Lake Desire Management Plan

April 1995

King County Surface Water Management
Everyone lives downstream

Washington State Department of Ecology

KCM

Lake Desire
Management Plan

Final Plan

Grant No. TAX 91113

April 1995

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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,

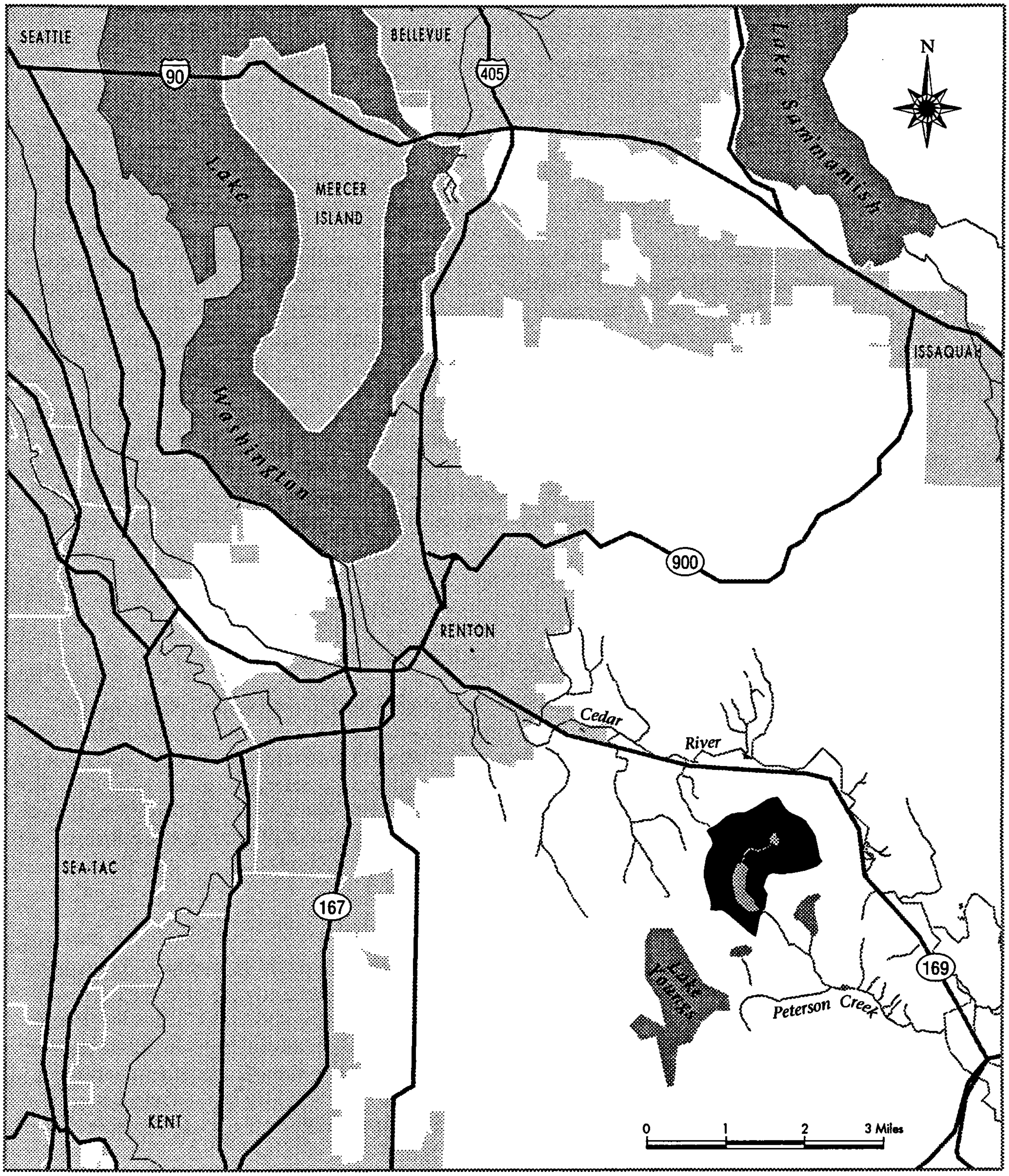

Figure 1-1: Lake Desire Watershed Location Map

