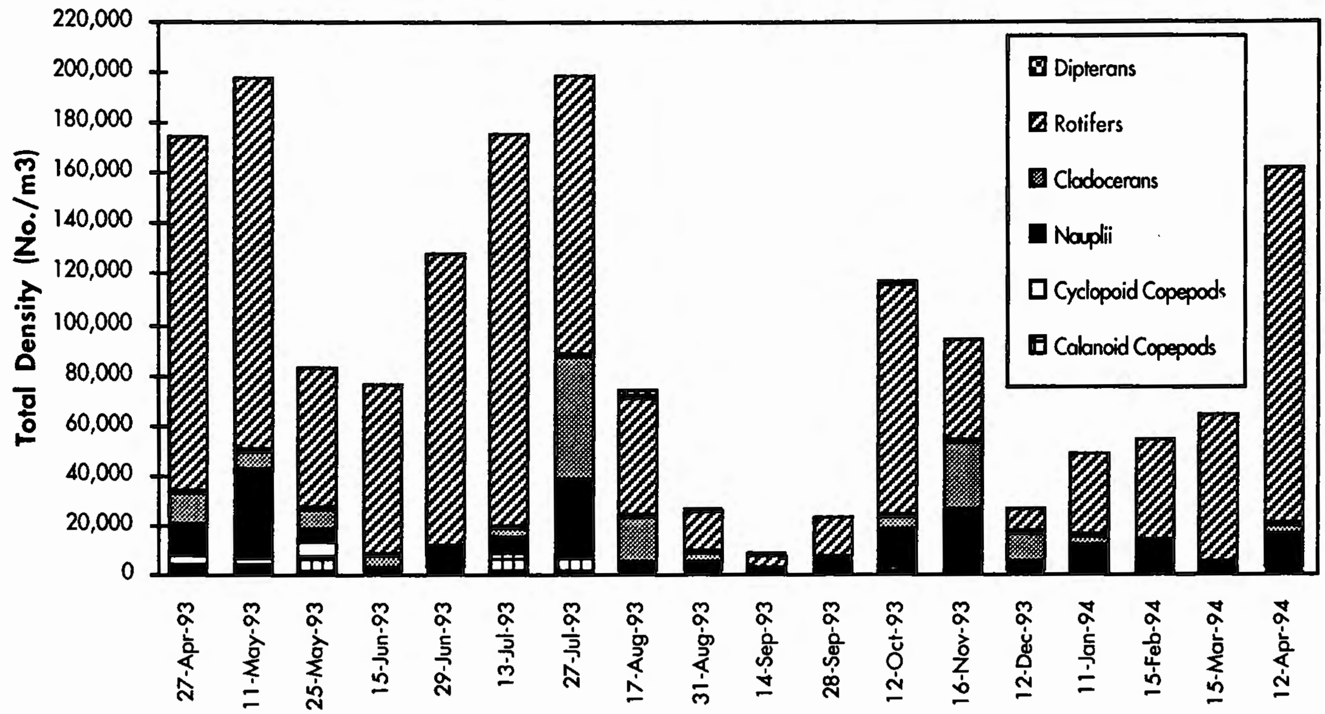
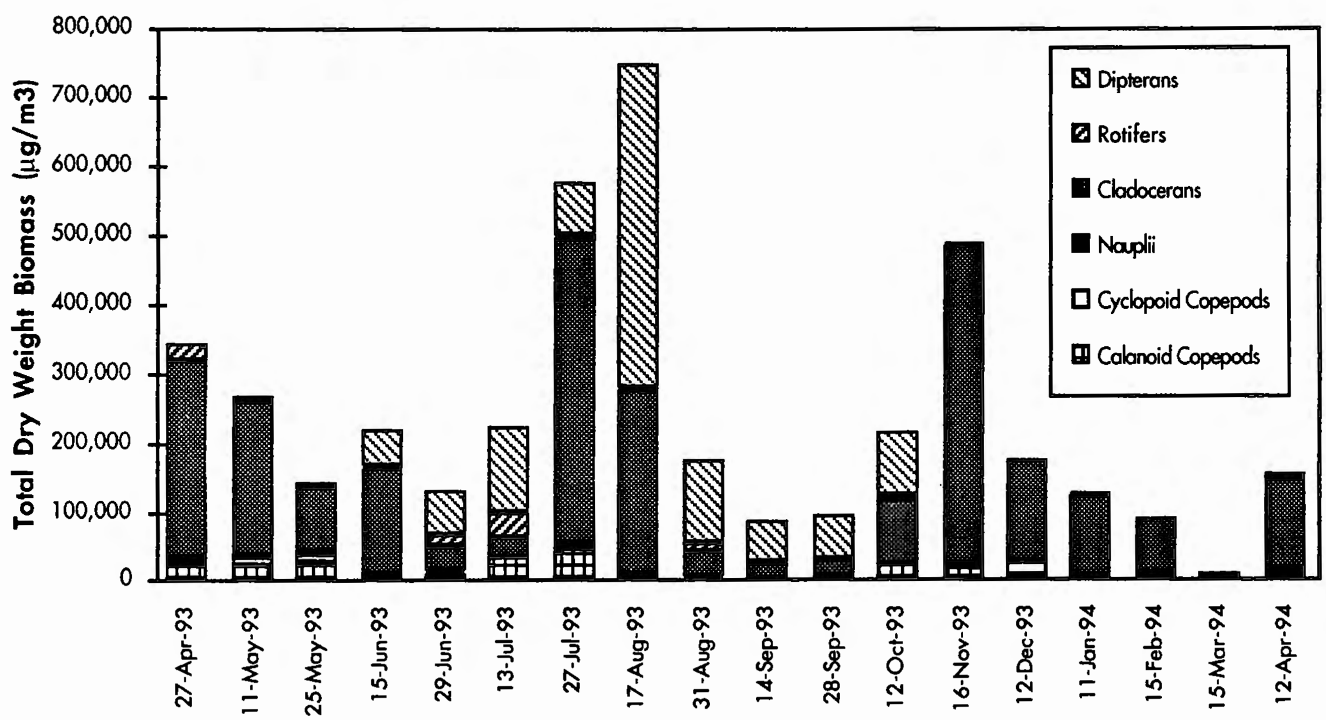


Figure 4–14 Lake Desire Zooplankton Biomass



Benthic macroinvertebrate densities ranged from 1,911 to 6,651 organisms/m^2 at the littoral station (2 meters) and 130 to 5,174 organisms/ m^2 at the deep station (5.5 meters). Littoral taxa included the genera, *Palpomyia*, *Asellus*, *Sialis*, and *Aeshidae,* and the families Chironomidae, Oligochaeta, and Pelecypoda. Chironomidae and *Asellus* made up the largest portion of littoral samples, with densities from 565 to 1,043 organisms/ m^2 and 11 to 134 organisms/m^2, respectively, for the three samples.

In the deep station, *Chaoborus* was the only taxon found. Densities ranged from 130 to 5,174 organisms/m^2 and increased from June through October. The most dramatic increase was noted between the August and October sampling periods where densities increased from 261 to 5,174 organisms/m^2, which may in part be due to improving oxygen conditions in the hypolimnion.

Bacteria

Fecal coliform bacteria, which originate in the intestinal tract of humans and other warm-blooded animals, were sampled to evaluate the potential failure of on-site septic systems and contamination from animal waste in the watershed. Fecal coliform bacteria are typically not harmful to humans. However, other bacteria and pathogens associated with human waste such as *Salmonella, Shigella, and Escherichia coli,* can affect human health. If fecal coliform bacteria densities are high, additional screening tests are usually necessary to assess both the source and potential pathogens present in a water body.

Fecal coliform samples were measured in the lake and at the lake inflow. In-lake geometric mean concentration was 3.8 coliform units/100 ml (n=18). Inflow concentration was slightly higher averaging 35.4 coliform units/100 ml (n=11). Both values are below water quality standards for freshwater. The Washington State Department of Ecology states that for lakes, fecal coliform bacteria should not exceed a geometric mean of 50 organisms/100 ml and not more than 10 percent of the samples should exceed 100 organisms/100 ml (WSDOE, 1992). The inflow tributary standard is also 50 organisms (coliform units)/100 ml (Class AA).

Fisheries

Lake Desire is known to have a high quality fish population. The Washington State Department of Fish and Wildlife rates the lake as a moderately important fishery. Fish species known to inhabit Lake Desire are shown in Table 4-8. Of particular importance is the presence of coho salmon juveniles in the lake. Peterson Creek is known to be used by salmonids. Sockeye and Chinook salmon utilize the lower stretches of Peterson Creek while coho salmon are believed to migrate up Peterson Creek to Lake Desire (King County, 1993b).

Table 4-8: Lake Desire Fish Species[a]

Scientific Name	Common Name
Oncorhynchus mykiss	Rainbow Trout
Oncorhynchus clarkii	Cutthroat Trout
Oncorhynchus kisutch	Coho Salmon
Perca flavescens	Yellow Perch
Pomoxis nigromaculatus	Black Crappie
Micropterus salmoides	Largemouth Bass
Ictalurus nebulosus	Brown Bullhead

[a]*Data from Bob Pfeifer, Washington State Department of Fish and Wildlife.*

Opening day creel surveys suggest that the fishery in the lake is relatively good. The creel survey is a tool used by fishery biologists to assess the success of the stocked rainbow trout fishery. Data is available from the early 1970's through 1994. Creel surveys during this time period as well as Washington Department of Fish and Wildlife Rainbow Trout stocking records are shown in Table 4-9.

Table 4-9: Stocking Records and Creel Survey for Lake Desire[a]

Year	Fish Stocked Fry	Catchable	Angler Days	Number of Fish Caught
1983	15,036	17,500	704	536
1984	3698	8731	644	460
1985	----	3442	201	326
1986	4405	4898	----	----
1987	----	8828	173	493
1988	----	9892	----	----
1989	4512	15,759	851	2455
1990	4510	9366	258	765
1991	4400	7200	----	----
1992	5000	7170	157	143
1993	4500	5000 [b]	----	----
1994	4500	8500	28[c]	8[c]

[a]*Data from Bob Pfeifer, Washington Department of Fish and Wildlife.*

[b]*100 to 200 Broodstock rainbow trout planted.*

[c]*Adverse weather conditions where present opening day which bias the opening day estimates.*

Table 4-10 illustrates the results of the combined fall and spring sampling efforts. Length frequencies for largemouth bass and yellow perch, the two predominant species, are shown in Figure 4-15.

Table 4-10: Combined Survey Catch for Fall and Spring Fishery Sampling at Lake Desire[a]

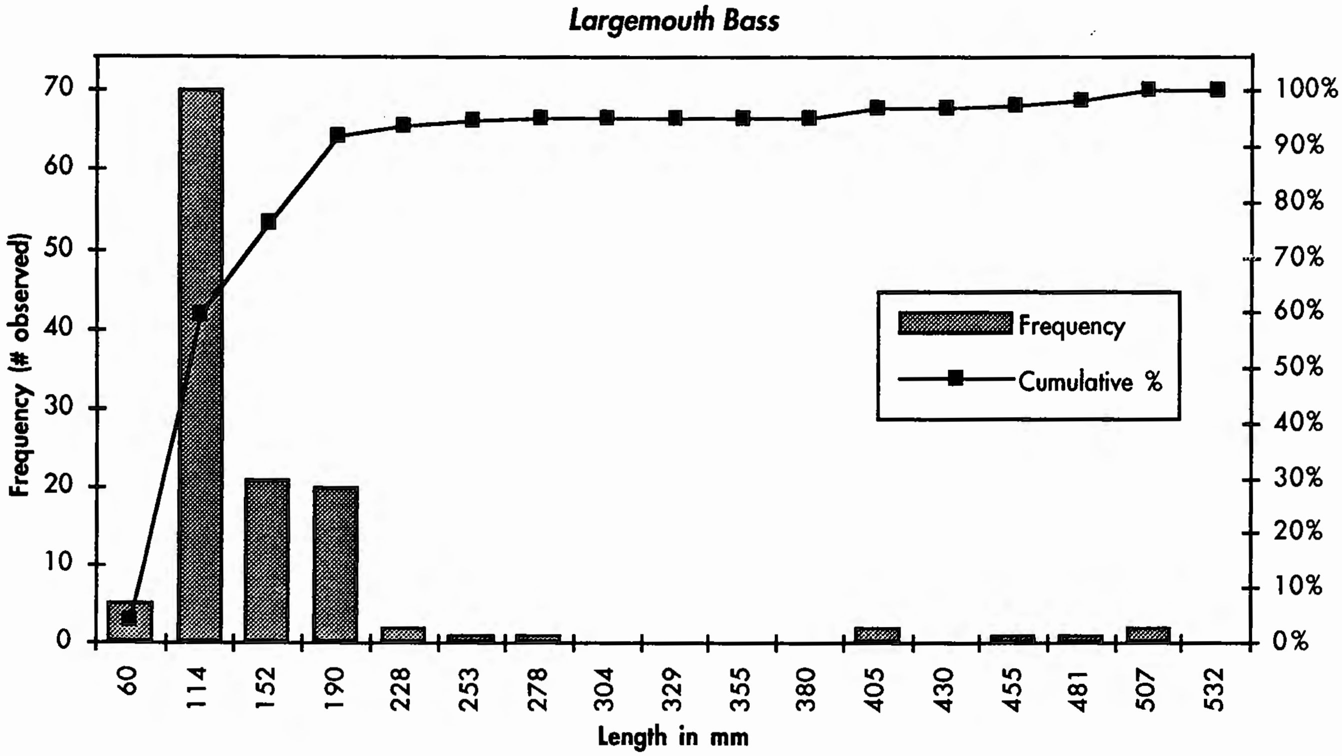
Species	Number of Fish Caught Electrofishing	Fyke Trap	% of Total
Largemouth Bass	114	13	62
Crappie	1	1	1
Yellow Perch	47	14	30
Sunfish	5	2	3.5
Brown Bullhead	3	2	2.5
Rainbow Trout	2	0	1
Total	172	32	100

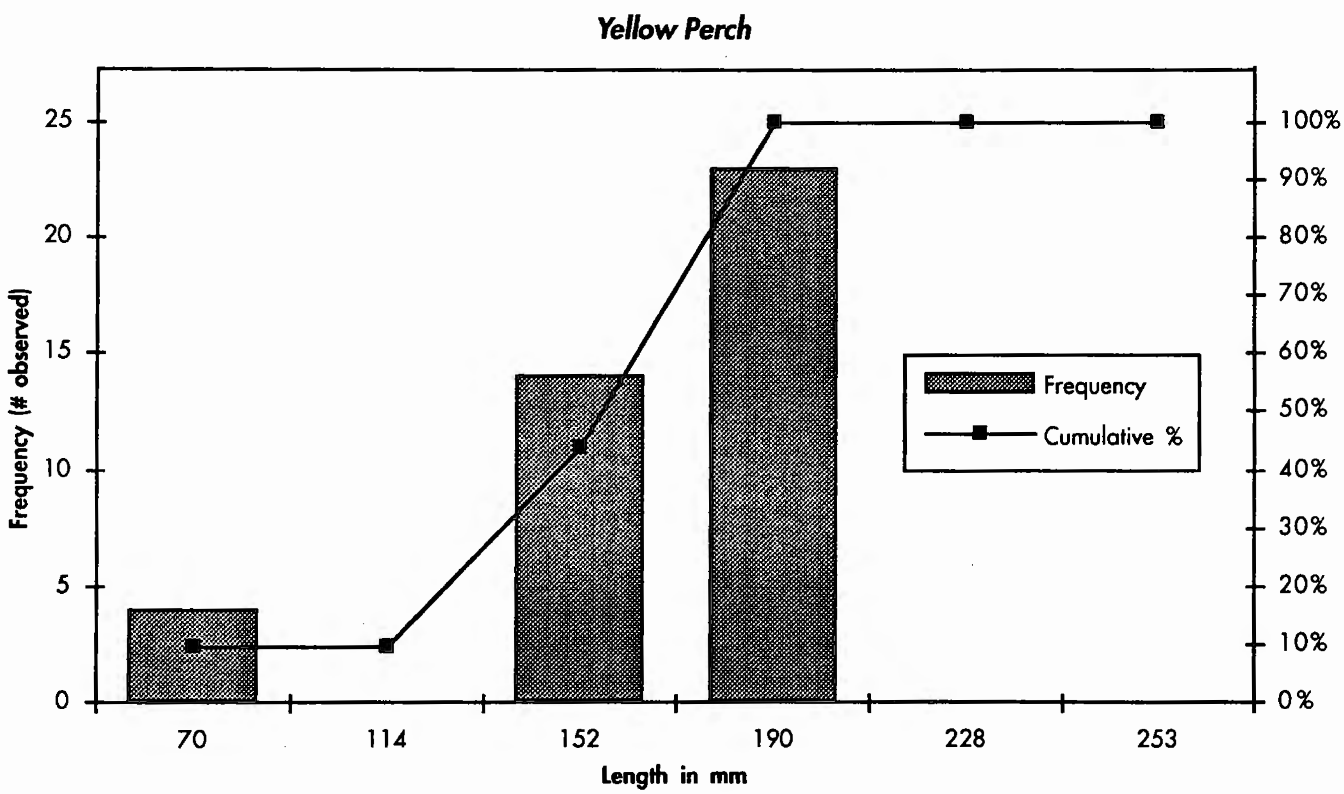
[a]*Data from KCM, 1994a.*

Eighty-seven percent of the total catch was bass during the fall sampling. In the spring, bass comprised only 14 percent of the total electrofished catch. Conversely, yellow perch made up 4.5 percent of the fall catch and 78 percent of the spring catch.

These results are not unusual given the life histories of each species. In the fall, a large number of small bass were present in the shallows but by spring, had most likely moved to deeper waters to avoid predation by the large spawners present in the shallows. The yellow perch populations, on the other hand, move into the shallow areas to spawn. During the fall, yellow perch are more likely to be in the

Figure 4–15 Lake Desire Fish Length Frequency (1993-1994)





deeper open water areas where electrofishing is less effective for characterizing fish distribution. The fyke-trap capture showed similar species trends to that of electrofishing.

Fish gut content analysis was completed as part of the fish population assessment. The gut content of the larger bass was empty which is not unusual for bass during the spawning season. Stomach contents of other fish indicated that the fish had been feeding on caddis fly larvae and unidentifiable zooplankton. No gut contents indicated predation on other fish, although the larger bass in the lake should be feeding on other fish (KCM, 1994a).

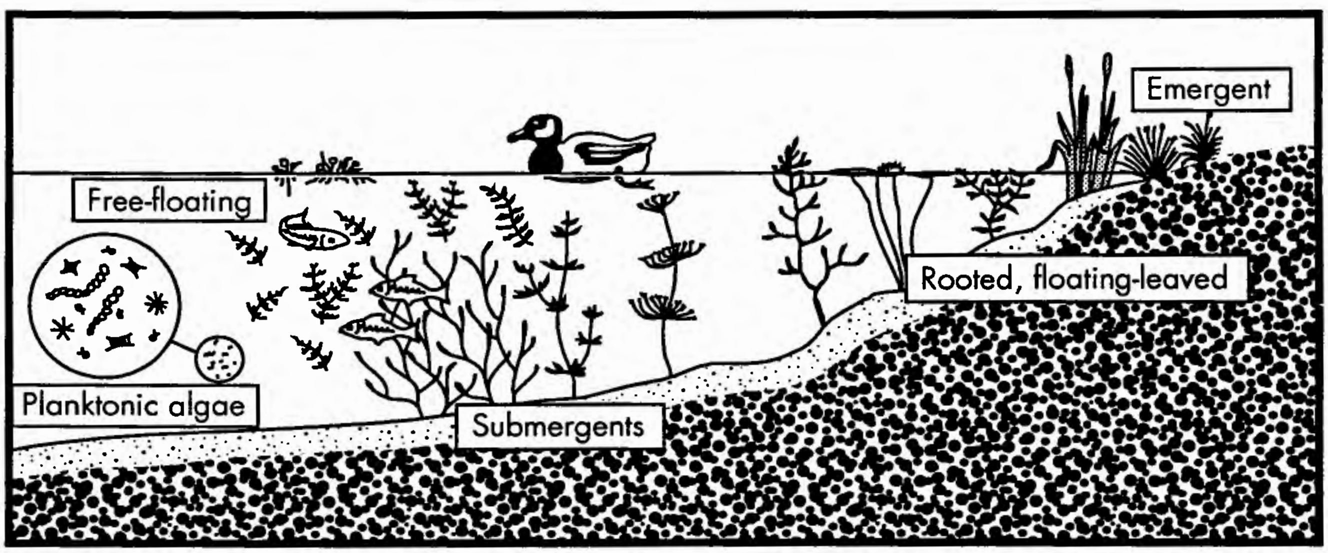
A lack of bass in the 290-400 mm range was consistent throughout the fisheries assessment. This size range represents 4-5 year old fish. It is possible that intermittent, poor lake water quality (e.g., extended low oxygen, high temperatures, toxicity, or turbidity) could have adversely affected this age class. However, no anecdotal evidence is available regarding fish kills in 1988 or 1989. Bass recruitment from subsequent years has been good suggesting that no ongoing problem is present with water quality effects on in-lake fisheries. A similar absence of 4-5 year old perch was also noted during the surveys.

Aquatic Plants

Aquatic plants or macrophytes are the large or visible plants located along the lake shoreline or *littoral* areas. Aquatic plants can be divided into three main groups: 1) emergent; 2) floating; and 3) submersed. The floating plants are also sometimes divided into two groups, freely-floating and rooted-floating. Figure 4-16 illustrates these community types and common examples of plants associated with each type.

Aquatic plants have many benefits including sediment and shoreline stabilization; benthic, fish, and wildlife food and habitat; and aesthetics. Most rooted macrophytes obtain their nutrients from bottom sediments rather than the water column and serve to bind some of the phosphorus during the active growing season which might otherwise be available for algal growth.

Figure 4-16 Macrophyte Community Types



Gibbons, M.V., H.L. Gibbons, and M.D. Sytsma, 1994b

Figure 4-17 illustrates the location of the major macrophyte beds in the lake. About 29 percent of the lake area supports macrophyte growth. The submersed community comprises the largest percentage of the plants by area in Lake Desire at 17 percent, followed by floating at 9 percent. Less than 3 percent of the aquatic plants are in the emergent category. Much of the shoreline of the lake has been altered, thereby reducing the total percentage of emergents found in the aquatic plant community. In other lakes where the shoreline is less impacted, the percentage of emergents is usually much higher.

Various plant species are found in the lake. Table 4-11 summarizes the species found in Lake Desire by community type. Three non-native plant species are included in the list: purple loosestrife, Eurasian milfoil, and white (or pink) water lily.

Table 4-11: Lake Desire Macrophyte Species

Scientific Name	Common Name
Brasenia schreberi	Watershield
Ceratophyllum desmersum	Coontail
Chara sp.	Muskgrass
Elodea canadensis	Water weed
Lythrum salicaria	Purple loosestrife
Myriophyllum spicatum	Eurasian milfoil
Najas flexis	Water nymph
Nitella sp.	Stonewart
Nuphar variegatum	Yellow water lily
Nymphaea ordorata	Fragrant white water lily
Potamogeton berchtoldii	Berchtold's pondweed
Potamogeton epihydrus	Ribbon-leaved pondweed
[a]*Sagittaria sp.*	Arrowhead
[a]*Utricularia vulgaris*	Bladderwort

[a]*These species were noted from historic surveys but not observed during 1993.*

The total phosphorus content measured in 15 aquatic plant samples averaged 0.244 percent (dry weight) in Lake Desire. Plant biomass and total phosphorus loading were also estimated for Lake Desire. Plant biomass averaged 160 g/m^2, while total phosphorus loading averaged 0.414 g/m^2.

WETLAND ASSESSMENT

The watershed contains two major wetlands, Cedar River Wetlands 14 and 15. The wetlands were described in Chapter 2 with additional background material found in King County, 1994a and Pentec Environmental Inc., 1994.

Wetlands play an important functional role in the Lake Desire watershed. The watershed wetlands are important in groundwater exchange, hydrologic support, erosion prevention/shoreline protection, water quality enhancement, biological or food chain support, and cultural/socioeconomic value.

Cedar River Wetland 14, a 43-acre, class one system, forms the headwaters of Peterson Creek. Peat extraction within the wetland and dredging of the outlet are the most extensive impacts that have occurred to the wetland itself. Only 6 of the 43 acres of Wetland 14 remain in pristine, forested-bog condition. The wetland watershed has also been impacted by extensive development to the northeast and in the upland area surrounding the wetland. The development to the northeast portion of the wetland watershed discharges stormwater to Wetland 14 from two small detention ponds.

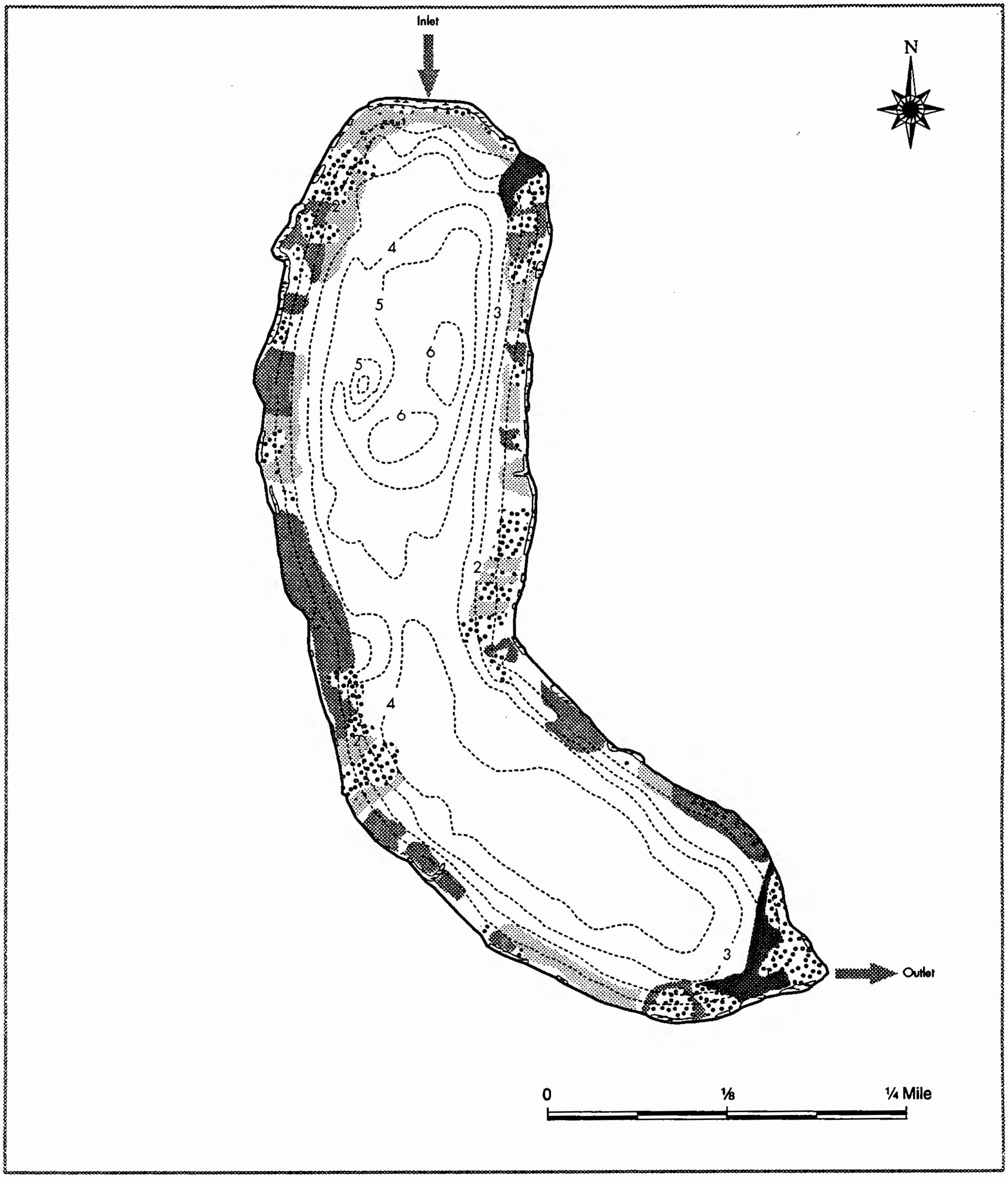


Figure 4-17: Lake Desire Macrophyte Map

--4-- Bathemetry (1 meter contours)

Vegetation

Emergent

Floating

Submerged, Sparse

Submerged, Moderate

Submerged, Dense

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Overall, Wetland 14 scored high for all functional values examined including groundwater recharge and discharge, biological support, and cultural/socioeconomic functions (Pentec Environmental, Inc., 1994). The wetland was one of the largest peat mines in Washington history. Thus, the wetland's functional value for water quality treatment has been impacted by this removal of peat. However, the wetland's peat deposits provide a scientific record for educational study and the area has been maintained largely as open-space provides benefits to fish, wildlife, and local residents. The wetland is also important in mitigating storm flow peaks and providing water to Peterson Creek.

Cedar River Wetland 15 is a 17-acre class one system which forms the main inlet to the lake. The wetland has been impacted by the building of East Lake Desire Drive SE through a portion of the wetland from which road runoff drains directly to the wetland without treatment. Visible pollution of the wetland from petroleum products and assorted trash originating with road runoff was observed on repeated visits to the lake inflow.

Even with the obvious impacts from the road crossing, the wetland's functional values remain largely intact. The wetland has considerable water storage capacity, some groundwater exchange, and high wildlife habitat value. The wetland may also be important in improving water quality from Wetland 14 (Pentec Environmental, 1994).

The lake shoreline has little vegetation present in many locations due to intensive shoreline development by many residents. As property development continues, the shoreline will likely become more developed and illegal filling may occur as well. Much of the northern shore of the lake has bare, eroded patches of land with some evidence of filling. The eastern lake shore has several areas where native vegetation remains. Generally, the wetland areas of the lake shoreline which had no houses were characterized by more native plants and less evidence of disturbance. The lake shorelines, although not specifically rated, were characterized as having minimal low functional value for all uses except for those associated with human use (Pentec Environmental, 1994).

NONPOINT POLLUTION

Nonpoint pollution originates from diffuse land use practices including animal keeping, on-site septic systems, forestry, land clearing, construction, and residential and urban uses. Pollutants are typically transported from land surfaces during rainfall into receiving waters such as wetlands, streams, and lakes. Nonpoint pollution is often a mix of constituents which are not readily associated with a single source as are point source pollutants which discharge from a single location. The diffuse character of nonpoint pollution makes its identification and control all the more difficult. Implementation of best management practices (BMPs) and structural controls is often the strategy taken to reduce nonpoint pollutants.

Septic Survey

Under normal conditions, septic tank and drainfield disposal systems which are properly designed, installed, maintained and operated are a negligible source of pollutants (particularly phosphorus) to surface waters. The degree of treatment provided by a fully functional septic system and the limited mobility of phosphorus in soil drainfields usually makes septic tank loading insignificant to overall water quality. The exception to this lies with drainfields which are close to the lake or a direct feeder stream (within 100 meters) and are within the surrounding water table elevation or where systems are obviously failing and significant amounts of effluent reach the water through overland flow (EPA, 1980).

Proper site conditions must exist for septic systems to perform effectively. Many lakeside lots are inappropriate for septic systems and lake problems have conclusively been associated with septic failures

(EPA, 1988b). Conditions that prevent or interfere with proper septic system function include unsuitable soils, high water tables, steep slopes, poor system design, poor maintenance, and improper use. Many of these conditions are found around lakes and can make a lakeside lot unsuitable for septic systems (KCM, 1994d).

Aerial Shoreline Analysis (ASA) and field surveys were used to assess on-site septic system nonpoint loading. Vegetation patterns indicative of septic system drainfield failures were noted for four sites on Lake Desire using ASA. The lack of additional findings using ASA may be attributed to the time of year, vegetation dormancy, and the presence of landscaping that may obliterate evidence of on-site septic system failure (KCM, 1994d).

There are 101 on-site septic systems in the Lake Desire watershed. Of these, 15.8 percent have been reportedly repaired or maintained (King County, 1993b). Only 13 percent of the systems in the study area have maintenance records on file with the Seattle-King County Department of Public Health. The average age of repaired systems is 23 years old, while unrepaired systems average 20 years in age. The Puget Sound Water Quality Authority maintains that most septic systems have a maximum effectiveness of 20-40 years. Subsequently, septic failures around Lake Desire may be a significant source of nutrients (King County, 1994c).

Within the Lake Desire watershed, 62 parcels were identified as containing systems that may require further inspection. Of those 62 parcels, 27 contained septic systems built prior to 1970 and 14 contained systems with no as-built records (KCM, 1994d). Systems installed prior to 1970 were not designed for efficient treatment and are more likely to have higher effluent concentrations. Figure 4-18 indicates the location and age range of probable failing or pre-failing on-site septic systems at Lake Desire.

The potential phosphorus loading to Lake Desire from septic systems was calculated based on per capita loading rates and the relative removal efficiency associated with the 101 on-site septic systems in the watershed. The loading assumptions are detailed in KCM, 1994d. Based on these assumptions, the potential phosphorus loading from septic systems is between 30 and 87 kilograms/year.

Other Residential-based Sources

Another source of nonpoint pollutant loading after septic systems is stormwater runoff from the shoreline lots surrounding Lake Desire. Homeowner use of pesticides and fertilizers, dumping of yard waste near the shoreline, or improper composting, and soil erosion on residential lots all contribute to nonpoint loading. The significance of this contribution is difficult to quantify because of the diffuse nature of the loading but was estimated for the lake nutrient budget (Chapter 6). The absence of shoreline vegetation on numerous waterfront lots only exacerbates the problem by allowing the delivery of the nonpoint load directly to the lake without buffering. Shoreline lots with heavily vegetative buffers offer considerable filtering of surface water runoff before it enters the lake than lots with no or minimal buffers.

Within the Lake Desire watershed, there are several animal-keeping operations which may contribute to phosphorus and nitrogen loading to the lake. This is particularly true in areas where pastures are overgrazed and manure is not properly disposed.

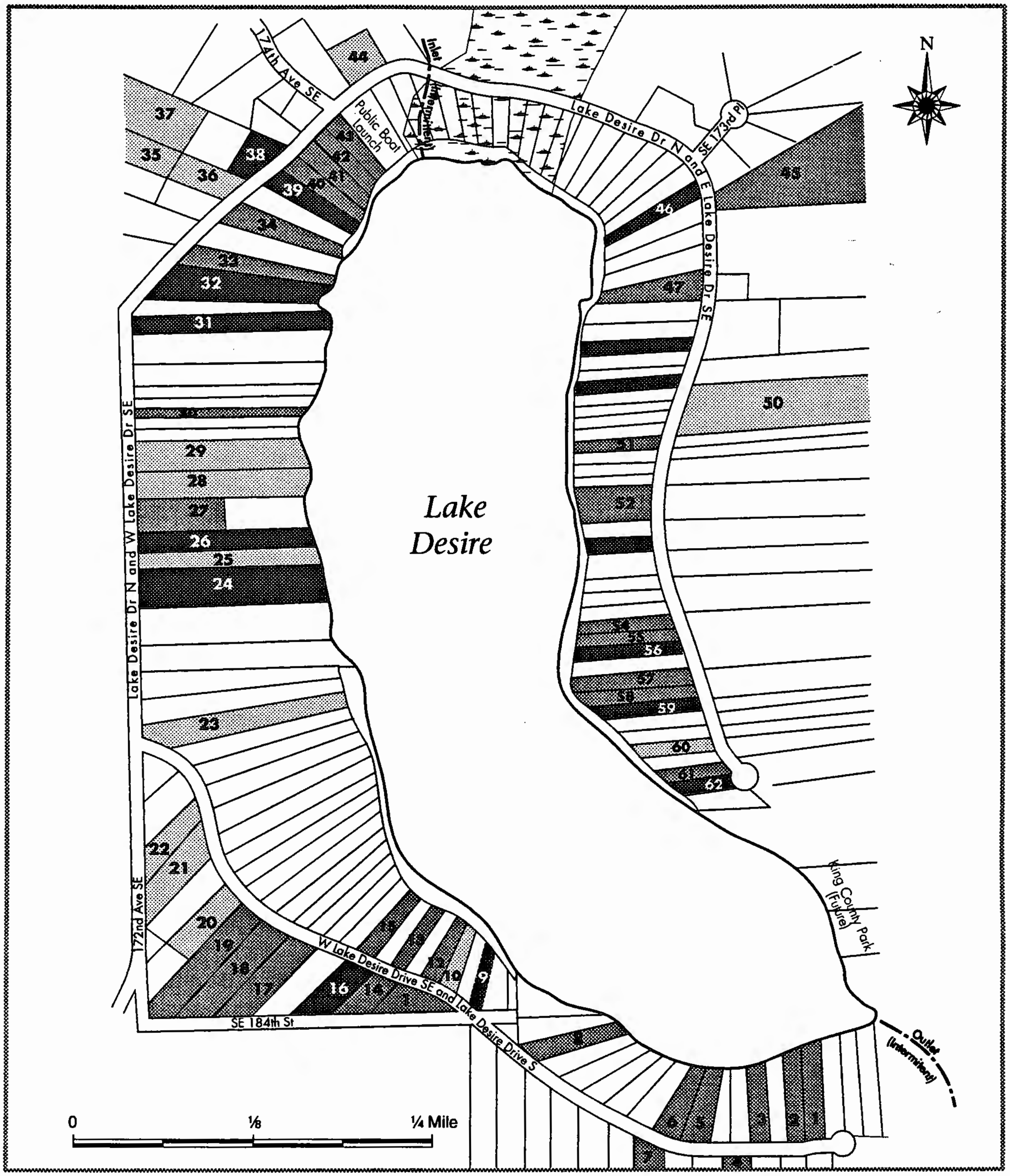

Figure 4-18: Possible Septic System Problem Sites

Wetland

17 Site Number (see King County 1994a, Appendix G)

Age of Septic System

10-20 years

>20 years

Unknown

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TROPHIC STATUS

Lakes are usually classified and compared by their trophic status or degree of biological productivity. Three water quality parameters can be used to assess trophic status: total phosphorus, chlorophyll *a*, and Secchi depth. The general relationship between these three lake water quality parameters and trophic status is summarized in Table 4-12. The first three columns give individual ranges to which actual measured Secchi, chlorophyll *a*, or TP values can be compared to establish a trophic classification for each parameter. The fourth column lists the ranges for trophic classification based on Carlson's Trophic State Index (TSI) which logarithmically transforms Secchi, chlorophyll *a*, and TP values.

Table 4-12: Summary of Trophic Classification and Associated Values.

Trophic Classification	SECCHI meters	CHL a µg/L	TP µg/L	Carlson's TSI Rating
Oligotrophic	<4	>4	<10	<40
Mesotrophic	4-10	2-4	10-20	40-50
Eutrophic	>10	>10	>20	>50

Lake Desire is eutrophic based on summer and annual average Secchi depth, chlorophyll *a* and total phosphorus concentrations. Table 4-13 summarize the trophic state variables and corresponding TSI values. Based on Carlson's Trophic State Index, Lake Desire is eutrophic, with an average TSI value of 55. The eutrophic range for Carlson's TSI usually lies between 45 and 65 TSI units.

Table 4-13: Lake Desire Trophic Status Summary

Time	Secchi meters	Chl a µg/L	TP[a] µg/L	TSI Secchi	TSI Chl a	TSI TP	TSI Average
Annual	2.0	14	42	50	56	58	55
Summer (Jun-Sept)	1.6	15	34	53	57	55	55

[a]*Volume-weighted Epilimnetic Concentrations.*

Lake Desire trophic parameters were compared to those of several local lakes. Lake Desire consistently ranks as one of the most biologically productive lakes in the County, second only to Cottage Lake. Of the eight lakes examined, Lake Desire had the second lowest summer Secchi depth, the second highest chlorophyll *a* summer average, and the highest summer total phosphorus concentration (Table 4-14).

Table 4-14: Comparison of Secchi, Chlorophyll *a*, and Total Phosphorus Concentration for Seven King County Lakes.

Lake[a]	Summer Secchi (m)	Summer Chl. a (µg/L)	Summer TP (µg/L)	Annual Secchi (m)	Annual Chl. a (µg/L)	Annual TP (µg/L)
Beaver1	1.0	15	20	1.2	11	28
Beaver2	2.3	4.9	11	2.5	4.2	18
Cottage	1.9	32	32	1.9	18	56
Desire	**1.6**	**15**	**34**	**2.0**	**14**	**42**
Pine	5.7	2.3	-	-	-	-
Spring	2.5	6.4	-	-	-	-
Shady	3.7	4.2	-	-	-	-
Twelve	3.6	7.3	6.3	-	-	-

[a]*Data sources: King County, 1993a; King County 1995; Metro, 1994; and Welch et al, 1993 .*

CHAPTER 5: LAKE WATER BUDGET

A water budget is a measure of the sources of water discharging to and flowing from a lake over the course of a typical year. A water budget was calculated for Lake Desire using field data and the Hydrologic Simulation Program-FORTRAN (HSPF) computer model. This chapter describes the Lake Desire water budget and the methods and data used to calculate it. It also describes how watershed development and associated changes in land cover affect the water budget.

METHOD OF ANALYSIS

As part of the Lake Desire Phase I Restoration Project, King County SWM personnel and local citizen volunteers conducted a field monitoring program from April 1993 through March 1994. Data obtained through this effort included precipitation, stream flow out of the lake, and lake surface elevation. Computer modeling was used to supplement the collected data to calculate of the lake water budget.