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CARTOGRAPHY & GRAPHICS

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

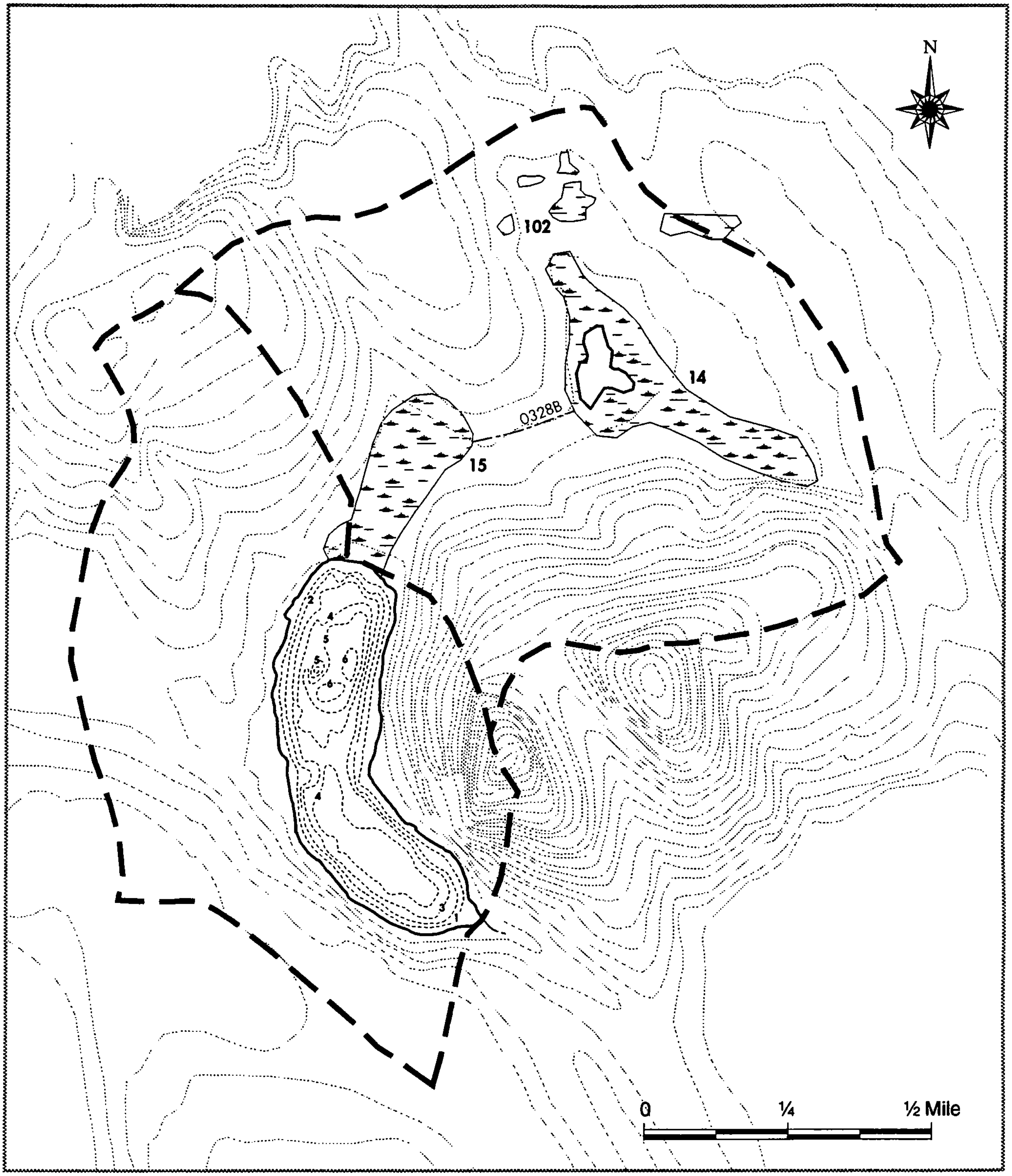

Figure 2-1: Lake Desire Water Features

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

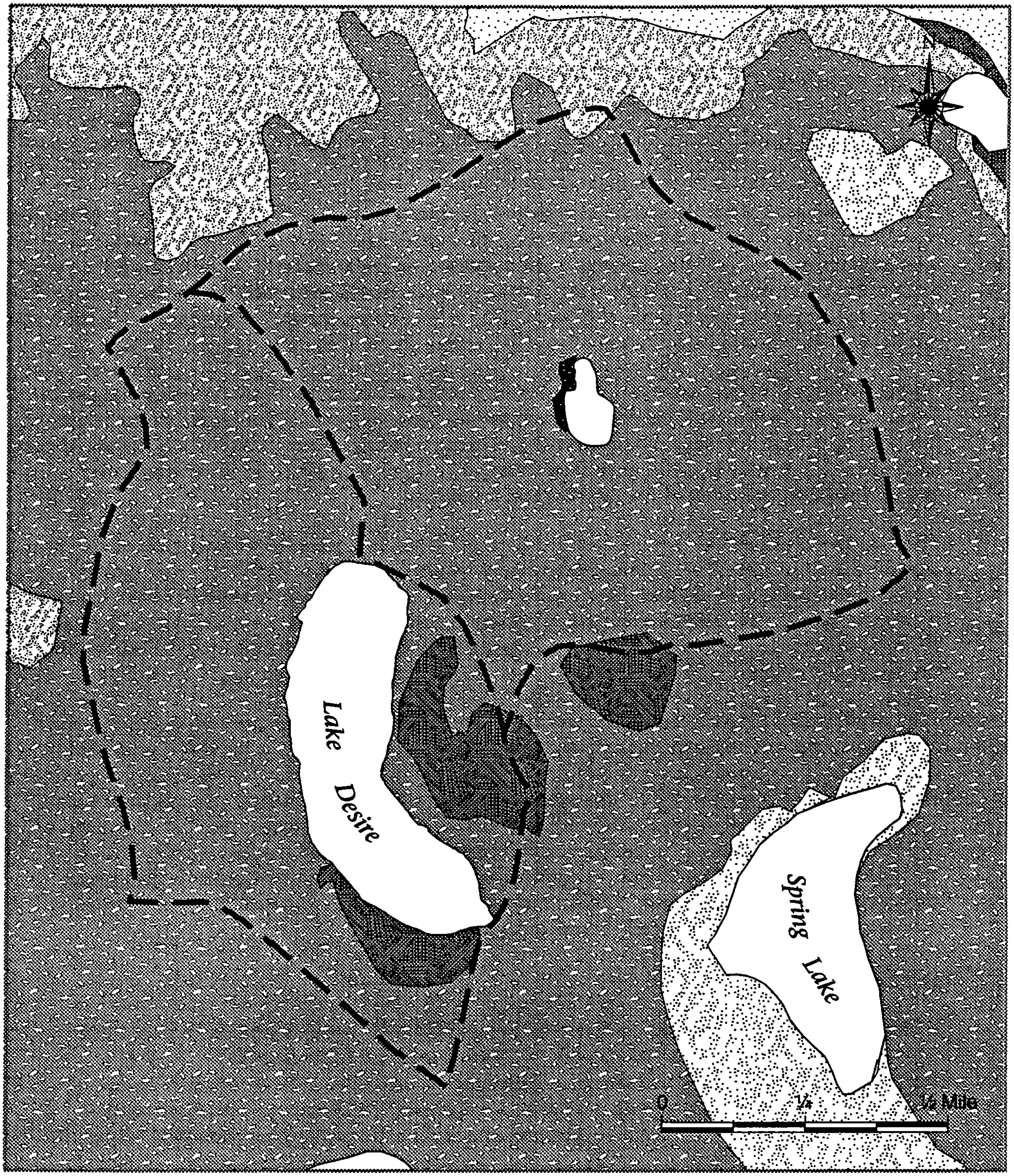

Figure 2-2: Lake Desire Geology

- 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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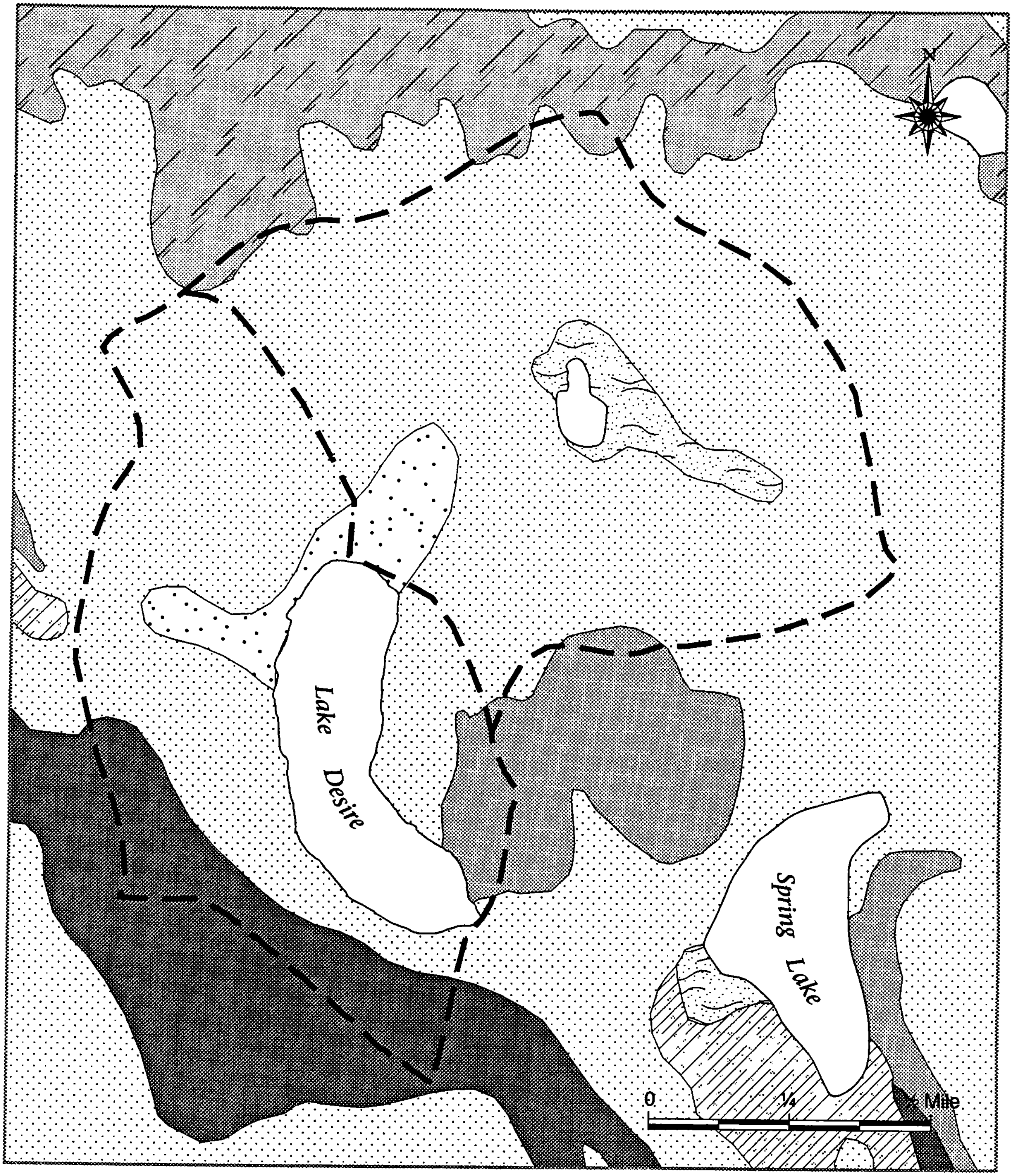