The Cedar River Basin (Peterson Creek subbasin) HSPF model, developed by King County in 1991 and updated in 1994, was obtained to perform the water budget calculations. The Lake Desire watershed, comprised of Peterson Creek subcatchments six and seven (P6 and P7), is located in the upper portion of the Peterson Creek subbasin of the Cedar River Basin or watershed (Figure 5-1). The model was revised so that only subcatchment areas and stream reaches relevant to the lake's water budget were included in the analysis. The model's input data files for current, historical, and future conditions and precipitation and evaporation data are included in Lake Desire Background and Technical Reports (King County, 1994a). Model output included simulated flows of water into and out of the lake and changes in lake water level.

Observed surface flows and lake level data were used to estimate groundwater inflows to the lake as a check on the model's simulation of groundwater inflow. This check was completed for the five months in which sufficient observed data were available (November 1993 through March 1994). Groundwater flow estimates completed during a separate hydrogeologic field study (Hong West, 1994) for the project were also used as a check on HSPF simulated groundwater flows.

Residuals resulting from water budget calculations (the volumes of water left over after all outflows are subtracted from all inflows) represent changes in lake water storage as reflected in fluctuating lake levels. Modeled lake levels were compared to observed lake levels to determine how well the model simulated the lake water budget.

DATA USED IN ANALYSIS

Pan evaporation data were not available for the entire period. Missing data were calculated using a program provided by King County and maximum and minimum daily temperature data for the period, which were available from the National Weather Service station at Monroe, WA. Calculated pan evaporation data were compared with observed data for the period in which both were available. Calculated values were found to be acceptable based on a plot of observed and calculated evaporation. Therefore, calculated values were used to fill in missing data.

Backwatering of the lake inflow due to the adjacent wetland area and the lack of a good hydraulic control location immediately upstream of the lake prevented the estimation of discharge data for the lake inflow.

The excellent record of lake levels was used in conjunction with the seasonal outflow data to evaluate model results. Data used as input for the HSPF model are summarized in Table 5-1.

Table 5-1: Description of Data Used in Water Budget

Location	Type of Data	Units	Data Interval	Period of Record (within analysis period)	Data Use
Lake Desire Outflow	Discharge	cfs	15 minutes	Nov. 6, 1993-Mar 31, 1994	Evaluate simulated vs. observed
Gary Dagan property	Lake Level	inches (datum unknown)	Daily	Apr. 1993-Mar 1994	Evaluate simulated vs. observed
Layton (near Spring Lake on SE 196th)	Precipitation	inches	15 minutes	Apr. 1993-Mar 1994	Model input
Puyallup	Pan Evaporation	inches	Daily	June 1993-Aug. 1993	Model Input
Calculated	Pan Evaporation	inches	Daily	Apr. 1993-May 1993 and Sept. 1993-Mar 1994	Model Input

Groundwater

Groundwater flow is typically the most difficult portion of the water budget to quantify because the entire cross-section of flow cannot be monitored. Therefore, groundwater flows are calculated based on field measurements at specific well or seepage meter locations, or based on water budget calculations used to solve for groundwater flow when all other inflows and outflows are known. All these approaches were used to determine groundwater flow into Lake Desire. Groundwater was assumed to flow into the lake only from Subcatchment P6, which surrounds the lake. The locations of the subcatchments draining to Lake Desire are shown on Figure 5-1. In the HSPF model, all groundwater in subcatchment P7 is assumed to flow into the wetland and enter the lake as surface water. Monthly groundwater flows from subcatchment P6 are listed in Table 5-2, along with surface flow and interflow from that subcatchment.

In Table 5-3, groundwater flows based on observed data are compared to those based on the final HSPF run and on field measurements taken by Hong West. Monthly groundwater flows calculated using the observed data were approximately four times greater on average than the groundwater flows simulated by HSPF; groundwater flows determined using the field data were 60 times lower on average than the groundwater flows simulated by the model.

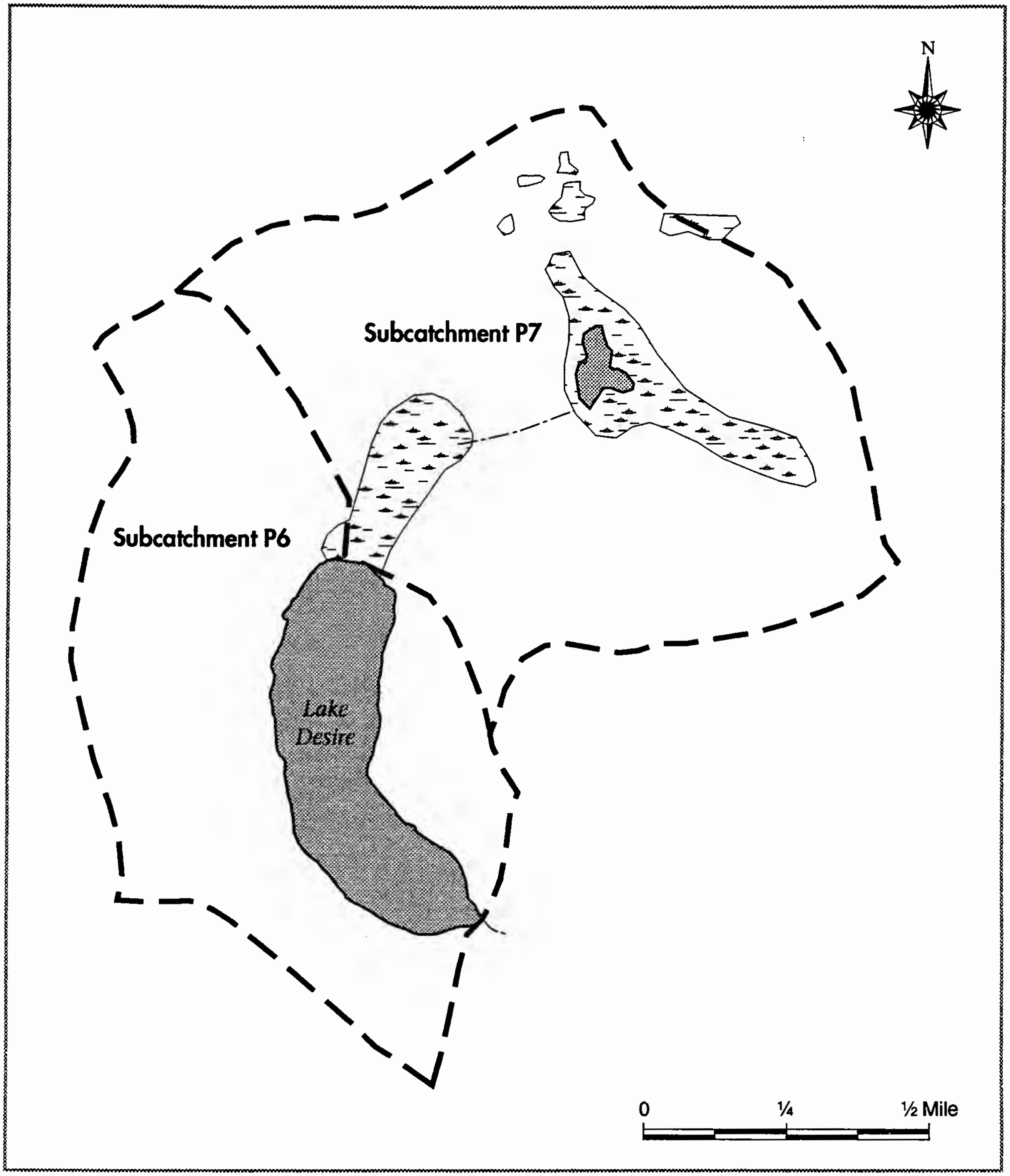

Figure 5-1: Lake Desire Subcatchment Boundaries

Subcatchment Boundary
Stream
Wetland
Lake

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Table 5-2: Monthly Flows for Subcatchment P6

Month	Total Surface Outflow (ac-ft)	Total Interflow Outflow (ac-ft)	Total Active Groundwater Outflow (ac-ft)	Total Of P6 Outflows (ac-ft)	Total Surface Outflow (cu. m)	Total Interflow Outflow (cu. m)	Total Active Groundwater Outflow (cu. m)	Total Of P6 Outflows (cu. m)
April	3.1	2.4	1.4	7.0	3836	3015	1788	8640
May	2.8	9.6	6.5	18.9	3431	11884	7966	23281
June	1.3	17.2	11.1	29.6	1550	21216	13696	36463
July	0.6	0.1	9.0	9.7	720	175	11044	11939
August	0.1	0.	7.3	7.4	147	37	9006	9190
September	0.1	0.0	5.7	5.8	168	4	7020	7192
October	1.3	0.0	5.0	6.4	1607	18	6205	7830
November	0.9	0.0	4.4	5.3	1050	53	5412	6515
December	2.7	3.2	7.9	13.8	3341	3947	9759	17047
January	1.9	10.4	14.2	26.5	2344	12773	17555	32672
February	2.4	34.3	16.4	53.1	2994	42249	20257	65501
March	2.8	54.1	28.0	84.9	3499	66695	34529	104722
Total	20.0	131.3	116.9	268.4	24687	162067	144238	330991

Table 5-3: Comparison of Calculated Groundwater Inflows to Lake Desire (values in cubic meters)

Month	Observed Data Water Balance	Final HSPF Calculated "Active" Groundwater	Hong West Field Determined
April	NA	1788	257
May	NA	7966	265
June	NA	13696	115
July	NA	11044	115
August	NA	9006	115
September	NA	7020	259
October	NA	6205	268
November	16410	5412	259
December	85338	9759	287
January	80708	17555	287
February	58625	20257	259
March	62003	34529	265

NA = Data not available
Final HSPF Calculated "Active" Groundwater from final current conditions run (DEEPFR = 0)
Hong West field data described in separate report "King County Lakes Lake Desire Hydrogeologic Evaluation"

Uncertainties in the groundwater flow estimates are due to the following factors:

- Limited field data were available to calculate the mass balance water budget used to solve for groundwater. Gauge lake outflow data were only available from November through March. Lake outflow data during the entire study year are necessary to calculate a mass balance water budget. Subsequently, the water budget could only be calculated for November 1993 through March 1994 and only these months were available for groundwater flow comparison.
- No observed data are available for surface water runoff from Subcatchment P6. Therefore HSPF simulated flows for surface runoff were used in the mass balance water budget calculation. Using a mix of observed and simulated data adds to the uncertainty of the mass balance groundwater flow estimates.
- Calculations of groundwater flows using observed data required use of HSPF simulated data for lake inflow from the wetland because backwatering prevented gauging of the inflow. Data from a gauge at a point further upstream where gauging conditions are more acceptable would reduce the uncertainty in this portion of the water budget.
- The wetland at the lake may act as a storage reservoir, gaining water during wet periods and releasing water during drier periods. This release and storage is difficult to quantify and may not be reflected in the temporal changes predicted by the water budget.
- Use of a limited number of monitoring sites and a limited frequency of observation during the groundwater field study contributes uncertainty to estimates of groundwater flow using field data. While available geologic data indicate that the lake is located on top of a 15- to 100-foot deep till layer (Hong West, 1994), contact of the lake bottom with an underlying aquifer at a point that was not monitored may result in underestimation of groundwater inflows to the lake.

Given these uncertainties and the fact that estimates of groundwater flow to Lake Desire are at best an order of magnitude determination (Hong West, 1994), the final HSPF simulation was used for the current conditions water budget presented in this report.

RESULTS

Model Verification

The acceptability of the model output was evaluated by comparing plots of simulated and observed lake level. The simulated lake levels are within 4 inches of the observed lake levels (see Figure 5-2). Observed and simulated stream inflows, outflows, precipitation, and evaporation were also compared (KCM 1994e).

Study Year Water Budget

Following examination of model output, monthly totals were calculated and plotted for all lake inflows and outflows (Figure 5-3). The percentages of total lake inflow from Subcatchment P6, Subcatchment P7, and precipitation and the percentages of total lake outflow to the outlet stream and evaporation for the study year are shown in Figure 5-4 and Table 5-4.

Figure 5–2 Lake Desire Observed vs Simulated Lake Level

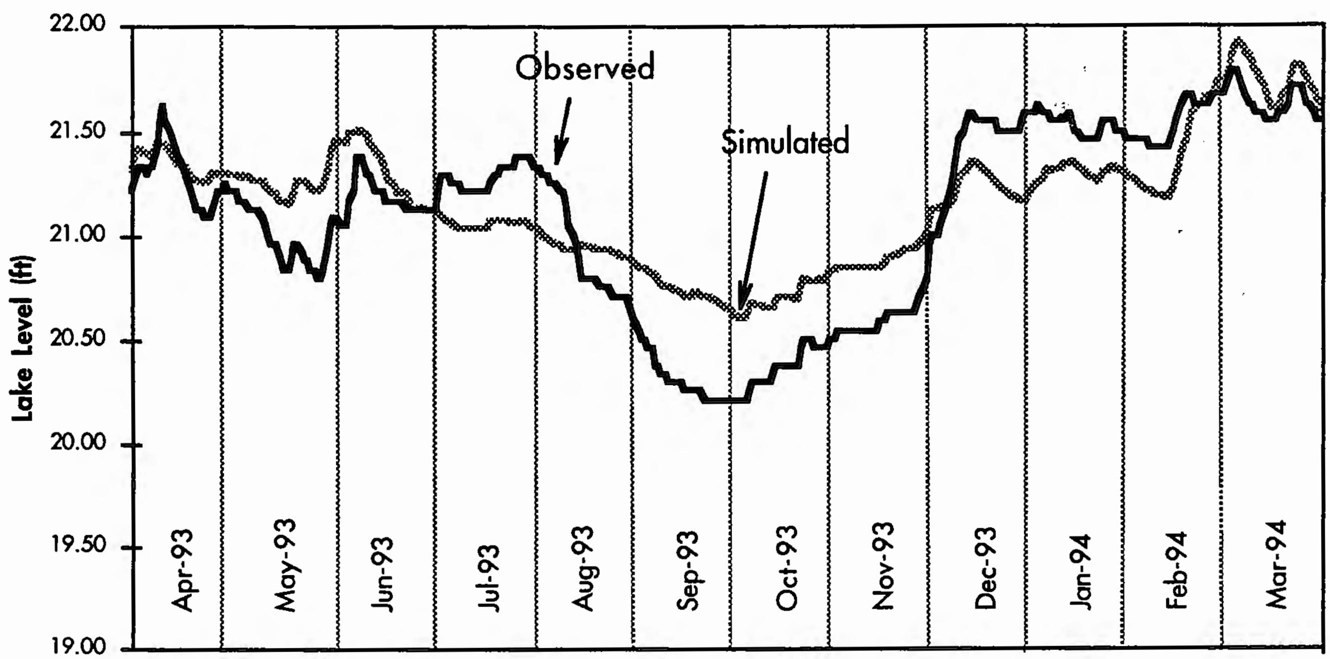


Figure 5–3 Lake Desire Monthly Water Balance Current Conditions

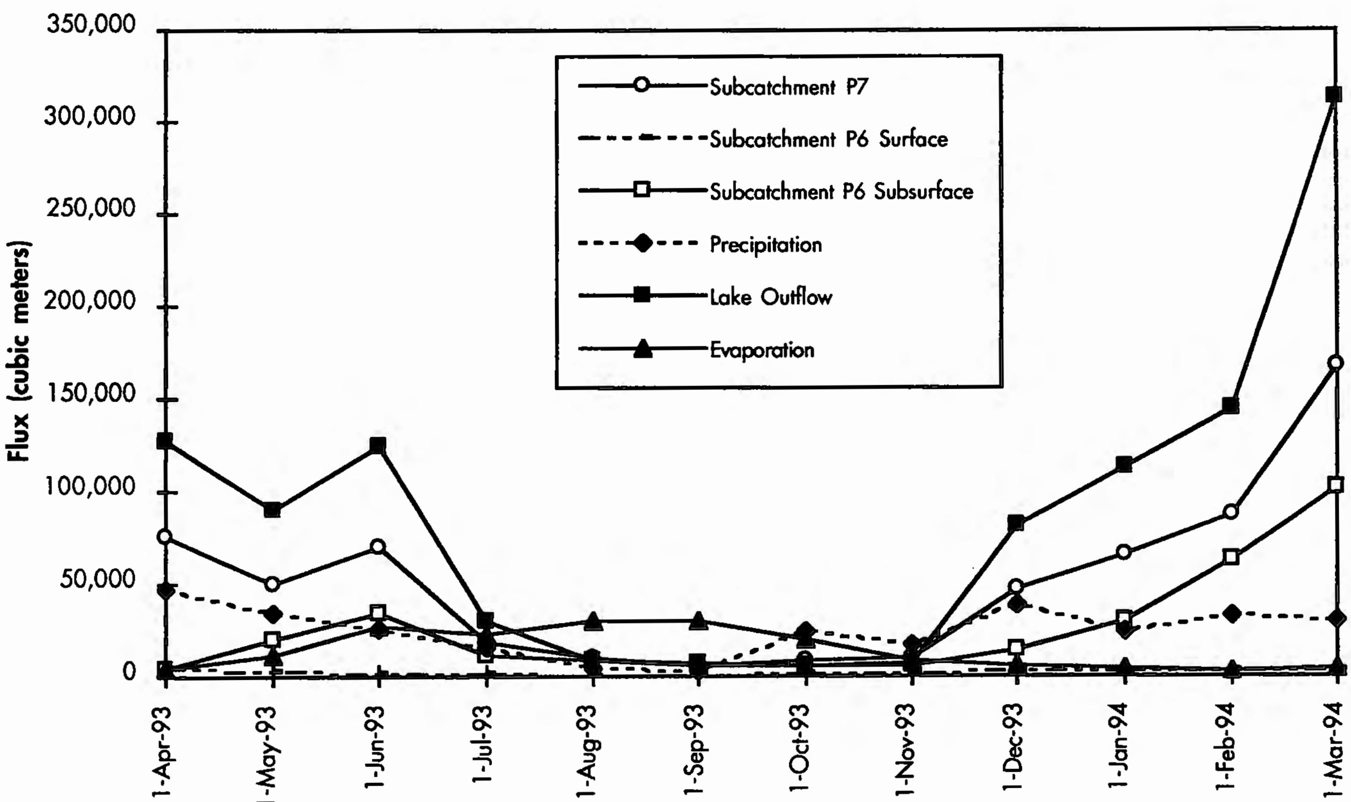


Figure 5-4 Lake Desire Annual Water Balance, Current Conditions

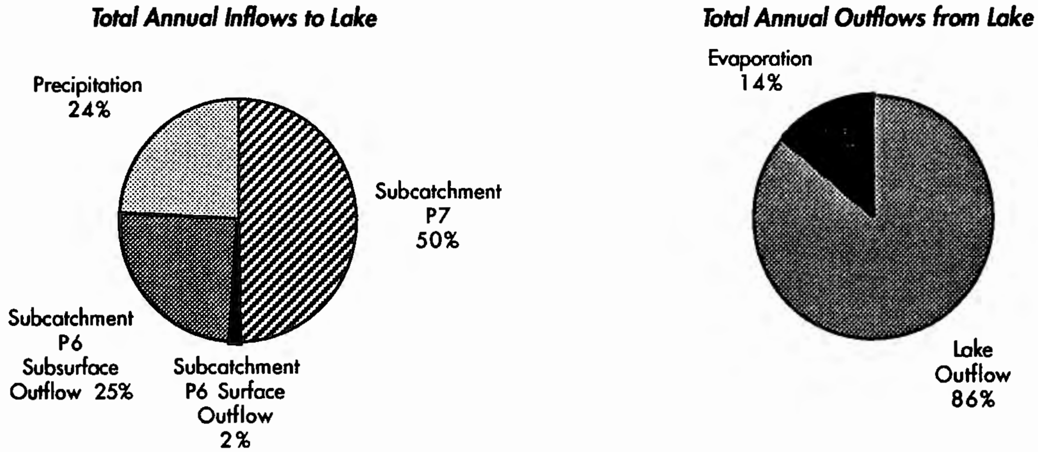


Table 5-4: Lake Desire Water Balance, April 1993 - March 1994

Month / Year	Sub-catchment P7	Sub-catchment P6 Surface	Sub-catchment P6 Subsurface	Precipita-tion	Lake Outflow	Evapora-tion
Apr 1993	75,820	3,830	4,810	46,710	127,320	3,960
May 1993	50,310	3,430	19,850	33,980	90,210	11,060
Jun 1993	70,120	1,550	34,920	25,520	124,200	27,380
Jul 1993	18,930	720	11,220	15,380	29,480	22,750
Aug 1993	10,250	150	9,040	3,610	8,510	29,600
Sep 1993	5,230	170	7,030	2,900	5,460	30,340
Oct 1993	8,310	1,600	6,230	24,200	5,230	19,520
Nov 1993	9,830	1,050	5,460	17,060	6,440	8,380
Dec 1993	47,630	3,340	13,710	38,030	81,510	5,390
Jan 1994	65,180	2,340	30,330	23,590	113,250	4,060
Feb 1994	87,490	3,000	62,500	33,020	143,520	2,330
Mar 1994	167,110	3,500	101,230	30,120	312,200	3,740
Total	616210	24680	306330	294120	1047330	168510

All measurements in cubic meters
Annual Balance:
Wetland Outflow + Basin P6 Surface and Subsurface Outflows + Precipitation - Lake Outflow - Evaporation = Change in Storage = 25,490 cubic meters

The total annual inflow to the lake for the study period was 1,241,340 cubic meters. The total annual outflow from the lake was 1,215,840 cubic meters. This represents a net gain in lake volume of 25,500 cubic meters, which is equivalent to an increase in lake elevation of approximately 4 inches.

There are many more pathways for water flowing into the lake than out of the lake. Almost half the inflow to the lake came from the Subcatchment P7. Annual subsurface flow to the lake (interflow and groundwater flow) from Subcatchment P6 was more than 10 times greater than surface flow from that subcatchment. Precipitation on the 80-acre lake accounted for 24 percent of the total annual inflow. Lake outflow occurred only through evaporation and the lake outlet stream. Outflow to the stream was more than six times greater than the evaporative loss for the year.

Monthly total precipitation during the study period (April 1993-March 1994) was compared to long-term monthly averages at Sea-Tac Airport and monthly pan evaporation totals for the period were compared to long-term monthly averages for Puyallup (KCM 1994e). This comparison showed that the spring and summer of the monitored year were wetter than usual and the autumn and winter were drier than usual. Pan evaporation data for the period closely approximated the long-term averages even though values were consistently higher than the long-term average between August and December 1993. Precipitation from April through July 1993 was consistently greater than the long-term average, while precipitation from August 1993 through March 1994 was generally less than the long-term average. Total annual precipitation at the Layton gauge (SE 196th St.) for the study period was 40.86 inches, compared to a long-term annual average of 38.31 inches at Sea-Tac.

Historical and Future Conditions Simulations

Historical and future conditions were simulated for comparison to current conditions to assess changes to the lake water budget due to changes in land cover. Data relating to land cover changes were developed by King County Surface Water Management as follows (D. Hartley, KCSWM Senior Hydrologist, 3 October 1994, Personal Communication):

- Historical conditions were determined by assuming all current grass and impervious cover to be forested.
- Current conditions were based on GIS analysis of aerial photography from the spring of 1989 and corrections based on field observations.
- Future conditions were determined using a combination of land use zoning as presented in the Soos Creek Community Plan and Community Plan Update, the King County Sensitive Areas Ordinance, and mapping of the urban growth boundary.

A discussion of the development of these land use scenarios is presented in the *Cedar River Current and Future Conditions Report* (King County 1993b). The scenarios referenced in that report were modified slightly by King County SWM to develop land cover data for current and future conditions. The modifications were based on new information on existing development proposals and open space acquisitions.

Changes in land cover are summarized in Table 5-5. As the Lake Desire watershed is developed, forest land cover decreases as it is converted to grassed land cover and impervious areas. The land cover data assumes no net loss of wetland areas to future development. All changes between current and future conditions are of greater magnitude than those between historical and current conditions.

Table 5-5: Distribution of Land Types Based on King County Data (values in acres)

	Historic Conditions	Current Conditions	Future Conditions
Forested	**698**	**556**	**121**
Till Forest Mild	622	489	93
Till Forest Moderate	69	60	23
Till Forest Steep	7	7	5
Grassed	**0**	**124**	**481**
Till Grass Mild	0	116	443
Till Grass Moderate	0	8	38
Till Grass Steep	0	0	0
Wetland	**63**	**63**	**63**
Impervious	**0**	**18**	**95**

Percentages of total annual inflows and outflows for historical and future conditions are shown on Figures 5-5 and 5-6. Monthly breakdowns for each water budget component and scenario (i.e., historical, current and future) are detailed in KCM 1994e.

Figure 5–5 Lake Desire Annual Water Balance, Historic Conditions

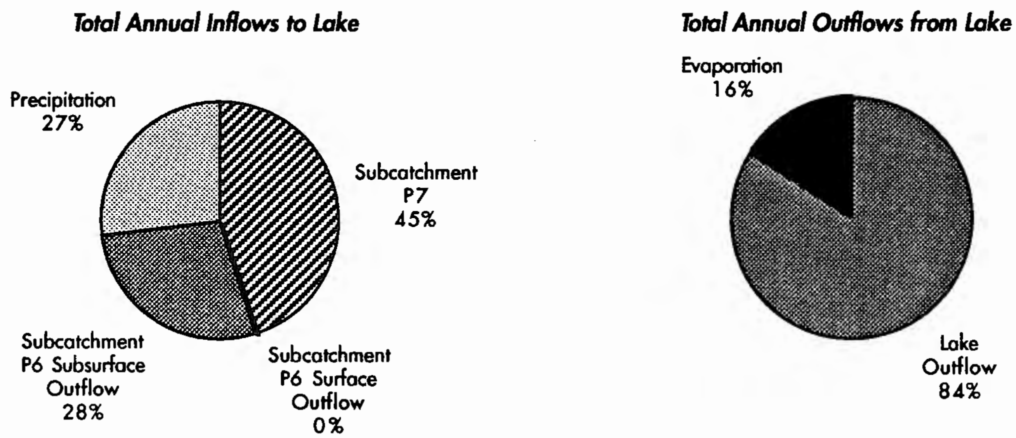
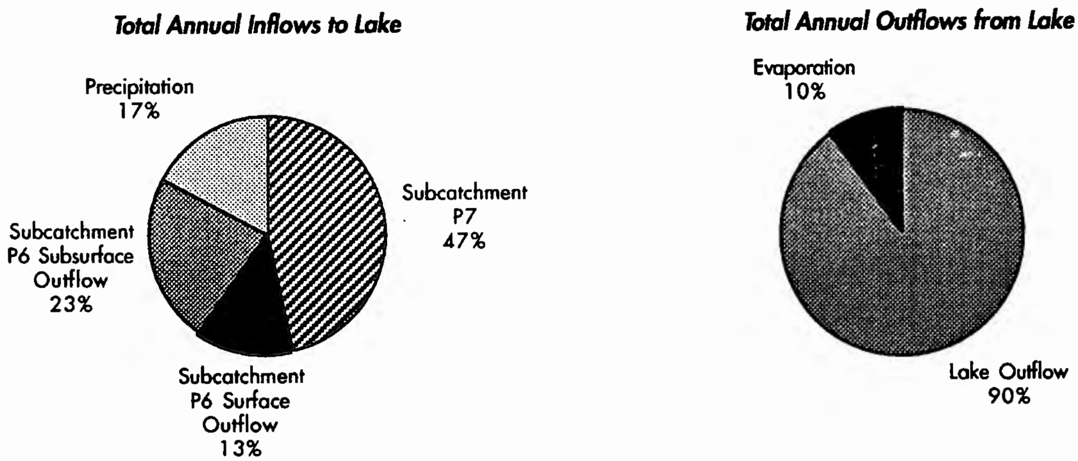


Figure 5–6 Lake Desire Annual Water Balance, Future Conditions



As the area tributary to Lake Desire develops, the following changes are predicted:

- Surface inflow will increase with the change in land cover from current to future conditions. This increase will be greater than the change from historical to current conditions.
- Interflow, which represents shallow subsurface flows generated by storm events that arrive at the lake faster than groundwater inflows, is predicted to increase during the winter as the subcatchment changes from current conditions to future conditions. Summer interflow under all scenarios is negligible. The difference in interflow volumes between historical and current conditions is minimal.
- Groundwater inflows will decrease as the subcatchment develops from current to future conditions. The difference in groundwater inflow between historical and current conditions is minimal.

Subcatchment hydrology will change much more between current and future conditions than it did between historical and current conditions. Maximizing forest retention, implementing stormwater best management practices and enforcing drainage regulations as the subcatchments develop will help to mitigate the changes associated with development.

CHAPTER 6: NUTRIENT BUDGET AND LAKE RESTORATION ANALYSIS

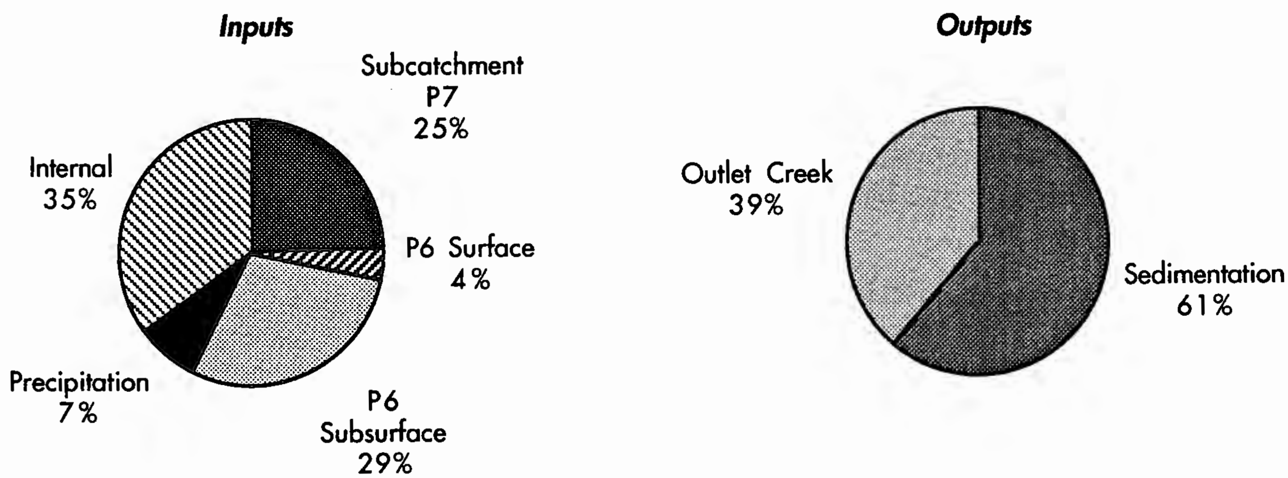
INTRODUCTION

A balanced nutrient supply (nitrogen and phosphorus) and multiple nutrient limitation of phytoplankton productivity in Lake Desire (KCM, 1993b and KCM, 1994b) suggests that reducing the loading of either nitrogen or phosphorus would result in reducing phytoplankton productivity in the lake, increasing water transparency. Because several biogeochemical processes in the lake ameliorate nitrogen deficiency (e.g., feedback from the sediments and nitrogen-fixation), management efforts which focus on reducing phosphorus loading will have the greatest long-term impact on phytoplankton productivity. Therefore, the nutrient budget and subsequent loading analysis was conducted for total phosphorus only.

METHOD OF ANALYSIS

Nutrient loading to Lake Desire was calculated on the basis of the water budget developed for the lake (KCM, 1994e) and nutrient concentrations measured in the lake, lake inlet and outlet, precipitation, and groundwater. Phosphorus sources were divided into five major components (Figure 6-1): internal loading, direct precipitation to the lake surface, overland flow from subcatchment P6 (the area immediately surrounding the lake), subsurface flow through subcatchment P6, and overland flow from subcatchment P7 (the area immediately upstream of the lake which contains Cedar River Wetlands 14 and 15).

Figure 6–1 Lake Desire Total Phosphorus Inputs and Outputs



The model used to define lake phosphorus loading is based on the assumption that phosphorus input to the lake equals phosphorus loss from the lake plus or minus the change in the total amount of phosphorus in the lake:

$$\Delta P = P7 + Int + Pre + P6surf + P6sub - Out - Sed$$

where:

ΔP	=	Change in phosphorus mass (storage) within the lake
P7	=	Lake inflow of phosphorus from upstream wetlands and watershed
Int	=	Internal input of phosphorus from sediments over and above phosphorus loss due to sedimentation
Pre	=	Direct precipitation of phosphorus to the lake surface
P6surf	=	Input of phosphorus from overland flow via subcatchment P6
P6sub	=	Input of phosphorus from subsurface flow via subcatchment P6
Out	=	Outlet loss of phosphorus
Sed	=	Loss of phosphorus to sediments minus phosphorus sediment/water exchange

Groundwater loading was determined by multiplying the subsurface inflow volume from subcatchment P6 by the mean groundwater concentration of total phosphorus (118 µg/L), as measured in the groundwater study (Hong West, 1994). This concentration was calculated using a conservative estimate of the potential phosphorus contribution from on-site waste disposal systems. The mean total phosphorus concentration of 80 µg/L, measured in the groundwater study (Hong West 1994), was considered to be a background level.

For the management plan, on-site waste disposal systems at Lake Desire were evaluated based on variety of sources including: 1) groundwater monitoring data; 2) review of the Seattle-King County Department of Public Health records; 3) the use of Aerial Shoreline Analysis and field surveys; and 4) the preliminary nutrient budget. The potential contribution of phosphorus to Lake Desire from on-site waste disposal systems was also estimated (KCM, 1994d) based on the following assumptions:

- Approximately 101 homes along the shoreline, all using on-site waste disposal systems
- Per capita nutrient loading of 4 grams total phosphorus per day (USEPA, 1988)
- Two persons in each residence
- Nutrient attenuation of 90 percent for the waste disposal systems, based on review of literature.

Surface loading from subcatchment P6 was calculated based on land use in the area as interpreted by King County SWM from existing land use information. Current land use in the subcatchment is approximately 49 percent forest, 25 percent rural 16 percent lake/wetland, 6 percent grass, 3 percent low density residential, and 1 percent impervious surface. Phosphorus loading concentrations for each land use were derived from literature values as summarized in Schueler, 1987. The overall phosphorus concentration estimated for subcatchment P6 overland flow was 196 µg/L (calculated using land use coefficients [Schueler, 1987] and existing land use for Lake Desire). This phosphorus concentration was multiplied by the volume of flow entering the lake via surface flows in the subcatchment as determined by the HSPF model.

Phosphorus loading from precipitation was estimated by multiplying the monthly precipitation volume falling on the lake surface by a mean concentration of 31 μg/L measured in rainfall samples collected by citizen volunteers throughout the study year. Six precipitation samples were analyzed for phosphorus. Two of the six had concentrations that exceeded the normal range for precipitation in this region; these were assumed to have been contaminated and were not used in the calculation of the mean concentration.

Inflow loading from the wetland was estimated by multiplying the inlet flow volume by the monthly mean phosphorus concentration of 52 μg/L. The monthly mean phosphorus concentration was calculated from samples collected by King County SWM at Station LDIN1 during routine monitoring events. Losses of phosphorus from outlet flows were estimated using the same method.

The monthly net gain in phosphorus from sediment phosphorus release and net loss of phosphorus to sedimentation were determined through the development of a transitional phosphorus model for Lake Desire. The model is the Vollenweider (1975) non-steady-state model as modified by Larsen et al. (1979). This model calculates whole-lake total phosphorus concentrations through the development of sediment release rates and sedimentation rates. The model was calibrated to simulate current lake conditions.

The change in lake phosphorus mass was calculated as the residual of the mass balance equation. A gain of phosphorus mass indicates that the weighted mean phosphorus concentration increased from that of the previous month. A decrease in lake phosphorus mass indicates that phosphorus was lost to the sediments, or through the outlet.

Sediment phosphorus release was also estimated from the accumulation of hypolimnetic phosphorus by using the regression of time versus the volume-weighted total phosphorus content in the hypolimnion (Welch et al., 1986). The sediment release rate determined by this method (9.05 μg/L per week) was used to calculate net internal nutrient loading. Release of phosphorus from the sediment was most intense during the 16-week period from mid-May through August. To be conservative, a 16-week period was used to calculate the net internal load.

RESULTS OF THE STUDY YEAR

The Lake Desire monthly phosphorus budget for the study year is presented in Table 6-1. Table 6-2 summarizes the annual nutrient budget based on existing conditions. Nutrient loading is presented graphically as percentages and total weight for each source in Figures 6-1 and 6-2, respectively.

Internal loading originates within the lake, primarily through the release of phosphorus from the sediments. External loading comes from the watershed or atmosphere. Approximately 35 percent of the phosphorus in the lake was from internal sources. The remaining 65 percent was from external sources including subcatchment P7 (the lake inflow), subcatchment P6 surface and subsurface flows, and direct precipitation (Figure 6-1).

The transitional phosphorus model developed for the nutrient budget was calibrated to simulate whole-lake, volume-weighted total phosphorus concentrations as observed during the study year. Observed whole lake phosphorus concentrations from July 13 and November 16, 1993 fluctuated for no apparent reason. Phosphorus concentrations in the epilimnion would be expected to decline during stratification due to phytoplankton uptake, while phosphorus concentrations in the hypolimnion would be expected to steadily increase from internal loading. Instead, total phosphorus concentrations in the epilimnion and metalimnion were variable for these two sampling dates. Rather than calibrate the model to mimic the unexplained ups and downs in the lake phosphorus concentrations, the data were smoothed out. This was

Table 6-1: Total Phosphorus Nutrient Budget; April 1993 to March 1994 (values in grams)

	INPUT					OUTPUT		
Month	P7 Lake Inflow	P6 Surface	P6 Subsurface	Precipitation	Internal	Sedimentation	Outlet	ΔLAKE STORAGE
1993								
April	4,018	751	568	1,448	4,775	0	4,711	6,849
May	2,314	672	2,342	1,053	5,186	0	3,067	8,501
June	5,189	304	4,121	791	17,417	0	5,837	21,984
July	0	141	1,324	477	5,764	0	1,445	6,261
August	0	29	1,067	112	1,940	0	221	2,927
September	0	33	830	90	4,636	0	306	5,283
October	0	314	735	750	3,630	0	0	5,429
November	806	206	644	529	0	0	0	2,185
December	2,143	655	1,618	1,179	0	12,613	3,912	-10,931
1994								
January	2,509	459	3,579	731	0	13,559	5,210	-11,490
February	3,500	588	7,375	1,024	0	13,921	6,028	-7,463
March	10,210	686	11,945	934	0	22,087	8,429	-6,741
Total	**30,689**	**4,838**	**36,148**	**9,118**	**43,348**	**62,180**	**39,166**	**22,794**

Table 6-2: Existing Nutrient Budget

Source	Amount (kg)	Percent of Total
Inflow		
P7, Lake Inflow	31	25
P6, Surface	5	4
P6, Subsurface	36	29
Precipitation	9	7
Internal	43	35
Total	**124**	**100**
Outflow		
Outlet	39	39
Sedimentation	62	61
Total	**101**	**100**
Δ Lake Storage	**23**	

done by establishing a linear regression using the total phosphorus concentrations measured on July 13, 1993 and November 16, 1993, and interpolating the values for the sample dates in between. Predicted monthly mean phosphorus concentrations versus observed and interpolated monthly mean values are shown in Figure 6-3.

Figure 6–2 Lake Desire Total Phosphorus Loading Inputs and Losses by Category

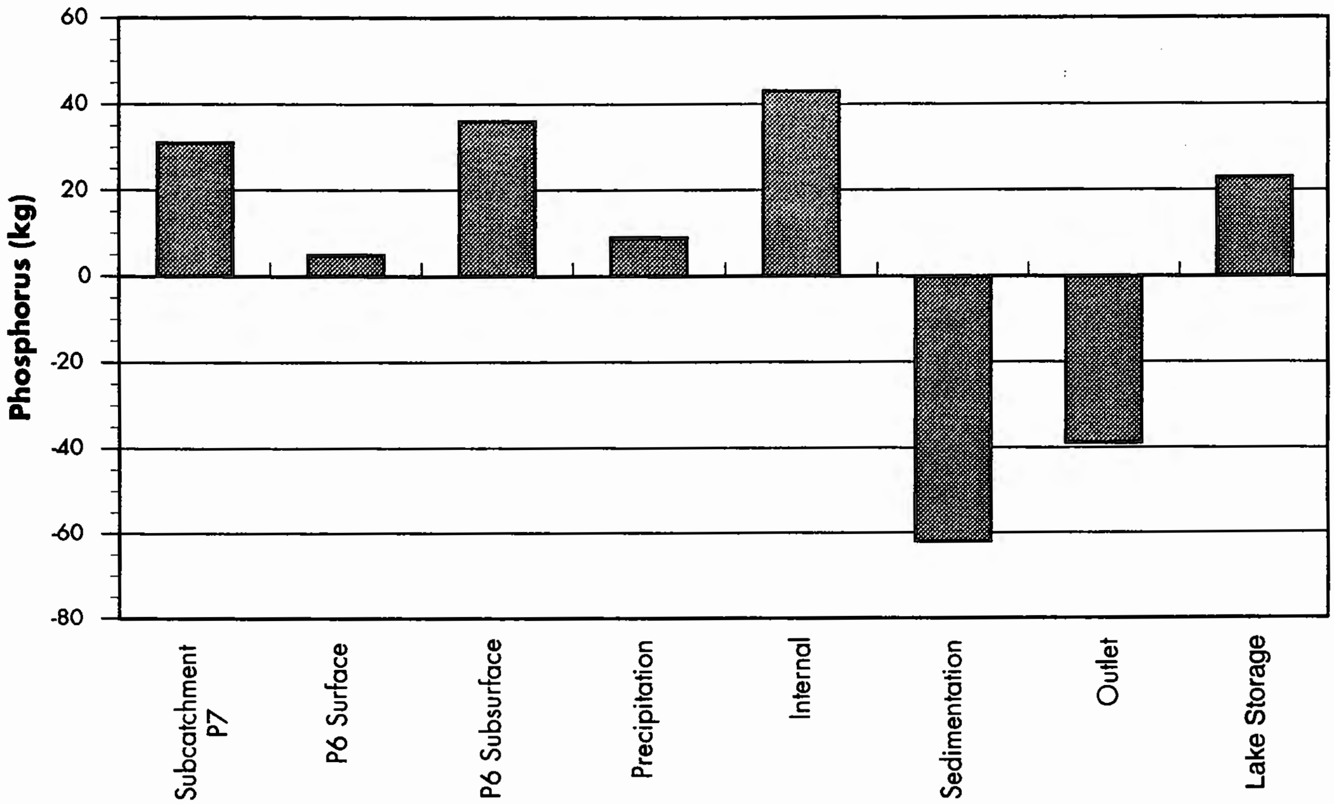
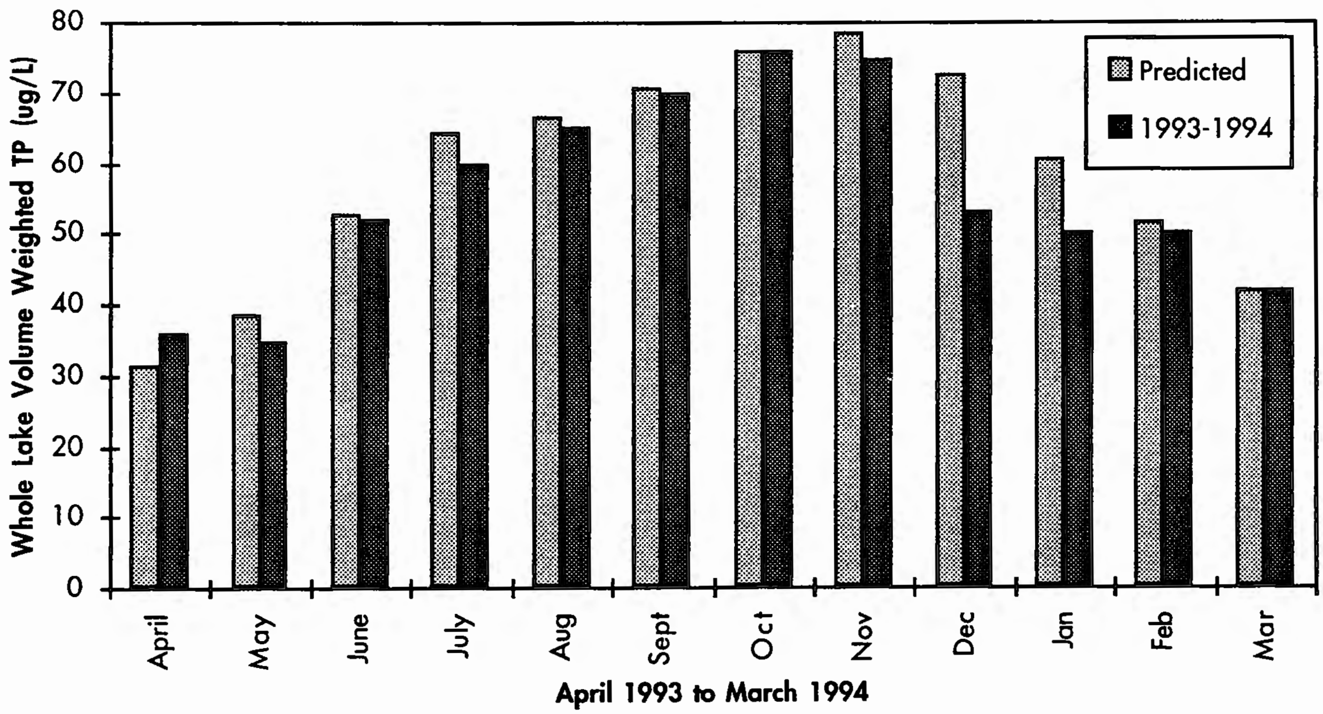


Figure 6–3 Lake Desire Modeled & Measured Volume Weighted, Whole Lake Total Phosphorus, April 1993 to March 1994



External Loading

The 31 kg of phosphorus from subcatchment P7 represents 25 percent of the total phosphorus loading during the study year, the second largest external source of phosphorus (Table 6-2). Phosphorus concentrations in the lake inflow averaged 52 µg/L, ranging from 31 to 119 µg/L throughout the year. The lake inflow provides the largest volume of water to the lake. The large volume of water as well as the moderately high phosphorus concentrations associated with subcatchment P7 results in the large external nutrient load to the lake from subcatchment P7.

The subsurface flows from subcatchment P6 contributed 29 percent of the total phosphorus loading during the study year. The 36 kg of phosphorus from subsurface flows includes both interflow and the flow from the shallow aquifer. The major source of total phosphorus loading from subsurface flows can be attributed to on-site waste disposal system outflows.

From the Lake Desire On-site Septic System Assessment, it was calculated that between 30 and 87 kg per year of total phosphorus could be attributed to on-site septic systems. This *estimate* was based on the average amount of phosphorus discharged in household wastewater (based on literature values) and a series of assumptions regarding the efficiency of the 101 septic systems along the lake shoreline. If a 90 percent efficiency is assumed on average, the loading estimate is as low as 30 kg per year. If a series of less conservative efficiencies are assumed, the loading estimate is as high as 87 kg per year.

Based on the calculated waste disposal loading range, the existing nutrient budget (Table 6-2), groundwater data, and on-site waste disposal system surveys and record reviews, on-site septic systems account for an estimated 30 kg per year of phosphorus. This represents 24 percent of the total nutrient budget, 37 percent of the external loading, and 83 percent of the P6 subsurface loading. The reasoning behind using the 30 kg per year estimate was based on the following information:

- In the groundwater analysis, it was estimated that approximately 15 percent of the total phosphorus entering the lake and 25 percent of the flow was from subsurface flow. This estimate was based on quarterly measured flow and water quality data and the hydrostratigraphy of the area.

- The lake model based on the Vollenweider (1975) non-steady-state model (which predicts whole-lake total phosphorus concentrations), integrates the information from the individual hydraulic phosphorus loading components (subsurface flows, surface, and precipitation sources) and internal phosphorus loading.

- The lake model is based on a mass-balance of total phosphorus using the measured data from the study year, literature values, and professional estimates where data gaps exist or are difficult to accurately measure. As with most modeling applications, certain components are more easily measured and assessed. In lakes, inflow, internal loading, precipitation, and surface runoff are the easiest to measure and predict, while groundwater and subsurface flows remain more difficult.

- As a check on the assumptions used to in the modeling analysis, the nutrient budget must balance on an annual cycle and modeled values should closely match measured values for existing conditions. Figure 6-3 represents the modeled versus the measured values for whole-lake volume weighted total phosphorus concentrations. From month to month, there generally is a good correlation between measured and modeled concentrations.

This model calibration (Figure 6-3) suggests that the assumptions upon which the model is based regarding its individual components (subsurface, internal, surface, and precipitation) are providing a good estimate of the interrelationship between the components. The lack of specific evidence regarding ongoing failure of on-site septic systems confirmed the choice to use the lower end of the loading range or 30 kg per year for on-site septic systems in the model

Surface water flows in subcatchment P6 (directly surrounding the lake) contributed 4 percent of the overall nutrient load to Lake Desire. The majority of the 5 kg of total phosphorus from surface water runoff in the subcatchment most likely originates from the properties adjacent to the lake.

Nine kilograms of phosphorus were attributed to direct precipitation. Generally, precipitation is considered a background component of the nutrient budget. Air quality influences the quality of precipitation and generally air pollution controls recommendations are not made in a lake watershed unless the loading from precipitation is considered significant.

Internal Loading

When oxygen concentrations in the hypolimnion (bottom waters) drop below 2 mg/L, anoxia in the sediments is likely to occur. Under anoxic (oxygen-starved) conditions, phosphorus bound in the sediments as iron phosphate is released to the water column. Conversely, as hypolimnetic oxygen concentrations increase above 2 mg/L, iron and phosphorus combine to form an insoluble precipitate that settles to the lake bottom. Phosphorus in the water column in phosphate form is available for phytoplankton uptake. Uptake occurs at any time of the year for blue-green algae, which can inhabit the nutrient-rich hypolimnion (during the stratified period) and migrate to the surface. Uptake occurs at fall turnover for algae that are restricted to the epilimnion during stratification.

In Lake Desire, the hypolimnetic dissolved oxygen concentration decreases rapidly to almost zero near the water-sediment interface during thermal stratification. Dissolved oxygen concentrations were less than 2 mg/L at the water-sediment interface from May to September. That condition enhances phosphorus release from the sediments and is reflected in the high hypolimnetic phosphorus concentrations. Hypolimnetic dissolved oxygen was depleted from April through October because of strong thermal stratification. Internal loading of phosphorus from lake sediments totaled 43 kg of phosphorus from April through October, providing 35 percent of the overall total phosphorus load to Lake Desire.

A total of 42 kg of phosphorus was estimated to be released from the sediment using the regression of time versus the volume-weighted total phosphorus content in the hypolimnion. This value agrees very well with the internal load estimated from the transitional mass balance model (within 2 percent) described above, lending confidence to the overall estimated values.

ANALYSIS OF HISTORICAL AND FUTURE CONDITIONS

The study year model was modified to simulate lake water quality under historical conditions (i.e., approximately 1960, prior to the most recent development surge and alteration of wetland Cedar River 14) and future conditions (i.e., full build-out per Soos Creek Community Plan [King County, 1991b]). For comparing the various restoration alternatives (mitigated future conditions), a future conditions scenario without mitigation (Scenario 3) and future scenarios using existing watershed regulations only were modeled (Scenario 7 or 8).

Phosphorus loading concentrations for surface waters were estimated based on the historical (1960) land use. The phosphorus concentration of 47 µg/L for water flowing into the lake from subcatchment P7 under historical conditions was taken from literature values for undisturbed wetland outflow (Reinelt et al., 1994). Surface water overland phosphorus concentration used for subcatchment P6 was 150 µg/L. Subsurface flows through subcatchment P6 were assigned a background phosphorus concentration of 51 µg/L as measured in the groundwater study (Hong West, 1994).

The phosphorus concentration of 72 µg/L for water flowing into the lake via subcatchment P7 under future conditions was taken from literature values for urbanized wetland outflow (Reinelt et al., 1994). Based on the future land use, the overall phosphorus concentration used for subcatchment P6 surface waters was 253 µg/L (calculated using land use coefficients [Schueler, 1987] and future land use for Lake Desire). Phosphorus concentrations for subsurface flows through subcatchment P6 remained the same as under current conditions at 118 µg/L. The current conditions value was calculated based on the number of homes along the shoreline (KCM, 1994c). Given the limitation of the soils and that the area is within an urban growth designation which includes sewering, it is not expected that any more homes built along the shoreline would use on-site waste disposal systems.

Table 6-3 summarizes the historical and future nutrient budget. A comparison of the historical, current, and future total phosphorus concentrations is presented graphically in Figure 6-4. The relative changes in loading for the three scenarios are presented in Figure 6-5.

Table 6-3: Historical and Future Nutrient Budget

Source	Historical Amount (kg)	Historical Percent of Total	Future Amount (kg)	Future Percent of Total
Inflow				
P7 Lake Inflow	23	33	58	21
P6, Surface	0	1	58	21
P6, Subsurface	16	22	46	17
Precipitation	9	13	9	3
Internal	21	31	105	38
Total	69	100	277	100
Outflow				
Outlet	32	45	121	51
Sedimentation	39	55	117	49
Total	71	100	238	100
ΔLake Storage	-2		39	

Figure 6–4 Lake Desire Modeled Total Phosphorus Concentrations Under Historical, Current, and Future Conditions

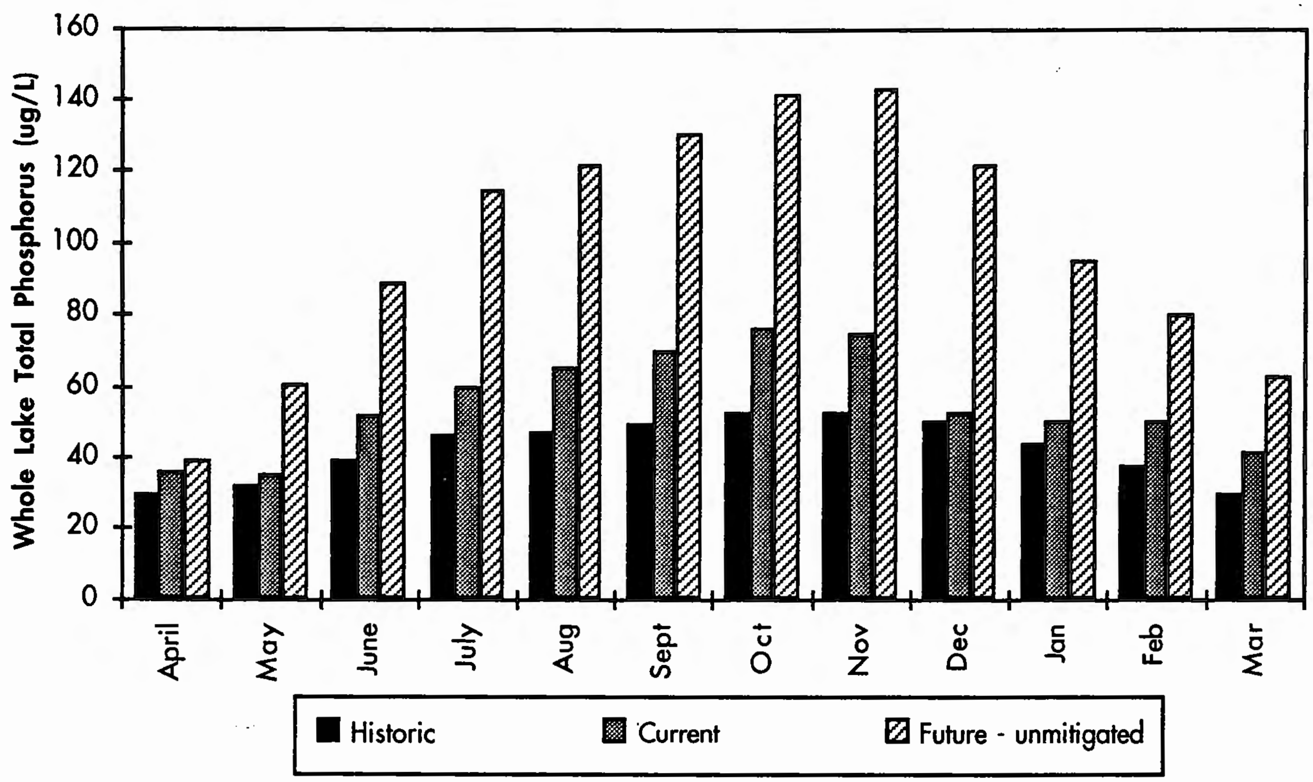
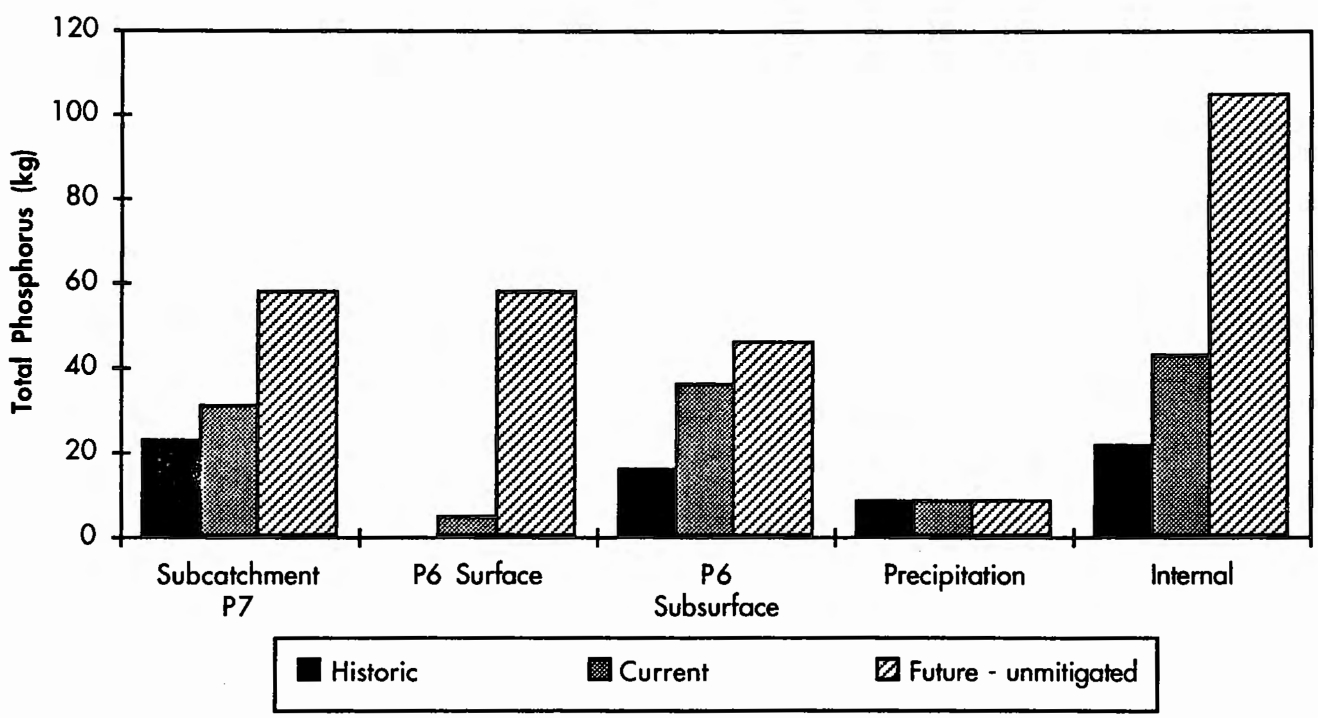


Figure 6–5 Lake Desire Modeled Phosphorus Loading by Source for Historical, Current & Future Conditions



RESTORATION ALTERNATIVES ANALYSIS

Both watershed management and in-lake restoration measures will be needed to improve existing Lake Desire water quality and prevent additional degradation in the future. Watershed management measures improve water quality by reducing pollutant loading to the lake from point and nonpoint sources in the watershed. In-lake restoration techniques typically control nutrients originating within the lake. Watershed and in-lake measures used to control nutrients are presented in Table 6-4.

TABLE 6-4: Lake Desire Management/Restoration Alternatives

Measures	Advantages	Disadvantages	Estimated Cost[a]
Dredging	• Removes nutrient-rich sediments • Reduces internal cycling • Enhances boating and swimming • Long-term solution (>20 yrs.)	• Resuspension of sediments • Disposal concerns • High cost	• Approximately $12/cu. yd.
Aluminum Sulfate Treatment	• Lowers lake phosphorus content • Inhibits release of phosphorus from sediments • Increases water column transparency	• Temporary measure (1-5 yr. effectiveness) • Potential toxic impacts • Increase in aquatic weed growth	• Alum: $92,000 (55 tons alum, 21 tons aluminate)
Hypolimnetic Aeration	• Maintains oxygen in the hypolimnion • Limits release of phosphorus from sediments • Increases habitat and food supply	• Difficulty in supplying adequate oxygen • Potential for premature destratification and subsequent algal blooms • No impacts on aquatic weeds	• Const: $300,000 • O&M: $14,500/yr. • Design & Engineering: $100,000 • SEPA: $50,000
Dilution	• Reduces nutrient concentrations through dilution and increased flushing	• Requires very large quantities of low-nutrient water • High operation cost • No impact on aquatic weeds	• NA[b]

[a] *Does not include associated costs such as taxes, engineering, administration, permitting, SEPA review, environmental monitoring, or construction management.*
[b] *NA - Measure would not meet project goals. Costs not estimated.*
[c] *EP - Existing programs are expected to cover costs.*

TABLE 6-4 (continued): Lake Desire Management/Restoration Alternatives

Measures	Advantages	Disadvantages	Estimated Cost[a]
Hypolimnetic Dilution	• Reduces nutrient concentrations through dilution and increased flushing of bottom waters • Maintains oxygen in the hypolimnion • Limits release of phosphorus from sediments • Increases habitat and food supply • Increases potential for fisheries enhancement in Swifty Creek	• Requires large quantities of low-nutrient water • No impact on aquatic weeds • Potential for premature destratification	• NA[b]
Hypolimnetic Injection and Withdrawal	• Reduces nutrient concentrations through dilution and increased flushing of bottom waters • Maintains oxygen in the hypolimnion • Limits release of phosphorus from sediments • Increases habitat and food supply • Increases potential for fisheries enhancement in Swifty Creek	• No impact on aquatic weeds	• NA[b]
Artificial Circulation	• Disrupts or prevents stratification • Provides aeration and oxygenation • Increases aerobic habitat • May limit sediment phosphorus release	• May or may not decrease algal biomass • May decrease water clarity • No impact on aquatic weeds	• NA[b]

[a] *Does not include associated costs such as taxes, engineering, administration, permitting, SEPA review, environmental monitoring, or construction management.*
[b] *NA - Measure would not meet project goals. Costs not estimated.*
[c] *EP - Existing programs are expected to cover costs.*

TABLE 6-4 (continued): Lake Desire Management/Restoration Alternatives

Measures	Advantages	Disadvantages	Estimated Cost[a]
LD-1 Catchment P7 Forest Retention	• Provides biofiltration potential • Reduces nutrient loading • Reduces amount of toxins entering the lake	• Requires resident participation	EP[c]
LD-2 Wetland Restoration and Enhancement	• Provides biofiltration potential • Reduces nutrient loading • Reduces amount of toxins entering the lake	• May require construction	EP[c]
LD-3 Shoreline Wetland Revegetation	• Provides biofiltration potential • Reduces nutrient loading • Reduces amount of toxins entering the lake • Improves fish and wildlife habitat • Reduces shoreline erosion	• Requires resident participation	$4,000
LD-4 Stormwater Treatment	• Provides biofiltration potential • Reduces nutrient loading • Reduces amount of toxins entering the lake	• May require construction	EP[c]
LD-5 Ditch Maintenance	• Increases Biofiltration • Improves Water Quality	• May require construction	EP[c]
LD-6 Homeowner BMPs	• Reduces nutrient loading • Reduces amount of toxins entering the lake • Reduces the amount of runoff water	• Requires resident participation	$3,000
LD-7 Sewering	• Reduces nutrient loading	• Requires construction	$2,000,000

[a] Does not include associated costs such as taxes, engineering, administration, permitting, SEPA review, environmental monitoring, or construction management.
[b] NA - Measure would not meet project goals. Costs not estimated.
[c] EP - Existing programs are expected to cover costs.

In-lake techniques that can be used to reduce nutrients and control subsequent algal growth include sediment removal (i.e., dredging), phosphorus inactivation and precipitation (e.g., aluminum sulfate treatment), hypolimnetic aeration, dilution, hypolimnetic withdrawal, and artificial circulation. Because of prohibitive cost and expected disposal difficulties, dredging is not recommended for reducing nutrients and controlling algal blooms in Lake Desire. A readily available, low nutrient water source does not exist in the vicinity of Lake Desire (Ron Spear, March 6, 1995, Personal Communication). Therefore, dilution is not considered a viable alternative for improving water quality. Hypolimnetic withdrawal is not a viable technique for Lake Desire because of the impact of low-quality hypolimnetic water on the outlet stream. Artificial circulation has had mixed success in controlling sediment phosphorus release and may actually increase the potential for algal blooms (Cooke et al., 1993b). Artificial circulation was therefore not considered as a technique for improving the water quality in Lake Desire. The two in-lake techniques that are considered viable for Lake Desire are hypolimnetic aeration and a buffered alum treatment.

Several watershed management and in-lake restoration measures were evaluated for their cost and overall impact on lake water quality (Table 6-4). Watershed measures included maintaining subcatchment P7 as open space, providing sewers in the nearshore area, and implementing best management practices (BMPs) throughout the watershed. In-lake restoration measures included a buffered alum treatment, hypolimnetic aeration, and a combination of alum and hypolimnetic aeration.

Watershed Measures

In analyzing the effectiveness of potential watershed management measures, future hydrologic conditions and phosphorus concentrations were assumed, except where specified otherwise.

- **Limited Forest Conversion in Subcatchment P7.** To simulate the impact on water quality of Lake Desire if subcatchment P7 remained primarily forested, the hydrologic conditions and phosphorus loading were modeled as current conditions.
- **Sewering in the Nearshore Area.** It was estimated that sewering in the nearshore area would reduce the phosphorus concentration in subsurface water flowing to the lake to the background level of 51 μg/L (Hong West 1994). The volume of subsurface flow entering the lake was estimated using the full build-out of future conditions in subcatchment P6.
- **Best Management Practices in Subcatchment P6.** It was estimated that implementing best management practices in subcatchment P6 would reduce phosphorus loading from surface flows in that subcatchment by 50 percent over 20 years. The initial (i.e., within five years) reduction in phosphorus loading would be low, and was estimated to be only 5 percent. Future hydrologic conditions were used to estimate the volume of flow entering Lake Desire via surface flows through subcatchment P6.

In-Lake Measures

The two in-lake techniques to control nutrients, and hence algal growth, were evaluated. Planning and regulatory permits are required for both. With any restoration technique, the length of long-term benefits will depend on lake and watershed management programs that continue to address water quality and algal blooms. Cost comparisons between the in-lake alternatives are difficult, due to the large number of variables involved. Whenever possible, recent costs from local projects were used to develop costs for a comparable project in Lake Desire.

Buffered Alum Treatment.

Adding aluminum sulfate (alum) lowers a lake's phosphorus content by precipitating phosphorus and retarding release from the sediments (Cooke et al., 1993a). When alum is added to the water column a polymer forms that binds phosphorus and organic matter. The aluminum phosphate-hydroxide compound (commonly called alum floc) is insoluble and settles to the bottom. Dramatic increases in water clarity typically occur immediately following an alum treatment, as suspended and colloidal particles are removed from the water column by the floc. Once on the sediment surface, alum floc retards phosphate diffusion from the sediment to the water through chemical binding.

Alum is a promising technique for reducing algae through physical removal during the application and through the long-term control of internal nutrient loading. The treatment does not kill the algae instantaneously in the water column but settles them to the lake bottom where they die over a period of up to two weeks. This longer time period and the location at the lake bottom greatly reduce the hazard of any toxins that might be released from the dying algae cells. Alum can also provide long-term reduction in the occurrence of algal toxicity if internal phosphorus loading (often a primary cause of blue-green blooms in eutrophic lakes) is reduced. Alum has also been found to reduce the sediment-to-water migration of blue-greens in Green Lake in Seattle (Welch, E.B., October 13, 1992, Personal Communication). Other nutrient inactivation techniques have been used with less success than alum. Calcium hydroxide or lime has recently been used in hardwater Alberta, Canada lakes to control nutrient supply and algal growth (Murphy et al. 1990; Kenefick et al. 1992). However, lime would not offer the same phosphorus-binding benefit in a softwater lake such as Lake Desire (Cooke et al. 1993b).

Alum has been used extensively in the United States with general success in controlling phosphorus release from lake sediments (Cooke et al., 1993b). Its effectiveness has lasted up to 20 years in some lakes (Garrison and Knauer, 1984; Cooke et al., 1993b) Although most case studies of alum treatments demonstrate multiple-year success, failures also have occurred. These have been attributed to insufficient dose, lake mixing, inadequate reduction in external nutrient inputs, and a high coverage of macrophytes.

Using alum is a stop-gap measure that may control sediment phosphorus release for several years (Cooke et al., 1993a). If external sources are not controlled, alum's effectiveness will decrease with time, as the alum layer on the sediments becomes covered by nutrient-rich silt and organic material. Therefore, the lake may need to be treated again. The duration of effectiveness for a specific lake is difficult to predict. Effectiveness and longevity of treatment increase where external nutrient sources have been controlled. Regular long-term water quality monitoring is required in an alum-treated lake to detect decreases in the treatment's effectiveness.

Alum dose should be based on the lake's pH, alkalinity, and potential aluminum toxicity (Cooke et al., 1993a) The use of sodium aluminate as a buffer would permit a greater alum dose to be used. As alum is added to a lake, pH and alkalinity decrease and dissolved aluminum concentrations increase. Alkaline lakes can tolerate higher alum doses than can softwater lakes. Relationships to determine safe alum doses are presented in Kennedy and Cooke (1982) and Cooke et al. (1993a). Adding alum to a lake with low to moderate alkalinity such as Lake Desire (i.e. average alkalinity = 22 mg $CaCO_3$/L at station 1), requires careful planning to ensure that pH and alkalinity are not lowered to levels that would stress resident aquatic biota. A buffering agent such as sodium aluminate has been applied with alum in several northeastern United States lakes and in Green Lake in Seattle, with high success in maintaining pH and alkalinity levels (Dominie, 1978; Cobbossee Watershed District, 1988; Jacoby et al., 1994). The use of sodium carbonate in the October 1991 alum treatment of Long Lake (Kitsap County, WA) was also highly successful in maintaining safe pH and alkalinity levels, as well as in improving lake water quality (Welch, E.B., October 13, 1992, Personal Communication).

Alum application in Lake Desire would reduce the amount of internal phosphorus loading from the sediments and might also bind some of the phosphorus from inflowing groundwater. Blue-green algal migration from sediments might be reduced by application of alum. Alum might need to be reapplied regularly to control blue-green blooms until surface water phosphorus inputs are reduced through watershed controls.

The use of alum salts may cause toxic conditions, although alum treatments have not resulted in adverse impacts on fish to date (Cooke et al., 1993b) and have not damaged invertebrate populations in well-buffered lakes (Cooke et al., 1993a; Narf, 1990). Invertebrate populations, however, may be more sensitive to alum application in softwater lakes. The alum/sodium aluminate treatment of Vermont's Lake Morey, a softwater lake (alkalinity = 30 to 50 mg/L CaCO3/L), unexpectedly resulted in a short-term decrease in density and species richness of benthic invertebrates (Smelzer, 1990). Benthic invertebrate densities were lower in Green Lake in Seattle following the 1991 alum/sodium aluminate treatment than in 1982 (Jacoby et al., 1994). While alum toxicity is a possible cause, other changes in the lake, such as increased carp predation, or degraded sediment quality due to extensive milfoil decay, may have contributed to the decline in benthic invertebrate densities. The absence of recent pre-treatment data for Green Lake makes identification of the causative factor(s) difficult. In both Green Lake and Lake Morey, water column pH was maintained through the use of a sodium aluminate buffer, a procedure that should have prevented the formation of toxic soluble aluminum forms (e.g., $Al(OH)^{2+}$ and Al^{3+}).

A whole-lake treatment of Lake Desire is recommended because it is likely that nutrient-rich sediments exist throughout the watershed and the entire lake is subject to mixing. Alum would primarily reduce internal phosphorus loading, which contributes approximately 35 percent of the annual phosphorus loading to Lake Desire. Treating the lake with 8 mg Al/L would require approximately 55 tons of alum and 20.4 tons of sodium aluminate. The cost of treating Lake Desire is estimated as $1,660/ton alum (costs include labor and materials, mobilization, demobilization, and taxes). Total costs for an alum treatment of Lake Desire would likely exceed $92,000. Monitoring and sample analysis costs could add additional fees to the overall project. This cost is low relative to dredging, especially if it remains effective for at least five years.

For modeling purposes, a buffered alum treatment was estimated to reduce internal loading 90 percent the first year, with a progressive decline in its effectiveness. The alum treatment was estimated to remain 25 percent effective at reducing internal loading by the fifth year, and be ineffective within 8 years.

Lake Desire currently has few aquatic macrophyte problems. By reducing algal populations and improving water clarity, alum could promote aquatic macrophyte growth at greater depths (Cooke et al. 1993a). An increase in water clarity might allow macrophytes to colonize greater depths at higher densities.

Jar tests and field verification would have to be conducted to establish the proper alum and sodium aluminate dose for Lake Desire. These tests would be part of the preliminary design of the project. However, dose and cost of an alum and sodium aluminate treatment in Lake Desire can be estimated on the basis of information from the October 1991 treatment of Green Lake in Seattle. Green Lake costs are appropriate to use to estimate costs for Lake Desire because they are fairly recent and because an alum/sodium aluminate treatment has not been performed anywhere else in the Northwest. The Green Lake dose was 12 mg Al/L (5.25 mg Al/L from alum and 6.75 mg Al/L from sodium aluminate).

Hypolimnetic Aeration.

Hypolimnetic aeration is a way to oxygenate the bottom waters of a lake without causing destratification. The technique typically uses air to raise cold hypolimnetic water to the surface of deep lakes, where it is aerated through contact with the atmosphere, losing gases such as carbon dioxide and methane, and returned to the hypolimnion (Olem and Flock, 1990). Phosphorus release from the sediments is limited by hypolimnetic aeration if there is sufficient iron in solution. In addition, hypolimnetic aeration increases habitat and food supply for cold-water fish species. The technique has been used with various levels of success (Cooke et al., 1993a). Unsuccessful treatments have been attributed to inadequate oxygen supplies to the system, disruption of stratification, or lack of iron.

Dissolved oxygen concentrations in Lake Desire's hypolimnion are below 2 mg/L during thermal stratification. Aeration of the hypolimnion could control the release of phosphorus from anoxic sediments. It is important, however, that hypolimnetic aeration not destratify the water column. Premature destratification can be toxic to aquatic life when bottom waters with little dissolved oxygen, low pH, and high concentrations of toxic gases mix with surface waters. Destratification can also stimulate algal growth by supplying hypolimnetic nutrients to surface waters and mixing algae throughout the water column. Lake Desire is a relatively shallow but strongly stratified lake. As such, destratification due to wind mixing could occur. However, there have been several lakes with similar geomorphology such as Newman Lake in eastern Washington, that have had successful hypolimnetic aeration systems installed (Ashley, K., April 1994, Personal Communication).

The effectiveness of hypolimnetic aeration depends on the presence of sufficient iron to bind phosphorus in the re-oxygenated waters. Moderate iron concentrations (annual mean = 470 μg/L) measured in Lake Desire indicate that available iron is sufficient to remove phosphorus from the water column at fall turnover. The mean hypolimnetic Fe:P ratio prior to turnover (September 14, 1993) was 17, and following turnover the ratios were approximately 13 throughout the water column. Ratios greater than 3 are optimal to promote iron phosphate precipitation at turnover (Stauffer, 1981). The relatively high Fe:P ratios indicate that there is sufficient iron to remove phosphorus from the water column during lake turnover.

There are two types of aeration systems designed for lake restoration; these are full-lift or partial-lift systems. A full-lift system is recommended for Lake Desire because the hydraulic characteristics of a partial-lift system are not as favorable in shallow applications. The circulation of hypolimnetic waters using an aerator is a function of the air lift length. In a shallow system the quantity of water that can move through the aerator is limited. Therefore, full-lift systems are more efficient in their ability to aerate shallow lakes. Based on costs developed for aerators in Lake Fenwick (Kent, Wash.) and Lake Stevens (Snohomish County, Wash.), the costs of hypolimnetic aeration in Lake Desire were estimated to be approximately $300,000 for construction and $14,500 per year for operation and maintenance (KCM, 1993a).

Hypolimnetic aeration was estimated to reduce internal loading by 75 percent. To model this, sediment phosphorus release within the model was reduced by 75 percent.

Modeling Scenarios

Eleven scenarios were simulated to determine whole-lake total phosphorus concentrations using the transitional non-steady state model developed for Lake Desire. They included the historical, current, and future conditions scenarios already described. The scenarios were as follows:

1. Historical Conditions
2. Current Conditions
3. Future Conditions - Unmitigated
4. Buffered Alum Treatment
5. Hypolimnetic Aeration
6. Combined Alum and Aeration
7. Watershed Package (All-Forest Retention, Watershed BMPs, and Sewer)
8. Watershed Package (Without Sewer)
9. Watershed Package plus Alum
10. Watershed Package plus Aeration
11. Watershed Package plus Alum and Aeration.

Using the lake model, the benefits of each restoration measure were assessed by estimating monthly whole-lake total phosphorus concentrations, from which summer mean concentrations were calculated. The relative effectiveness of each alternative was then compared using summer means (Table 6-5). Restoration measures were also evaluated based on their external or internal loading reduction effectiveness (Figure 6-6).

Results

A comparison of the summer total phosphorus concentrations estimated for all modeled scenarios is shown in Table 6-5. For all modeled scenarios, full watershed build-out was assumed so that the long-term effectiveness of each restoration alternative could be evaluated. For contrast, summer in-lake total phosphorus concentrations were included for existing conditions for select in-lake and watershed treatments. Concentrations in Table 6-5 are modeled values and represent the relative effectiveness of the various watershed and/or in-lake loading reduction measures on in-lake water quality.

Benefits of Watershed Measures

A mass balance for each watershed scenario was developed to estimate the mass of total phosphorus which would be prevented from entering Lake Desire in the future as the result of each measure or combination of measures (Figure 6-6). The specific loading benefits for implementation of each watershed measure are as follows:

- **Limited Forest Conversion in Subcatchment P7.** Restoring the wetlands and maximizing open space in subcatchment P7 could reduce the future phosphorus load from that subcatchment by 30 kg TP per year or 51 percent.
- **Sewering in the Nearshore Area.** Sewering the nearshore areas could result in a 26 kg TP per year or 56 percent reduction in future subsurface loading.
- **Best Management Practices in Subcatchment P6.** BMPs in subcatchment P6 would reduce future phosphorus loading by 26 kg per year or 45 percent.

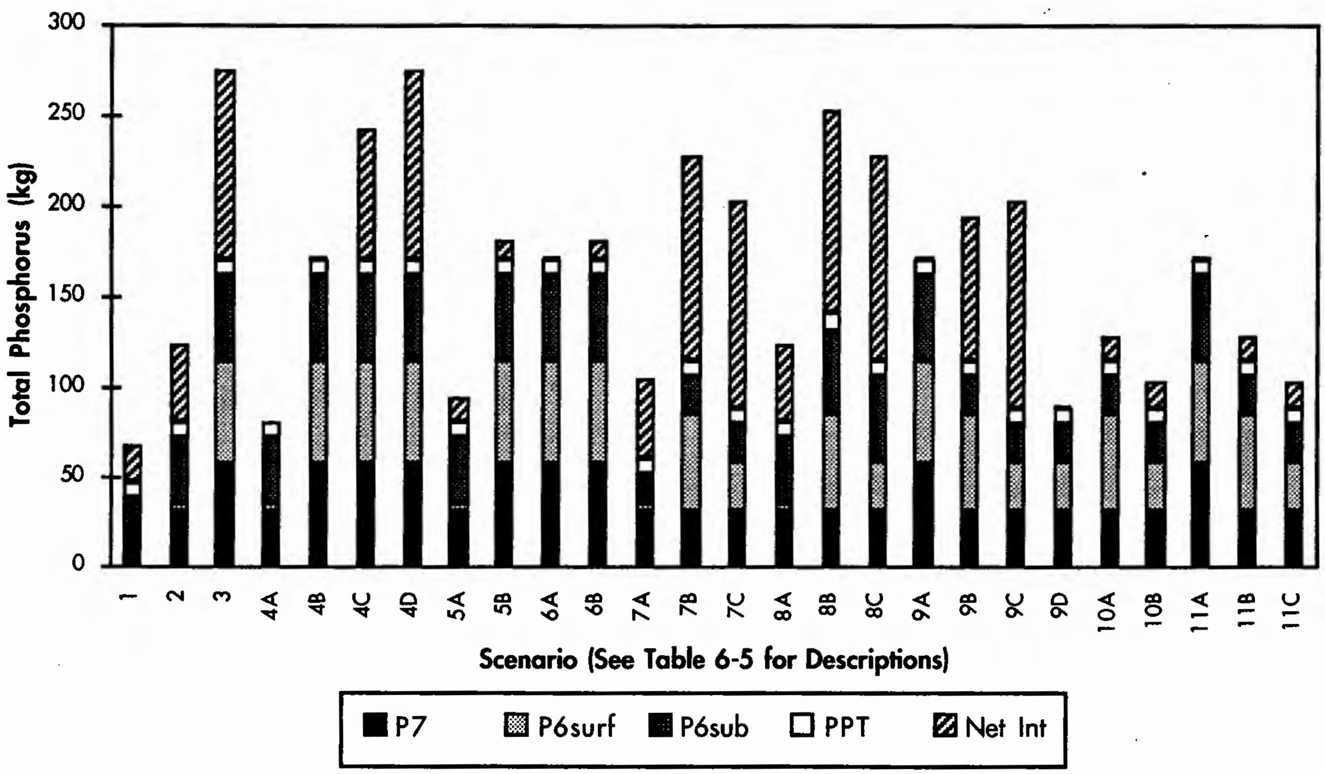
Under future conditions, the three watershed measures (Scenario 7, Table 6-5) would result in a summer total phosphorus value of 110 μg/L in the first five years and a value of 106 μg/L after 20 years (This assumes that the effectiveness of watershed best management practices increase from five percent to 50 percent during the 20 year evaluation period). To evaluate the effectiveness of sewering alone, watershed measures were also evaluated without sewers (Scenario 8, Table 6-5). Although sewering results in a 30 kg TP reduction annually under future land use conditions, summer whole-lake total phosphorus concentration is reduced by only 5 μg/L.