Figure 2-3: Lake Desire Soils

- 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

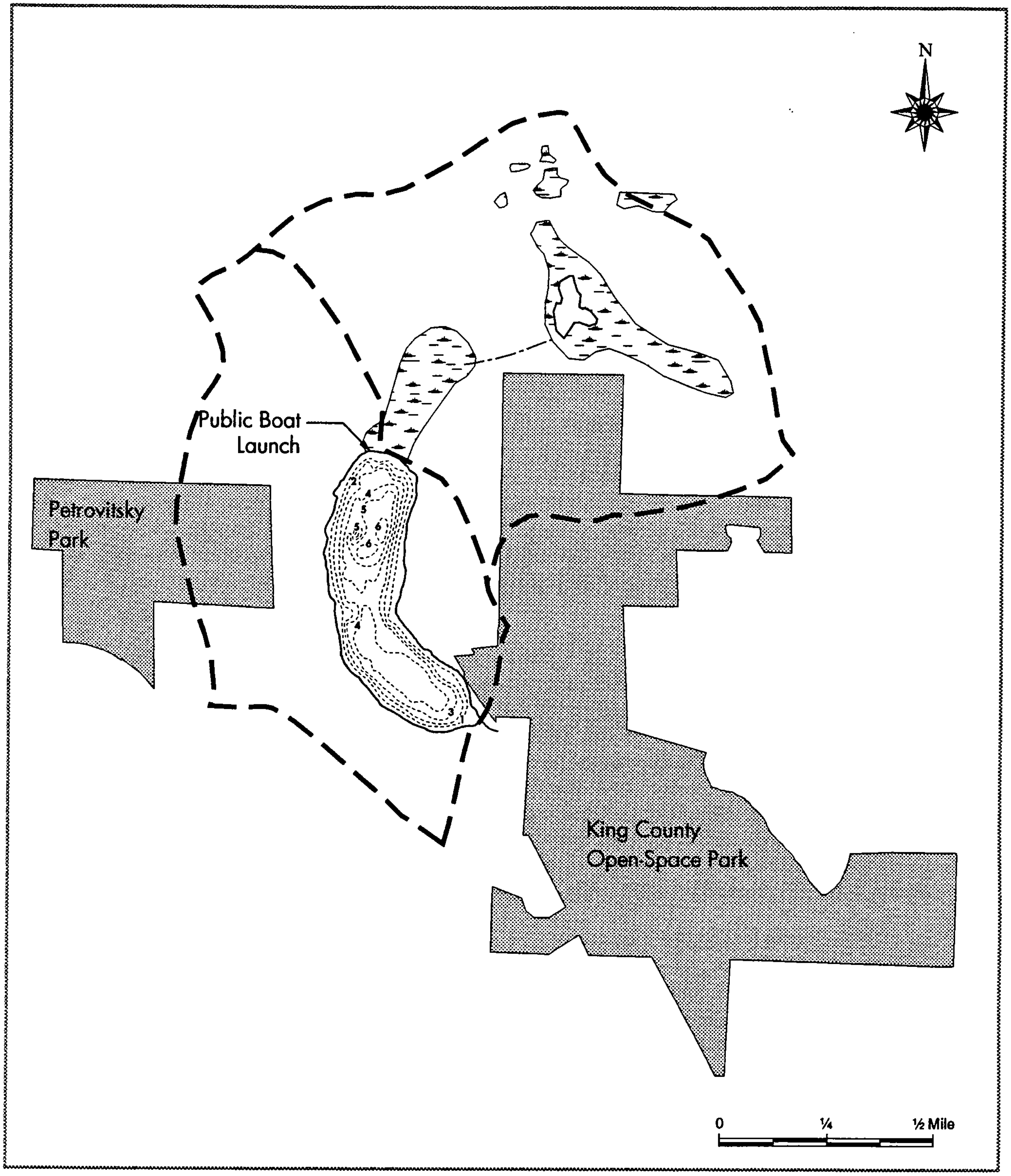

Figure 2-4: Lake Desire Public Access

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.