Table 6-5: Summer TP Concentration Under Modeled Scenarios

Scenario	Summer TP [a] (µg/L)
1. Historic	46
2. Current	59
3. Future	114
4. Buffered Alum Treatment	
A. 1st year–90 percent internal load reduction	35[b]
B. 1st year–90 percent internal load reduction	46
C. 5 years–25 percent internal load reduction	95
D. 8 years–0 percent internal load reduction	114
5. Hypolimnetic Aeration	
A. 75 percent internal load reduction	46[b]
B. 75 percent internal load reduction	58
6. Combined Alum plus Aeration	
A. 1st year–90 percent internal load reduction	46
B. 5 years–65 percent internal load reduction	58
7. Watershed Package–All[c]	
A. Approximately 5 years	60[b]
B. Approximately 5 years	110
C. Approximately 20 years	106
8. Watershed Package–Without Sewers	
A. Approximately 5 years	64[b]
B. Approximately 5 years	115
C. Approximately 20 years	110
9. Watershed Package–All plus Alum	
A. Year 1	46
B. Approximately 5 years after alum	91
C. Approximately 20 years without alum	106
D. Approximately 20 years with alum @ 20 years	36
10. Watershed Package–All plus Aeration	
A. Approximately 5 years	52
B. Approximately 20 years	48
11. Watershed Package–All plus Alum and Aeration	
A. 1st year	46
B. 5th year	52
C. 20 years (without additional alum added)	48

[a] *Using modeled whole-lake June–September concentrations.*
[b] *In-lake concentration based on existing conditions and specified mitigation.*
[c] *Watershed Package includes forest retention in P7, BMPs in P6 and P7, and sewering along Lake Desire.*

Figure 6–6 Lake Desire Annual Total Phosphorus Loading for Modeled Scenarios



Benefits of In-lake Measures

The overall benefits for each in-lake restoration measure were also evaluated by the overall mass of total phosphorus which would be reduced in Lake Desire. The specific benefits to lake internal loading and summer whole-lake total phosphorus concentration are the following:

- **Buffered Alum Treatment.** Application of alum to Lake Desire is expected to reduce internal loading by 90 percent. Existing loading would be reduced from 43 kg TP per year to 4.3 kg TP per year. Summer whole-lake concentration is predicted to average 33 µg TP/L for existing conditions. Based on future land use, loading would be reduced from 104 kg TP per year to 10 kg per year (Figure 6-6) with a summer whole-lake average of 46 µg/L (Table 6-5) after the first year of alum application. Alum would over time become less effective at reducing internal loading and reapplication would be needed every 5-8 years to maintain improved water quality.

- **Hypolimnetic Aeration.** Construction of an in-lake hypolimnetic aeration system is expected to reduce internal loading by 75 percent. Existing total phosphorus loading would be reduced to 11 kg TP per year while future internal loading would be reduced to 26 kg per year (Figure 6-6). Summer whole-lake total phosphorus concentration would average 44 µg/L for existing conditions and 58 µg/L for future conditions (Table 6-5).

Recommendation

The whole lake summer mean total phosphorus concentrations predicted by the lake model indicate that watershed measures alone (including sewering of the shoreline) are not enough to improve existing water quality or prevent the future decline in water quality. This is due to the high rate of sediment phosphorus release occurring in the summer months and the subsequent internal loading to the lake.

The in-lake restoration activities examined for this analysis would reduce the internal loading to Lake Desire by as much as 94 kg TP per year with alum treatment and 76 kg TP per year if hypolimnetic aeration is used. Alum would achieve the maximum phosphorus load removal and subsequent reduction in summer whole-lake total phosphorus concentration and appears at first glance to be the preferred choice for addressing internal loading. However, it is unlikely that alum could be pursued successfully as a long-term treatment option for Lake Desire. This is in part due to the permitting issues involved with alum use (single or repeated applications), the questionable long-term toxicity effects to benthic organisms and other lake plant and animals, and the long-term costs associated with repeated applications.

Aeration, although a less proven technique than repeated alum treatments in shallow lakes, increasingly has been successfully used with in other shallow lake systems (Ashley, K., April 1994, Personal Communication). Aeration, like alum, also provides a significant improvement to lake water quality in the short-term. Over time as external loading increases, watershed controls would become increasingly important in maintaining the benefits of in-lake aeration on water quality.

Based on the alternatives analysis, the preferred plan for the restoration of Lake Desire would be the implementation of the full watershed package, plus aeration for long-term oxygenation of the hypolimnion, and an initial alum treatment to break the internal cycling sequence. Installing a hypolimnetic aerator and implementing all the watershed management measures are recommended to maintain the improved water quality long-term. An alum treatment is recommended after the start-up of the aeration system to ensure an improvement in water quality initially and to increase the probability that the aeration will be effective long-term. Engineering analysis for construction of the in-lake hypolimnetic aeration can be found in Appendix F.

Watershed management measures typically take time to implement and may not result in immediate, measurable improvements in lake water quality. However, the long-term protection of Lake Desire will depend on reducing external nutrient sources. Under future conditions, aeration alone will not significantly improve water quality from that of current, unmitigated conditions. The duration of the benefits and overall long-term costs associated with in-lake restoration activities will be impacted by how effective the watershed management measures are at reducing the overall loading to Lake Desire. The more effective watershed control measures are in the future, the greater likelihood that internal loading will remain significantly reduced by in-lake aeration, granting continued improvement in water quality.

CHAPTER 7: LAKE AND WATERSHED MANAGEMENT

MANAGEMENT APPROACH

Lake Desire is a very productive lake characterized by frequent and intense algal blooms in the spring and fall which degrade the lake for a variety of recreational activities including swimming, boating, and fishing. The aesthetic appeal normally associated with the lake also dramatically decreases during the bloom periods. Existing water quality (and associated lake productivity) is unacceptable to the majority of residents who live on the lake and many people from surrounding urban areas who utilize the lake for recreational purposes.

Based on the "historical" water quality data, the lake system has been characterized as a productive system since the early 1970s. Examination of the sediment phosphorus profiles (Chapter 4) suggests that productivity in Lake Desire has increased recently (within the past 60 years). Two major watershed scale changes have occurred during this time period which may account for this shift in lake productivity. These watershed changes include: 1) the logging of the watershed and the beginning of shoreline development in the 1930's; and 2) the beginning of peat excavation in Cedar River Wetland 14 in the 1960s.

It is unlikely that watershed loading levels can be restored to pre-logged conditions or prior to the peat excavation of Cedar River Wetland 14. However, a reasonable long-term management goal is to maintain lake productivity at a level between historical and existing trophic conditions. By focusing on maximizing external loading reductions in the watershed and minimizing existing internal loading and subsequent future increases in internal loading, the long-term management goal of improved trophic conditions can be achieved.

The management approach for the restoration of Lake Desire, then, is designed to address both watershed and in-lake sources of nutrients which contribute to the existing water quality problems. Restoration of Lake Desire will require a long-term commitment to reducing future watershed nutrient loading through source control best management practices, restoration of watershed wetlands, restoration of the existing wetland shoreline, retrofitting of existing stormwater facilities for pollutant removal, and the removal and management of non-native aquatic plants. In the near-term, in-lake water quality is proposed to be addressed using a combination of a buffered alum treatment and an in-lake aeration system to reduce internal nutrient cycling in the lake which contributes to eutrophic lake water quality. Watershed measures, which in the short-term, are not likely to result in an immediate improvement of lake water quality are nonetheless essential to reduce future watershed loading which would otherwise exacerbate current lake water quality conditions and reduce the effectiveness of in-lake measures under future conditions.

LAKE AND WATERSHED MANAGEMENT GOALS

Lake and watershed management goals were established by the Lake Desire community and were used in the restoration alternatives analysis and in the development of the subsequent management plan recommendations. The eight management plan goals are as follows:

- Improve Water Quality and Lake Trophic Status;
- Restore Watershed Wetlands;
- Protect Human Health;
- Protect Property Values;

- Maintain a Healthy Lake Fishery Habitat;
- Control Invasive, Nonnative Aquatic Plants;
- Educate and Involve Watershed Residents in Lake Restoration and Protection; and
- Work More Effectively with Government to Improve and Protect Lake Water Quality.

Improving lake water quality is the primary management goal for the lake. If lake water quality is improved, many of the remaining management goals, including protection of human health, lake property values, and the lake fisheries will also be met. Through in-lake aeration of the lake hypolimnion (LD-9) and the implementation of watershed measures, internal lake phosphorus loading should be reduced resulting in less frequent and severe algal blooms and improved lake water quality. Improving lake water quality will also reduce water quality related dermatitis and the risk of blue-green toxic algal bloom occurrence, thereby improving human health protection. Improved lake water quality resulting in swimmable, fishable, and boatable waters will also protect existing and future property values. In-lake aeration will also benefit the lake fisheries and general aquatic habitat by expanding the oxygenated area of the lake to include the currently oxygen depleted lake hypolimnion.

The remaining management goals of restoring watershed wetlands, controlling invasive nonnative aquatic plants, and education and involvement of the watershed residents are designed to be accomplished through the remaining management plan recommendations. To achieve these lake management plan goals, an effective working relationship with government and watershed residents will be needed. Without a combined long-term commitment and investment by watershed residents and government, the goal of improving lake water quality will likely remain unmet for Lake Desire.

RECOMMENDATIONS

The 14 recommendations for the lake management plan (Table 7-1) are divided into four groups: (1) watershed measures; (2) in-lake measures; (3) aquatic plant management; and (4) monitoring. Watershed recommendations address forest retention, wetland restoration, shoreline revegetation, stormwater treatment, ditch maintenance, homeowner source control best management practices, and sewers. These measures are designed to reduce existing and future external pollutant loading to the lake from watershed sources. Implementation of watershed measures is essential to the long-term restoration of Lake Desire water quality.

In-lake restoration measures including buffered alum treatment and in-lake aeration will result short-term in lake water quality improvement. It is important to note that long-term gains made through in-lake measures, however, will not be maintained unless watershed measures are successfully implemented.

Details of the watershed and in-lake measures, the aquatic plant management, and monitoring recommendations are described in the following sections. This chapter also includes a brief discussion of implementation of the management plan. The State Environmental Policy Act (SEPA) checklist and determination of non-significance (DNS) for the plan has been included in Appendix D. Public comment and responses on the draft management plan are included in Appendix G.

Watershed Measures

LD-1 Subcatchment P-7 Forest Retention-*Forest retention should be maximized in the Peterson-7 subcatchment in the Cedar River basin in areas zoned AR-2.5-P following the recommendations of the Cedar River Draft Basin and Nonpoint Action Plan (King County, 1995) for mandatory open space retention and areal clearing limits for individual lots as minimum guidelines.*

Table 7-1: Lake and Watershed Recommendations

No.	Recommendations	Lead Implementor(s)[a]	Cost
	Watershed Measures		
LD-1	Subcatchment P-7 Forest Retention	King County	EP[b]
LD-2	Wetland Restoration	KCSWM	EP[b]
LD-3	Shoreline Wetland Revegetation	KCSWM/LDCC	$4,000
LD-4	Stormwater Treatment	King County	EP[b]
LD-5	Ditch Maintenance	Roads/KCSWM	EP[b]
LD-6	Homeowner BMPs	LDCC/KCSWM/SKCDPH	$3,000
LD-7	Sewering	SCWSD/LDCC	EC[c]
	In-Lake Measures		
LD-8	Buffered Alum Treatment	LDCC/KCSWM	$92,000
LD-9	Aeration (design and engineering)	LDCC/KCSWM	$100,000
	Aeration (SEPA)		$50,000
	Aeration (construction)		$340,000
	ongoing O/M $17,500/year[d]		
	Aquatic Plant Management		
LD-10	Milfoil Removal	LDCC/KCSWM	$20,000
LD-11	Purple Loosestrife Removal	LDCC/KCSWM	$5,000
LD-12	Lake Access through Hand Pulling	LDCC/KCSWM	EP [b]
	Monitoring		
LD-13	Lake, Fishery, and Watershed Monitoring	LDCC/KCSWM/WSDFW/ MIT	$70,000 [d]
LD-14	Wetland Monitoring	KCSWM	$5,000
		Total	$689,000
		Total with 5-year O/M	$796,000[d]

[a]*KCSWM-King County Surface Water Management; LDCC-Lake Desire Community Club; MIT-Muckleshoot Indian Tribe; Roads-King County Roads Division; SKCDPH-Seattle King County Department of Public Health; SCWSD-Soos Creek Water and Sewer District; and WSDFW-Washington State Department of Fish and Wildlife.*

[b] *EP-existing programs are expected to cover costs.*

[c] *EC-the estimated cost for sewering lake properties is two million dollars but has not been included here.*

[d] *Four percent inflation factor assumed for O/M and monitoring costs.*

Watershed phosphorus loading from the Peterson-7 subcatchment is already a major contributor to eutrophic conditions in Lake Desire. Twenty-five percent or 31 kg TP per year of the total phosphorus budget originates from the lake inflow (Peterson-7 subcatchment). All efforts including maximizing forest retention and establishment of clearing limits should be implemented to minimize future phosphorus loading to Lake Desire. The current zoning for most of this catchment is one unit per 2.5 acres. Under this zoning, much of the forested land could be converted into 2.5 acre homesteads. At modeled build-out, this level of development, although rural in character, will contribute an estimated 58 kg TP per year, an increase of 47 percent over existing phosphorus loading from this subcatchment.

Forest retention is the most effective mechanism by which future loading can be significantly decreased in this portion of the watershed. Because the current development density for much of the catchment area is below the threshold for standard stormwater treatment requirements, structural controls for reducing phosphorus loading have limited application. Forest retention and open space dedication of the upper lake watershed area is essential to the long-term restoration and protection of lake water quality.

Currently, a large portion of the Peterson-7 subcatchment is proposed for inclusion in King County's 4 to 1 program as a pilot project. The 4:1 program allows for rural property owners with properties contiguous to the Urban Growth Boundary Line to have the opportunity to obtain urban designation in exchange for dedicated open space. The program allows for the redesignation of one acre of property as urban for every four acres of property designated as permanent open space. This designation would allow for a major portion of the subcatchment to remain forested and meet the intent of the forest retention recommendation.

Little opportunity exists for similar application of forest retention in the remaining portions of the lake watershed due to the zoning of most of the Peterson-6 subcatchment area within the Urban Growth Boundary line. Voluntary retention of forest should be encouraged within the Peterson-6 subcatchment where possible.

LD-2 Wetland Restoration and Enhancement- *Restoration and enhancement of Cedar River Wetlands 14 and 15 should be pursued through open space acquisition; restoration of the natural habitat, water quality, and detention functions; and the establishment of wetland management areas. Implementation of all actions should be coordinated with the recommendations in the proposed Cedar River Draft Basin and Nonpoint Action Plan (King County, 1995).*

Cedar River wetland 14 forms the headwaters of the Lake Desire watershed and plays an important role in nutrient cycling and subsequent loading to the lake. Commercial peat extraction between 1960 and 1990 has resulted in significant wetland alteration and functional value loss. The long-term reduction of watershed nutrient loading is linked to the restoration of the wetland's hydrologic and water quality functional values. Restoration activities should at a minimum include increased ponding and soil saturation, establishment of a 100 to 200 foot wide vegetative buffer, noxious weed removal, and native vegetation planting.

Cedar River Wetland 15 abuts the northern edge of Lake Desire and surrounds the main inlet to the lake. The wetland has been bisected by road construction of E. Lake Desire Drive and is abutted to the west by a small horse pasture. Restoration of the wetland buffer and pretreatment of road runoff should be included in proposed future road modifications to reduce existing roadway flooding.

LD-3 Shoreline Wetland Revegetation-*A native vegetation buffer should be reestablished along the Lake Desire shoreline to filter surface water runoff to the lake and stabilize the lake shoreline.*

Currently, there is little vegetation between many lakefront homes and Lake Desire. In places where shoreline vegetation is absent, surface water runoff and septic system inputs from poorly operating systems enter the lake directly, degrading lake water quality.

Surface water from the residential properties adjacent to the lake currently contribute 5 kg TP per year or four percent to the total phosphorus lake loading. The majority of this surface loading originates from the properties most closely associated with the lake. Under modeled future land build-out, this surface loading is expected to increase to 58 kg TP per year or 21 percent of the future total phosphorus lake loading. Shoreline vegetation should be restored on a volunteer basis to maximize the shoreline buffer between private residences and the lake which will, in turn, reduce the current and future total phosphorus loading; reduce shoreline erosion; and improve wildlife habitat.

The King County Sensitive Areas Ordinance (King County, 1990b) requires a 100, 50, or 25 foot setback for wetlands depending upon classification for all new development and establishes guidelines for activities which are allowable adjacent to a wetland area. The shoreline of Lake Desire has not been classified by the King County wetlands inventory (King County, 1991a). However, by definition the shoreline meets the criteria for wetland delineation and could require setback for new development or for some shoreline activities. Prior to any shoreline alterations, the King County Department of Development and Environmental Services, shorelines review section should be consulted.

LD-4 Stormwater Treatment-*For land parcels in the Urban Phase I area around Lake Desire "all known, available, and reasonable methods of prevention, control, and treatment" (AKART) for total phosphorus control should be utilized to meet the intent of the updated Soos Creek Community Plan P-suffix conditions. For areas outside of the Urban Phase I area, AKART equivalent phosphorus control should be applied where new development will create 5,000 square feet of new impervious surface subject to vehicular use. For areas which drain to watershed bogs or fens, the management objectives of the King County Surface Water Design Manual 1995 update for bog/fen protection should be applied.*

In the restoration analysis, external nutrient loading from surface water runoff has been identified as a significant source of phosphorus to Lake Desire under future land use conditions. Given that the lake already experiences degraded water quality and that any in-lake restoration technique's benefits will be offset by unmitigated future phosphorus loading, stormwater treatment should be utilized to maximize total phosphorus removal from new stormwater runoff sources in the watershed.

The extent of the future threat of phosphorus loading to lake water quality was also recognized in the Soos Creek Community Plan Update (King County, 1991b). The water quality analysis performed in the development of the Lake Desire Management Plan supplies additional support for the implementation of the existing P-suffix condition which was placed on the Urban Phase 1 area around Lake Desire. The P-suffix condition states:

> "Properties in the Lake Desire Drainage Basin shall meet all water quality and quantity requirements as outlined by the King County Surface Water Management Division. These requirements must be in compliance with the State Growth Management Act. Special attention should be given to increased retention/detention requirements and clearing restrictions on undeveloped parcels *and stormwater treatments which will ensure that the quality of discharge waters shall be equal to or better then current Lake Desire Water Quality* [emphasis added]."

To meet the intent of this condition, AKART should be applied in the watershed area or area draining to Lake Desire. Currently the AKART standard or interim best management practices for phosphorus sensitive lakes is as follows:

- A wet pond or combined detention/wet pond with a permanent pool volume equal to 4.5 times the volume of runoff from the mean annual storm (VB/VR=4.5).
- Roof downspout infiltration is required unless shown to be unfeasible, and forest or native vegetation retention should be maximized.
- To encourage maximum forest retention, pond volume can be reduced by the following schedule:

Forest (%)	VB/VR ratio
25	4.25
30	4.00
40	3.50
50	3.25
60	3.00

- Forest retention areas should be in tracts dedicated to the County. Buffers without trails can be counted in the percent forest figure.

The VB/VR ratio is the volume of the wet pond basin divided by the volume of the runoff from the mean annual storm. The mean annual storm is equal to 0.46 inches at Sea-Tac. Runoff can be estimated using a runoff coefficient of 0.9 for impervious area and 0.25 for all other pervious area. Forested areas in tracts dedicated to the County need not be included in the calculation of pond sizing (i.e. zero new runoff volume assumed). If this method is used in other areas, and Sea-Tac precipitation statistics under estimate the rainfall as judged by the isopluvial distribution of the 2-year 24-hour precipitation, the mean annual rainfall should be adjusted upward.

Although current King County SWM designs are not complete for a sand filtration treatment system, incorporation of sand filters into stormwater treatment facility designs can be voluntarily pursued by new development to achieve additional total phosphorus removal and the AKART standard. However, upon completion of the sand filtration design by the SWM Division, the AKART standard for Lake Desire will be revised to include a combined wet pond/sand filter treatment system which will maximize total phosphorus removal.

Moreover, where soil are suitable, on-site infiltration of stormwater runoff can be pursued as alternative, if equivalent or better total phosphorus removal can be achieved. Soils are considered suitable for infiltration if at least two feet of soil exist where one of the four following soil conditions are met:

- The cation exchange capacity of the soil equals or is greater than five milliequivalents;

- The organic content of the soil is equal to or greater than five percent;

- The grain size distribution of site soils is equivalent to not more than 25 percent gravel by weight (75 percent passing the #4 sieve) and of that passing the #4 sieve, either (1) 50 percent minimum passes the #40 sieve and two percent minimum passes the #100 sieve, or (2) 25 percent minimum passes the #40 sieve and five percent minimum passes the #200 sieve; and

- The infiltration rate is 2.4 inches/hour or less.

LD-5 Ditch Maintenance-*Ditch maintenance protocols for roads within the watershed will be reviewed by SWM with the Roads Division to identify areas where enhanced maintenance activities could increase lake water quality protection.*

The existing land development pattern combined with the future watershed zoning will provide few opportunities for implementation of *King County Surface Water Design Manual*-based water quality treatment facilities (see LD-1). Thus, surface water quality protection will rely more heavily on source control strategies and BMPs including the management of the roadside drainage system. Ditch maintenance activities may include the retention of ditch vegetation, minimization of soil disturbance during maintenance, maximization of open-ditch system use (versus closed, culvert systems), and involvement of the Lake Desire Community Club in trash removal and other appropriate citizen-based maintenance activities. These additional maintenance activities will reduce the erosion of soil, increase pollutant removal of stormwater runoff in vegetated ditch areas, and reduce the transport of trash to the lake.

LD-6 Homeowner BMPs-*Residential best management practices (BMPs) should be promoted to the watershed residents and facilitated by the Lake Desire Community Club and the SWM Division.*

Sub-surface loading from on-site septic systems was estimated as 30 kg TP per year. Although, the soil type present in the majority of the shoreline area is not optimal for wastewater treatment, the on-site septic system evaluation (see Chapter 4) conducted during the study did not identify any significant pollution problems. However, due to the age of many septic systems and the surrounding soil types present, on-site wastewater disposal may represent a more significant nutrient source to the lake in the future.

In all likelihood, the area around Lake Desire will probably have sewers in the future. In the interim, phosphorus loading from on-site septic systems should be minimized through residential best management practices. Voluntary dye-testing by individual homeowners is a relatively unobtrusive means for residents to evaluate the significance of their contribution to lake nutrient loading. Systems which are not operating properly can be identified through dye testing and professionally repaired. If a significant number of failures are identified that cannot be repaired, sewering of the lake shoreline should be given a higher priority by the community and the Soos Creek Water and Sewer District.

Surface water runoff from residential properties adjacent to the lake currently contributes 5 kg TP per year or four percent of the total phosphorus lake loading. The majority of this load originates from properties directly adjacent to the lake. Under modeled future build-out conditions, surface loading is expected to increase to 58 kg TP per year. Again, much of this future load will be contributed by the adjacent lake properties.

Source control BMPs are the most effective means for preventing pollutants from entering surface waters from nonpoint sources. For example, revegetation of shoreline properties (LD-3) provides a buffer between yard activities and the lake and will help reduce pollutant loading as surface waters runoff. Additional residential BMPs including lawn fertilization, yard maintenance, proper household hazardous waste disposal, animal waste control, and the use of low phosphate household and garden products will also need to be implemented to reduce impacts from current and future total phosphorus loading to the lake. The details for each residential BMP are described below and should be the target of an educational outreach focus by the Lake Desire Community Club (LDCC).

- **Septic tank and drainfield maintenance**. A workshop should be conducted with the LDCC in conjunction with King County SWM and the Seattle-King County Department of Public Health to assist lake-side watershed residents in: (1) conducting dye testing of their septic systems to ensure the proper system functioning; (2) establishing an annual inspection schedule for their septic tanks and drainfields; and (3) performing routine maintenance as necessary. The Lake Desire Community Club should pursue discounted fees from private septage companies for community sponsored multiple site pump-out days.

- **Lawn fertilization and yard maintenance.** Alternatives to standard lawn and yard maintenance practices should be implemented by residents including minimal use of organic fertilizers, reduction in lawn size, regular thatching and aeration if lawns are retained, incorporation of native plants in new landscaping, soil enhancement through mulching and composting rather than chemical fertilization, and integrated pest management techniques for pest control.

- **Proper household hazardous waste disposal.** Alternatives for common household cleaning products are available from the Seattle-King County Department of Public Health and should be pursued by residents. Household hazardous waste should be properly disposed of at King County household hazardous waste collection sites.

- **Animal waste control.** Waterfowl feeding should be discouraged by lakeside residents and at the public fishing dock. Pet and domestic animal waste should be properly disposed of away from the lake and surface water pathways which reach the lake.

- **Low phosphate garden and household products.** Voluntary use of low phosphate garden and household products should be promoted by the Lake Desire Community Club.

The King County SWM Lake Stewardship Program offers an annual BMP workshop which addresses lawn fertilization and yard maintenance activities, proper household hazardous waste disposal, animal waste control, and the use of alternative lawn and household products. The LDCC should offer to host the workshop in 1996.

LD-7 Sewering-*The eventual sewering of Lake Desire shoreline properties is recommended to reduce sub-surface phosphorus loading to the lake and protect human health.*

A variety of watershed restoration measures was evaluated for the lake restoration alternatives analysis including sewering. Although loading from on-site septic systems was estimated to be 30 kg TP per year, the effect of sewering alone is not expected to result in a significant decrease in summer total phosphorus concentrations in Lake Desire under modeled existing or future land use conditions. It is expected over the short-term due to sewering alone, a 4 µg/L decrease in whole-lake phosphorus concentration will occur and long-term, a 5 µg/L decrease. On the other hand, with aeration, modeled whole-lake summer total phosphorus concentration would in the short-term be decreased by 18 µg/L and in the long-term by 56 µg/L. Additionally the cost of sewering versus the relative benefit produced in terms of improved lake water quality is small compared with the implementation of other watershed and in-lake measures. Nonetheless, some incremental benefit to lake water quality could be achieved through sewering shoreline properties if independent funding can be procured.

If sewering does occur, the short-term gains of phosphorus reduction from existing properties may be offset by increased shoreline density and associated nonpoint pollutant loading increases. Therefore, the implementation of sewering is a low priority and is recommended only in the event that human health or lake trophic status is threatened.

In-lake Measures

LD-8 Alum Treatment-*A whole-lake buffered alum treatment is recommended for reducing the in-lake phosphorus concentration and associated lake trophic status as a short-term solution for improving in-lake water quality.*

To most effectively reduce summer whole-lake total phosphorus concentration short-term, a single alum application is recommended at the onset of in-lake aeration. A buffered alum treatment is predicted to reduce internal loading by approximately 90 percent during the first year to 4.3 kg/yr. As a result of the initial alum treatment, whole-lake concentrations would be substantially lower for the first few years, averaging 35 µg/L from June to September based on current modeled whole-lake phosphorus concentration estimates (Table 6-5).

In the future, modeled internal loading in Lake Desire is expected to increase to 105 kg TP per year (Table 6-3). Although repeated alum treatments could reduce future internal loading to 10.5 kg TP per year and result in a modeled summer total phosphorus concentration of 46 µg/L (Table 6-5), within 5-8 years after application, the effectiveness of an alum treatment will have declined and a repeat treatment will be needed to maintain in-lake water quality goals. Because of the short-term benefits to internal loading reduction, the potential concerns regarding aquatic toxicity associated with alum, and the permitting issues and costs associated with repeat treatments, in-lake aeration is the recommended in-lake activity for the long-term internal loading control.

LD-9 Aeration -*Hypolimnetic aeration is recommended as a long-term solution to reduce summer whole-lake phosphorus concentration and improved lake trophic status.*

Aeration is recommended as the preferred long-term in-lake restoration measure for four reasons: (1) its cost effectiveness for reducing internal loading; (2) the benefit to aquatic habitat through hypolimnetic oxygenation; (3) minimal permitting problems associated with its implementation compared with other in-lake measures; and (4) in combination with watershed controls, lake trophic status goals can be met.

Modeled current in-lake summer total phosphorus concentration averages 60 µg/L (Table 6-5). Internal loading currently contributes 35 percent of the annual phosphorus load (Table 6-2) to Lake Desire and aeration is predicted to reduce this load by 75 percent. Based on existing total phosphorus loading, hypolimnetic aeration would result in a an average summer mean whole-lake phosphorus concentration of 44 µg/L.

Under the future land use scenario, modeled internal loading will increase to 105 kg TP per year (Table 6-3) and corresponding whole-lake summer concentrations are predicted to increase to 114 µg/L (Table 6-5). Hypolimnetic aeration only would reduce the modeled summer average whole-lake total phosphorus concentration to 58 µg/L (Table 6-5). Without watershed controls, hypolimnetic aeration would not result in significant lake water quality improvement under the future land use scenario. However, the preferred alternative of hypolimnetic aeration combined with watershed controls would maintain a modeled average in-lake total phosphorus concentration of 48 µg/L (Table 6-5), which meets the long-term goal of improved lake trophic status.

Two full lift aerators are proposed for meeting the internal phosphorus reduction goal of 75 percent. The complete engineering analysis and detailed cost estimate for in-lake hypolimnetic aeration is included in Appendix F.

Aquatic Plant Management

LD-10 Milfoil Removal-*A milfoil management plan should be developed by the Lake Desire Community Club, the SWM Division and other affected parties which targets eradication of the species.*

During the 1993 aquatic plant survey, *Myriophyllum spicatum* or Eurasian watermilfoil was observed in several areas of the lake. The level of milfoil observed, however, did not appear to present nuisance conditions at the time. Milfoil, however, can quickly become a problematic plant and timely efforts should be made to eradicate the plant from the lake in the near-term. Diver dredging, selective herbicide use, and public education should be the primary mechanisms explored for milfoil management. Targeted removal of milfoil will be especially important if increased lake clarity occurs as a result of in-lake restoration measures and growing conditions are optimized for its spread.

LD-11 Purple Loosestrife Removal-*Purple loosestrife should be removed annually by shoreline residents until the plant is eradicated. If biocontrols become available for use in King County, application for their use at Lake Desire should be explored.*

Purple loosestrife (*Lythrum salicaria*) is a state noxious weed which invades wet pastures, wetlands, stream and river banks, lake shores, irrigation and roadside ditches, and stormwater detention/treatment facilities. Purple loosestrife harms these aquatic areas by crowding out native wetland plants including cattail, bulrushes, sedges, and hardhack. When purple loosestrife overruns an area, a monoculture of vegetation is established and waterfowl, wildlife, amphibian, and aquatic insect diversity are reduced. Purple loosestrife is a prolific reproducer via seed production and root propagation. Just a few plants can quickly spread to an entire lake shoreline in a year or two.

Purple loosestrife is already widespread throughout the state and full eradication is unlikely. In smaller areas, including lake shorelines, eradication can be achieved through the diligent, annual efforts of shoreline residents. Removal methods include hand pulling of plant stems and roots, clipping flower heads prior to seeding to prevent further spread, mowing, mulching with plastic, and restoration of cleared areas with native vegetation. Biocontrols (e.g. insects) may be available in the near future for purple loosestrife control. If available, they may present an alternative to hand removal methods. Prior to any removal of purple loosestrife, the King County Department of Development and Environmental Services, shorelines review section should be consulted.

LD-12 Lake Access through Hand Pulling -*Where desired, residential lake access restricted by aquatic plant growth should be achieved by selective hand removal of plants to clear an open area no greater than 10 feet in width. Where practical, adjacent neighbors should establish shared access so that <u>maximum retention</u> of shoreline aquatic plants is achieved.*

Aquatic plants were not identified as a significant lake problem by lake residents during the project study. However, some residents have pointed out a minor problem of lake access where thick growths of aquatic lilies are present. The white water lily, *Nymphaea ordorata*, is a non-native plant which was introduced into many lakes throughout the state as an ornamental plant. The lily plants tend to reproduce well and form dense surface coverage that is difficult to navigate through. Hand pulling plants should provide sufficient access to the lake where entry is restricted. Total plant removal should be minimized in order to maintain the natural benefits of shoreline stability, nutrient removal, and aquatic habitat afforded by aquatic plants. Prior to any aquatic plant removal, the King County Department of Development and Environmental Services, shorelines review section should be consulted.

Monitoring

LD-13 Lake, Fishery, and Watershed Monitoring-*A long-term in-lake and watershed monitoring program should be developed by the Lake Desire Community Club, King County SWM, Muckleshoot Indian Tribe (MIT), and the Washington State Department of Fish and Wildlife (WDFW) to evaluate the effectiveness of in-lake and watershed restoration and protection measures.*

The lake, fishery, and watershed monitoring program should focus on evaluating the effectiveness of watershed phosphorus control measures on the maintenance and improvement of in-lake trophic status. The MIT and WDFW shall be invited to participate in the development of the final monitoring program. To the extent possible, lakeside residents, the MIT, and the WDFW, in conjunction with a local high school environmental class or other volunteer group should be trained to perform individual components of the lake and watershed monitoring program. A proposed 5-year monitoring program for the lake is summarized in Table 7-2.

Table 7-2: Lake Desire Water Quality Monitoring Program

Component	Sampling Frequency	Stations	Parameters[a]
In-lake	Monthly	1 station, 0,1,2,3,4,5 meters	Temp., pH, DO, Cond., TP, Ortho-P, TN
	Same	1 station	Secchi depth
	Same	1 station, water column composite (@0.5m, 1.5m, 2.5m, and 3.5m)	Chl a, Phaeo a, Phytoplankton species, biovolume, and identification
	Same	1 station, vertical tow	Zooplankton species, enumeration, and identification
	6 times/year	1 station, surface only	FC, Turb., Alk., color
	Quarterly	2 stations, deep spots, each meter	Al, Fe
Inlets/Outlets	Monthly	2 stations	Temp., pH, DO, Cond., TP, Ortho-P, TN, FC (inflow)
Sediment characterization	Every five years	three depth strata (0-2m, 2-4m, and >4m) four cores from each stratum, analyzed top 0-2 and 2-10 cm increments	TP, TN, % solids, Total Organic Carbon, AL, and Fe
Benthic Invertebrates	Once prior to alum application, twice post-alum application	littoral and deep stations	Density, identification to genus except for chironomid and oligochaete families
Fisheries Analysis	Twice during the monitoring period	To be determined	To be determined

[a]Parameters are abbreviated as follows: Temp.-temperature, DO-dissolved oxygen, Cond.-conductivity, TP-total phosphorus, Ortho-P-orthophosphate, , TN-total nitrogen, Turb.-turbidity, Alk.-alkalinity, Chl a - chlorophyll a , Phaeo a-pheophytin a, FC-fecal coliform, Al-aluminum, and Fe-iron.

LD-14 Wetland Monitoring- *Vegetation monitoring should be performed for restored wetland areas three years post restoration to ensure successful vegetation establishment.*

Restoration of Cedar River Wetlands 14 and 15 should include monitoring of revegetated areas for plant survival. In areas where significant plant mortality has occurred, replanting should be performed in cooperation with the wetland property owners and the SWM Division.

Cost/Benefit Analysis for Management Plan Implementation

One of the principal concerns in implementing lake management plan actions is whether the benefits derived from the preferred alternative actions equal or exceed the cost of their implementation. Granted, there are multiple benefits to good water quality that go beyond property value including fish and wildlife habitat, water supply, and aesthetics. However, for the purpose of this analysis, the "benefits" of good water quality through the implementation of the Lake Desire Management Plan were correlated only to the direct effect on shoreline property values.

The complete cost/benefit methods and analysis has been included in Appendix E. The analysis focused on the 126 shoreline properties located on Lake Desire. It was assumed that the greatest economic benefit (or potential loss) related to lake water quality was garnished by shoreline properties and that the majority of implementation costs (two-thirds for this cost/benefit analysis) would be borne by those properties which received the greatest benefit.

In order to evaluate the relative benefits of management plan implementation on lake water quality, the proportion of shoreline property values which would increase due to the successful implementation of the lake and watershed management plan (the benefit) was estimated (Appendix E). This estimated property value increase was then compared with the draft plan implementation costs of the preferred alternative's lake and watershed actions (Table 7-1).

Based on 1993 assessed property values, shoreline properties currently account for 26 percent of the total assessed watershed value or about $17.5 million. Shoreline property values at Lake Desire have increased at the rate of 4 percent between 1989 and 1993, which corresponds well with King County-wide averages of 4 to 5 percent for the same period.

For this analysis, three 10-year property value forecasts were completed for the shoreline properties: (1) no action alternative with an assumed annual increase in property value of four percent; (2) preferred alternative with a one percent annual impact on shoreline assessments above the no action alternative (total increase is five percent); and (3) preferred alternative with a three percent annual impact on shoreline assessments above the no action alternative (total increase seven percent). The property values for individual shoreline parcels are shown in Appendix E, Table 1. Based on the forecast assumptions, the total shoreline property value increase by the year 2006 ranges from $46.6 million for the no action alternative to between $60.1 and $89.6 million for the preferred alternative, which yields a net property value benefit of $13.5 to $43.0 million with implementation of the management plan over 10 years.

Annual differences between the no action and preferred alternative scenarios were also calculated. Table 7-3 shows the annual change in shoreline property value for the two alternatives for each of the forecast scenarios. The difference between the preferred and no action alternatives equals the benefit to shoreline property values that can be attributed to the management plan. The financial benefits range from $187,000 after one year to as much as $9,000,000 in the year 2006 (Table 7-3).

Table 7-3: Lake Desire Shoreline Property Assessment Comparison

Year	No Action Alt.: Annual Change in Property Assessment 4%/Yr. (1994 $)	2006 Preferred Alt.: Annual Change in Property Assessment 5%/Yr. (1994 $)	Annual Difference Between No Action & 5%	2006 Preferred Alt.: Annual Change in Property Assessment 7%/Yr. (1994 $)	Annual Difference Between No Action & 7%
1996[a]	$18,729,366	$18,729,366		$18,729,366	
1997[b]	$749,174	$936,467	$187,294	$1,311,056	$561,882
1998[b]	$1,528,314	$1,919,758	$391,444	$2,713,885	$1,185.571
1999[b]	$2,338,620	$2,952,213	$613,593	$4,214,913	$1,876,292
2000[b]	$3,181,339	$4,036,291	$854,952	$5,821,012	$2,639,673
2001[b]	$4,057,766	$5,174,573	$1,116,807	$7,539,539	$3,481,773
2002[b]	$4,969,250	$6,369,769	$1,400,519	$9,378,362	$4,409,112
2003[b]	$5,917,194	$7,624,725	$1,707,531	$11,345,903	$5,428,709
2004[b]	$6,903,055	$8,942,428	$2,039,373	$13,451,172	$6,548,116
2005[b]	$7,928,351	$10,326,017	$2,397,666	$15,703,809	$7,775,458
2006[b]	$8,994,659	$11,778,785	$2,784,126	$18,114,131	$9,119,473
Cumulative Increase	$46,567,722	$60,061,026	$13,493,305	$89,593,782	$43,026,059

[a]*Beginning Assessed Value*
[b]*Annual Assessed Value Change*

To complete the cost/benefit analysis, property values associated with the management plan must be compared to costs associated with the plan. The plan implementation costs exclusive of operation and maintenance costs or financial expenses are $649,000. Assuming that shoreline properties receive the most benefit from management plan (in terms of property value) and in turn bear two-thirds of the implementation costs, a total of $432,700 in implementation costs would be paid by shoreline residents. In this simplified cost/ benefit analysis, the 10-year benefit in shoreline property value—$13 to $43 million (see Table 7-3)— exceeds the implementation cost.

Funding of the management plan implementation was assumed to come from a single financial instrument payable through annual revenue from a lake management district (LMD; see description below). Assumptions regarding borrowing rates and the payment schedule are detailed in Appendix E. Table 7-4 shows the total bond cost with interest and the payment schedule for shoreline properties, as well as an example of the LMD assessment each year for a $250,000 property. The cost on a $250,000 property ranges from $581 to $592 at the beginning of the 10-year period and from $316 to $381 in 2006.

The analysis indicates that the property tax benefit derived from implementation of the management plan exceeds the costs of the implementation activities. A variety of factors could affect the analysis presented and the potential revenue which could be generated from property owners, including higher shoreline property values attributed to the preferred alternative, amortization period, and implementation impact on remaining watershed properties. More definitive results regarding the cost/benefit of management plan implementation could be gained using comparative analysis with another lake which has previously undergone restoration. However, the analysis performed for Lake Desire does indicate the potential benefit to shoreline property value from management plan implementation.

Table 7-4: Preferred Alternative Cost And Property Tax Comparisons (1994 $)

Year	Total Annual Bond Payment	Shoreline Portion of Bond Payment (2/3 of Total)	Tax Per $1,000 Assessed Value–5% Preferred Alt.	Example: 5% Preferred Alt. Property Tax: Assessed Value = $250,000	Tax Per $1,000 AV: 7% Preferred Alt.	Example: 7% Preferred Alt. Property Tax: Assessed Value = $250,000
1997	$69,806	$46,537	$2.37	$591.60	$2.32	$580.54
1998	$69,806	$46,537	$2.25	$563.43	$2.17	$542.56
1999	$69,806	$46,537	$2.15	$536.60	$2.03	$507.07
2000	$69,806	$46,537	$2.04	$511.05	$1.90	$473.90
2001	$69,806	$46,537	$1.95	$486.71	$1.77	$442.89
2002	$69,806	$46,537	$1.85	$463.54	$1.66	$413.92
2003	$69,806	$46,537	$1.77	$441.46	$1.55	$386.84
2004	$69,806	$46,537	$1.68	$420.44	$1.45	$361.53
2005	$69,806	$46,537	$1.60	$400.42	$1.35	$337.88
2006	$69,806	$46,537	$1.53	$381.35	$1.26	$315.78
10 Year Total	$698,060	$465,373		$4,796.60		$4,362.92

MANAGEMENT PLAN IMPLEMENTATION

A combination of grant funding, local revenue from lake management district (LMD) formation, and private sector funding is proposed in order to fund implementation of the Lake Desire Management Plan over an initial 10-year period. Operation and maintenance costs for the lake aeration system will need to be continued indefinitely and a mechanism for funding such activity will need to be identified.

Grants

Implementation funding for the management plan could be obtained potentially from three grants sources: 1) Washington State Department of Ecology Centennial Clean Water Fund (CCWF) grants; 2) Ecology Aquatic Weed Management Fund (AWMF) grants; and 3) U.S. Environmental Protection Agency (EPA) Clean Lakes or Nonpoint grant funds. All grants are either statewide or regional programs and are awarded annually on a competitive basis. Both CCWF and EPA Clean Lakes grants could be used to fund 50 percent of in-lake restoration measures and potentially 75 percent of watershed and monitoring measures. USEPA Nonpoint grants could also be used to fund up to 75 percent of watershed measures. Up to 75 percent of the project costs for Lake Desire aquatic plant management activities could be met through AWMF funding.

Lake Management Districts

An LMD uses a community-defined assessment to raise revenue for lake protection or improvement activities. Property owners on or near a lake pay a special charge on their property, either annually or on a one-time basis. LMDs can be formed for up to a 10-year period. LMDs have been formed and operated successfully in Snohomish and Thurston counties. Grant matching funds could be generated and/or specific management plan recommendations could be implemented through LMD formation.

Section 36.61 of the Revised Code of Washington (RCW) describes the process for LMD formation. According to the law, an LMD can be initiated through a petition to the County Council by property owners of at least 15 percent of the acreage within the proposed LMD boundary or by the Council who can adopt a resolution of intention. The petition or resolution of intention needs to include the following information: (1) proposed lake protection or improvement activities; (2) total amount of money to be raised; (3) whether money will be collected annually or one-time only; (4) amount of assessment (one-time or annual); (5) duration of LMD; and (6) proposed LMD boundaries.

After the petition is adopted or the resolution of intention is passed, a public notice is sent and a public hearing is held. This is followed by a special election in which each property owner has one vote for every dollar of proposed assessment. The proposed LMD must be approved by a simple majority of the votes cast. If there is a positive vote, the County Council adopts an ordinance to create the LMD. If there are no appeals, the King County Assessor prepares a special assessment roll which lists each property and the proposed special assessment. There is a second public hearing at which individuals can raise objections to the amount of the special assessment. The County Council may revise the special assessment roll in response. Then the special assessment roll is confirmed and billing can proceed. The money is administered by the County but a community-based advisory board can be appointed by the Council to oversee the project expenditures.

Preliminary Schedule

Management plan implementation is contingent on a variety of items including: (1) the availability of both public and private funding; (2) the successful award of public funding; and (3) the successful formation of an LMD. A Washington State Department of Ecology Centennial Clean Water Fund grant application was submitted in February, 1995, for Phase II implementation of the *Lake Desire Management Plan.* Listed below is a preliminary schedule for management plan implementation which assumes that successful grant award will occur in 1995 and private-sector funding/LMD formation will be pursued for matching the CCWF grant revenues.

• Apply for CCWF Grant Funding	February 1995
• Final Management Plan	April 1995
• Transmittal of Management Plan to Metropolitan King County Council	May 1995
• Initiate Lake Management District (LMD)	July 1995
• Initiate Implementation	January 1996
• Complete LMD Formation	September 1996

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APPENDICES

A. Glossary and Conversion Units

APPENDIX A.
GLOSSARY OF TERMS

Aerobic - Condition characterized by the presence of oxygen.

Algae - Single or multi-celled, non-vascular plants containing chlorophyll. Algae form the base of the food chain in aquatic environments.

Algal bloom - Heavy growth of algae in and on a body of water as a result of high nutrient concentrations.

Alkalinity - The acid combining capacity of a (carbonate) solution, its buffering capacity.

Allochthonous - Arising in another biotope, from outside of the lake basin (Gr. *allos* other, *chthon* land).

Anaerobic - Absence of oxygen (Gr. *an* without, *aer* air).

Anoxic - Lack of oxygen.

Aphotic zone - That part of a body of water to which light does not penetrate with sufficient intensity to maintain photosynthesis.

Autochthonous - Arising in the biotope under consideration, from within the lake basin (Gr. *autos* self, same, *chthon* land).

Autotrophic - The nutrition of those plants that are able to construct organic matter from inorganic (Gr. *autos* self, *trophein* to nourish).

Benthic - Bottom area of the lake (Gr. *benthos* depth).

Biochemical Oxygen Demand (BOD) - The decrease in oxygen content in milligrams per liter of a sample of water in the dark at a certain temperature over a certain period of time due to microbial respiration.

Biogenic - Arising as a result of life processes of organisms (Gr. *bios* life, *genos* origin).

Biomass - The total organic matter present (Gr. *bios* life).

Buffer - A mixture of weak acids and their salts which (in solution) is able to greatly minimize changes in the hydrogen-ion concentration.

Chlorophyll - The green pigments of plants (Gr. *chloros* green, *phyllon* leaf).

Colloids - substances that are distributed in a liquid as large aggregates of molecules; they are intermediate between true solutions and suspensions.

Colluvium-a loose deposit of rock debris accumulated at the base of a cliff or slope.

Consumers - Organisms that nourish themselves on particulate organic matter (Lat. *consumere* to take wholly).

Core - Sample of soil or sediment taken in such a way as to keep the vertical characteristic of the sediment undisturbed.

Decomposers - Organisms, mostly bacteria or fungi, that break down complex organic material into its inorganic constituents.

Detritus - Settleable material suspended in the water: organic detritus, from the decomposition of the broken down remains of organisms; inorganic detritus, settleable mineral materials.

Dimictic lake - A lake which circulates twice a year.

Drainage Basin - The area drained by, or contributing to, a stream, lake, or other water body.

Drumlin-a streamlined hill or ridge of glacial drift.

Ecosystems - Any complex of living organisms together with all the other biotic and abiotic (non-living) factors which affect them.

Electrolytic conductivity - The unit is the electrical conductivity, expressed in "reciprocal ohms," of a column of liquid 1 cm^2 in cross section and 1 cm high possessing a resistance of 1 ohm. In dilute solutions the conductivity is approximately proportional to the concentration.

Epilimnion - The turbulent superficial layer of a lake lying above the metalimnion (Gr. *epi* on, *limne* lake).

Euphotic zone - That part of a water body where light penetration is sufficient to maintain photosynthesis.

Eutrophic - Waters with a good supply of nutrients and hence a rich organic production (Gr. *eu* well, *trophein* to nourish).

Fall turnover - A natural mixing of thermally stratified waters that commonly occurs during early autumn. The sequence of events leading to a fall turnover includes 1) cooling of surface waters, 2) density change in surface water that produces convection currents from top to bottom, and 3) circulation of the total water volume by wind action. The turnover generally results in a uniformity of the physical and chemical properties of the water.

Fecal Coliform bacteria - A group of organisms common to the intestinal tract of vertebrates.

Glacial drift-a general term for unconsolidated sediment transported by glaciers and deposited directly on land or in the sea.

Glacial till-predominately unsorted and unstratified glacial drift, deposited directly by and underneath a glacier without subsequent reworking by meltwater, and consiting of heterogenneeous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.

Hardpan-a cemented or compacted and often clay-like layer of soil that is impenetrable by roots.

Holomictic - Lakes that are completely circulated to the bottom at the time of winter cooling (Gr. *holos* entire, *miktos* mixed).

Humus substances - Organic substances only partially broken down, which occur in water mainly in a colloidal state (humus colloids). Humic acids are large-molecule organic acids that dissolve in water (Lat. *humus* soil).

Hydrogen sulfide gas - A gas resulting from the reduction of sulfate containing organic matter under anaerobic conditions which is frequently found in the hypolimnion of eutrophic lakes.

Hypolimnion - The deep layer of a lake lying below the metalimnion and removed from surface influences (Gr. *hypo* under, *limne* lake).

Isohyetals-a series of lines representing a constant depth of total precipitation for a given return frequency.

Isopleth - A line for the same numerical value of a given quantity (Gr. *isos* equal, plethos quantity).

Lenitic - slowly flowing (Lat. *lenis* mild, soft).

Limiting nutrient - Essential nutrient which is the most scarce in the environment relative to the needs of the organism.

Limnology - The study of inland waters (Gr. *limne* lake).

Littoral - The shoreward region of a body of water.

Metalimnion - The layer of water in a lake between the epilimnion and hypolimnion in which the temperature exhibits the greatest difference in a vertical direction (Gr. *meta* between, *limne* lake).

Moraine-debris, as boulders or stones, deposited by a glacier.

Morphology - Study of configuration or form (Gr. *morphe* form, *logos* discourse).

Nannoplankton - Those organisms suspended in open water which because of their small size cannot be collected by nets. They can be recovered by sedimentation or centrifugation (Gr. *nannos* dwarf).

Net production - The assimilation surplus in a given period of time after subtracting the amount of dissimilation in the same time ierval.

Niche - The position or role of an organism within it community and ecosystem.

Nutrient - Any chemical element, ion, or compound required by an organism for the continuation of growth, reproduction, and other life processes.

Oligotrophic - Waters that are nutrient poor and have little organic production (Gr. *oligos* small, *trophein* to nourish).

Outwash- glacial drift deposited by meltwater streams beyond an active glacier.

Oxidation - A chemical process that can occur in the uptake of oxygen.

Periphyton - The biological community attached to substrate (such as rocks, sediments, aquatic plants) that is primarily composed of algae.

pH - The negative logarithm of the hydrogen ion activity.

Pheophytin - A pigment resulting from chlorophyll degradation found in dead algae or suspended organic matter.

Photosynthesis - Production of organic matter (carbohydrate) from inorganic carbon and water in the presence of light (Gr. *phos, photos* light, *synthesis* placing together).

Phytoplankton - Free floating microscopic plants (algae) (Gr. *phyton* plant).

Primary production - The production of organic matter from inorganic materials within a certain period of time by autotrophic organisms with the help of radiant energy (Lat. *primus* first, *producere* to bring forward).

Producers - Organisms that are able to build up their body substance from inorganic materials (Lat. *producere* to bring forward).

Profundal - The deep region of a body of water below the light-controlled limit of plant growth (Lat. profundus deep).

Residence time - The average length of time that water or a chemical constituent remains in a lake.

Respiration - An energy-yielding oxidation which can occur in aerobic or anaerobic conditions.

Secchi disc - A 20-cm (8-inch) diameter disc painted white and black in alternating quadrants. It is used to measure light transparency in lakes.

Sediment - Solid material deposited in the bottom of a basin.

Sorb - The process of a compound adhering to a particle.

Stability of stratification - The work that must be done to destroy or equalize the density stratification existing in a lake.

Stagnation period - The period of time in which through warming (or cooling) from above a density stratification is formed that prevents a mixing of the water mass (Lat. *stagnum* a piece of standing water).

Standing crop - The biomass present in a body of water at a particular time.

Suspension - Very finely divided particles of an insoluble solid material dispersed in a liquid (Lat. *suspendere* to suspend below).

Thermocline - (Gr. *therme* heat, *klinein* to slope.) Zone of temperature decrease. See metalimnion.

Trophic state - Term used to describe the productivity of the lake ecosystem and classify it as oligotrophic, mesotrophic, or eutrophic.

Watershed - See drainage basin.

Watershed management - The management of the natural resources of a drainage basin for the production and protection of water supplies and water-based resources.

Zooplankton - The animal portion of the plankton (Gr. *zoion* animal).

Conversion of SI or Metric Units to English Units			
SI or Metric		**English**	
1	kilometer (km)	0.62	miles
1	meter (m)	3.28	feet
1	centimeter (cm)	0.39	inches
1	millimeter (mm)	0.04	inches
1	micrometer (μm)	0.00004	inches
1	hectacre (ha)	2.477	acres
1	square meter (m^2)	10.764	square feet
1	cubic meter (m^3)	35.32	cubic feet
1	cubic centimeter (cm^3)	0.061	cubic inches
1	liter (L)	0.26	gallons
1	milliliter (mL)	0.20	teaspoons
1	kilogram (kg)	2.205	pounds
1	gram (g)	0.035	ounces
1	milligram (mg)	0.015	grains
1	milligram/liter (mg/l)	1	part per million .
1	microgram/liter (μg/L)	1	part per billion
1	degree Celsius (°C)	x 9/5 + 32	degree Fahreheit

Abbreviation	Definition
AKART	All known, available, and reasonable methods of prevention, control, and treatment.
AWMF	Aquatic Weed Management Fund
BMPs	Best Management Practices
CCWF	Centennial Clean Water Fund
cfs	cubic feet per second
DMS	Department of Metropolitan Services
HSP-F	Hydrologic Simulation Program-FORTRAN
LD	Lake Desire
LMD	Lake Management District
Metro	Municipality of Metropolitan Seattle
P6	Peterson 6 subcatchment of the Peterson Creek Subbasin of the Cedar River Watershed
P7	Peterson 7 subcatchment of the Peterson Creek Subbasin of the Cedar River Watershed
SAO	Sensitive Area Ordinance
SEPA	State Environmental Policy Act
SWM or KCSWM	King County Surface Water Management
TAC	Technical Advisory Committee
UGB	Urban Growth Boundary
USDA	United States Department of Agriculture
USEPA or EPA	United States Environmental Protection Association
USFW	United States Department of Fish and Wildlife
USGS	United States Geologic Survey
VB/VR	Wetpond basin volume divided by volume of the runoff from the mean annual storm
WAC	Washington Administrative Code
WSDFW	Washington State Department of Fish and Wildlife
WSDOE or DOE	Washington State Department of Ecology

B. Public Access

Lake Desire Public Access Inventory
December 27, 1994

The lake's primary beneficial uses of Lake Desire include fishing, boating, aquatic habitat, and aesthetics. Access to these lake uses is provided via: (1) a Washington Department of Fish and Wildlife (WDFW) public boat launch on the northern shore and (2) a 382-acre King County open-space park located on the eastern shoreline (Figure 1).

The WDFW launch has been historically operated for seasonal access but was recently upgrade (physically) and opened for year-round access beginning last year. The lake is stocked every spring by the WDFW with trout and has one boat launch, a newly constructed fishing pier, paved parking for thirty vehicles, handicapped access, pit toilets, and trash collection.

The forested open-space park occupies an extensive area to the east of the lake including a hill which affords views of both Lake Desire and Spring Lake. The open-space park reaches the Lake Desire shoreline near the outlet at the southern end of the lake (Figure 1). Future plans for this forested park include the formal development of year-round public access through two-miles of existing pedestrian/equestrian trails, formalized shoreline access via the pedestrian trails, park signage, picnic tables, and parking for 10 vehicles. Currently, the park trails can be entered from W. Lake Desire Drive or W. Spring Lake Drive.

Less than a quarter of a mile from the lake is Petrovitsky Park (Figure 1), a 108 acre King County park facility operated year-round for passive and active recreational use. The park currently has a baseball/softball field, a lighted soccer field, a children's play area, pedestrian trails, and parking for 100 vehicles. The park's Phase II development will include additional baseball and soccer fields. The master plan for the park (attachment 1) shows a final designs with 6 lighted tennis courts, four baseball fields, two soccer fields, parking for 200 vehicles, picnic shelter, and foot trail access to W. Lake Desire Drive.

A public access inventory by element per the Washington State Department of Ecology's Centennial Clean Water Fund public access requirements is included below. The public access inventory includes both elements from facilities adjacent to the lake and nearby Petrovitsky Park.

1) Park Identification Signs:

- The WDFW Boat Launch is currently signed at its W. Lake Desire Drive entrance.
- Interpretive and location signage for the King County Open-Space Park is currently being developed.
- Petrovitsky Park is signed at its entrance from Petrovitsky Road.

2) Boat Launch:

- There is an existing boat launch on Lake Desire located on the northern edge of the lake with access via W. Lake Desire Drive. The launch is operated by WDFW for non-motorized boats. The facility is open year-around.

3) Parking Area:

- Paved parking is provided at the boat launch for thirty vehicles.
- Parking for 10 vehicles will be provide at the open-space park trail head located via W. Spring Lake Drive.
- Parking for 100 vehicles is currently provided at Petrovitsky park.

4) Garbage Receptacles:

- A garbage receptacle is located at the boat launch.
- Garbage receptacles are located at Petrovitsky Park.

5) Picnic Area:

- The fishing pier serves as an informal picnic area at the launch. From the pier, Mount Rainier can be viewed.
- Petrovitsky Park currently has __ picnic tables.

6) Sani-Kans or Portable Toilets:

- A permanent handicapped accessible pit toilet has been installed at the boat launch.
- Sani-Kans are installed at Petrovitsky Park but will be replaced with permanent facilities once the sewer extension to the park is complete.

7) Play Area:

- An active recreational area including a children's play area, soccer field, baseball field, and an open meadow is located at Petrovitsky Park.

8) Swimming Area:

- The lake has no formal swimming beach, however, access to the lake for swimming activities occurs informally from the boat launch and at the open-space shoreline access areas.

9) Fire Pits:

- No fire pits are located in any of the park facilities.

10) Permanent Restroom Facilities:

- The boat launch has a permanent pit toilet installed, but no running water is available on-site.
- Permanent facilities, including running water, will eventually be located in Petrovitsky Park.

11) Portable Water Supply:

- A portable water supply will eventually be available in Petrovitsky Park

12) Fishing Pier/Floats:

- The WDFW constructed a fishing pier in 1993 as part of the upgrading of the boat launch area. The pier provides fishing access to the lake for 10-20 individuals and is heavily used year-round. From the pier, Mount Rainier as well as much of the lake can be viewed.

13) Nature Trails:

- Two miles of pedestrian/equestrian trails are located in the open-space park. The trails provide access to both Lake Desire and Spring Lake shorelines as well as hilltop view of both lakes. The park area trail system is linked to the nearby Cedar River and Lake Youngs Trails.
- Petrovitsky Park, upon completion of the park master plan will have additional pedestrian trails through the forested portion of the park located in the eastern and northern portions of the park. These trails will be connected with the existing park trails located in the active recreation area.

Per DOE requirements, phase II projects which total less than $400,000 must provide items 1 through 6 as the minimum requirement for public access. For projects between $400,000 and $800,000, items 1-9 must be provided. For projects greater than $800,000, public access elements 1-13 must be present.

At present, items 1-6, 12, and 13 are met with adjacent water access. If the definition of public access is expanded to included the recreational facilities of Petrovitsky Park, item 7 is also met at present. Upon completion of the Petrovitsky Park master plan and the open-space park future development, items 9, 10, and 11 will be met. Currently, there are no future plans by the County to develop a swimming area at Lake Desire. The lake has not been used historically for swimming except by a few residents. The dark tannic water color probably is related to is low use for swimming and its high use for fishing, boating, fish and wildlife habitat, and aesthetics

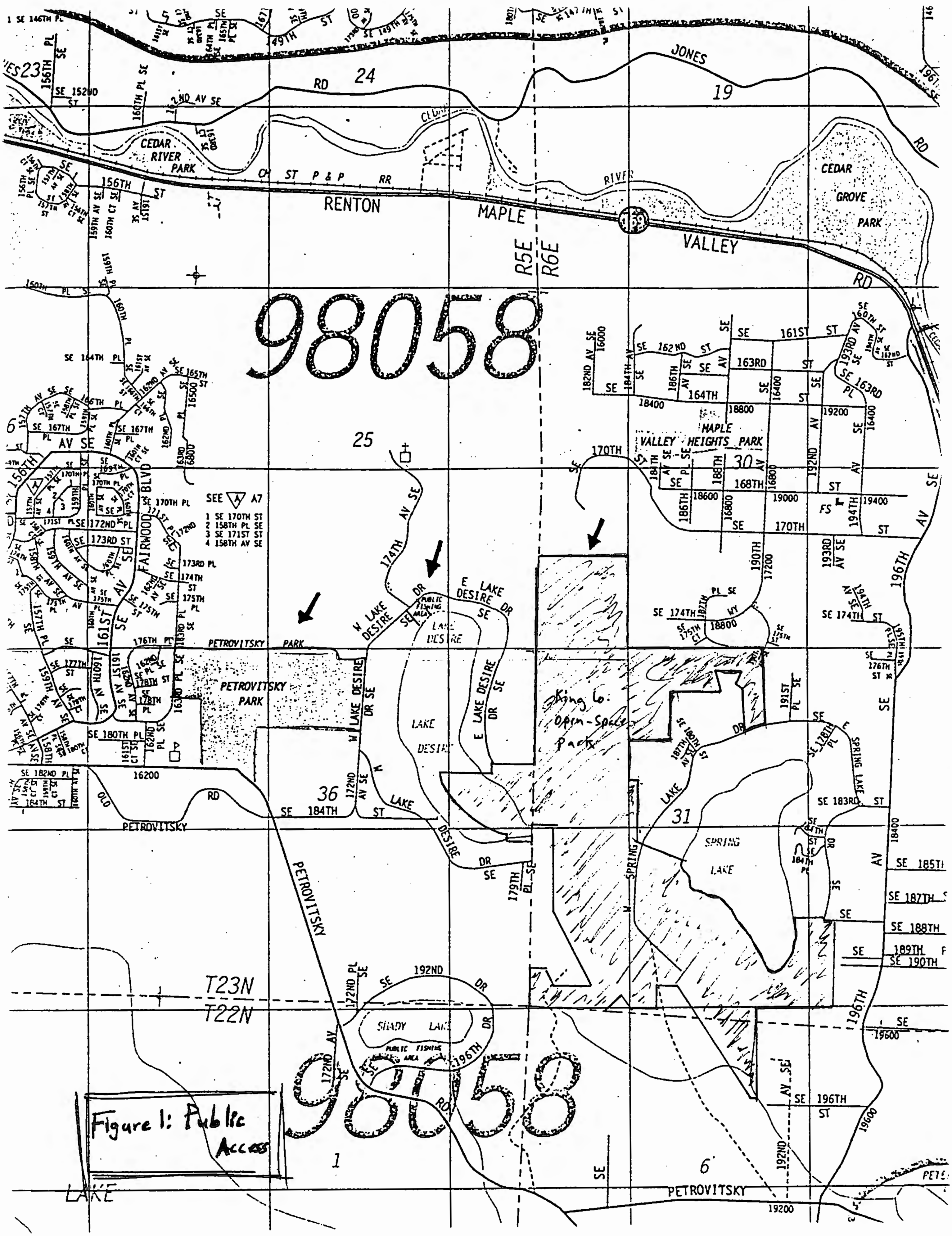
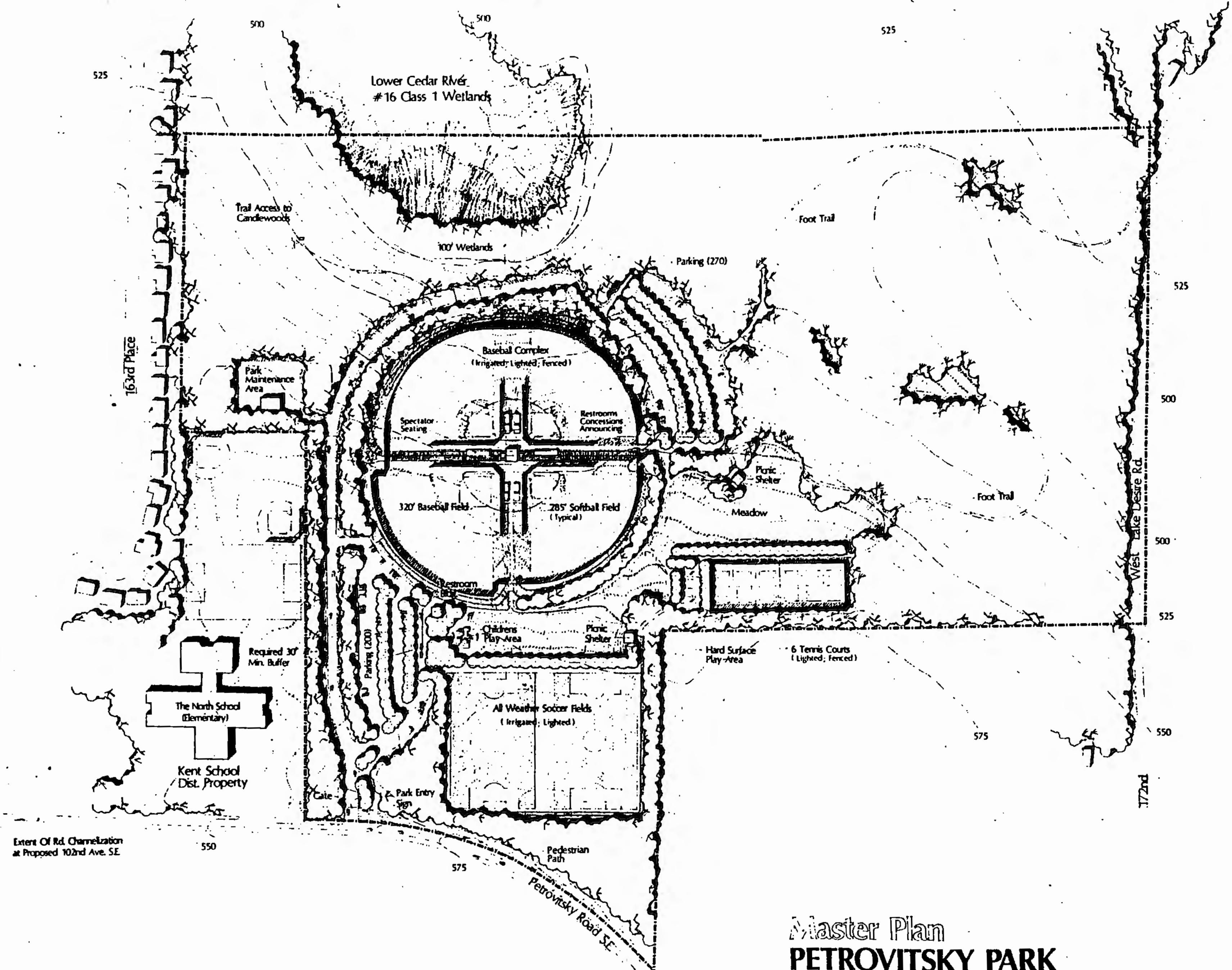


Figure 1: Public Access



Master Plan

PETROVITSKY PARK

KING COUNTY PARKS & RECREATION

JONGEJAN · GERRARD · McNEAL

0' 50' 100'

Attachment 1

C. Sampling Locations Descriptions

Lake Desire Station Descriptions

Station	Description	Depth (meters)
DESIRE1	North lake basin in-lake sampling station, located at maximum lake depth	0,1,2,3, 4,5,&6
DESIRE2	South lake basin in-lake sampling station, located at maximum lake depth	0,1,2,3, 4,&5
LDIN1	Tributary 0328B at inlet to Lake Desire	0
LDOUT1	Tributary 0328B at outlet from Lake Desire	0
LDW1	The combined outflow channel from Cedar River Wetland 14 and southeastern drainage area. The site is located downstream of the confluence of LDW2 and LDW3.	0
LDW2	A channel has been created which flows east to west along the south-side of Cedar River Wetland 14. The sample site is located 10-20' upstream of the intersection of this channel with the main wetland outflow channel.	0
LDW3	The outflow channel from Cedar River Wetland 14 upstream of the confluence with LDW1 into LDW2. No samples were taken at this location during Jan-Mar. 94.	0
LDW4	Inflow to Cedar River Wetland 14. Sample site is approximately 40-50' north of wetland edge but downstream of the confluence of two small tributaries which drain to the wetland.	0
LDSRP1	Shadow Ridge Detention Pond outflow located adjacent to 190th Ave SE. Sample was take 10-15' downstream of pond outflow.	0
LDSRP2	Shadow Ridge Detention Pond outflow located along SE 174th Way. Sample was taken 10-15' downstream and within the biofiltration swale.	0
LD1 and LD2	Tony Sieger residence, west-side of Lake Desire, 126 Lake Desire Rd.	0
LD3 and LD4	Tony Sieger undeveloped lot on the north end of Lake Desire	0
LD5 and LD6	Steve Crowley residence on the southeast side of Lake Desire, 360 Lake Desire Dr.	0

D. SEPA Checklist

King County
Surface Water Management Division
Department of Public Works
700 Fifth Avenue Suite 2200
Seattle, WA 98104
(206) 296-6519
(206) 296-0192 FAX

April 13, 1995

TO: Lake Desire Project File

FR: Sharon Walton, Lake Desire Project Manager

RE: *Lake Desire Management Plan* SEPA checklist addendum

For the *Lake Desire Management Plan*, non-project SEPA checklist (Determination of non-significance [DNS] dated March 2, 1995), under Section 5a. fish, salmon should underlined in addition to bass and trout. This was an inadvertent omission in the original SEPA checklist which was brought to my attention by the Muckleshoot Indian Tribe in their comment letter dated March 23, 1995.

Given (1) the non-project nature of the DNS and (2) that supporting documents to the DNS clearly document the presence of salmonids (and thus this correction does not represent new information) a new determination is not warranted. For all project actions in the plan, separate SEPA compliance will be completed as stated in the *Lake Desire Management Plan*, non-project SEPA checklist.

cc: SEPA Distribution list

King County Surface Water Management Division
Lake Desire Cost Benefit Analysis

January 1995

KCM

KCM, Inc.
1917 First Avenue, Seattle, WA 98101-1027

Technical Memorandum
Lake Desire Cost Benefit Analysis

Prepared for
Sharon Walton
King County Surface Water Management Division

Prepared by
KCM
KCM, Inc.
1917 First Avenue
Seattle, WA 98101-1027

principal author
Bill Jones

Project No
2390026-023

DETERMINATION OF NON-SIGNIFICANCE

Name of Proposal: Lake Desire Management Plan

Description of Proposal: Water quality management plan for Lake Desire and its watershed.

Location of Proposal: The plan contains both project and nonproject actions that will apply to Lake Desire and its watershed in unincorporated King County

Responsible Official: Paul Tanaka

Position/Title: Director, King County Department of Public Works

Address: 400 Yesler Way
Room 700
Mail Stop 7Y
Seattle, Washington 98104-2637

Phone: (206) 296-6500

DATE: 3-2-95 SIGNATURE: [signature]

Proponent and Lead Agency: King County Department of Public Works
Surface Water Management Division

Contact Person(s): Sharon Walton, Senior Limnologist
(206) 296-8382

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The lead agency for this proposal has determined that it does not have a probable significant adverse impact on the environment. An Environmental Impact Statement (EIS) is not required under RCW 43.21C.030(2)(c). This decision was made after review of a completed environmental checklist and other information on file with the lead agency. THIS INFORMATION IS AVAILABLE TO THE PUBLIC ON REQUEST (for a nominal photocopying fee).

THE DETERMINATION OF NON-SIGNIFICANCE (DNS) is issued under WAC 197-11-340(2); the lead agency will not act on this proposal until after March 17, 1995. Comments must be submitted or postmarked by this date.

You may appeal this determination by filing a Notice of Appeal with the responsible official of the lead agency given above. In accordance with King County Code 27.48.010 and 27.48.020, all appeals to the Zoning and Subdivision Examiner must be accompanied by a check for $125.00 at the time of submittal to the lead agency. The check should be made out to the King County Surface Water Management Division. This notice will then be filed with the Zoning and Subdivision Examiner's Office and a hearing date will be set. You will be notified two weeks in advance of the hearing date. You should be prepared to make factual objections. A Notice of Appeal is a letter stating the following:

1. The name of the proposal
2. The action to which you object (the DNS)
3. The agency taking the action (Public Works)
4. The basis for the objection (why the proposal would have significant adverse impact on the environment)
5. Your name and how you can be reached

Any Notice of Appeal for this Determination of Non-Significance must be received or postmarked no later than March 17, 1995. You should be prepared to make specific factual objections. If you have any questions regarding this project, please call Sharon Walton, Senior Limnologist, at 296-8382.

If you wish to file a Notice of Appeal, please send it to:

Jim Kramer, Manager
King County
Surface Water Management Division
700 Fifth Avenue, Suite 2200
Seattle, WA 98104

If you have any questions about the procedures for SEPA appeals, please call the Zoning and Subdivision Examiner at (206) 296-4660.

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KING COUNTY
ENVIRONMENTAL CHECKLIST

Purpose of the Checklist:

The State Environmental Policy Act (SEPA), Chapter 43.21 RCW, requires all governmental agencies to consider the environmental impacts of a proposal before making decisions. An environmental impact statement (EIS) must be prepared for all proposals with probable significant adverse impacts on the quality of the environment. The purpose of this checklist is to provide information to help you and the agency identify impacts from your proposal (and to reduce or avoid impacts from the proposal, if it can be done) and to help the agency decide whether an EIS is required.

Instructions for Applicants:

This environmental checklist asks you to describe some basic information about your proposal. Governmental agencies use this checklist to determine whether the environmental impacts of your proposal are significant, requiring preparation of an EIS. Answer the questions briefly, with the most precise information known, or give the best description you can.

You must answer each question accurately and carefully, to the best of your knowledge. In most cases, you should be able to answer the questions from your own observations or project plans without the need to hire experts. If you really do not know the answer, or if a question does not apply to your proposal, write "**do not know**" or "**does not apply.**" Complete answers to the questions now may avoid unnecessary delays later.

Some questions ask about governmental regulations, such as zoning, shoreline, and landmark designations. Answer these questions if you can. If you have problems, the governmental agencies can assist you.

The checklist questions apply to all parts of your proposal, even if you plan to do them over a period of time or on different parcels of land. Attach any additional information that will help describe your proposal or its environmental effects. The agency to which you submit this checklist may ask you to explain your answers or provide additional information reasonably related to determining if there may be significant adverse impact.

Use of Checklist for Nonproject Proposals:

Complete this checklist for nonproject proposals, even though questions may be answered "**does not apply.**" In addition, complete the SUPPLEMENTAL SHEET FOR NONPROJECT ACTIONS (PART D).

For nonproject actions, the references in the checklist to the words **"project," "applicant,"** and **"property or site"** should be read as **"proposal," "proposer,"** and **"affected geographic area,"** respectively.

A. BACKGROUND

1. *Name of the proposed project, if applicable:*

   Lake Desire Management Plan

2. *Name of Applicant:*

   King County Department of Public Works
   Surface Water Management (SWM) Division

3. *Address and phone number of applicant and contact person:*

   Sharon Walton, Senior Limnologist
   King County SWM Division
   700 Fifth Avenue, Suite 2200
   Seattle, WA 98104
   Phone: (206) 296-8382
   FAX: (206) 296-0192

4. *Date checklist prepared:*

   February 27, 1995

5. *Agency requesting checklist:*

   King County Department of Public Works
   SWM Division

6. *Proposed timing or schedule (including phasing, if applicable):*

   Implementation of the management plan is proposed to be funded through Centennial Clean Water Fund (CCWF) grant, private sector funding, and lake management district formation. CCWF application will occur in February, 1995. Lake management district formation will be initiated in July, 1995 and is proposed to be completed in September, 1996. Depending upon implementation funding, design and engineering for in-lake aeration system could be initiated in 1996, completed, and installed in 1997. Depending upon funding, the remaining management plan activities would be initiated and performed between 1997-2002.

7. *Do you have any plans for future additions, expansion, or further activity related to or connected with this proposal? If yes, explain.*

No additional work is planned beyond what is currently contained in the management plan.

8. *List any environmental information you know about what has been prepared, or will be prepared, directly related to this proposal:*

Lake Desire Management Plan, Draft Plan, prepared by King County and KCM, Inc., January 1995; Final Plan, April 1995 (proposed).

Lake Desire Background and Technical Reports, prepared by King County and KCM, Inc., December, 1994

9. *Do you know whether applications are pending for governmental approvals of other proposals directly affecting the property covered by your proposal? If yes, explain.*

King County is intending to assist the Lake Desire community in the formation of a lake management district to fund a portion of the implementation costs of the lake management plan. The process for lake management district formation will be initiated in 1995. If formed, the lake management district will be operational for five-years. Additional private sector funds may also be available to fund a portion of the project costs for in-lake aeration.

King County is also intending to apply for additional funds from the Washington State Department of Ecology Centennial Clean Water Fund to cover a portion of the implementation costs.

Several residential development proposals are in various stages of governmental approval. The development of these properties without implementation of the lake management will likely result in a worsening of lake water quality.

10. *List any government approvals or permits that will be needed for your proposal, if known:*

Environmental Checklist
King County Council adoption of the Lake Desire Management Plan
Washington State Department of Ecology Approval

11. *Give a brief, complete description of your proposal, including the proposed uses and the size of the project and site. There are several questions later in this checklist that ask you to describe certain aspects of your proposal. You do not need to repeat those answers on this page. (Lead agencies may modify this form to include additional specific information on project description.)*

The proposal will involve the implementation of watershed measures, in-lake measures, aquatic plant management measures, and long-term lake, fishery, and watershed monitoring programs as described in Chapter 7 of the Lake Desire Management Plan. The watershed measures will be applied throughout the Lake Desire watershed. The lake is 80 acres in size and will be the site for alum treatment (one-time application) and installation of an in-lake aeration system. Separate SEPA compliance will be conducted for in-lake measures.

12. *Location of the proposal. Give sufficient information for a person to understand the precise location of your proposed project, including a street address, if any, and section, township, and range, if known. If a proposal would occur over a range of area, provide the range or boundaries of the site(s). Provide a legal description, site plan, vicinity map, and topographic map, if reasonably available. While you should submit any plans required by the agency, you are not required to duplicate maps or detailed plans submitted with any permit applications related to this checklist.*

Lake Desire is located in the Cedar River watershed approximately 5 miles northwest of Maple Valley in King County, Washington (Figure 1). Access to the lake is via Petrovitsky Road, which passes to the south of the lake. Petrovitsky Road connects with 140th Way SE, a major roadway extending south from Highway 169 approximately 2 miles east of Interstate 405. West Lake Desire Road, a minor road branching off of Petrovitsky Road via SE 184th St., provides access to the Washington State Department of Fish and Wildlife operated public boat launch, located on the northern shore of the lake, and the 400 acre open space tract along the south eastern side of the lake (Figure 2). The watershed includes portions of Section 25 and 36, R5E, T23N and Sections 30 and 31, R6E, T23N.

B. ENVIRONMENTAL ELEMENTS

1. Earth

a. *General description of the site (underline one): Flat, rolling, hilly, steep slopes, mountainous, other.*

The watershed topography ranges from 500 to 860 feet above mean sea level. The majority of the watershed is a mixture of gently sloping forested hills with several moderate sized wetlands in the valleys.

b. *What is the steepest slope on the site (approximate percent slope)?*

To the east of the lake, a steep hill rises 360 vertical feet in approximately 1000 horizontal feet (approximate slope, 20%).

c. *What general types of soils are found on the site (for example, clay, sand, gravel, peat, muck)? If you know the classification of agricultural soils, specify them and note any prime farmland.*

The predominate soil type in the watershed is AgC-Alderwood Gravely Sandy Loam (slope 6-15%). Other soil types present include AgB- Alderwood Gravely Sandy Loam (slope 0-6%), AgD- Alderwood Gravely Sandy Loam (slope 15-30%), Everett Gravely Sandy Loan (slope 6-15%), and Or-Orcas Peat.

d. *Are there surface indications or history of unstable soils in the immediate vicinity? If so, describe.*

The King County Sensitive Area Folio shows the hillslope immediately to the east to be an erosion and landslide hazard area (King County, 1990).

e. *Describe the purpose, type, and approximate quantities of any filling or grading proposed. Indicate source of fill.*

Does not apply.

f. *Could erosion occur as a result of clearing, construction, or use? If so, generally describe.*

Not applicable to the plan itself. Erosion could result during the installation of the in-lake aeration system. Appropriate measures will be taken to prevent sediment and turbid water from entering the lake.

g. *About what percent of the site will be covered with impervious surfaces after project construction (for example, asphalt or buildings)?*

Not applicable to the plan itself. A 300-400 square foot building will be constructed to house the air compressor for the in-lake aeration. The final design and location of the compressor building remains to be determined. The existing boat launch is a likely site pending final system design and approval by the Washington State Department of Fish and Wildlife.

h. *Proposed measures to reduce or control erosion, or other impacts to the earth, if any:*

Not applicable to the plan itself. Appropriate measures will be taken during construction to control erosion. All disturbed areas will be stabilized following construction.

2. Air

a. *What types of emissions to the air would result from the proposal (for example, dust, automobile, odors, industrial, wood smoke) during construction and when the project is completed? If any, generally describe and give approximate quantities, if known.*

Not applicable to the plan itself. Minor dust emissions during the construction of the compressor building could occur in the immediate area. No impacts to air quality will occur upon completion of the project construction.

b. Are there any off-site sources of emissions or odors that may affect your proposal? If so, generally describe.

Does not apply.

c. Describe proposed measures to reduce or control emissions or other impacts to air, if any:

Appropriate dust control will be employed if necessary.

3. Water

a. Surface:

1) Is there any surface water body on or in the immediate vicinity of the site (including year-round and seasonal streams, saltwater, lakes, ponds, and wetlands)? If yes, describe type and provide names. If appropriate, state what stream or river it flows into.

Lake Desire and Peterson Creek Tributary 0328B.

2) Will the project require any work over, in, or adjacent to (within 200 feet) the described waters? If yes, please describe and attach available plans.

Not applicable to the plan itself. Implementation of the lake management plan will attempt to improve the trophic status of Lake Desire through in-lake restoration techniques and watershed control measures. Alum application will occur on the lake and will not have any land surface impacts. Temporary modification of water quality will occur during the alum application process. Construction of the in-lake aeration system will take place during the summer to minimize land and water impacts. Once installed, the aeration system may possibly have a short-term impact on water quality by stirring up the sediments. Separate SEPA compliance will be conducted for in-lake measures.