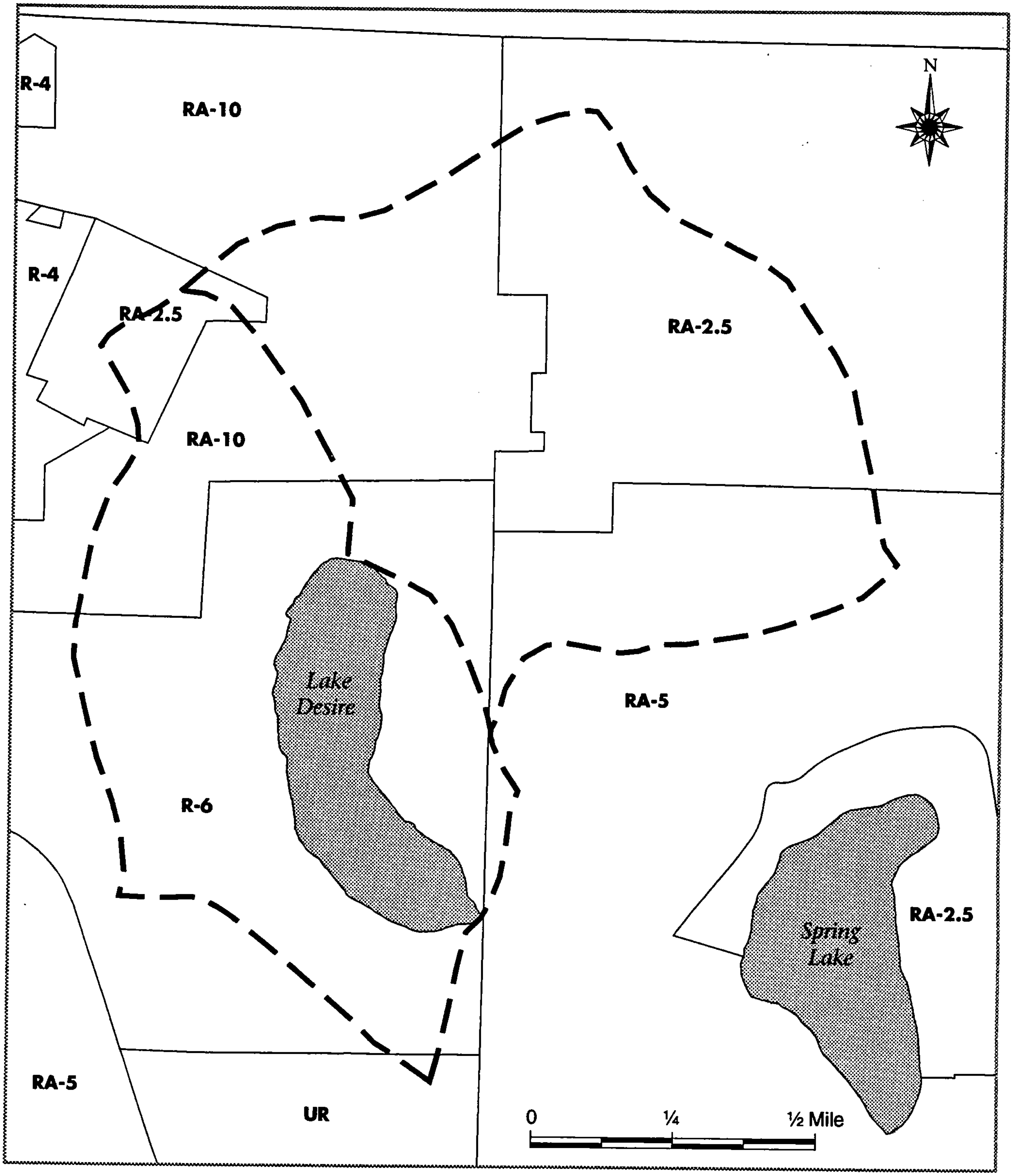

Figure 2-5: Lake Desire Zoning

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

0 ¼ ½ Mile

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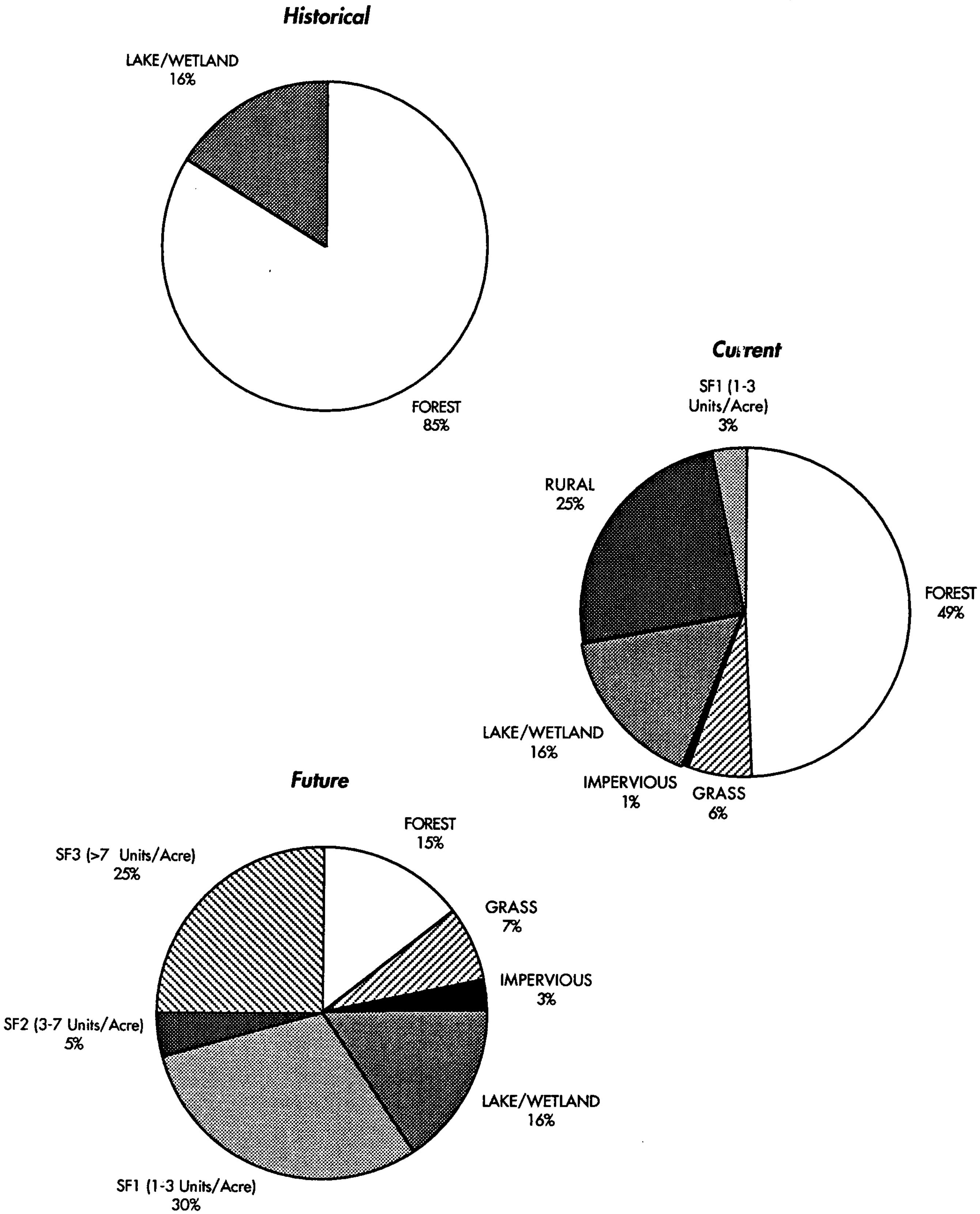
Figure 2–8 Lake Desire Historical, Current, and Future Land Use