3) Estimate the amount of fill and dredge material that could be placed in or removed from surface water or wetlands and indicate the area of the site that will be affected. Indicate the source of fill material.

Does not apply.

4) *Will the proposal require surface water withdrawals or diversions? Give general description, purpose, and approximate quantities, if known.*

Does not apply.

5) *Does the proposal lie within a 100-year floodplain? If so, note location on the site plan.*

Does not apply.

6) *Does the proposal involve any discharges of waste materials to surface waters? If so, describe the type of waste and anticipated volume of discharge.*

Does not apply.

b. *Ground:*

1) *Will ground water be withdrawn, or will water be discharged to ground water? Give general description, purpose, and approximate quantities, if known.*

Does not apply.

2) *Describe waste material that will be discharged into the ground from septic tanks or other sources, if any (for example: domestic sewage, industrial chemicals, agricultural, etc.). Describe the general size of the system, the number of such systems, the number of houses to be served (if applicable), or the number of animals or humans the system(s) are expected to serve.*

Does not apply.

c. *Water Runoff (including stormwater):*

1) *Describe the source of runoff (including stormwater) and method of collection and disposal, if any (include quantities, if known). Where will this water flow? Will this water flow into other waters? If so, describe.*

Not applicable to the plan itself. Stormwater from the compressor building will be minimal and will flow through existing treatment systems, be infiltrated into the ground, or directed to a vegetated area prior to entering the lake depending upon final site design.

2) Could waste materials enter ground or surface waters? If so, generally describe.

Not applicable to the plan itself. All implementation activities are designed to improve water quality in and around the lake.

d. Proposed measures to reduce or control surface, ground, and runoff water impacts, if any:

Not applicable to the plan itself. The final project plans for in-lake measures will address the possible short-term impacts from construction activities related to the installation of the in-lake aeration system. These impacts are expected to be insignificant compared with the long-term benefits associated with lake aeration.

4. Plants

a. Check or underline types of vegetation found in the watershed:

_x_ deciduous tree: alder, maple, aspen, other
_x_ evergreen tree: fir, cedar, pine, other
_x_ shrubs
_x_ grass
_x_ pasture
___ crop or grain
_x_ wet soil plants: cattail, buttercup, bulrush, skunk cabbage, other
_x_ water plants: water lily, eelgrass, milfoil, other
___ other types of vegetation

b. What kind and amount of vegetation will be removed or altered?

Not applicable to the plan itself. If the compressor building is located at the boat launch, no vegetation removal will be needed. If another location is used, as much as 500 square feet of vegetation may require removal.

c. List threatened or endangered species known to be on or near the site:

Does not apply.

d. Proposed landscaping, use of native plants, or other measures to preserve or enhance vegetation on the site, if any:

Revegetation of watershed wetlands and lake shoreline with native plants is included among plan recommendations.

5. Animals

a. *Underline any birds and animals which have been observed on or near the site, or are known to be on or near the site:*

___ birds: hawk, heron, eagle, songbirds, other
___ mammals: deer, bear, elk, beaver, other
___ fish: bass, salmon, trout, herring, shellfish, other

b. *List any threatened or endangered species known to be on or near the site:*

Bald eagle.

c. *Is the site part of a migration route? If so, explain.*

The lake and watershed wetlands provide resting sites for waterfowl during annual migration. The lake and wetland also support resident waterfowl populations.

d. *Proposed measures to preserve or enhance wildlife, if any:*

Restoration of the lake shoreline should improve wildlife habitat. In-lake aeration is also expected to improve aquatic habitat.

6. Energy and Natural Resources

a. *What kinds of energy (electric, natural gas, oil, wood stove, solar) will be used to meet the completed project's energy needs? Describe whether it will be used for heating, manufacturing, etc.*

Not applicable to the plan itself. Electric power will be used to run the on-shore compressor.

b. *Would your project affect the potential use of solar energy by adjacent properties? If so, explain.*

Does not apply.

c. *What kinds of energy conservation features are included in the plans of this proposal? List other proposed measures to reduce or control energy impacts, if any:*

Does not apply.

7. **Environmental Health**

a. *Are there any environmental health hazards, including exposure to toxic chemicals, risk of fire and explosion, spill, or hazardous waste, that could occur as a result of this proposal? If so, describe.*

Does not apply.

1) *Describe special emergency services that might be required.*

Does not apply.

2) *Proposed measures to reduce or control environmental health hazards, if any:*

Does not apply.

b. *Noise:*

1) *What types of noise exist in the area which may affect your project (for example: traffic, equipment operation, other)?*

Does not apply.

2) *What types and levels of noise would be created by or associated with the project on a short-term or a long-term basis (for example: traffic, construction, equipment operation, other)? Indicate what hours noise would come from the site.*

Not applicable to the plan itself. Short-term noise would be expected during the construction process for in-lake aeration. Construction activities will likely take place from April-October during normal working hours.

3) *Proposed measures to reduce or control noise impacts, if any:*

Not applicable to the plan itself. Hours of construction will be limited to comply with local noise ordinances. Long-term, noise will be emitted from the building due to the compressors inside, however, the final noise level is expected to be below local noise thresholds or standards.

8. Land and Shoreline Use

a. What is the current use of the site and adjacent properties?

The lake is primarily used for fishing, boating, and swimming. Primary access is to the lake is from the Washington State Department of Fish and Wildlife boat launch operated at the north end of the lake and local resident shoreline access. Access to the lake also occurs from a large open space park which runs along the eastern portion of the lake watershed connecting to the lake at its south eastern end. The properties adjacent to the lake are used for residential or recreational uses. The remaining watershed properties are used primarily for residential uses.

b. Has the site been used for agriculture? If so, describe.

Agricultural activities in the watershed are minimal. There are several animal-keeping operations in the watershed.

c. Describe any structures on the site.

Not applicable to the plan itself. At the proposed location for the compressor building (the boat launch), a fishing pier, paved parking and permanent pit toilets exist.

d. Will any structures be demolished? If so, what?

Does not apply.

e. What is the current zoning classification of the site?

RS-7200-P (six units per acre) or single family residential is the zoning designation in the immediate lake shoreline area. Other zoning designation of lesser density (AR-2.5-P [1 unit per 2.5 acres] and AR-5-P [one unit per five acres]) are present in the remaining portions of the watershed.

f. What is the current comprehensive plan designation of the site?

The King County Comprehensive Plan designates the area immediately around the lake as urban. The remaining portions of the watershed have been designated as urban, rural, or open space.

g. If applicable, what is the current shoreline master program designation of the site?

The entire shoreline is designated rural.

h. Has any part of the site been classified as an "environmentally sensitive" area? If so, specify.

The northern shoreline area include a portion of Cedar River Wetland 14, a class 1 wetland based on the King County Wetlands Inventory (1990).

i. Approximately how many people would reside or work in the completed project?

Does not apply.

j. Approximately how many people would the completed project displace?

Does not apply.

k. Proposed measures to avoid or reduce displacement impacts, if any:

Does not apply.

l. Proposed measures to ensure the proposal is compatible with existing and projected land uses and plans, if any:

Does not apply.

9. Housing

a. Approximately how many units would be provided, if any? Indicate whether high-, middle-, or low-income housing.

Does not apply.

b. Approximately how many units, if any, would be eliminated? Indicate whether high-, middle-, or low-income housing.

Does not apply.

c. Proposed measures to reduce or control housing impacts, if any:

Does not apply.

10. Aesthetics

a. What is the tallest height of any proposed structure(s), not including antennas? What is the principal exterior building material(s) proposed?

Not applicable to the plan itself. The design for the compressor building has not been completed. It is expected that the structure will not exceed 12 feet in height. Standard materials (concrete, brick, and wood) will be used to construct the compressor building.

b. What views in the immediate vicinity would be altered or obstructed?

Does not apply.

c. Proposed measures to reduce or control aesthetic impacts, if any:

No aesthetic impacts are anticipated. If appropriate, landscaping will be incorporated into the final design for the compressor building site.

11. Light and Glare

a. What type of light or glare will the proposal produce? What time of day would it mainly occur?

Does not apply.

b. Could light or glare from the finished project be a safety hazard or interfere with views?

Does not apply.

c. What existing off-site sources of light or glare may affect your proposal?

Does not apply.

d. Describe proposed measures to reduce or control light and glare impacts, if any:

Does not apply.

12. Recreation

a. What designated and informal recreational opportunities are in the immediate vicinity?

The boat launch area offers fishing and boating opportunities. A newly constructed fishing pier provides opportunity for shore fishing as well. The open space park along the eastern portion of the lake offers viewpoints of the lake and shoreline access to the lake through a series of wildland trails. Petrovitsky Park to the west of the lake offers both active and passive recreational opportunities including soccer, tennis, softball, baseball, picnicking, and hiking.

b. Would the proposed project displace any existing recreational uses? If so, describe.

No displacement of existing recreational uses would be expected. The plan is expected to enhance recreational uses of the lake by improving lake trophic status.

c. Proposed measures to reduce or control impacts on recreation, including recreation opportunities to be provided by the project or applicant, if any:

Does not apply.

13. Historic and Cultural Preservation

a. Are there any places or objects listed on, or proposed for, national, state, or local preservation registers known to be on or next to the site? If so, generally describe.

Does not apply.

b. Generally describe any landmarks or evidence of historic, archaeological, scientific, or cultural importance known to be on or next to the site.

Cedar River Wetland 14 was one of the largest peat mines in the history of Washington. Peat coring from the wetland have been used by the scientific community.

c. Describe proposed measures to reduce or control impacts, if any:

Does not apply.

14. Transportation

a. *Identify public streets and highways serving the site, and describe proposed access to the existing street system. Show on-site plans, if any.*

Access to the lake is via Petrovitsky Road, which passes to the south of the lake. Petrovitsky Road connects with 140th Way SE, a major roadway extending south from Highway 169 approximately 2 miles east of Interstate 405. West Lake Desire Road, a minor road branching off of Petrovitsky Road, provides access to the Washington State Department of Fish and Wildlife operated public boat launch, located on the northern shore of the lake, and the 400 acre open space tract along the south eastern side of the lake (Figure 2).

b. *Is the site currently served by public transit? If not, what is the approximate distance to the nearest transit stop?*

Yes. Metro routes 145 and 148 serve the Lake Desire area.

c. *How many parking spaces would the completed project have? How many would the project eliminate?*

Does not apply.

d. *Will the proposal require any new roads or streets, or improvements to existing roads or streets, not including driveways? If so, generally describe (indicate whether public or private).*

Does not apply.

e. *Will the project use (or occur in the immediate vicinity of) water, rail, or air transportation? If so, generally describe.*

Does not apply.

f. *How many vehicular trips per day would be generated by the completed project? If known, indicate when peak volumes would occur.*

Does not apply.

g. *Proposed measures to reduce or control transportation impacts, if any:*

Does not apply.

15. Public Services

a. Would the project result in an increased need for public services (for example: fire protection, police protection, health care, schools, other)? If so, generally describe.

Does not apply.

b. Proposed measures to reduce or control direct impacts on public services, if any:

Does not apply.

16. Utilities

a. Underline utilities currently available at the site: electricity, natural gas, water, refuse service, telephone, sanitary sewer, septic system, other.

b. Describe the utilities that are proposed for the project, the utility providing the service, and the general construction activities on the site or in the immediate vicinity that might be needed.

Not applicable to the plan itself. The compressor building will need to have electrical lines connected to it.

C. SIGNATURE

The above answers are true and complete to the best of my knowledge. I understand that the lead agency is relying on them to make its decision.

Signature: Sharon L. Walton

Title: Senior Limnologist

Date Submitted: Feb 28, 1995

SUPPLEMENTAL SHEET FOR NONPROJECT ACTIONS

I How would the proposal be likely to increase discharge to water; or production of noise?

This proposal will not result in any increases in these categories.

II How would the proposal be likely to affect plants, animals, fish, or marine life ?

This proposal is intended to improve the future environment for aquatic animals and fish by providing a watershed management plan to protect water quality from degradation due to new development in the watershed.

III How would the proposal be likely to deplete energy or natural resources.

This proposal will have no impact on energy or natural resources.

IV How would the proposal be likely to use or affect environmentally sensitive areas or areas designated (or eligible or under study) for governmental protection; such as parks, wilderness, wild and scenic rivers, threatened or endangered species habitat, historic or cultural sites, wetlands, floodplain, or prime farmlands ?

The proposal would improve environmentally sensitive areas in a positive manner as this plan is designed to reduce the contamination in vactor waste from entering the environment. This will be done by building vactor waste receiving stations throughout the County thus making it more convenient and cost efficient to dispose of this contaminated waste in an appropriate manner. Issues relating to individual selected sites will be addressed in depth at the time of selection.

V How would the proposal be likely to affect land and shoreline use, including whether it would allow or encourage land or shoreline uses incompatible with existing plans.

This proposal will not affect shorelines of the state.

VI How would the proposal be likely to increase demands on transportation or public services and utilities?

This proposal will reduce traffic on the roadways by providing more vactor waste receiving stations throughout the County thus reducing the driving time and distance for the vactor trucks. This proposal will have no impact on public services or utilities. Any increase flow into the Metro sanitary lines will be so insignificant that no impact will occur.

VII Identify if possible, whether the proposal may conflict with local, state, or federal laws or requirements for the protection of the environment.

This proposal will increase compliance with federal, state, and local environmental laws and ordinances.

E. Cost/Benefit Analysis

LAKE DESIRE PROPERTY ASSESSMENT IMPACT

INTRODUCTION

The Preferred Alternative watershed improvements will cost approximately $649,000. To pay for the improvement costs a Lake Management District (LMD) has been proposed. The LMD has the authority to assess property taxes on properties located within the LMD. These taxes will be used to pay a portion of the improvements and activity costs. Tax assessments will be combined with other public-private funding methods to pay for the Preferred Alternative.

The following analysis assesses the impact the improvements may have on the property values located in the LMD. The analysis focuses on the 126 shoreline properties surrounding Lake Desire. The principal concern is whether the benefits derived from the Preferred Alternative equal or exceed the alternative costs. To address that concern it is important to know what portion of property value increases to shoreline properties (1) can be attributable to the Preferred Alternative improvements, and (2) whether the property tax generated from that portion pay for the preferred improvements?

Setting

Preferred Alternative improvements will include in-lake measures, watershed measures, aquatic plant management, and monitoring. These activities will improve the existing lake water quality and prevent future degradation of the watershed and the Lake.

How the Preferred Alternative improvements will impact the property values depends in large part on the perception of the improvements as adding market value to the properties within the watershed. Property values may increase beyond a no action (no improvement) alternative, if property owners and buyers perceive that the improvements contribute to the value of the property. Obvious examples are instances where improvements result in dramatic changes in Lake and watershed quality – eliminating algal blooms, allowing swimming and other recreational activities that have been curtailed, reducing the incidence of water quality related human health problems, reducing odors, improving fisheries, etc. These are some quality of life measures which impact market value and affect property assessments. Presumably, the more dramatic the benefits from the lake improvements the greater the impact on property values.

Degradation of Lake Desire and the surrounding watershed has occurred. Some examples include odor problems, milfoil growth, algal blooms, and aesthetic concerns. However, swimming and lake recreational activities (e.g., boating, fishing, etc.), as well as other activities have continued despite these problems. Property assessment values have also kept pace with the property assessment rates in King County. These two factors imply that while there are problems with Lake Desire's water quality they may not be easily detected in the property value assessments.

The degree that the Preferred Alternative will produce dramatic changes in Lake and watershed activities, may be difficult to measure through property value changes. It is assumed in this analysis, though, that there will be some increase in property value assessments between the No Action and Preferred Alternative.

METHODOLOGY AND ANALYSIS

Methodology

The methodology used for analyzing the property assessment impacts was a comparison of property values with and without implementation of the Preferred Alternative recommendations. The comparison is for a selected time period. The difference between the property values, assuming it is possible to hold all other variables constant, is the quantitative impact from the improvements. The impact is then compared to the cost of the improvements to determine if the benefit as reflected in greater property values exceed the cost. A second evaluation is also made to determine whether the property tax assessment payments can pay for the improvements.

The critical variables in the methodology is the length of the term or number of years that are to be analyzed and the estimated impact on property values that are to be attributed to the improvements; both are somewhat subjective. Ten years have been selected for two reasons. First, the LMD, which can have a life of up to ten years, may exercise server funding sources including bonds. Bonds rely on property taxes for payment and often have a ten year amortization period. Second, the Lake Desire Preferred Alternative improvements are to have a long term effect on the water quality. Second, the five year period for implementing the preferred alternative would not be adequate to reflect the Preferred Alternative property value changes from the water quality improvements.

Estimating the additional value to shoreline property assessments that is attributable to the Preferred Alternative is difficult. Since the analysis is being completed prior to implementation of the Preferred Alternative, it is not possible to measure the actual impact. The typical estimation method is to rely on other lakes and shoreline properties that have undergone similar improvements and use them as a model for the Lake Desire analysis. While there have been a number of other lakes in the region that have undergone water qualify improvements none have had property value evaluations that could be used in this analysis.

Therefore, a range of values attributable to the Preferred Alternative impact on property values is used. The values selected for this analysis range from a minimal 1% increase to annual property values to 3% annual property value increase. The rise in property values was estimated to begin in 1997 after Preferred Alternative implementation.

The annual rate of property value change is held constant. In reality the rates will probably fluctuate over the ten year study period. It is unlikely, though, that property value changes would lessen the beneficial impact from the Preferred Alternative unless the improvements are unable to maintain Lake Desire water quality and the lake further degrades. A more likely scenario would be that under the No Action Alternative Lake

Desire degradation would continue and depress property values. This would increase the property value benefit from the Preferred Alternative.

Shoreline Parcels: Existing Conditions

The 126 shoreline property values have been analyzed because they are most sensitive to changes in lake quality. The remaining properties in the watershed may also experience property value changes due to the Preferred Alternative, but the degree of change would be more difficult to measure.

Currently, the 126 parcels along Lake Desire's shoreline account for about 26% of the total assessed value of the watershed or about $17.5 million of $64.1 million (1993 assessed value). However, the benefit from the Preferred Alternative Improvements. 1989 and 1993, shoreline property values increased about the same rate as King County properties -- experiencing a sharp increase in the 1989-1990 period and then smaller annual increases since 1990. King County has averaged about four-five percent between 1989-1993, while Lake Desire's average for the same period has been over four percent (Table 1).

Forecasting

Three 10 year forecasts have been completed for the shoreline parcels. One forecast is for the No Action alternative. The No Action Alternative assumes no water quality improvements will be implemented during the 10 year period -- property values will be increasing at a 4% annual rate. A second forecast is for the Preferred Alternative to add a 1% annual increase in shoreline property assessments above the No Action Alternative -- shoreline property values will rise at a 5% annual rate. The third forecast is for the Preferred Alternative with a 3% annual increase in shoreline property assessments above the No Action Alternative -- shoreline property values will rise at a 7% annual rate.

The property value results from the forecast are displayed in Table 1. By the year 2006 property assessments will be approximately $30.4 million for the No Action Alternative and between $40.9 million to $48.8 million for the Preferred Alternative. The Preferred Alternative results in an increase in shoreline property values by 2006 of $10.5 to $18.4 million compared to the No Action Alternative.

The comparative annual differences between the No Action and Preferred Alternatives are also important. Table 2 displays the incremental change in annual shoreline property values for the No Action and Preferred Alternatives. By taking the difference between the No Action and the Preferred Alternatives it is possible to calculate the annual benefit in shoreline property assessments attributed to the Preferred Alternative. The benefits range from a low of $187 thousand in 1997 to a high of $9.1 million by 2006.

Analysis and Results

The final step of the analysis is to compare the forecasts with the Preferred Alternative improvement costs. The Preferred Alternative capital improvement costs and activities are $649 thousand. While Lake Desire shoreline properties account for about 26% of the total assessed value of the watershed, it is assumed that shoreline properties will receive a disproportionate share of the benefit from Preferred Alternative improvements. Therefore, shoreline properties will pay a larger share of the Preferred Alternative improvement costs. For purposes of this analysis, 2/3 of the Preferred Alternative improvement costs will be paid by the shoreline properties. This figure is based upon King County Surface Water Management's experience with LMD formation at Beaver Lake. where 2/3 of the cost is to be paid by the shoreline parcels. Shoreline property share of the Preferred Alternative costs will be about $432.7 thousand.

The 10 year cumulative benefit to shoreline property values (Table 2) that is attributable to the Preferred Alternative improvements exceed the cost of the Preferred Alternative ($432.7 thousand). By 2006 the total improvement benefit to shoreline property values ranges from $13.4 million to $29.5 million. Annual benefits to shoreline property values in the initial two years (1997 and 1998) for the 5% Preferred Alternative is below the Preferred Alternative costs but rise above the improvement costs beginning in 1999.

Paying for the cost of the project through taxes on the increased value of the property is a function of the revenues that can be generated by the tax levy. While the additional property values exceed the project cost, it still may not be possible to raise sufficient taxes to pay for the improvements.

For this comparison it is assumed that the capital costs will be funded at one time by a single financial instrument. The LMD has borrowing and bonding authority so a ten year bond has been selected for the analysis with a yield or interest rate of 8.45% (closing utility bond rate for January 26, 1995). Semi-annual payments (two/year) will be made to retire the bond. The total semi-annual payment is $34,903 or about $65,806/year for all the Preferred Alternative improvement. The 2/3 portion to be paid by the shoreline property owners is $23,268 semi-annually or $45,537 annually.

Table 3 displays the total bond cost with interest, the 2/3 portion to be paid by the Lake Desire shoreline properties, the range of annual tax assessments per $1,000 assessed value necessary to cover the $45.5 thousand annual bond payment, and an example of the typical tax assessment to be paid by a shoreline property with a $250 thousand assessed value.

Under this scenario, property assessment rate per $1,000 would be adjusted annually to pay the bond. As property values increased (Table 2) the assessment rate would decline. Property tax rates as presented in Table 3 would range from a high of $2.32/$1,000 to $2.37/$1,000 assessed value in 1997 to a low of $1.26/$1,000 to $1.53/$1,000 assessed value by 2006.

An example has been included to calculate the typical cost to an individual shoreline property. If a shoreline property has a $250 thousand assessed value in any year of the amortization period, the property will be taxed the amount that is displayed in Table 3. The cost to a property in 1997 will range from $580.54 to $591.60 and decline by the year 2006 to between $315.78 to $381.35.

Conclusion

The results that are presented in this analysis indicate that the property tax benefit derived from the Preferred Alternative exceed the costs of the Preferred Alternative improvements and activities (Table 2). Under the taxing scheme analyzed and displayed in Table 3, tax assessment rates are adjusted so shoreline properties pay a 2/3 share of the Preferred Alternative improvements and activities ($465.3 thousand).

There are a number of variables that could affect the analysis presented and revenue generated from the property tax. Among them are the following.

- Higher property values to shoreline properties than attributed to the Preferred Alternative in this analysis could reduce the tax rate per $1,000 assessed value,

- Longer amortization period could lower the semi-annual payment and lengthen the time period for paying the bond, and

- Higher than expected impact on remaining watershed property values could increase the tax revenue generation.

Adjustments or changes in any one or combination of the variables will have an impact on the potential revenue generation.

In addition, further study using a comparative analysis would provide more definitive results regarding the benefit/cost analysis. For example, another lake which has previously undergone water quality improvements could be used as a model. Thus, refining the estimated impact on property values in the Lake Desire watershed resulting from improved water quality.

TABLE 2: LAKE DESIRE SHORELINE PROPERTY ASSESSMENT COMPARISON

YEAR	No Action Alt.: Annual Change in Property Assessment 4%/Yr. (1994 $)	Alt.: Annual Change in Property Assessment 5%/Yr. (1994 $)	Annual Difference Btw. NA & 5%	Alt.: Annual Change in Property Assessment 7%/Yr. (1994 $)	Annual Difference Btw. NA & 7%
1996*	$18,729,366	$18,729,366		$18,729,366	
1997**	$749,174	$936,467	$187,294	$1,311,056	$561,882
1998**	$1,528,314	$1,919,758	$391,444	$2,713,885	$1,185,571
1999**	$2,338,620	$2,952,213	$613,593	$4,214,913	$1,876,292
2000**	$3,181,339	$4,036,291	$854,952	$5,821,012	$2,639,673
2001**	$4,057,766	$5,174,573	$1,116,807	$7,539,539	$3,481,773
2002**	$4,969,250	$6,369,769	$1,400,519	$9,378,362	$4,409,112
2003**	$5,917,194	$7,624,725	$1,707,531	$11,345,903	$5,428,709
2004**	$6,903,055	$8,942,428	$2,039,373	$13,451,172	$6,548,116
2005**	$7,928,351	$10,326,017	$2,397,666	$15,703,809	$7,775,458
2006**	$8,994,659	$11,778,785	$2,784,126	$18,114,131	$9,119,473
10 Year Cumulative A.V.	$46,567,722	$60,061,025	$13,493,303	$89,593,781	$43,026,058
10 Year Cumulative Benefit			$13,493,303		$29,532,687

Note: percentage figure in column heading refers to property value annual increase.
*Beginning Assessed Value
**Annual Assessed Value Change.

TABLE 3: PREFERRED ALTERNATIVE COST AND PROPERTY TAX COMPARISONS*

YEAR	Total Annual Bond Payment	Shoreline Portion of Bond Payment (2/3 Total Cost)	Tax Per $1,000 AV: 5% Preferred Alt.	Preferred Alt. Property Tax: Property = $250K AV**	Tax Per $1,000 AV: 7% Preferred Alt.	Example: 7% Preferred Alt. Property Tax: Property = $250K AV**
1997	$69,806	$46,537	$2.37	$591.60	$2.32	$580.54
1998	$69,806	$46,537	$2.25	$563.43	$2.17	$542.56
1999	$69,806	$46,537	$2.15	$536.60	$2.03	$507.07
2000	$69,806	$46,537	$2.04	$511.05	$1.90	$473.90
2001	$69,806	$46,537	$1.95	$486.71	$1.77	$442.89
2002	$69,806	$46,537	$1.85	$463.54	$1.66	$413.92
2003	$69,806	$46,537	$1.77	$441.46	$1.55	$386.84
2004	$69,806	$46,537	$1.68	$420.44	$1.45	$361.53
2005	$69,806	$46,537	$1.60	$400.42	$1.35	$337.88
2006	$69,806	$46,537	$1.53	$381.35	$1.26	$315.78
10 Year Cumulative	$698,060	$465,373		$4,796.60		$4,362.92

*1994 dollars

**AV = Assessed value.

TABLE 1: LAKE DESIRE SHORLINE PROPERTY TAX ASSESSMENT COMPARISONS

PARCEL NUMBER	1994 Assessed Value (1994 $)	1993 Assessed Value (1994 $)	1991 Assessed Value (1994 $)	1989 Assessed Value (1994 $)	% Change Assessed Value 1989-95 (1994 $)	2006 Property Value No Action: 4% Rise AV (1994 $)	2006 Property Value Preferred Alt. 5% Rise AV (1994 $)	2006 Property Value Preferred Alt. 7% Rise AV (1994 $)
SE 25 23 05								
252305-9031	67,132	61,464	44,830	31,771	8%	$142,547	$181,742	$218,047
252305-9018	171,288	168,792	127,835	102,961	6%	$295,922	$362,738	$436,822
252305-9030	161,044	158,704	136,123	114,581	4%	$228,024	$269,111	$325,263
252305-9033	84,136	85,072	61,991	48,980	6%	$156,159	$194,052	$233,380
(BLOCK 4)						$0	$0	$0
400840-0225	330,668	325,832	282,287	242,842	3%	$451,644	$529,384	$640,272
400840-0235	150,592	148,408	116,043	89,282	6%	$264,302	$324,953	$391,207
400840-0240	187,668	184,912	157,021	136,056	3%	$260,085	$305,698	$369,632
400840-0245	185,952	183,248	155,153	123,112	4%	$286,392	$343,454	$414,472
400840-0250	154,388	152,152	120,246	95,901	5%	$256,117	$311,526	$375,429
400840-0255	223,860	220,584	197,064	120,759	8%	$461,911	$585,711	$703,072
400840-0260	172,276	202,280	147,448	121,494	6%	$304,324	$374,622	$450,950
400840-0270	165,932	163,488	135,073	104,579	5%	$270,789	$328,344	$395,816
400840-0275	19,500	23,400	17,045	10,443	10%	$50,808	$67,359	$80,522
400840-0280	13,104	16,848	12,258	5,736	15%	$53,538	$77,353	$91,758
400840-0285	13,104	16,848	12,258	5,736	15%	$53,538	$77,353	$91,758
400840-0290	13,104	16,848	12,258	5,736	15%	$53,538	$77,353	$91,758
400840-0295	1,040	1,040	12,258	5,736	2%	$1,295	$1,491	$1,807
(BLOCK 5)						$0	$0	$0
400840-0300	13,104	16,848	12,258	5,736	15%	$53,538	$77,353	$91,758
400840-0305	10,608	10,608	12,258	5,736	10%	$27,572	$36,536	$43,678
400840-0310	13,312	17,264	12,608	6,031	15%	$52,010	$74,505	$88,446
400840-0315	13,728	18,096	13,192	6,619	14%	$49,343	$69,567	$82,701
400840-0320	13,728	18,096	13,192	6,619	14%	$49,343	$69,567	$82,701
400840-0325	13,728	18,096	13,192	6,619	14%	$49,343	$69,567	$82,701
400840-0330	53,664	54,288	39,576	26,476	9%	$123,196	$159,427	$191,009
400840-0335	38,532	45,344	33,039	7,354	39%	$1,011,496	$2,089,314	$2,408,579
400840-0340	43,004	54,288	39,576	26,476	9%	$98,724	$127,758	$153,066
400840-0345	162,656	160,264	140,676	115,170	4%	$231,828	$273,944	$331,063
400840-0350	272,220	268,216	246,213	211,953	3%	$348,806	$403,904	$489,092
400840-0360	86,840	86,840	100,867	88,105	0%	$87,343	$96,587	$117,498
400840-0365	217,100	213,928	189,592	154,589	4%	$307,660	$363,156	$438,924

TABLE 1: LAKE DESIRE SHORLINE PROPERTY TAX ASSESSMENT COMPARISONS

PARCEL NUMBER	1994 Assessed Value (1994 $)	1993 Assessed Value (1994 $)	1991 Assessed Value (1994 $)	1989 Assessed Value (1994 $)	% Change Assessed Value 1989-95 (1994 $)	2006 Property Value No Action: 4% Rise AV (1994 $)	2006 Property Value Preferred Alt. 5% Rise AV (1994 $)	2006 Property Value Preferred Alt. 7% Rise AV (1994 $)
400840-0370	81,224	81,224	81,838	68,837	2%	$97,217	$111,123	$134,733
						$0	$0	$0
NE 36 23 05						$0	$0	$0
362305-9031	360,880	355,576	327,934	305,942	2%	$421,370	$479,377	$581,502
362305-9004	4,784	5,408	26,384	19,857	-5%	$2,968	$2,994	$3,677
(BLOCK 1)						$0	$0	$0
400840-0005	103,064	117,728	85,807	72,808	6%	$176,139	$215,463	$259,520
400840-0010	104,520	119,600	87,208	74,279	5%	$177,774	$217,265	$261,713
400840-0015	235,664	232,232	206,520	187,095	2%	$295,350	$340,565	$412,567
400840-0020	106,288	121,368	89,192	76,044	5%	$178,760	$218,003	$262,656
400840-0025	93,288	90,168	66,077	26,476	19%	$513,806	$786,064	$927,854
400840-0030	53,768	59,696	43,545	37,066	5%	$91,469	$111,793	$134,663
400840-0035	53,768	59,696	43,545	37,066	5%	$91,469	$111,793	$134,663
400840-0040	198,016	195,104	169,512	138,556	4%	$285,973	$338,776	$409,313
400840-0045	74,464	76,128	55,453	29,123	13%	$247,657	$344,011	$409,502
400840-0050	84,708	97,656	71,214	58,247	6%	$150,833	$185,957	$223,813
400840-0055	84,188	97,656	71,214	58,247	6%	$149,907	$184,816	$222,439
400840-0060	95,836	111,592	81,371	68,396	6%	$165,433	$202,755	$244,168
400840-0065	183,144	180,440	153,051	126,495	4%	$268,215	$318,585	$384,818
400840-0071	90,740	103,480	75,417	62,512	6%	$159,242	$195,781	$235,699
400840-0075	202,956	199,992	178,151	127,231	5%	$337,849	$411,210	$495,530
400840-0080	93,288	108,576	79,152	66,189	6%	$162,025	$198,809	$239,390
400840-0085	93,288	108,576	79,152	66,189	6%	$162,025	$198,809	$239,390
400840-0095	347,984	373,568	278,901	174,593	9%	$852,094	$1,116,354	$1,335,969
400840-0100	279,604	275,496	258,705	216,366	3%	$361,631	$419,500	$507,889
400840-0105	62,400	62,400	79,152	66,189	0%	$61,421	$67,643	$82,322
400840-0110	226,824	223,496	204,535	185,036	2%	$275,978	$316,438	$383,553
400840-0115	266,916	263,016	245,396	197,392	3%	$363,970	$426,485	$515,836
400840-0120	20,800	20,800	23,349	46,333	-6%	$11,141	$10,932	$13,465
400840-0125	100,880	100,880	105,653	76,486	3%	$140,411	$165,172	$199,700
400840-0130	171,808	169,312	143,712	117,376	4%	$254,932	$303,564	$366,585
(BLOCK 2)						$0	$0	$0
362305-9024	258,856	245,960	197,764	175,328	4%	$372,859	$441,483	$533,431
362305-9022	291,720	287,456	222,397	199,009	4%	$436,010	$519,903	$627,754

TABLE 1: LAKE DESIRE SHORLINE PROPERTY TAX ASSESSMENT COMPARISONS

PARCEL NUMBER	1994 Assessed Value (1994 $)	1993 Assessed Value (1994 $)	1991 Assessed Value (1994 $)	1989 Assessed Value (1994 $)	% Change Assessed Value 1989-95 (1994 $)	2006 Property Value No Action: 4% Rise AV (1994 $)	2006 Property Value Preferred Alt. 5% Rise AV (1994 $)	2006 Property Value Preferred Alt. 7% Rise AV (1994 $)
362305-9020	297,752	293,384	229,052	206,217	4%	$437,197	$519,559	$627,545
362305-9026	165,204	154,856	134,372	110,757	4%	$236,586	$279,821	$338,135
362305-9034	263,900	260,000	229,519	189,302	3%	$370,554	$436,828	$527,816
362305-9089	204,880	201,864	216,794	154,883	3%	$283,703	$333,405	$403,139
362305-9002	338,104	333,112	298,865	296,970	1%	$381,305	$430,940	$523,091
362305-9099	344,500	339,456	305,869	291,233	2%	$403,788	$459,708	$557,602
(BLOCK 3)						$0	$0	$0
400840-0200	184,808	182,104	161,690	124,142	4%	$281,209	$336,462	$406,125
400840-0205	84,240	90,480	65,960	52,952	6%	$153,357	$189,868	$228,429
400840-0210	181,844	179,192	158,422	137,233	3%	$240,967	$280,820	$339,835
400840-0215	89,440	90,480	65,960	52,952	6%	$162,823	$201,589	$242,529
400840-0220	84,240	90,480	65,960	52,952	6%	$153,357	$189,868	$228,429
						$0	$0	$0
362305-9019	288,340	284,128	250,533	232,840	2%	$354,975	$407,930	$494,339
362305-9069	180,024	210,288	153,285	140,616	5%	$282,792	$340,415	$410,655
362305-9029	250,172	246,480	217,727	199,892	2%	$311,381	$358,580	$434,447
362305-9101	201,084	198,120	212,824	193,714	0%	$207,108	$230,063	$279,743
362305-9025	74,880	74,880	88,375	75,456	0%	$76,278	$84,555	$102,836
(BLOCK 6)						$0	$0	$0
400840-0375	217,828	214,656	192,511	154,589	4%	$310,352	$366,708	$443,172
400840-0380	76,908	97,656	71,214	58,247	6%	$136,944	$168,834	$203,204
400840-0385	150,696	148,512	121,180	66,631	10%	$406,871	$543,093	$648,819
400840-0390	76,908	97,656	71,214	58,247	6%	$136,944	$168,834	$203,204
400840-0395	132,132	147,784	107,755	81,634	7%	$257,858	$323,509	$388,721
400840-0400	167,908	165,464	129,469	105,021	5%	$276,335	$335,608	$404,510
400840-0410	115,752	114,088	104,603	62,659	8%	$240,812	$305,832	$367,059
400840-0415	42,484	43,368	31,638	26,182	6%	$74,600	$91,728	$110,429
400840-0420	45,240	48,880	35,607	29,123	6%	$80,666	$99,477	$119,725
400840-0425	134,992	133,016	103,785	78,986	6%	$240,752	$296,906	$357,337
400840-0430	52,884	53,768	39,226	32,653	6%	$92,236	$113,266	$136,375
						$0	$0	$0
362305-9087	252,148	248,456	224,032	184,889	3%	$345,748	$405,563	$490,479
362305-9075	51,064	54,288	79,152	66,189	-1%	$45,335	$48,959	$59,702
(BLOCK 7)						$0	$0	$0

TABLE 1: LAKE DESIRE SHORLINE PROPERTY TAX ASSESSMENT COMPARISONS

PARCEL NUMBER	1994 Assessed Value (1994 $)	1993 Assessed Value (1994 $)	1991 Assessed Value (1994 $)	1989 Assessed Value (1994 $)	% Change Assessed Value 1989-95 (1994 $)	2006 Property Value No Action: 4% Rise AV (1994 $)	2006 Property Value Preferred Alt. 5% Rise AV (1994 $)	2006 Property Value Preferred Alt. 7% Rise AV (1994 $)
400840-0435	61,880	61,880	85,807	72,808	-1%	$55,945	$60,626	$73,903
400840-0440	168,116	165,672	136,123	107,080	5%	$270,809	$327,555	$394,959
						$0	$0	$0
362305-9027	71,604	69,368	77,868	77,809	-1%	$64,210	$69,473	$84,702
(BLOCK 8)						$0	$0	$0
400840-0445	85,488	108,576	79,152	66,189	6%	$148,478	$182,186	$219,374
400840-0450	200,876	197,912	171,614	150,765	3%	$267,749	$312,379	$377,985
400840-0455	190,112	187,304	159,706	136,791	3%	$265,674	$312,763	$378,115
400840-0460	209,924	206,856	182,354	164,297	2%	$267,222	$309,046	$374,274
400840-0465	185,328	182,624	155,153	126,054	4%	$276,422	$329,479	$397,843
400840-0470	43,680	38,480	28,019	35,742	2%	$51,057	$58,098	$70,473
400840-0475	57,096	76,128	55,453	42,361	7%	$110,430	$138,309	$166,216
400840-0480	225,784	222,456	200,566	181,800	2%	$278,584	$320,278	$388,105
400840-0485	212,784	209,664	185,506	165,915	2%	$271,932	$314,729	$381,128
400840-0490	173,420	170,872	125,150	95,019	7%	$335,589	$420,354	$505,164
400840-0495	85,488	108,576	79,152	66,189	6%	$148,478	$182,186	$219,374
400840-0505	150,904	148,720	140,910	135,615	1%	$165,782	$186,430	$226,408
400840-0510	169,416	166,920	141,027	109,580	5%	$268,325	$323,506	$390,199
400840-0515	193,232	190,424	148,965	138,115	4%	$274,387	$324,006	$391,591
400840-0520	219,648	216,424	196,597	177,829	2%	$269,432	$309,413	$374,979
						$0	$0	$0
362305-9112	78,520	90,480	24,516	0	45%	$3,191,344	$7,172,208	$8,218,725
362305-9045	60,008	59,696	25,567	63,101	7%	$122,541	$155,076	$186,183
362305-9092	24,440	28,080	20,430	13,973	8%	$54,576	$70,254	$84,213
362305-9023	24,440	28,080	20,430	13,973	8%	$54,576	$70,254	$84,213
362305-9113	30,576	36,192	0	0	4%	$45,260	$53,869	$65,056
362305-9021	26,312	29,744	21,714	15,297	8%	$56,245	$71,802	$86,135
						$0	$0	$0
SE 36 23 05						$0	$0	$0
(BLOCK 1)						$0	$0	$0
401080-0005	48,984	54,288	39,576	33,095	6%	$85,077	$104,391	$125,700
401080-0010	215,228	212,056	188,191	168,562	2%	$273,704	$316,482	$383,287
401080-0015	199,992	197,080	171,380	150,618	3%	$265,608	$309,668	$374,730
401080-0021	124,644	155,688	113,475	100,608	5%	$203,012	$246,069	$296,645

TABLE 1: LAKE DESIRE SHORLINE PROPERTY TAX ASSESSMENT COMPARISONS

PARCEL NUMBER	1994 Assessed Value (1994 $)	1993 Assessed Value (1994 $)	1991 Assessed Value (1994 $)	1989 Assessed Value (1994 $)	% Change Assessed Value 1989-95 (1994 $)	2006 Property Value No Action: 4% Rise AV (1994 $)	2006 Property Value Preferred Alt. 5% Rise AV (1994 $)	2006 Property Value Preferred Alt. 7% Rise AV (1994 $)
401080-0027	39,520	39,520	40,860	59,570	-3%	$27,765	$28,680	$35,135
401080-0035	78,832	78,832	88,492	113,846	-3%	$56,251	$58,278	$71,372
401080-0040	188,292	185,536	158,422	137,968	3%	$257,856	$302,391	$365,714
401080-0045	214,812	211,640	187,724	160,178	3%	$288,512	$337,093	$407,830
401080-0050	90,116	88,296	96,664	70,602	3%	$119,075	$138,693	$167,848
401080-0055	87,724	105,352	76,934	64,130	6%	$152,571	$187,258	$225,475
401080-0060	201,708	198,744	174,649	154,295	3%	$263,255	$305,908	$370,300
401080-0065	221,312	224,744	193,795	149,147	5%	$346,681	$417,101	$503,190
401080-0070	238,004	234,520	204,769	185,183	3%	$304,979	$353,157	$427,642
(BLOCK 2)						$0	$0	$0
362305-9032	64,012	85,384	62,225	49,274	6%	$118,479	$147,151	$176,982
TOTAL	$17,205,292	$17,526,080	$14,870,261	$12,464,495		$30,407,761	$40,959,978	$48,845,889

F. Engineering Analysis

Technical Memorandum

KCM

Date: May 4, 1995

To: Sharon Walton, King County Surface Water Management Division

c: *Central Files*

From: Harry L. Gibbons

Project No.: 2390026-022

Subject: Lake Desire Hypolimnetic Aerator Engineering Analysis

Following is our engineering analysis of the Hypolimnetic Aerator at Lake Desire.