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

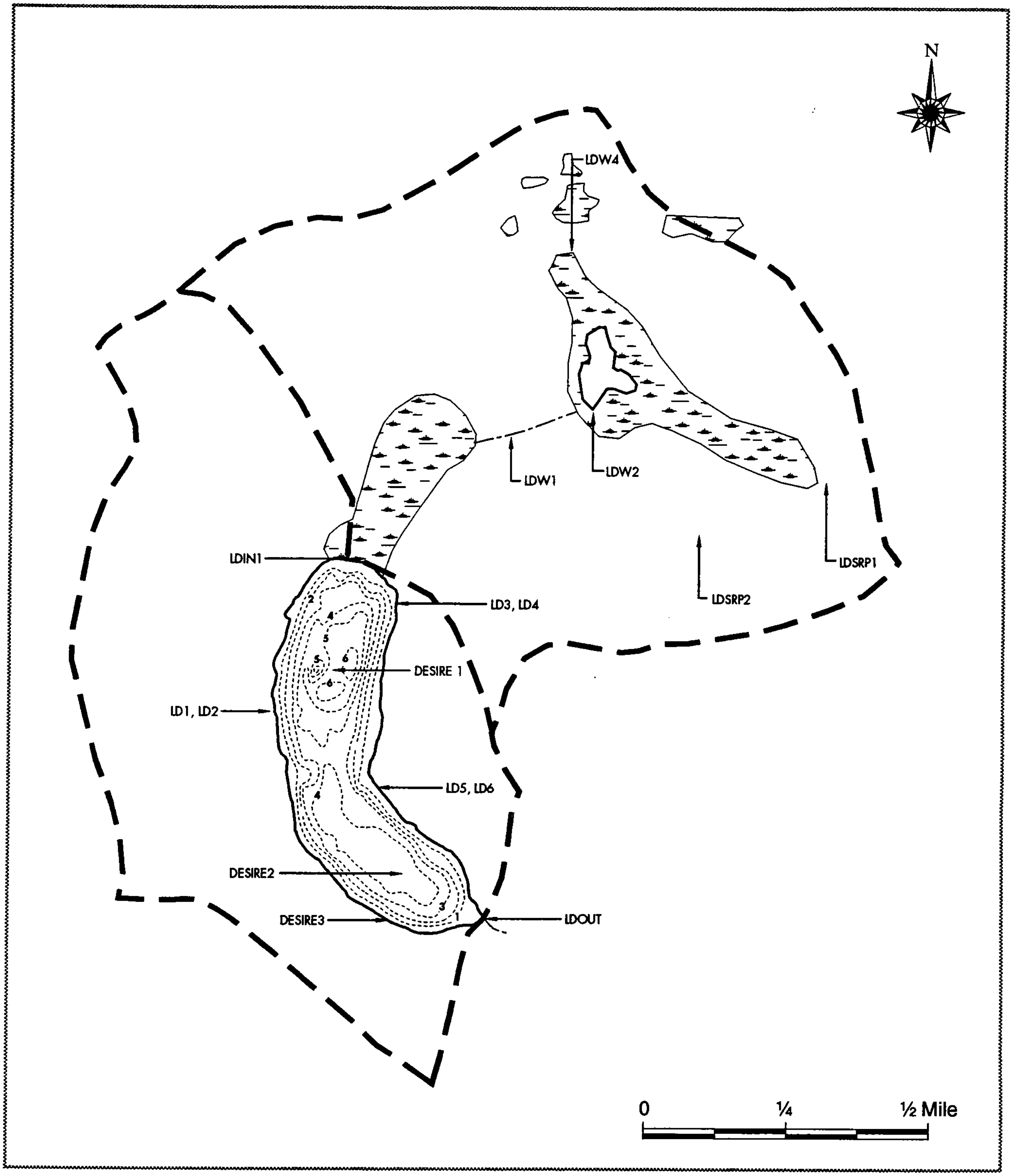


Figure 3-1: Lake Desire Monitoring Locations

- 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

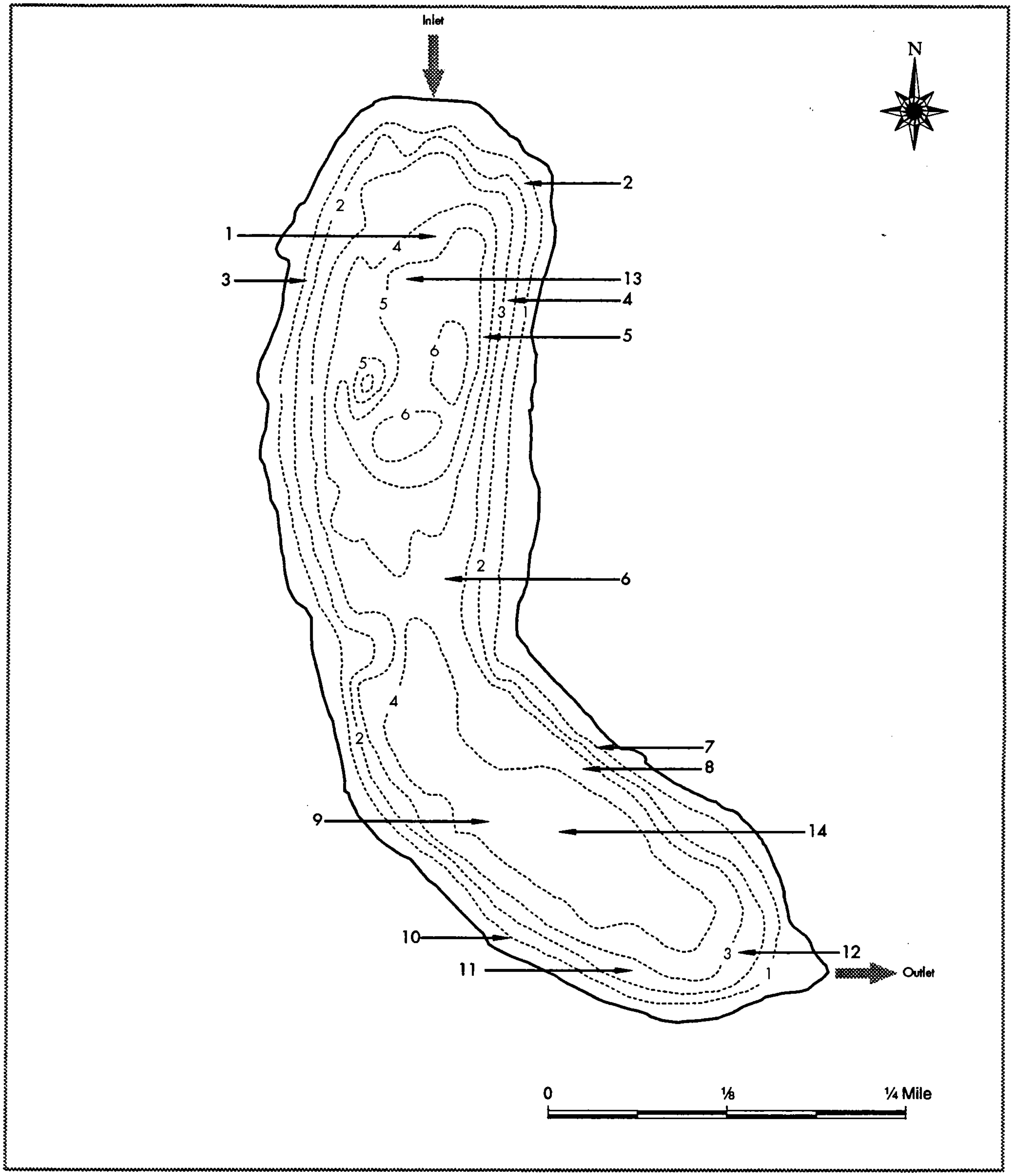

Figure 3-2: Lake Desire Sediment Sampling Locations

--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^{TM} 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.

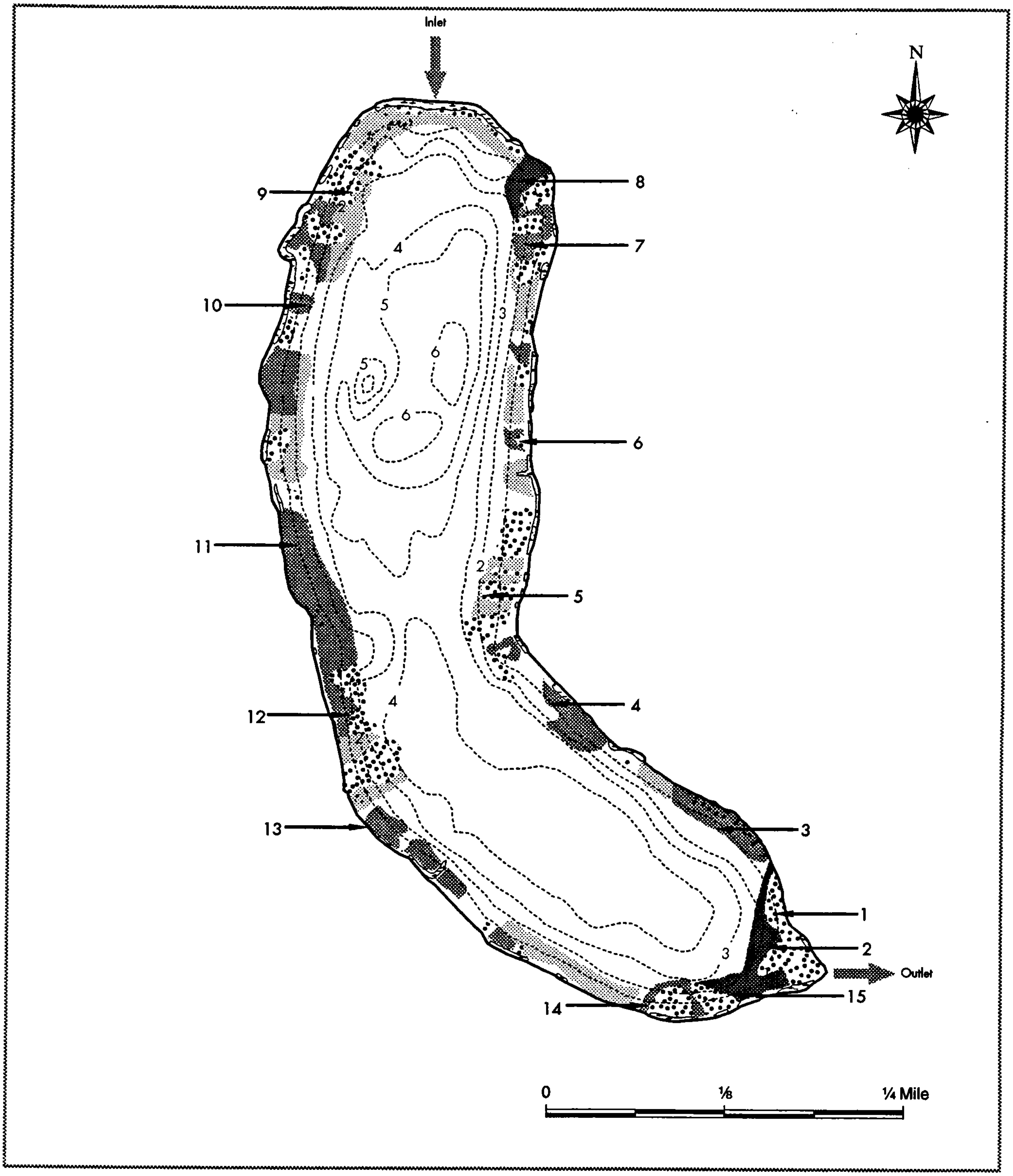
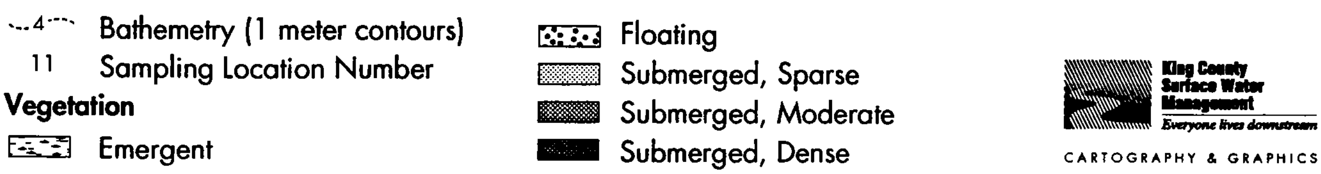


Figure 3-3: Lake Desire Macrophyte Sampling Locations



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.

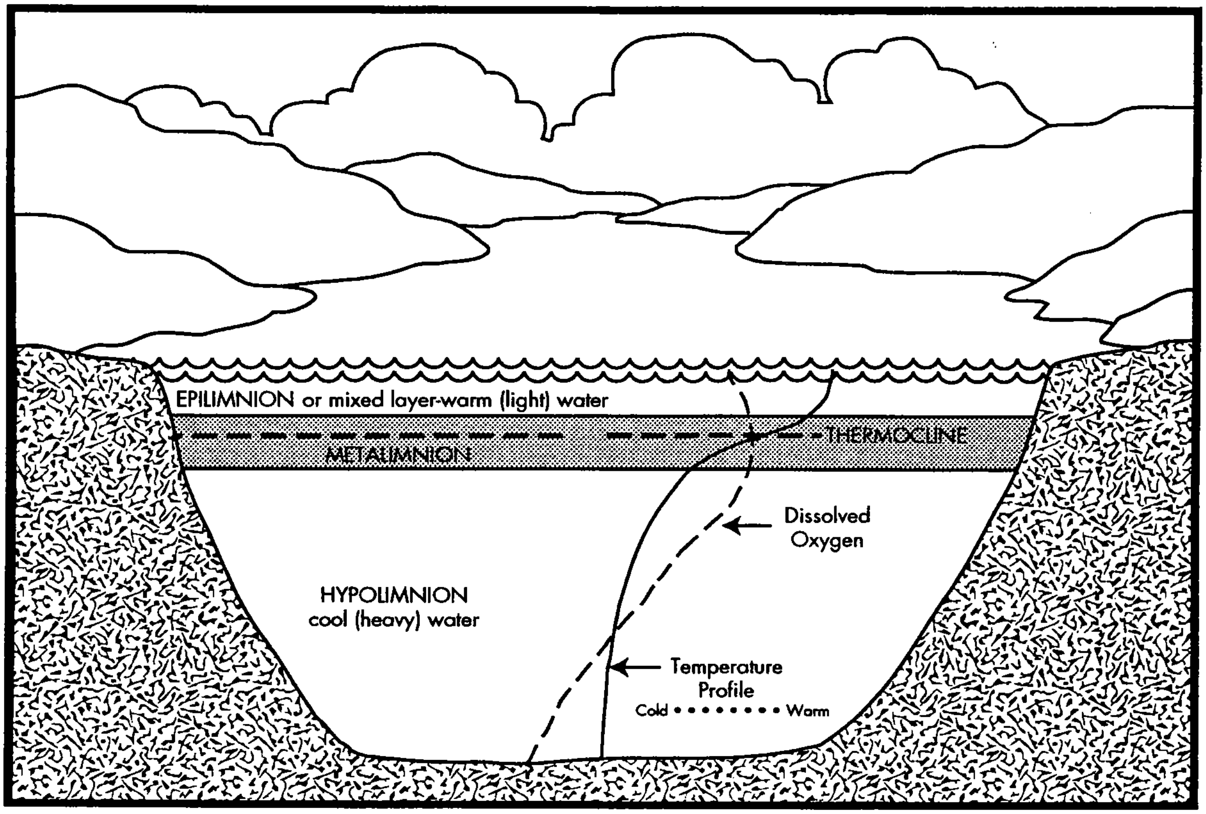
Figure 4-2 illustrates five representative temperature profiles for Lake Desire during the study period. The difference between surface temperatures in the spring (May 25, 1993) and summer profiles (August 31, 1993) is unusually small due to the cool summer of 1993. A summary of selected water quality 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.

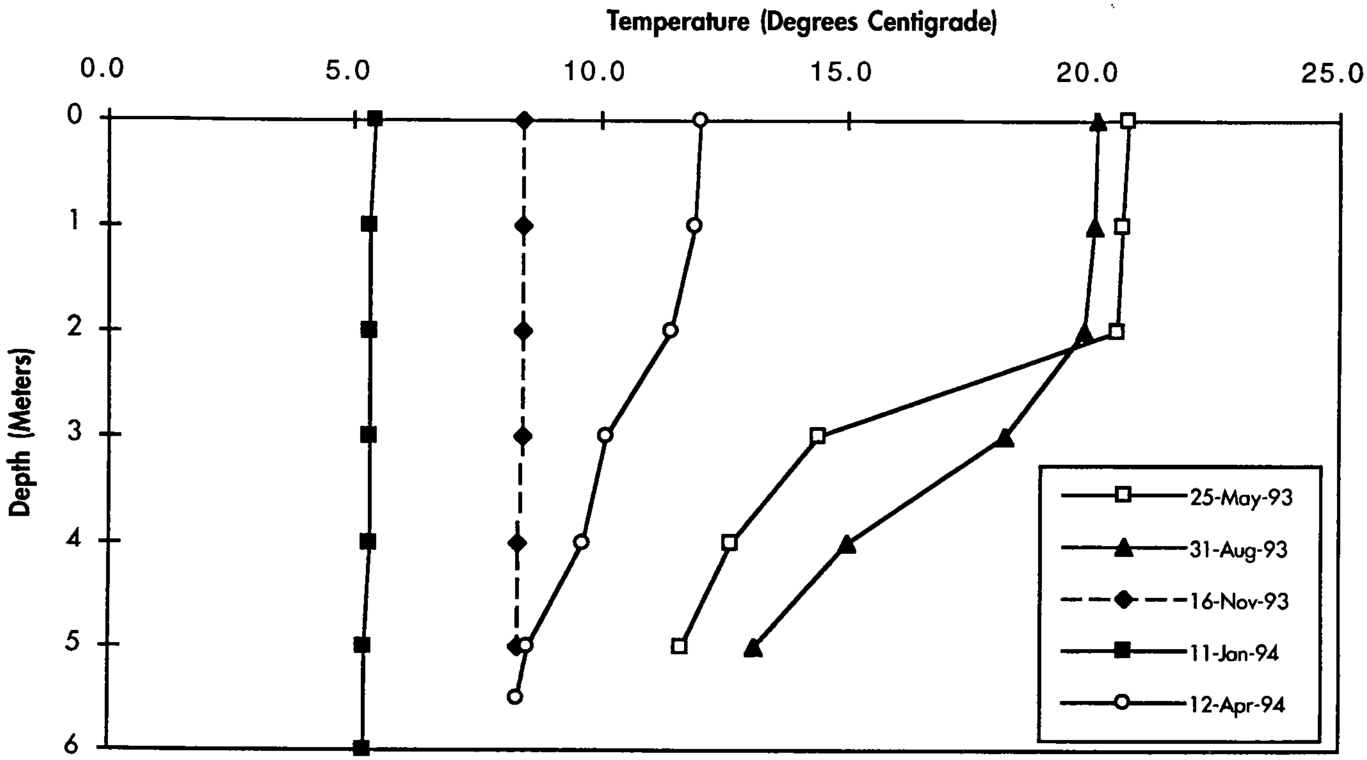
Lake Desire's transparency is naturally influenced by its wetland inflows which are high in organic acids, giving the lake its natural tea color. Figure 4-4 illustrates the inter-relationships between Secchi depth, color, and chlorophyll *a* (a measure of algal biomass) in the lake. Color concentration 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