LAKE DESIRE HYPOLIMNETIC AERATOR ENGINEERING ANALYSIS
KING COUNTY SURFACE WATER MANAGEMENT DIVISION

INTRODUCTION

The draft Lake Desire Management Plan was issued for review in January 1995. The management plan evaluated the Lake Desire watershed and presented several recommendations for enhancing water quality in the watershed. The preferred long term in-lake activity recommended in the management plan was hypolimnetic aeration. Aeration was recommended for the following reasons:

- It is cost effective for reducing the internal loading of phosphorus.
- It is beneficial to aquatic habitat.
- Minimal permitting problems are associated with implementation compared with other in-lake measures.
- In combination with watershed controls, lake trophic status goals can be met.

This engineering analysis will develop design criteria, analyze alternatives, size facilities, and estimate costs for the recommended alternative.

DESIGN CRITERIA

Physical Characteristic

The design criteria for a hypolimnetic aeration system must consider physical lake characteristics of Lake Desire and oxygen depletion rates. Relevant physical characteristics are shown in Table 1. The bathymetric contours are shown in Figure 1.

As shown in Figure 1, the lake bottom is separated into two basins divided by a slight rise. The maximum depth in the north basin is 6.5 meters and the maximum depth in the south basin is approximately 4.5 meters. The slight rise that separates the two basins is at a depth on 3.5 meters. This topographic feature raises concerns about the flow between the two basins. A major consideration in the design is, with a single aerator placed at the deepest point in the north basin, whether interbasin flow would be sufficient to aerate the south basin.

Our opinion is based on experience from observing the diffusion of oxygen in other hypolimnetic aeration systems, that there will not be sufficient interbasin flow to aerate the south basin. Furthermore, if additional mixing energy is added to the system to create interbasin flow, the potential for destratifying the lake increases. The rise between the basins is at a depth of approximately 3.5 meters. As the thermocline depth varies from 2 to 4 meters, and creating flow across the rise between the basins may disturb the thermocline. It is recommended that an aerator be placed in each basin. The aerators would be located in the central portion, at the deepest point, in both north and south basins. Figure 1 shows the proposed locations for the two aerators.

The hypolimnetic volume (i.e., the area below 3 meters depth) of the north basin is 162,000 m^3. The hypolimnetic volume of the south basin is 124,000 cubic meters. The aerators can be the same size and have sufficient aeration capacity to meet the design goal of 2 mg O2/L. Although the basins have different volumes, the hypolimnetic areas of the two basins are roughly equal.

TABLE 1
LAKE DESIRE PHYSICAL CHARACTERISTICS

Lake volume	1,147,155 m^3
Hypolimnetic volume	290,430 m^3
Surface area	287,328 m^2
Mean depth	4 m
Maximum depth	6.5 m
Thermocline depth	2-4 m
Watershed area	335 hectares

The maximum depth in the south basin is approximately 4.5 meters. The air and water flows through the south basin aerator must be limited to reduce the possibility of destratifying this portion of the lake. It may be advisable to install a control structure to maintain lake levels during the summer months.

Oxygen Depletion Rate

Figures 2 and 3 show the temperature and dissolved oxygen profiles for Lake Desire from data collected in 1993 and 1994. These data indicate that the dissolved oxygen levels drop to less than 2 milligrams per liter (mg/L) from May through September. This oxygen level is too low to support most animal life. The hypolimnetic aeration system is designed to provide enough oxygen to the lake to keep oxygen levels above 2 mg/L. Higher oxygen levels will minimize the internal cycling of phosphorus. The hypolimnetic volume was estimated to be 290,430 m^3 based on temperature and oxygen data. The estimate of the maximum oxygen depletion rate was based on the oxygen data. During the period of peak oxygen demand the oxygen level dropped 3.0 mg/L in 14 days. This corresponds to an oxygen depletion rate of 0.214 mg O_2 per day per liter. Taken over the entire hypolimnetic volume this results in an oxygen demand of 62.2 kilograms O_2 per day. Due to the limited data on which this estimate is based, it is prudent to add a safety factor when sizing the aerator. The aerators will be sized to provide a total of 100 kilograms O_2 per day.

ALTERNATIVES ANALYSIS

There are two general types of hypolimnetic aerators, a full lift aerator and a partial lift aerator. In a full lift aerator (Figure 4) air is injected into the riser tube which lifts the water to the lake surface and oxygenates it before the water is degassed and returned to the hypolimnion. A partial lift aerator (Figure 5) operates much like the full lift aerator except that the water is degassed in a chamber beneath the water surface before it returns to the hypolimnion. The relative shallow depth and the design constraints, in terms of vertical depth required, favors the full lift system over the partial lift system.

The potential concerns regarding the shallow depth include:

- Increased hypolimnetic turbidity due to disruption of the bottom sediments
- Hypolimnetic warming resulting in destratification
- Increase in the hypolimnetic volume which can lead to destratification
- Increased water movement caused by the aerator which may lead to destratification.

Several elements can be incorporated into the design to prevent these effects from occurring. The elements include positioning the aerators at the deepest portion of each basin; splitting and directing the outlet flow parallel to the lake bottom; and installing insulating foam on the inlet and outlet tubes to minimize heat transfer to the hypolimnion, to use a conservatively large volume for the hypolimnion volume in sizing calculations and to incorporate turn down capability in the air supply system.

Aeration System Sizing

The basis for design of a full lift aerator is taken from from a paper by Ken Ashley titled *Oxygen Transfer in Full Lift Hypolimnetic Aeration Systems (1990)*. The paper describes the design of a full lift aeration system for St. Mary Lake in British Columbia, Canada. The air flow requirements for St. Mary Lake were calculated to be 200 standard cubic feet per minute (scfm). Results from the Ashley paper indicated that oxygen transfer rates achieved at St. Mary Lake ranged from 23 to 30 percent and averaged 27 percent using fine bubble diffusers with a pore size of 140 microns. The oxygen transfer rate assumed for the Lake Desire aerator will be 20 percent because the shallow depth of the air diffuser placement will reduce the oxygen transfer efficiency.

Air Flow Calculation

The following calculations determine the required air flow to transfer 100 kg of oxygen per day to the lake.

Total oxygen required	100 kg O_2 / 20 % = 500 kg O_2/day
Oxygen content of air	0.189 kg O_2 / kg air
Weight of air required	[500 kg O_2 / day] / [0.189 kg O_2 / kg air] = 2,646 kg air / day
Volume of air required	[2,646 kg air /day] / [0.0367 kg air / cf] = 72,085 cf/day
Air flow rate	[72,085 cf / day] / [1,440 min/day] ≐ 50 cfm

The total air flow rate required is 50 cubic feet per minute (cfm), or 23.6 liters per second. Normally air flow will be split equally between the two aerators. The piping will be arranged so that the air flow rate to the two aerators can be adjusted.

Water Flow Rate Calculation

The water flow rate can be determined by using an empirical equation developed in a paper by Taggart and McQueen, *A Model for Design of Hypolimnetic Aerators* (1982). The equation is based on the air flow rate, height of water in the riser tube, and riser diameter. The equation is as follows:

$$Ql = 5.14(L)^{0.698}(Qg)^{0.459}(5.75)^{D/2}$$

where Ql is the water flow in liters per second (L/s), L is the height of the riser tube in meters (m), Qg is the air flow rate (L/s) and D is the diameter (m). The height of the riser tube is assumed to be 6.5 meters. The air flow rate, Qg, is 11.8 L/s. The riser tube diameter will be assumed to be 1 meter.

The calculated water flow rate for Lake Desire is 139 L/s (12,020 m^3/day). The hypolimnetic volume of the north basin of 162,000 cubic meters will be turned over approximately every 14 days. The hypolimnetic volume of the south basin of 124,000 cubic meters will be turned over approximately every 10 days.

The equation predicts a water velocity of 0.6 feet per second (fps) in the 1-meter diameter riser tube. This is substantially lower than the 2.3 to 3.3 fps observed at St. Mary Lake. The observed water-to-air flow ratio for St. Mary Lake was 15:1. Although the equation predicts a water-to-air flow ratio of 11:1 for Lake Desire, the potential exists for the water flow to be greater than the predictions. While a higher water flow would improve transfer of oxygen to the hypolimnion, it could cause destratification. Therefore, we recommend that the aeration system have the capability to turn down air flows, especially during the spring when thermal stratification is not as well developed.

Preliminary Design

Figure 6 shows the proposed full lift aerators for Lake Desire. The aerator box and riser tubes will be constructed of fiberglass reinforced plastic (FRP). The top of the aerator box will be covered with aluminum grating. The in-lake portion of the air supply pipeline will be 3-inch diameter high density polyethylene (HDPE). The piping will switch to schedule 40 aluminum in the aerator. The aluminum air piping will be fitted with a circular air header that will hold the porous diffusers. The air header and diffuser assembly will be constructed so that the entire piece can be removed from the surface of the aerator box. The aerator box will be approximately 15 feet by 6 feet; approximately 3 feet will show above the water surface.

If the mixing energy produced by adding 25 scfm to the aerator in each basin is too great, the lake system may become destratified. A way of reducing mixing energy is to reduce the water flow through the aerator by reducing air flow. The problem with this approach is that the reduced air and water flow may not provide sufficient oxygen to the lake to prevent anaerobic conditions in the hypolimnion.

Oxygen Delivery

The amount of oxygen that can be delivered at lower flows can be improved by utilizing a pure oxygen supply to supplement the air stream to the hypolimnetic aerator. Pure oxygen (90%) can be generated through a process called pressure swing adsorption (PSA). PSA systems are being used at Newman Lake in eastern Washington to provide aeration and at Lake Fenwick in Kent to supplement aeration capacity. The predesign air flow rate of 25 scfm per aerator is equivalent to 581 pounds of oxygen per day with the normal ambient 20 percent oxygen content in air. The air flow rates could be reduced when using pure oxygen to address the problem of adding too much mixing energy to the hypolimnion. The gas flow rate can be reduced to 15.5 scfm (1.3 scfm 90% oxygen and 19.1 scfm air) to deliver the equivalent amount of oxygen as the predesign system using 25 scfm of air. This method represents a 22 percent reduction in the air flow.

In addition to being able to deliver the same amount of oxygen at a lower flow rate, the PSA systems would deliver gas with a higher concentration of oxygen. When mixing high purity oxygen and air, the resulting gas has a higher percentage of oxygen which enhances oxygen transfer. Assuming 1.3 scfm 90% oxygen and 19.1 scfm air the resulting gas would have an oxygen content of 25 percent rather than the atmospheric concentration of 20 percent.

Henry's Law states that the saturation pressure of a gas in solution, in this case oxygen, is equal to the partial pressure times the coefficient of absorption (a constant at given pressure and temperature). The partial pressure of oxygen in the air flow is directly proportional to the percentage of oxygen in the air/oxygen mixture. In the example sited above where the oxygen concentration is increased from 20 to 25 percent, the partial pressure of oxygen increases by 32 percent. The saturation concentration (Cs) of oxygen in solution at typical hypolimnetic conditions (5 degrees C) is 12.8 mg/L. At 25 percent oxygen the Cs is raised to 15.6 mg/l. The driving force for oxygen transfer is equal to the difference between the Cs and the concentration in the hypolimnion.

Water flow through the aerator is proportional to the gas flow through inlet tube. At reduced gas flow rates, the water flow through the aerator will decrease. In the example with 15.5 scfm, the water flow through the aerator would be reduced to approximately three fourths of the water flow rate when 20 scfm of air is delivered. However the driving oxygen gradient has been increased by 50 percent. The net increase in oxygen transfer to the hypolimnion is 13 percent at the reduced flow rate based on three fourths of the water flow times 150 percent increased oxygen transfer.

Pure oxygen could be added to the compressed air flow so that the total output of the system would equal 40 scfm during periods of high hypolimnetic oxygen demand. The air and oxygen system would deliver 512 pounds of oxygen per day, or 28 percent more oxygen than the system proposed without the pure oxygen system.

Compressor Requirements

Typically, aeration systems include two air compressors, each capable of supplying the total air flow required. The Lake Desire would require two 10 horsepower (hp) compressors, one for each aerator, and one standby compressor. The standby compressor would act as back-up or would be used to augment the air flow during periods of high hypolimnetic oxygen demand. If installed, the PSA system would require a compressor that operated continuously in addition to the compressors that provide air flow to the hypolimnetic aerator; therefore, the energy use with the PSA system would be higher. A single PSA system could supply oxygen to both aerators. The air system piping can be arranged so that if the hypolimnetic aerator compressor fails the PSA compressor can be used, without producing pure oxygen, to operate the aerator. As the backup compressor could power the PSA system as well, a total of three compressors would be required for the proposed Lake Desire system.

Costs

The cost of installing a PSA oxygen generation system (Table 2) represents a significant investment in terms of the overall project cost.

The additional annual O&M costs associated with operating the oxygen system compressor on a continuous basis is approximately $3,000 per year. Maintenance costs of the oxygen generation equipment includes changing the oil and filters in the system and maintaining coolant levels in the air dryer. The total O&M cost for the complete aeration system is $17,500.

TABLE 2
PRESSURE SWING ADSORPTION SYSTEM COSTS
AIRSEP MODEL AS-160

ITEM	DESCRIPTION	COST
AS-160 Oxygen Generator	2.67 scfm PSA oxygen generator	$7,800
Air Receiver	120 gallon	700
Refrigerated Air Dryer	32 scfm @ 50 F	1,050
Oxygen Surge Tank	80 gallon	500
Oil Filters	Coalescing oil removal	220
Mercoid Switch	Float switch for auto shut down	330
Auto Drains		480
Additional Piping		1,600
Subtotal		$12,560
Installation	60% of Material Cost	7,540
Total		**$20,100**

The construction budget is shown in Table 3. The construction cost estimate does not include engineering, administrative, legal or land acquisition costs. The cost estimate was based on the following assumptions:

- A building site can be found within 500 feet of the lake shore.
- The building site will be centrally located between the north and south basins.
- The building is constructed of concrete and is partially buried.
- No easements are required for the pipeline right-of-way.
- Three-phase electrical power is located with 100 feet of the building site.
- There are no special drainage, soils conditions or landscaping requirements.

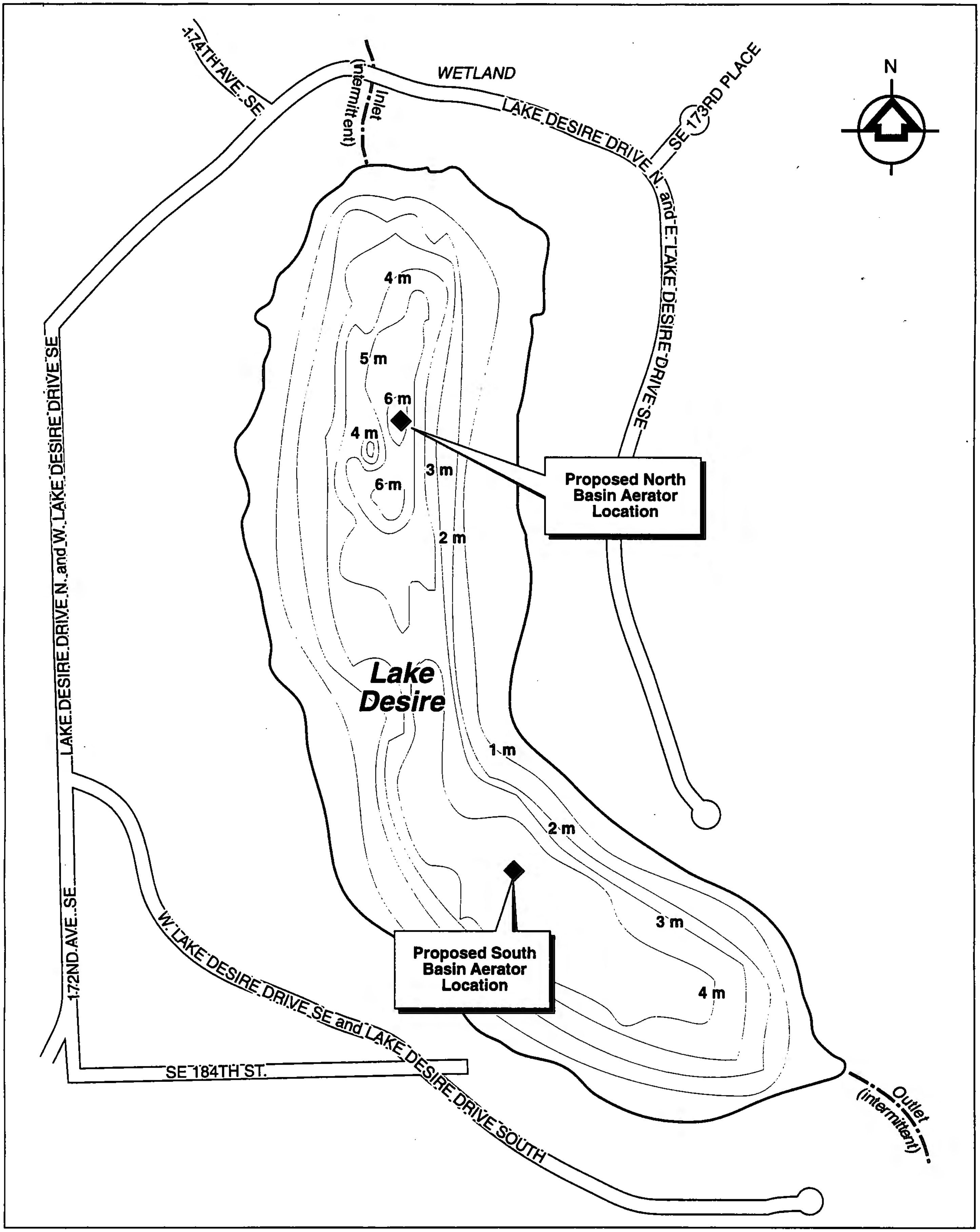
Engineering design and construction services for this project are estimated to be $100,000. The engineering design fees are based on the aeration system recommended by this report. Construction services include bid proposal evaluation and recommendations, attendance at weekly construction meetings, submittal reviews, and pay estimate review.

KCM recommends that the County include a PSA system in the project design for the following reasons:

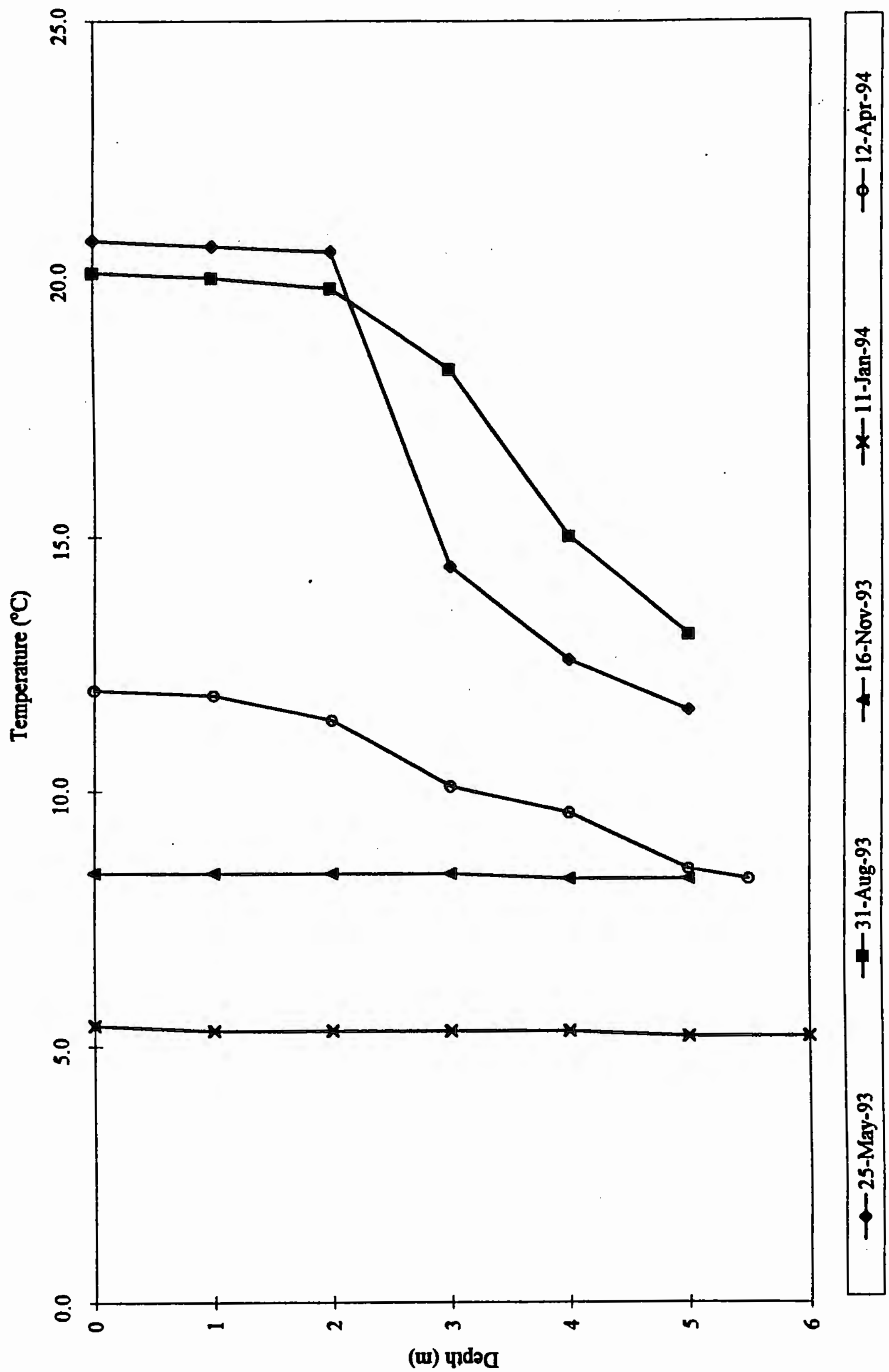
- It is able to transfer an equivalent amount of oxygen to the hypolimnion at a flow rate of 75 percent of the predesign system.
- It has the same general compressor requirements as the predesign system which allows the County to maintain redundant capacity in case one compressor fails.
- It provides a means of reducing mixing intensity in the hypolimnion during periods of weak stratification.

TABLE 3
HYPOLIMNETIC AERATION SYSTEM
PRELIMINARY CONSTRUCTION COST ESTIMATE

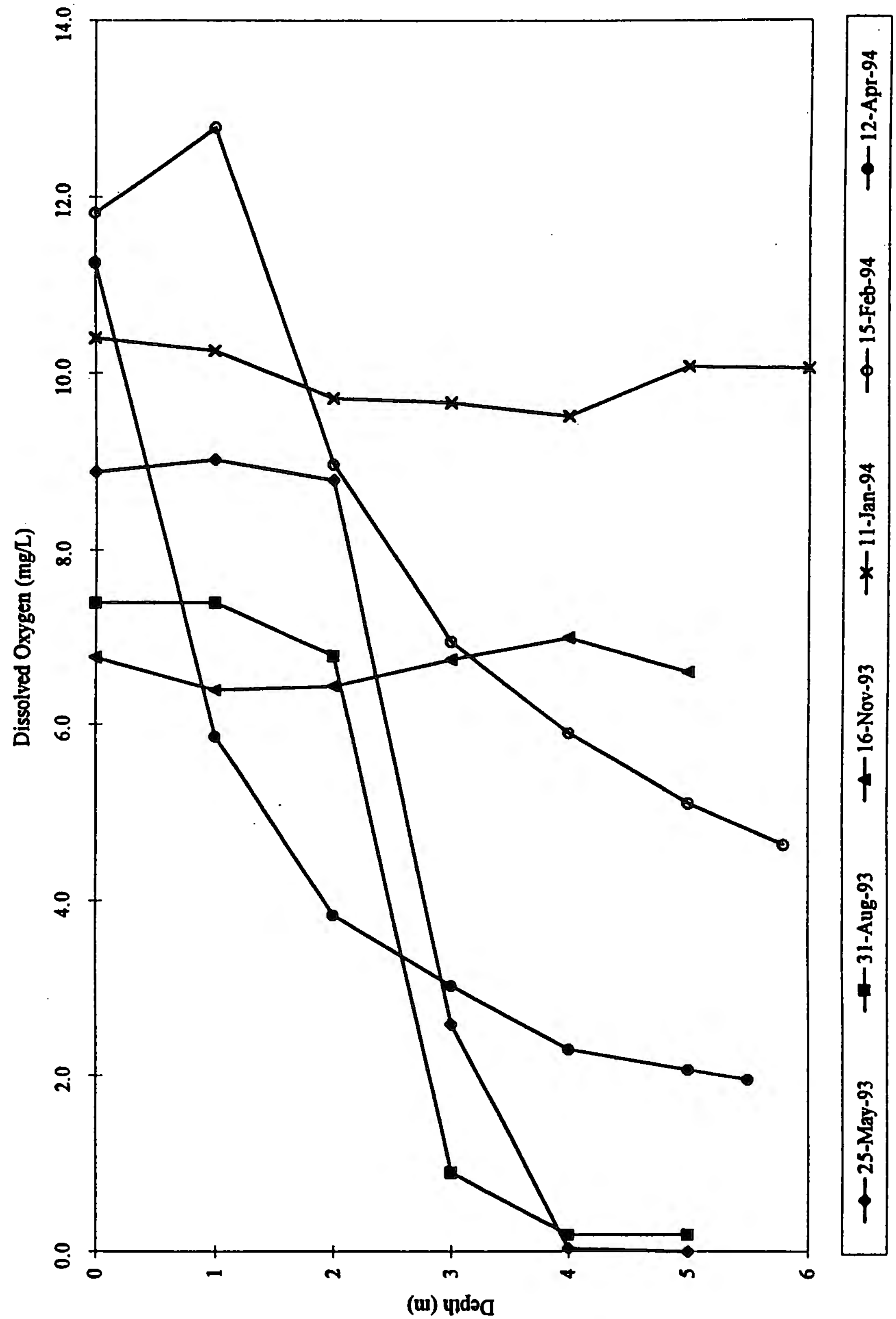
ITEM	APPROXIMATE AMOUNT	COST
Excavation, haul and disposal	120 cubic yards	$1,500
Foundation Material	50 cubic yards	1,000
Building	Lump Sum	65,000
Rotary Screw Compressor system	Three 10 hp compressors and piping	36,000
PSA Oxygen System	Lump Sum	20,100
Acoustical board	Lump Sum	500
Electrical	Lump Sum	8,000
Heating and Air Conditioning	Lump Sum	2,500
Final grading and landscaping	Lump Sum	3,000
3" dia. pipeline	500 lineal feet	6,500
3" Butterfly Valve	two	1,000
3" dia. Air Hose	2,400 lineal feet	15,000
Anchors	Lump Sum	1,000
Diffusers and piping	Lump Sum	8,000
Inlet and outlet FRP pipes	Lump Sum	8,000
Separator box	Lump Sum	80,000
Security fencing	Lump Sum	2,0000
Warning signs	Lump Sum	600
Subtotal		$259,700
Contingency (20%)		51,940
Subtotal		$311,640
Washington State Sales Tax		25,560
Total		**$337,200**



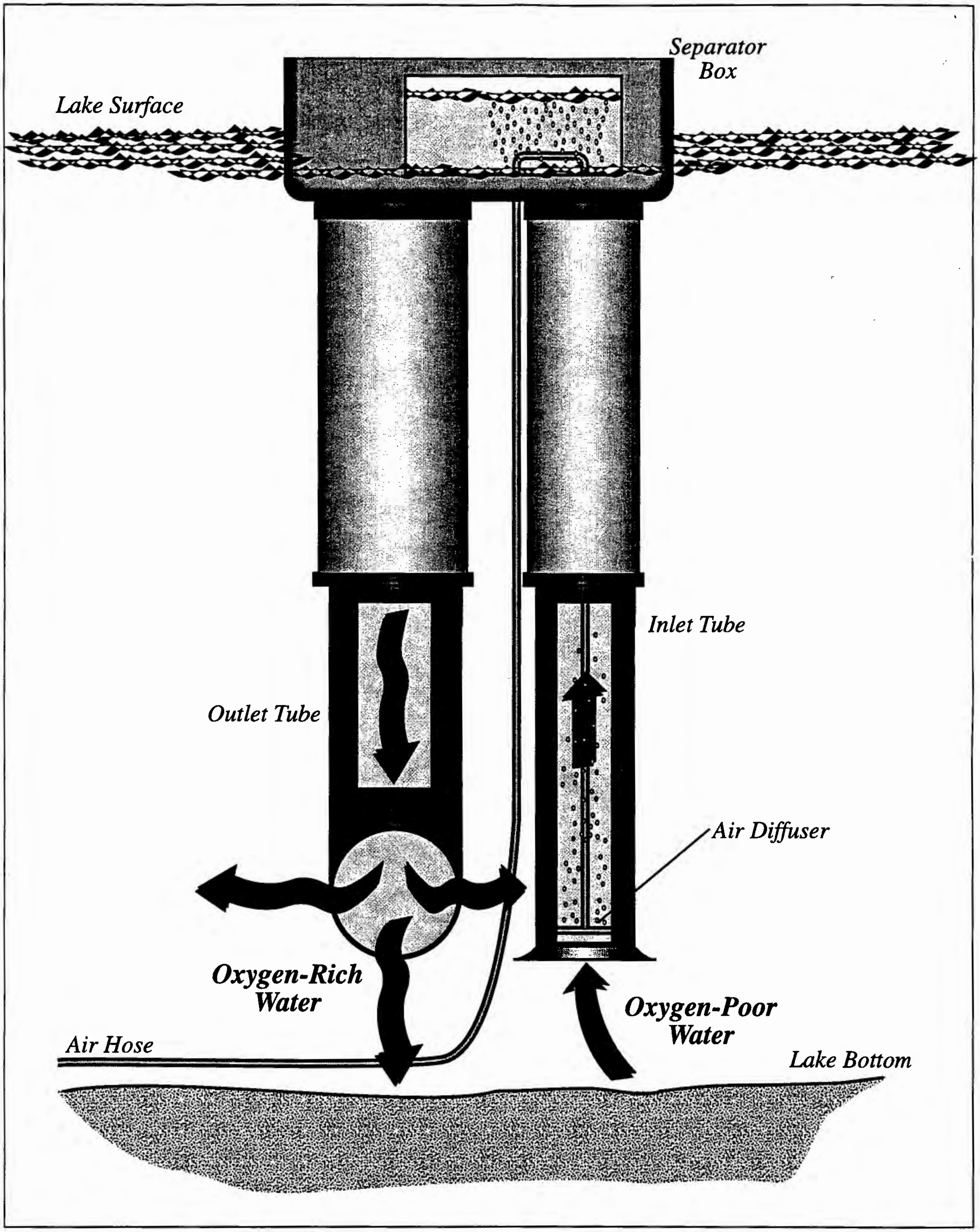
KCM 1917 First Avenue Seattle, Washington 98101	King County Surface Water Management LAKE DESIRE HYPOLIMNETIC AERATOR ENGINEERING ANALYSIS	Figure 1. BATHYMETRIC CONTOURS AND PROPOSED AERATOR LOCATIONS



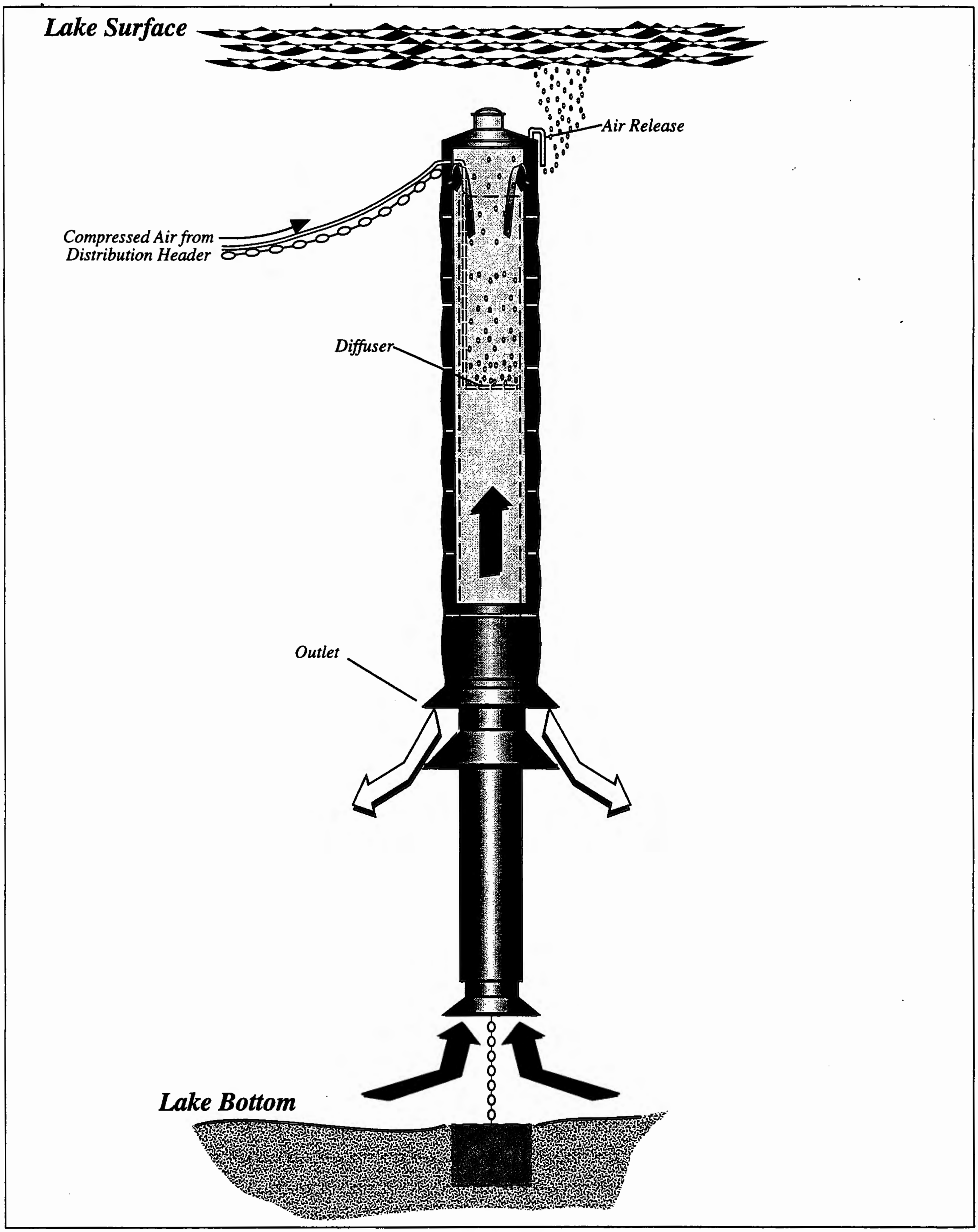
KCM *1917 First Avenue* *Seattle, Washington 98101*	King County Surface Water Management LAKE DESIRE HYPOLIMNETIC AERATOR ENGINEERING ANALYSIS	Figure 2. TEMPERATURE PROFILES



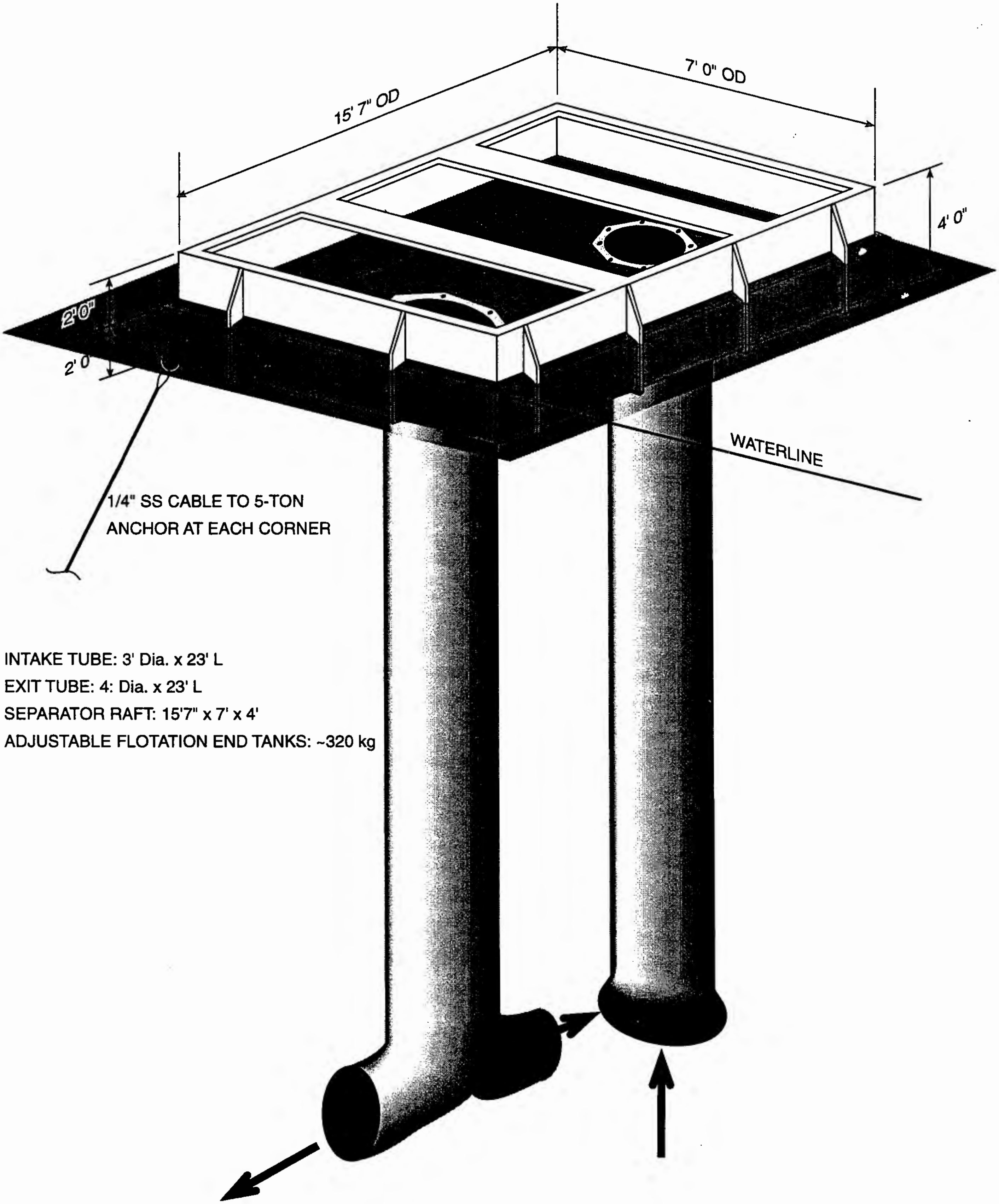
KCM *1917 First Avenue* *Seattle, Washington 98101*	King County Surface Water Management LAKE DESIRE HYPOLIMNETIC AERATOR ENGINEERING ANALYSIS	Figure 3. DISSOLVED OXYGEN PROFILES



KCM 1917 First Avenue Seattle, Washington 98101	King County Surface Water Management LAKE DESIRE HYPOLIMNETIC AERATOR ENGINEERING ANALYSIS	Figure 4. FULL-LIFT HYPOLIMNETIC AERATOR



KCM 1917 First Avenue Seattle, Washington 98101	King County Surface Water Management LAKE DESIRE HYPOLIMNETIC AERATOR ENGINEERING ANALYSIS	Figure 5. PARTIAL-LIFT HYPOLIMNETIC AERATOR



KCM *1917 First Avenue* *Seattle, Washington 98101*	King County Surface Water Management LAKE DESIRE HYPOLIMNETIC AERATOR ENGINEERING ANALYSIS	Figure 6. PROPOSED LAKE DESIRE HYPOLIMNETIC AERATOR

G. Public Comment Letters and Responses

King County Department of Public Works

King County Surface Water Management

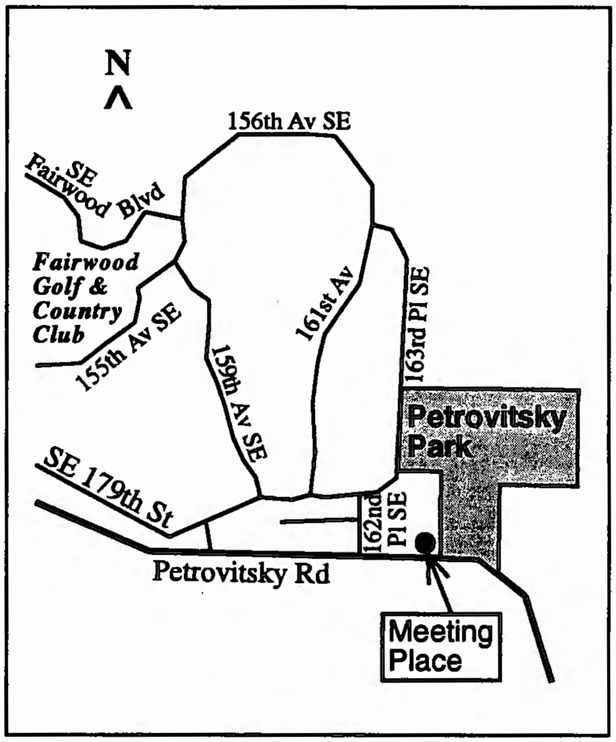
Everyone lives downstream

Public Meeting

The King County Surface Water Management Division (SWM) invites you to a Public Meeting on the draft Lake Desire Management Plan. Come share your comments regarding Lake Desire.