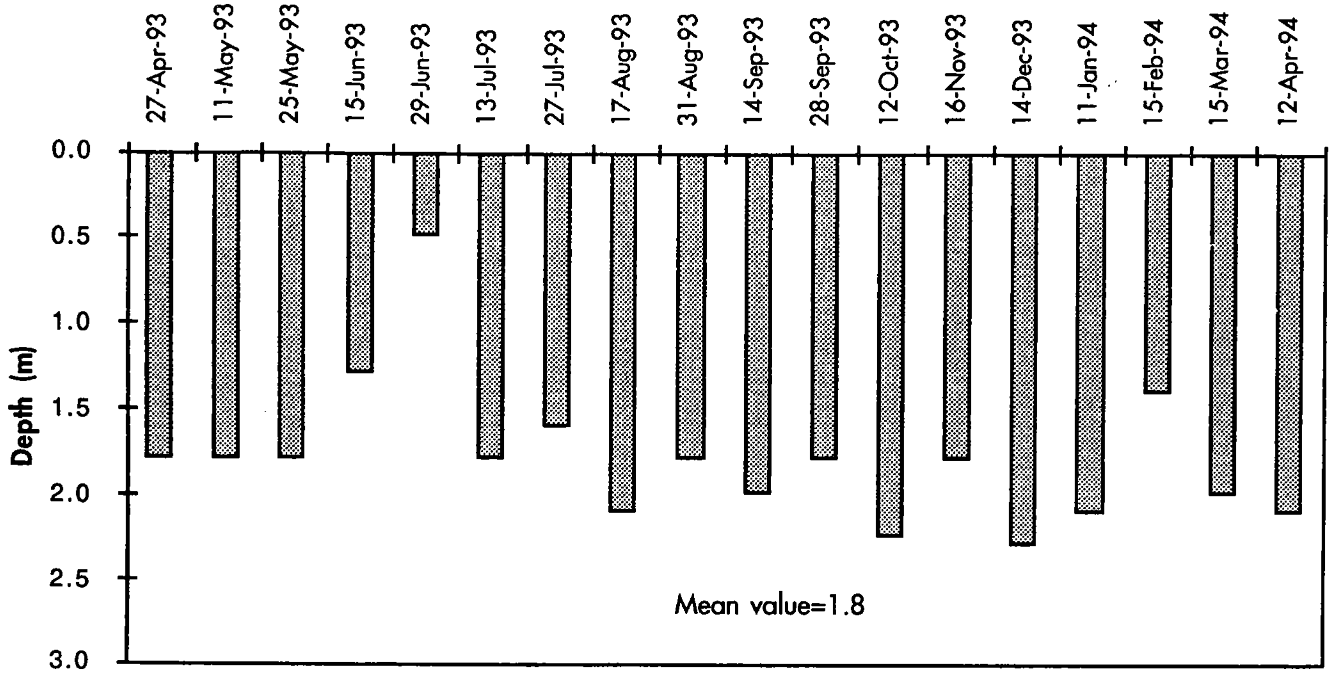


Figure 4–4 Lake Desire Chlorophyll *a*, Color, Secchi Depth Interrelationship

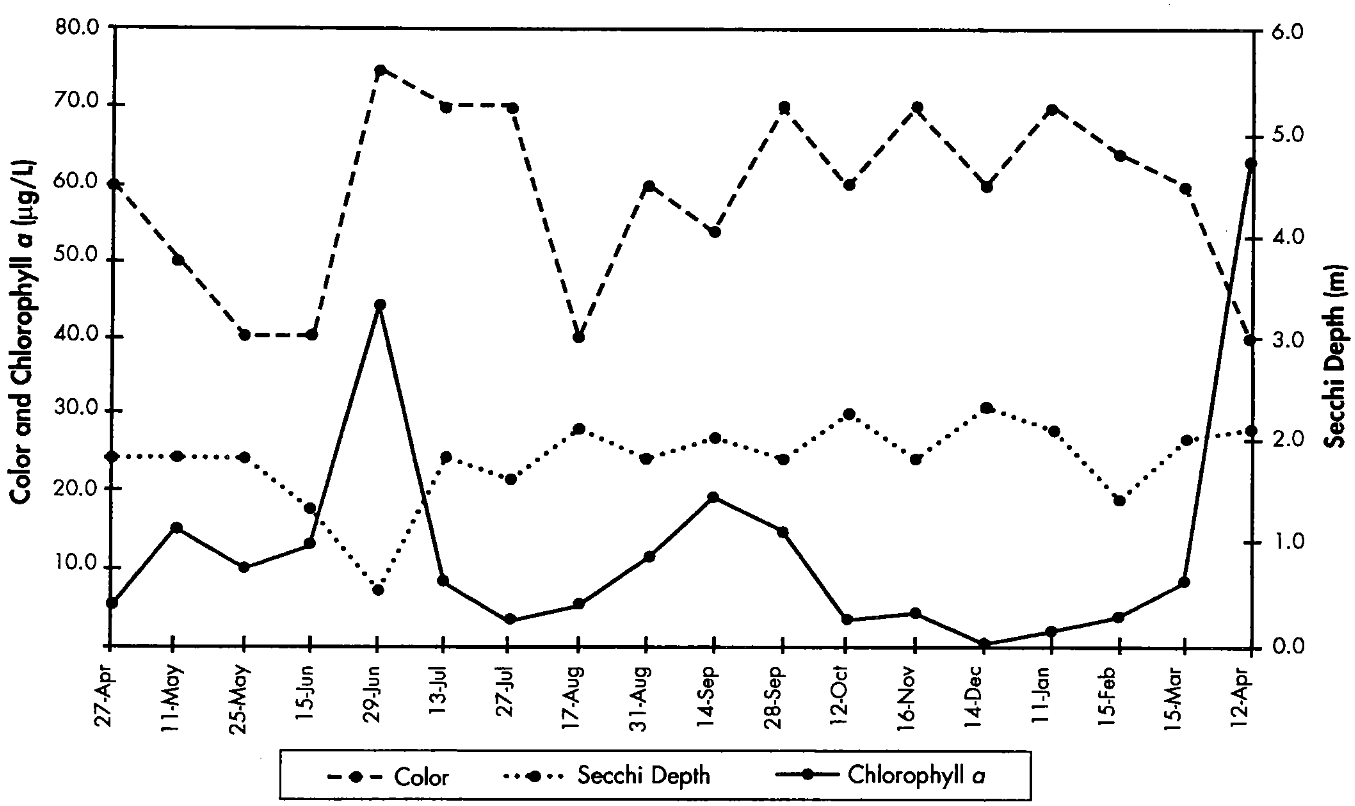
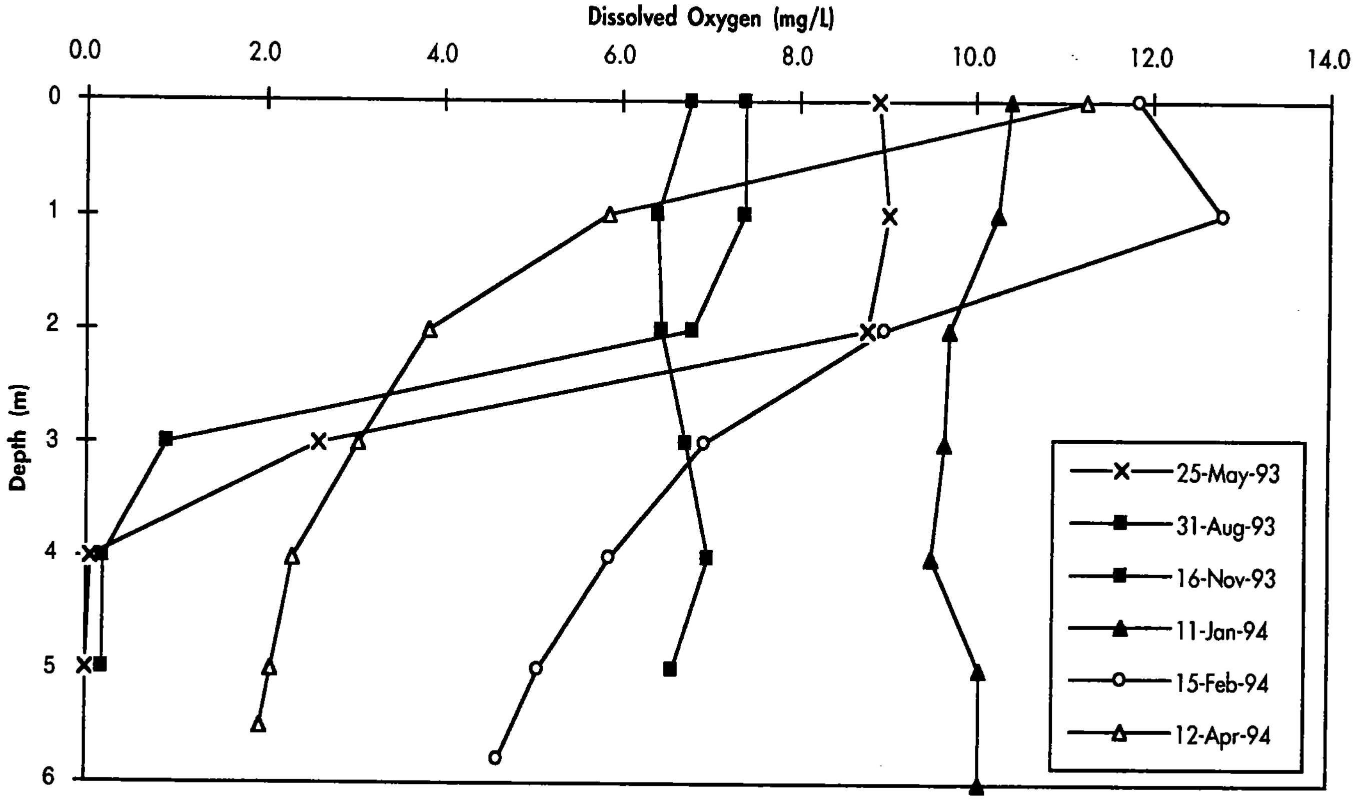


Figure 4–5 Lake Desire Dissolved Oxygen Profiles



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.