Date: Wednesday, February 15, 1995
7:00 PM - 9:00 PM

Location: Ridgewood Elementary School Library
18030 - 162nd Pl. SE
Renton



Purpose of the Project: The overall goal of the project is to develop a long-term lake and watershed management plan which will improve the water quality of Lake Desire. The project began in 1993 with a detailed one-year study of the physical, chemical, and biological components of the lake and watershed. With input from the community, eight lake and watershed management goals were set. The draft plan developed from these goals contains 14 recommendations which address watershed and in-lake water quality, aquatic plant control, monitoring, and contingency actions.

Status of the Project: King County SWM is seeking public comment on the draft Lake Desire Management Plan. Comments may be presented at the public meeting or submitted in writing to:

Sharon Walton, Project Manager
King County Dept. of Public Works
Surface Water Management Division
700 Fifth Avenue, Suite 2200
Seattle, WA 98104

The public meeting will be an opportunity to learn more about the plan and the proposed actions for restoring Lake Desire.

We hope you can join us.

For more information: Call Sharon Walton, Project Manager, at 296-8382. Copies of the plan are available through the Lake Desire Community Club and the King County Fairwood Branch Public Library.

Funded in part by a Washington State Department of Ecology Centennial Clean Water Fund grant.

Text will be made available in large print, Braille, or audio tape as requested.

King County
Department of Public Works

Surface Water Management Division
700 Fifth Avenue, Suite 2200
Seattle, WA 98104
(206) 296-6519

Lake Desire
Public Meeting
Wednesday, February 15th

Duplicate mailings? Change of address?

Call SWM at 296-6519 or send your label, with the correct address clearly marked, to:
King County Surface Water Management,
Attention: Front Desk/Reception
700 Fifth Avenue, Suite 2200
Seattle, WA 98104
Please allow 6 - 8 weeks for changes.

Flyer text can be made available in alternative formats. Sign language interpretation can be provided at events if requested in advance. Call to arrange accommodations. Voice: Pat Johnson 296-8029
TDD: King County Information 296-0100

King County
Surface Water Management Division
Department of Public Works
700 Fifth Avenue Suite 2200
Seattle, WA 98104
(206) 296-6519
(206) 296-0192 FAX

AGENDA

Lake Desire Management Plan

Public Meeting

Ridgewood Elementary
Renton, WA

February 15, 1995
7:00-9:00 p.m.

1.	Introductions	5 minutes
2.	Meeting Overview	5 minutes
3.	Lake Desire Management Plan -Sharon Walton, King Co. Surface Water Mgt.	40 minutes
4.	In-lake Restoration Techniques -Debra Bouchard, KCM Inc. -Harry Gibbons, KCM Inc.	15 minutes
5.	Comments, Question, and Answers	35 minutes
6.	Preferred Management Plan Alternative Selection	5 minutes
7.	Meeting Closing	5 minutes

Funded in Part through a Washington State Department of Ecology Centennial Clean Water Fund Grant

RECYCLED PAPER

King County
Surface Water Management Division
Department of Public Works
700 Fifth Avenue Suite 2200
Seattle, WA 98104
(206) 296-6519
(206) 296-0192 FAX

March 9, 1995

TO: Lake Desire Technical Advisory Committee Member

FR: Sharon Walton, Lake Desire Project Manager SPW

RE: Response to public comments on the Draft Lake Desire Management Plan

The lake management plan was presented to the public on February 15, 1995. Twenty members of the public were present and had general questions on the in-lake treatments, alum toxicity, the contribution of phosphorus from on-site septic systems, and funding of plan implementation. The public was asked to vote on their preferred restoration scenario. By a margin of 5:1, the public supported the combined in-lake treatments of alum and aeration verses aeration alone.

Written comments were due on the management plan this past March 3, 1995. Only a single comment letter was received on the plan. Enclosed you will find a copy of the comment letter as well as a response to the comment letter which will be enclosed in the final plan.

The degree to which on-site septic system contribute to the phosphorus loading to the lake has been repeatedly raised by the public as well as in the attached comment letter. To address this phosphorus loading issue, additional detail will be provided in the nutrient budget chapter regarding the project team's arrival at the final loading estimate from on-site septic systems which was used in the lake phosphorus model. The response to item 5 of the enclosed comment letter will give you an idea of the content of the text additions for the final plan.

If you have any questions regarding the comments received on the draft plan or how they will be incorporated into the final plan, please let me know by Thursday, March 16, 1995. My phone number is 296-8382.

Thanks again for all of your work on the project. You can expect to see your final copy of the plan in April.

cc: Bill Eckel, Manager, Water Quality Unit

Hedges & Roth Engineering, Inc.

ENGINEERS
PLANNERS
SURVEYORS
AM/FM/GIS

March 3, 1995

King County Surface Water Management Division
Department of Public Works
700 Fifth Avenue, Suite 2200
Seattle, Washington 98104

Attn: Ms. Sharon Walton, Lake Desire Project Manager

Re: Review of Draft Management Plan

Dear Ms. Walton,

Thank you for the opportunity to provide input on the Draft Management Plan for Lake Desire. Attached is a brief report which provides background for our positions. All of our recommendations are based upon the preliminary and draft Plans, background and technical reports, which you supplied to us.

(1) *We are disappointed that there has been no analysis regarding the use of freshwater dilution of the lake as an alternative for in-lake treatment.

(2) *As with the preliminary draft Plan, this draft Plan together with the supporting background and technical reports provide much support for the connection of the area to sewers. Please see report no. 8 and our review of this draft, which is enclosed, and our response to the preliminary draft report.

(3) *The final report should include a cost benefit analysis which includes figures for all of the watershed recommendations. Four of the seven watershed recommendations costs have not been projected. These hidden costs should be shown. In order for the community to better analyze the data we recommend that the cost benefit analysis clarify which measures are long-term (such as sewering) or short-term (such as alum treatment).

(4) *The special requirement increasing wetponds beyond the Surface Water Design Manual by a factor of 4.5 is unnecessary. Please keep in mind the SWDM uses AKART (all known, available, and reasonable methods of prevention, control and treatment) with VB/VR = 1 not 4.5. It is our understanding that only six ponds have been built using the 1990 standard, and that none of them are experiencing problems nor are they expected to. We respectfully suggest that prior to your encouragement of these extreme measures that your Division wait until a peer review and analysis is completed.

(5) -In reviewing the external nutrient budget, **septic systems account for more than 83%** of the P6, Subsurface loading. Your reports have been very clear that for the **long-term** benefits it is the external loading which needs to be resolved. Septics account for over 83% of the external loading and up to 48% of the total load for Lake Desire.

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-Over 16% of the on-site septic systems in the area have failed at some time.

(5) -Based upon the technical reports it is very likely that a majority of the existing septic systems may be reaching the end of their effective lives.

-Removing sewer effluent from flowing into the lake provides the greatest long-term benefit.

(6) *Although the area in question has a full service designation within the Urban Growth Area for King County, the vast majority of the lots have been previously built upon. A great amount a land is currently within King County's Park and or Open Space program. Further, it is our understanding that in addition to unrealistic land use scenarios, the model also assumes NO constraints are in place. To suggest that the requirements of the drainage manual or the Sensitive Areas Ordinance will not be followed further skews the results of the modeling. We feel that it is very misleading for the modeling to be based upon a land use scenario which we know WILL NOT occur. We suggest that the area be remodelled with realistic characteristics of the land and regulations upon the development of that land.

If there are questions regarding the above, please do not hesitate to contact me at 869-9448. We would like Surface Water Management and the Technical Advisory Committee to review and consider our recommendations for the final plan.

Very truly yours,

HEDGES & ROTH ENGINEERING, INC.
Bellevue Office

Helen E. Nilon

HEN:nh

attachments enclosed: Hedges & Roth review: Engineering Analysis

cc: Ron Speer, Operations Manager, Soos Creek Water & Sewer District
John Roth, Jr., District Engineer
Katherine Maxwell, MT, CR, Hedges & Roth Engineering
Lake Desire Management Plan Technical Advisory Committee

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& Roth Engineering, Inc.
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Lake Desire Management Plan

Comments on the
Draft, January 1995

Reviewed on behalf of Soos Creek Water and Sewer District.

Reviewed by: Mark A. Thompson, P.E.
Hedges & Roth Engineering, Inc.
14450 NE 29th PL Suite 101
Bellevue, WA 98007
(206) 869-9448

Objectives

The goals outlined by the Lake Desire Management Plan are proper and very acceptable. The plan's objective is to:

- Provide education and involvement opportunities for the public throughout the project to foster public ownership and commitment to the development and implementation of the lake management plan;
- Quantify and characterize the physical, chemical and biological components of the lake and its surrounding watershed;
- Develop a nutrient and water budget which can be used as an analytical tool for the evaluation of restoration alternatives and development of a lake management plan;
- Identify existing sources of point and non-point pollution to estimate their importance in determining the trophic condition of Lake Desire,; and
- Develop a comprehensive management plan for the improvement and protection of water quality in Lake Desire.

The study succeeded in these goals to a great degree. This review presents options to increase the measure of success of this study.

Septic Drain Field Loading

Lake Desire was found to be the third worst lake out of 16 lakes surveyed by Metro between 1972 and 1974. Only Cottage Lake and Lake Ballinger had poorer water quality. Although many factors enter into such a determination, phosphorus loading to the lake is a primary factor, contributing to low transparency and high algal biomass. (E.G. Welch, 1980, "The Ecological Effects of Wastewater") This generalization was specifically shown to be true in Lake Desire for most of the year, except November. (see Figure 4-6) The largest external contributor of phosphorus was found to be from subsurface flows into the lake. (Table 6-2)

Septic systems are the greatest producer of this phosphorus. The septic systems are contributing somewhere between 30 to 87 kg phosphorus (TP) annually to the lake. (page 6-6) The report is correct to provide both numbers showing the lower and upper end of an engineering estimate. The lower number assumes peak operating conditions, or 90 percent efficiency in removal. **Efficiency may not be this good because of the age of some of the septic systems and the poor soils in the drain fields. This is reflected in the higher number of 87kg phosphorus loading.**

Septic systems, then, are contributing 24 to 48 percent of the total phosphorus in Lake Desire. This includes the internal loading from the bottom of the lake which has built up over the years. (Table 6-2) After the proposed alum treatment, this bottom loading will be reduced by 90 percent. Then the septic systems will be providing between 35 and 61 percent of the loading; by far, the number one cause of pollution to Lake Desire.

This fact is unrefuted and the report admits that long-term benefits can only be realized by removing the external sources of pollution. However, the report references work done on the HSPF computer model showing little benefit from sewering. Unfortunately, we cannot say much in detail about this work, since the report does not state the parameters used in the model.

From an overall perspective, the results of the model are suspect. Logically, the effect of removing such a large fraction of nutrients <u>should</u> make a corresponding improvement in the quality of Lake Desire. If the HSPF computer model results do not show that improvement, then those results should be questioned.

Cost/Benefit Analysis

The cost for the Lake and Watershed Recommendations would be financed by property assessments to the 126 property owners of the proposed Lake Management District (LMD). The benefit to the LMD was estimated to be from 13 to 30 million dollars in estimated increases in shoreline property market value.

The cost of <u>four out of seven</u> watershed recommendations was <u>not</u> included in the final assessment figure. (Table 7-1) These implementation costs are to come from either mandatory development restrictions or <u>additional</u> assessments to the LMD. Development restrictions include open space retention and building set-backs and clearing limits for which the property owner is not compensated. Also, some wetland property owners will be approached for acquisition of open space in Recommendation LD-2. The cost of this recommendation is not included in the report and may be born by the LMD.

These hidden costs should be shown. From the standpoint of the property owner, they are very real, even though they are not up-front, construction costs. These assessment costs are required to be disclosed to potential buyers during the sale of property and combine to make it less valuable.

The report states "the cost of sewering versus the relative benefit produced in terms of improved lake water quality is small compared with the implementation of other watershed and in-lake measures." (pg. 7-9) The cost of four out of seven watershed recommendations was not included or implied to be zero. (Table 7-1) Without a complete cost estimate, there is no way to make this comparison. Such a comparison would be an important part of this report.

The report goes on to say "if sewering does occur, the short-term gains of phosphorus reduction may be offset by increased shoreline density and associated nonpoint pollutant loading." This is obviously a mistake. We raise two points about this. First, sanitary sewers and other watershed measures provide <u>long-term</u> benefits by removing the external sources of pollution. It is the in-lake measures that provide short-term gain. The second point is that if this report finds that limiting development is in the best interest of the lake, then zoning regulations, not sewer restrictions, are the best tool for doing this. Such intentions should be directed to the appropriate agency.

LD-4 Stormwater Treatment

Another development cost added by this plan is the increased requirement for stormwater treatment. It was interesting to note that this was recommended based on future modeled conditions even though current conditions show surface runoff to be the smallest source of lake nutrients, giving only 5 kg TP as compared to 30 - 87 kg for septic sewers. Implementation of this plan would increase the size of treatment ponds 4.5 times over the 1990 standard. One of the justifications made in adopting the 1990 standard was that it represented all known, available, and reasonable methods of prevention, control, and treatment (AKART). If it was reasonable at that time, how can increasing the standard by 4.5 be reasonable now? What is the rationale behind this number? We are concerned that there hasn't been enough time to evaluate the effectiveness of the current design standard, since very few systems have been built. It may be too soon to propose increasing it.

Treatment ponds are sized to contain the volume of rain from the mean annual 24 hour runoff. The given runoff coefficients of 0.9 and 0.25 seem to imply using the rational method. The currently accepted method is SBUH. Was it the intent of the report to change this?

Summary

Much media attention has been given lately to non-point source pollution and the public is being educated about this new danger. The message is that we are dealing with point sources of pollution that have a readily identifiable discharge points, but that there is another, newly identified enemy to our environment found in the runoff from our roads and lawns. This message has been so successfully administered to the point where we are now beginning to forget about point-source pollution, such as septic tank leachate.

This review has in mind the same goals as the Lake Desire Management Plan. Those goals include the identification of existing sources of pollution and utilizing all known and reasonable methods of prevention, control, and treatment. Sanitary sewer service would be an important part of the long-term solution for Lake Desire, as it has in other lakes around the country. It should be the first recommendation in this report.

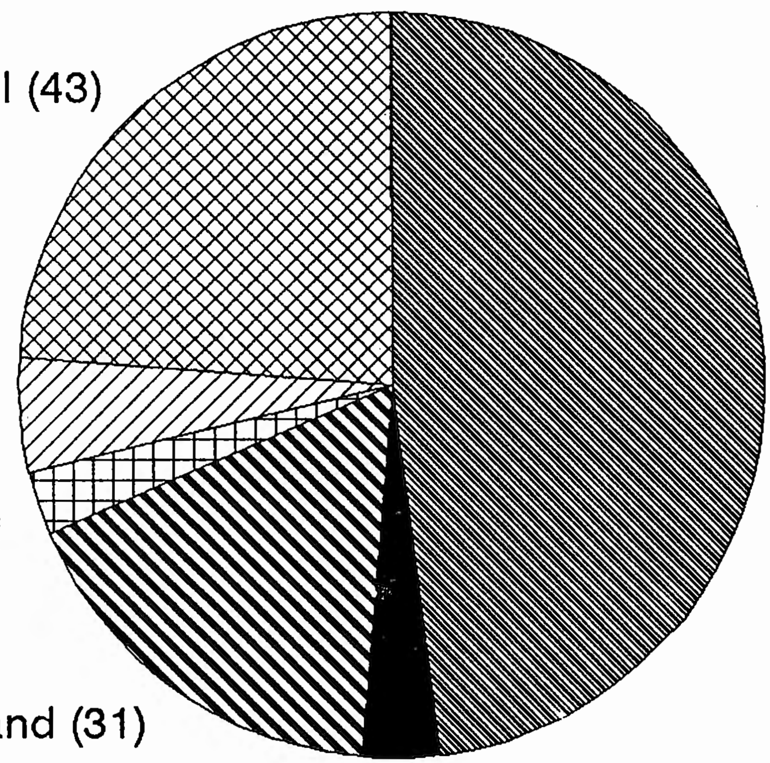
by: [signature]

Mark A. Thompson

Internal & External Phosphorus Loading

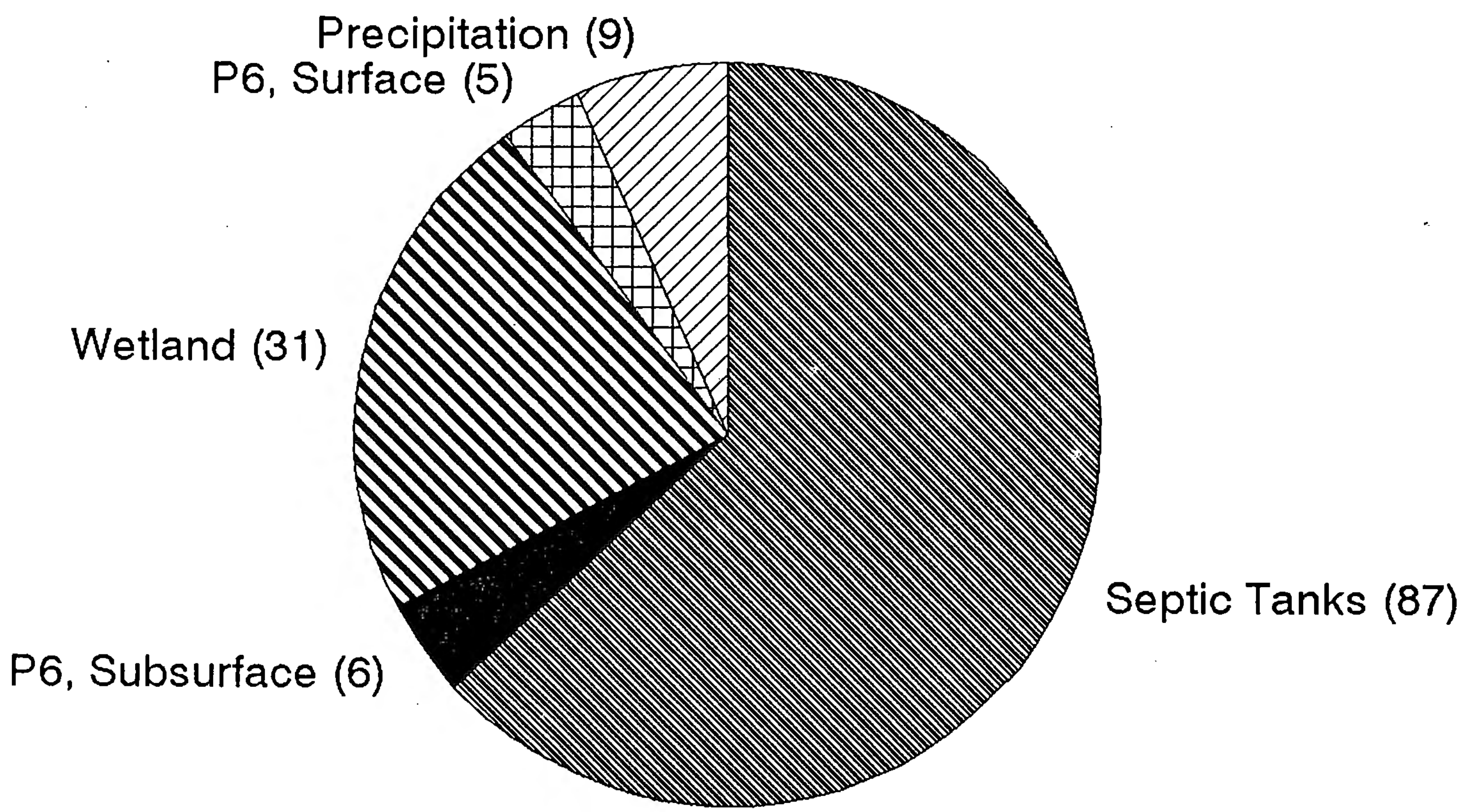
(Kg per year)

Table 6-2



External Phosphorus Loading
(Kg per year)

Table 6-2



DRAFT Response
Hedges and Roth Eng. Inc. Comments on Lake Desire
March 9, 1995

1. Dilution as an in-lake restoration alternative is usually feasible where large amounts of low-nutrient water is readily available. As stated in previous discussion with the Lake Desire Technical Advisory Committee and in both the preliminary draft and draft management, dilution was not considered a feasible alternative due to the lack of low-nutrient water supply. Water rights/permits for non-domestic uses are increasingly rare in the current climate of water conservation and the projected water supply needs predicted for the Puget Sound region.

In order for dilution to be successful, a flushing rate of 10 to 15 percent per day is typically needed annually (Cooke, Welch, Peterson, and Newroth, 1994). The lake volume for Lake Desire is 921 acre-feet which would suggest that 30 to 45 million gallons per day (mgd) would be needed to make dilution a feasible alternative. I spoke with Ron Spear, Operations Manager of the Soos Creek Water and Sewer District regarding the availability of water for dilution He confirmed that the water supply is not available from the District..

If the water was available, it would cost an estimated $48,000 per day including dechlorination of the water to provide 30 mgd to Lake Desire. To give you the order of magnitude of such a supply, the Soos Creek Water and Sewer District currently serves 50,000 customers at 3.5 mgd. The district would have to increase their current supply by a factor of eleven in order to meet the volume needed for effective dilution.

2. The management plan agrees that an incremental benefit to lake water quality is associated with sewers. Please see additional explanation under response 5.

3. The final report will not include costs associated with watershed recommendations which are not proposed to be funded through the implementation strategy detailed in Chapter 7 of the plan. The intent of structuring the management plan costs as shown in Chapter 7 is to distinguish the actions which are proposed to be implemented through private and/or grant funding. Recommendations LD-3, LD-6, LD-8, LD-9, LD-10, LD-11, LD-13, and LD-14, are proposed to be funded through a combination of lake management district (LMD) revenues, private sector funding, and grant. The cost benefit analysis was performed to show the benefits which could be directly attributed to the funding of these specific actions versus the cost of funding them through an instrument such as a LMD.

In the attached comments submitted by Mark Thompson, he states that the hidden costs should be shown. For recommendations LD-1 for forest retention, there is no additional cost to property owners associated. The costs associated with LD-2, wetland restoration, are anticipated to come from existing programs and do not represent a new cost to watershed property owners. Similarly, costs associated with recommendation LD-4, stormwater treatment, are not new costs because of the existing p-suffix conditions in the Lake Desire watershed which require additional stormwater quality treatment. The recommendation is intended to clarify what is needed to meet the intent of the p-suffix condition.

Sewering costs were not included in the cost/benefit analysis because the project team determined that sewering was not an essential watershed measure for meeting the lake and watershed management goals (Table 6-5). The project team has determined that in-lake aeration combined with watershed best management practices and forest retention represent the most cost effective solution to improving in-lake water quality. If sewering costs where to be include (at an estimated cost of two million dollars), the costs would be much greater than the proposed benefits to lake water quality.

4. The King County Surface Water Design Manual is currently being updated for 1996 to be consistent with the requirements of the Washington State Department of Ecology's Stormwater Manual. If you are interested in participating in its review please contact Amanda Oliveira at 296-1912.

In your comments you stated that a VB/VR (volume of basin permanent pool to volume of runoff from the mean annual storm) 4.5 is unnecessary. Substantial research has gone into the 1996 Design Manual update including the new sizing recommendations for wetponds and the anticipated phosphorus removal expected with such designs. It is estimated that a VB/VR ratio of 3.0 provides a total suspended solids removal of 80 percent and a total phosphorus removal efficiency of 35 percent. In order to achieve a 50 percent removal efficiency for total phosphorus, a VB/VR of 4.5 is recommended. Removal of 50 percent of total phosphorus inputs to sensitive lakes is proposed in the design manual update and is supported by the State manual requirements for mitigation of water quality sensitive areas (minimum requirement #7)

The 1990 Surface Water Design Manual does not require all known, available, and reasonable methods of prevention, control, and treatment (AKART) for phosphorus control for the Lake Desire watershed and represents the base stormwater standards for King County. AKART standards are currently required by a variety of p-suffix in various sensitive watersheds such as Lake Desire. The Soos Creek Community Plan Update (1991) p-suffix condition for the Lake Desire Urban Phase 1 states:

> "Properties in the Lake Desire Drainage Basin shall meet all water quality and quantity requirements as outlined by the King County Surface Water Management Division. These requirements must be in compliance with the State Growth Management Act. Special attention should be given to increased retention/detention requirements and clearing restrictions on undeveloped parcels *and stormwater treatments which will ensure that the quality of discharge waters shall be equal to or better then current Lake Desire Water Quality* [emphasis added]."

Most facilities built using the 1990 design manual have been built for water quantity control. Those which have been built based on the 1990 design manual for water quality control certainly do not meet the definition of AKART due to their minimal effectiveness for phosphorus control. Thus, the existing requirements of the design manual do not begin to meet the intention of the p-suffix condition and so recommendation LD-4 was developed as part of the lake management plan to establish an appropriate treatment standard.

5. For the management plan, on-site septic systems at Lake Desire were evaluated based on variety of sources including: 1) groundwater monitoring data; 2) review of the Seattle-King County Department of Public Health records; 3) the use of Aerial Shoreline Analysis and field surveys; and 4) the preliminary nutrient budget.

Based on the existing nutrient budget (Table 6-2), septic systems account for as much as 30 kg per year of phosphorus or 24 percent of the total nutrient budget, 37 percent of the external loading, and 83 percent of the P6 subsurface loading. The reasoning behind using the 30 kg per year estimate verses the 87 kg per year estimate is as follows:

> From the Lake Desire On-site Septic System Assessment, it was calculated that between 30 and 87 kg per year of total phosphorus could be attributed to on-site septic systems. This estimate was based on the average amount of phosphorus discharged in household wastewater (based on literature values) and a series of assumptions regarding the efficiency of the 101 septic systems along the lake shoreline. If a 90 percent efficiency is assumed on average, the loading estimate is as low as 30 kg per year. If a series of less conservative efficiencies are assumed, the loading estimate is as high as 87 kg per year.
>
> In the groundwater analysis, it was estimated that approximately 15 percent of the total phosphorus entering the lake and 25 percent of the flow was from subsurface flow. This estimate was based on quarterly measured flow and water quality data and the hydrostratigraphy of the area.
>
> The lake model based on the Vollenweider (1975) non-steady-state model (which predicts whole-lake total phosphorus concentrations), integrates the information from the individual hydraulic phosphorus loading components (subsurface flows, surface, and precipitation sources) and internal phosphorus loading. This lake model is the standard in the field of limnology. Hydrologic Simulation Program-Fortran (HSPF) modeling was used only to generate existing, current, and future flows for developing the lake water budget.
>
> The lake model is based on a mass-balance of total phosphorus using the measured data from the study year, literature values, and professional estimates where data gaps exist or are difficult to accurately measure. As with most

modeling applications, certain components are more easily measured and assessed. In lakes, inflow, internal loading, precipitation, and surface runoff are the easiest to measure and predict, while groundwater and subsurface flows remain more difficult.

As a check on the assumptions used to in the modeling analysis, the nutrient budget must balance on an annual cycle and modeled values should closely match measured values for existing conditions. Figure 6-3 represents the modeled versus the measured values for whole-lake volume weighted total phosphorus concentrations. From month to month, there generally is a good correlation between measured and modeled concentrations.

This model calibration suggests that the assumptions upon which the model is based regarding its individual components (subsurface, internal, surface, and precipitation) are providing a good estimate of the interrelationship between the components. The lack of specific evidence regarding ongoing failure of on-site septic systems confirmed the project team's choice to use the lower end of the loading range or 30 kg per year for on-site septic systems in the model. If additional information had come to light from the on-site septic system survey work or groundwater analysis or in the model calibration which suggested a higher contribution was appropriate (greater than 30 kg per year), the nutrient budget and the corresponding lake model would have been adjusted to better represent the available information.

The 16 percent on site septic system "failure rate" discussed in the plan (pg. 4-38) correctly represents a "repair rate" recorded by the Seattle-King County Department of Public Health. For the final plan, the nomenclature will be corrected. The repair rate may include such activities as upgrading of the septic system based on the addition of rooms to a home or physical repair of the system due to failure. The rate does not provide any quantitative information regarding total phosphorus loading from on-site septic systems.

The age of septic systems was identified as a concern of the management plan. With the designation of the area immediately around the lake as a full services area with the Urban Growth Area , sewers are already proposed for portions of the lake. In all likelihood most of the shoreline will probably become sewered in the future, making the age of the on-site systems a moot point.

A loading reduction benefit to the lake would be realized if sewer effluent was removed. However, the project team still supports the conclusion based on the modeling analysis that only a small incremental benefit would be realized through sewering and that subsequent improvement to water quality will only occur with in-lake treatment. Long-term maintenance of improved water quality from in-lake measures, however, will only be realized through the successful implementation of watershed measures in combination with ongoing operation and maintenance of the in-lake aeration system.

6. The future land use, modeled for the management plan, takes into account the best available information regarding future land use in the lake watershed. The future land use model scenario did model the existing open and park spaces as it currently exists. Figure 2-7 which shows the future land cover which was used in the model and reflects the open and park spaces as forested land cover.

Although the unmitigated future land use scenario assumes no watershed mitigation measures, scenarios 7 and 8 in Table 6-5 represent two mitigated future conditions based on a best professional assessment of the future conditions/regulations present in the watershed including forest retention in the P7 catchment, stormwater regulations, and sewering (scenario 7 only). Additional text can be added to the modeling discussion to reflect that modeling of a realistic scenario has been performed as part of the modeling analysis.

King County
Surface Water Management Division
Department of Public Works
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April 11, 1995

Leslie J. Groce
Environmental Planner
Fisheries Department
Muckleshoot Indian Tribe
39015 - 172nd Avenue Southeast
Auburn, WA 98092

Dear Ms. Groce:

Thank you for your comment letter dated March 23, 1995, regarding your review of the *Lake Desire Management Plan* and Environmental Checklist. As stated in our phone conversation of April 11, 1995, I would like to apologize for my oversight in not directly involving the Muckleshoot Indian Tribe in the development of the *Lake Desire Management Plan*.

At the time of the development of the plan's technical advisory committee, the salmonid resource value of Lake Desire was considered low. Also, I was aware of the larger ongoing Surface Water Management Division's planning effort in the Cedar River basin (the *Cedar River Basin and Nonpoint Action Plan*) which includes the participation of Tribal fishery staff in the analysis of salmonid habitat in the Lake Desire Watershed and Peterson Creek subcatchment. In the future, as implementation of the *Lake Desire Management Plan* proceeds, the participation of the Muckleshoot Indian Tribe will be directly requested.

Per our phone conversation, you confirmed the receipt of the additional technical materials provided by my co-worker, Fran Solomon, during my absence. In our conversation, you also agreed that any impacts to salmonids or any additional information needed to assess potential impacts related to the proposed in-lake restoration actions of the plan could be addressed under separate SEPA compliance associated with those specific activities. Your concerns regarding impact to salmonids have been noted and will be addressed at the point prior to the implementation of in-lake restoration actions.

To provide clarification of what is know about salmonid usage (specifically coho) in Lake Desire, the limited information on coho salmonid usage originates from the work of Bob Pfeifer, Fisheries Biologist, Washington Department of Fish and Wildlife. The historical records of WDFW show spotty usage by salmonids coho juveniles in the lake. No salmonid usage was observed during the November 1993 and May 1994 fisheries assessment (conducted by the project's consultant, KCM Inc. [Wayne Daley, KCM Fisheries Biologist]) using electrofishing and fyke net traps.

Response to your specific comments on the plan are as follows:

Management Plan

p. 2-7 and p. 4-30: Salmon will be added to the checklist. Prior to implementation of any proposed in-lake restoration action, any potential salmonid impacts will be addressed.

p. 4-38: This point has been noted already, the text has been revised to reflect that 15.8 percent represents a repair/maintenance rate rather than purely a failure rate.

p.6-17: The reference has been provided. Additional concerns will be addressed at the time of implementation of in-lake actions.

p. 6-19: The three watershed measures examined included sewers, forest retention, and watershed best management practices. The text on page 6-19 will be clarified.

p. 6-20, Table 6-5: Both 7A and 8A represent existing watershed land use conditions while 7B and 8B where modeled based on future land use conditions. This was used to evaluate the significance of watershed measures alone, with and without sewers.

p. 6-22: Table 6-3 list the future loading values for the watershed. For the Peterson-7 subcatchment 58 kg total phosphorus are predicted based on future conditions. The predicted percent decrease in total phosphorus loading would be 51 percent for forest retention.

p. 7-1, LD-1: On page 7-3 and 7-4 the recommendation LD-1 is discussed including the voluntary retention of forest in the Peterson-6 subcatchment. More detailed land use recommendations for the Peterson Creek drainage area were provided in the *Cedar River Draft Basin and Nonpoint Action Plan.*

p. 7-9, LD-7 Sewering: The benefits of sewering remain low due to the timing and overriding effect of internal loading on summer total phosphorus concentration in the lake under existing and unmitigated future conditions. The loading from subsurface flows (partially from septics) occurs year-round while internal loading predominately occurs during May-August and thus, has a much larger impact on summer lake water quality.

p. 7-9, LD-8 Alum Treatment: Recommendation LD-13, page 7-11, and Table 7-2 detail the proposed monitoring program including the analysis of impacts to the lake fisheries. Benthic invertebrate sampling will be added to Table 7-2 for the final plan.

p. 7-11, LD-13 Monitoring: The Tribal Fisheries Department will be invited to participate in the final development of the monitoring program and its implementation prior to plan implementation.

Environmental Checklist

p. 10, 5a.
The underlining of salmon on the checklist was an omission which will be corrected. An addendum to the checklist will be issued which notes the historical use of coho salmonids in the lake.

Supplemental Sheet for nonproject actions.
The *Lake Desire Management Plan* itself is considered a non-project action. Therefore the supplemental sheet was completed.

Thanks again for you comments on the *Lake Desire Management Plan*. I look forward to working with you more closely in the implementation of the plan and in the restoration of Lake Desire water quality. A final copy of the plan will be forwarded to you in early May. Please call me if you have any additional questions, comments, or concerns at 296-8382.

Sincerely,

Sharon P. Walton

Sharon P. Walton
Senior Limnologist

SW:gmc7

cc: Bill Eckel, Manager, Water Quality Unit
Lake Desire Technical Advisory Committee
Keith Hinman, Manager, Basin Planning Unit
ATTN: Roz Glasser, Manager, Cedar River Basin and Nonpoint Pollution Action Plan
Gino Lucchetti, Senior Ecologist

MUCKLESHOOT INDIAN TRIBE

FISHERIES DEPARTMENT

March 23, 1995

Sharon Walton
Senior Limnologist
Lake Desire Project Manager
King County Surface Water Management Division
700 Fifth Avenue, Suite 2200
Seattle, Washington 98104

RE: Draft Lake Desire Management Plan Review

Dear Ms. Walton:

First, thank you for the extension for review of the Lake Desire Management Plan to March 24, 1995. This extension was necessary because neither Rod Malcom nor I received a copy of this Plan for review until March 17, 1995. The Usual and Accustomed fishing area (U&A) of the Muckleshoot Indian Tribe encompasses King County and portions of Snohomish and Pierce Counties. Within this area, the Tribe has co-management responsibility (with WDFW) for the salmonid fisheries resource, including the resource present in the Cedar River watershed, which drains Peterson Creek and Lake Desire. For this reason, it is unfortunate that the Fisheries Department of the Muckleshoot Tribe was not aware of, nor asked to participate in the Technical Advisory Committee that assisted in the development of the Lake Desire Management Plan.

As I explained to Fran Solomon, there are many questions regarding information presented in the Plan. Most could probably be clarified if you could provide a copy of the *Lake Desire Background and Technical Reports* (King County, 1994a), referenced throughout this document. Of particular interest are the fisheries surveys conducted in November 1993 and May 1994, groundwater monitoring methodology, and wetland monitoring methodology.

Though the presence of salmonids (specifically coho) in Lake Desire is referenced throughout the document, no concrete information regarding numbers, age class or times of use are presented. This information is critical, especially in light of the Plan's recommendation to treat the lake with alum. Does this information exist and/or are there plans to develop more information regarding salmonid use in the lake prior to alum treatment? This is of particular concern since salmon use is not indicated in the Environmental Checklist for this project (see below).

Muckleshoot Tribe fisheries staff would like the opportunity to review *Cooke et al 1993b*, which documents the impact of alum treatment of lakes on fish. Of particular concern is the impact of the flocculant in the water column on the gills of fish residing in the lake. Have other lakes that contain salmonids been treated with alum; what were the short- and long-term impacts of the treatment on the salmonid population? How does aeration affect the flocculant? Finally, since the flocculant settles to and seals the lake bottom, it seems unlikely that alum treatment has little impact to the macroinvertebrate population in the lake.

The cost of aerators for Lake Fenwick and Lake Stevens is referenced on p.6-18. Are there data available that show the improvements in these lakes as a result of aeration? Are the systems used in these lakes similar to the hypolimnetic aeration system proposed for Lake Desire? Lake Newman is also referenced; what is the fisheries population in this lake and how successful are the hypolimnetic aeration systems?

Attachment I also details concerns regarding the Environmental Checklist for this project. Of particular concern is that salmon were NOT identified in Section 5a, p.10 of the Environmental Checklist, despite the fact that their presence in Lake Desire is referenced throughout the Management Plan. Is the information regarding vactor waste pertinent to the Lake Desire project?

Understanding that separate SEPA compliance will be conducted for in-lake measures, fisheries staff at the Muckleshoot Indian Tribe look forward to enhanced communication as part of a cooperative effort towards ensuring our common goals in the successful implementation of the Lake Desire Management Plan. If you have any questions or concerns regarding these comments, please feel free to contact me at 939-3319 ext. 128.

Sincerely,

Leslie J Groce

Leslie J. Groce

cc: RM, MIT
Bill Eckel, SWM

Attachment I
Draft Lake Desire Management Plan Review
Muckleshoot Indian Tribe Fisheries Department Suggested Modifications

p. 2-7
"Chinook and sockeye salmon utilize the main stem of Peterson Creek while coho salmon are known to migrate up Tributary 0328B to Lake Desire."

AND p.4-30
"Lake Desire is known to have a high quality fish population. The Washington State Department of Fish and Wildlife rates the lake as a moderately important fishery.... Of particular importance is the presence of coho salmon juveniles in the lake...." (King County, 1993b)

Please refer to cover letter for concerns.

p.4-38
Septic survey -"There are 101 on-site septic systems ....15.8 percent have reportedly failed at some time ..." (King County, 1993b)

How was this percentage determined? In past studies, pumping of a septic tank has been improperly considered a failure.

p.6-17
"The use of alum salts may cause toxic conditions, although alum treatments have not resulted in adverse impacts on fish to date (Cooke et al. 1993b) and have not damaged invertebrate populations in well-buffered lakes ..."

Please provide this reference, if possible. Refer to cover letter for additional concerns.

p.6-19
Modeling scenarios list - Watershed Package (all three measures) = ?

p.6-20, Table 6-5
It is difficult to understand why there is a difference in TP between 7A and B and 8A and B.

p.6-22, and elsewhere
"reduce the future phosphorus load from that subcatchment by 30 kg TP per year."

To put this number in perspective, include a % decrease (I wasn't sure which number I should divide by to determine this value).

p.7-4, LD-1
Minimum forest retention should be recommended for the Peterson-6 subcatchment area so that at the very least this information could be incorporated as part of SEPA mitigation as the area is built out. This was also recommended as part of the P-suffix conditions in the Soos Creek Community Plan Update (p.7-6).

Clustering homes as far away as possible from the lake should also be considered, similar to the townhouse zoning proposed in the Soos Creek Community Plan for Big Soos and Soosette Creeks.

p.7-9, LD-7 Sewering
Is the reason sewering does not significantly improve TP levels because the housing density remains low when sewers are not available? If that's the case, the wording is fine. If not, this document should be

consistent with the recommendations of the Soos Creek Community Plan and Growth Management that require sewering in areas with urban designations.

Reference, p.2-9

"Under this new zoning, sewer and water service must be present to realize the density associated with the designation of RS-7200-P..... new development lot size will be restricted to 12,500 sq ft. .... for on-site septic systems."

p.7-9, LD-8 Alum Treatment

A pre- and post-treatment monitoring program should be recommended, including a thorough evaluation of the existing salmonid fisheries resource, and short- and long-term impacts of the treatment on this resource. Impacts on benthic organisms should also be evaluated.

p.7-9, LD-9 Aeration

Please refer to cover letter for concerns.

p.7-11, LD-13 Monitoring

At a minimum, staff of the Tribal Fisheries Department should be informed of the results of the fisheries studies. Even better, Tribal staff would like to participate in the development and implementation of the monitoring program for Lake Desire.

King County Environmental Checklist

p.10, 5a.

Salmon are not underlined, indicating they are not present on the site. This is contradictory to the text of the Lake Desire Management Plan, and contrary to WDFW information.

Supplemental Sheet for nonproject actions

Is this pertinent to the Lake Desire project?