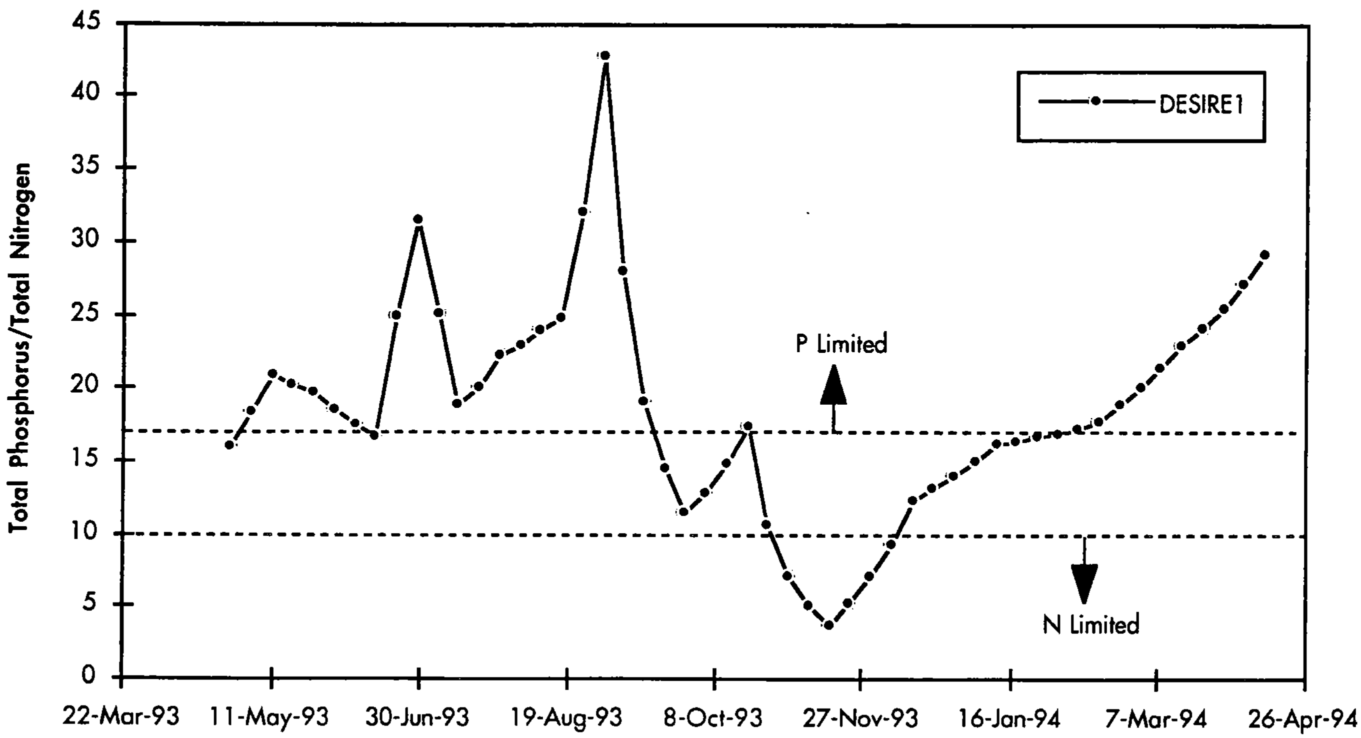
Nutrient Limitation

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



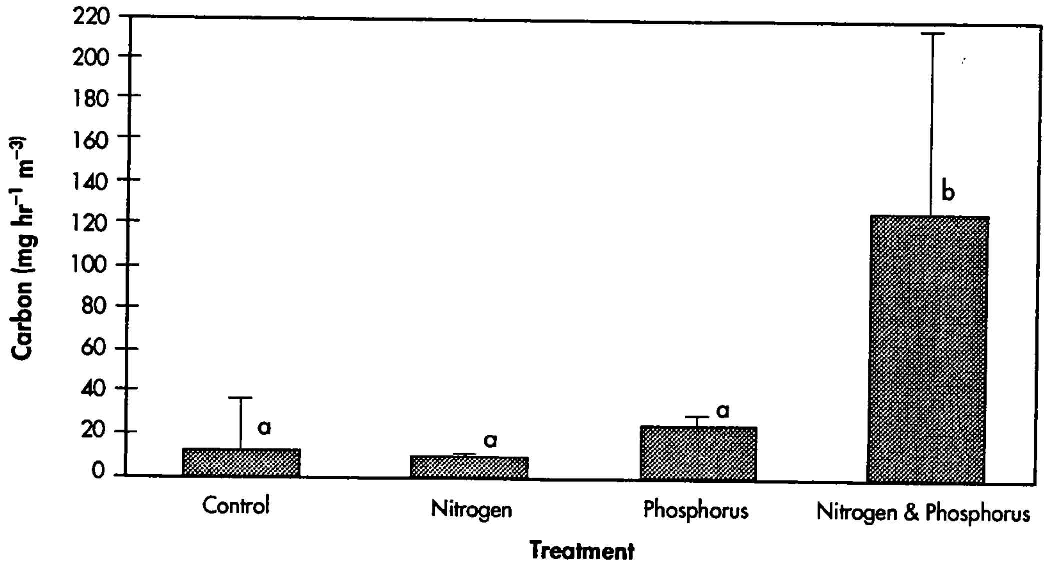
conclusively that both phosphorus and nitrogen limited algal growth during the in-lake experiment (KCM, 1994b). Phytoplankton enrichment response, measured as mg carbon hr^{-1} m^{-3} showed a threefold increase with the addition of both phosphorus and nitrogen (Figure 4-7). The results from both bioassays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

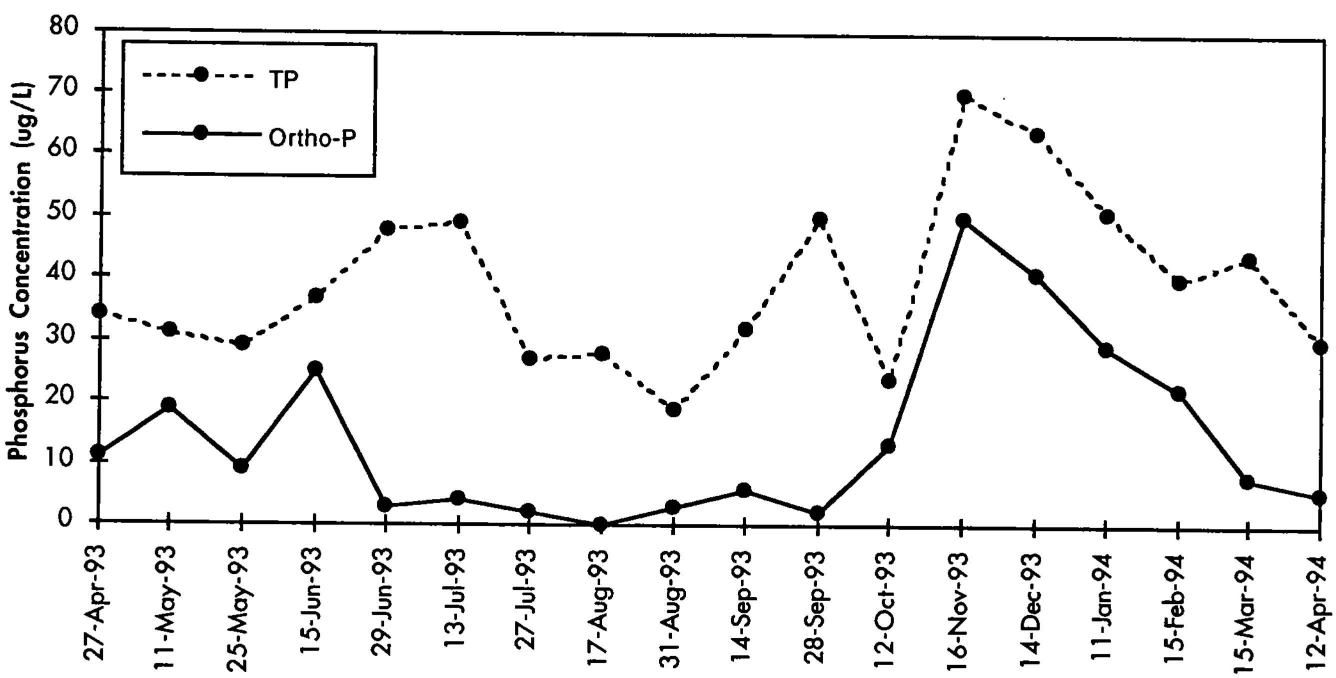
Phosphorus was measured as both total phosphorus (TP) and ortho-phosphorus (ortho-P) during the study period. Total phosphorus represents both organic and inorganic forms of phosphorus. Ortho-P generally represents the portion (dissolved) of phosphorus that is available for algal growth. Annual TP and 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

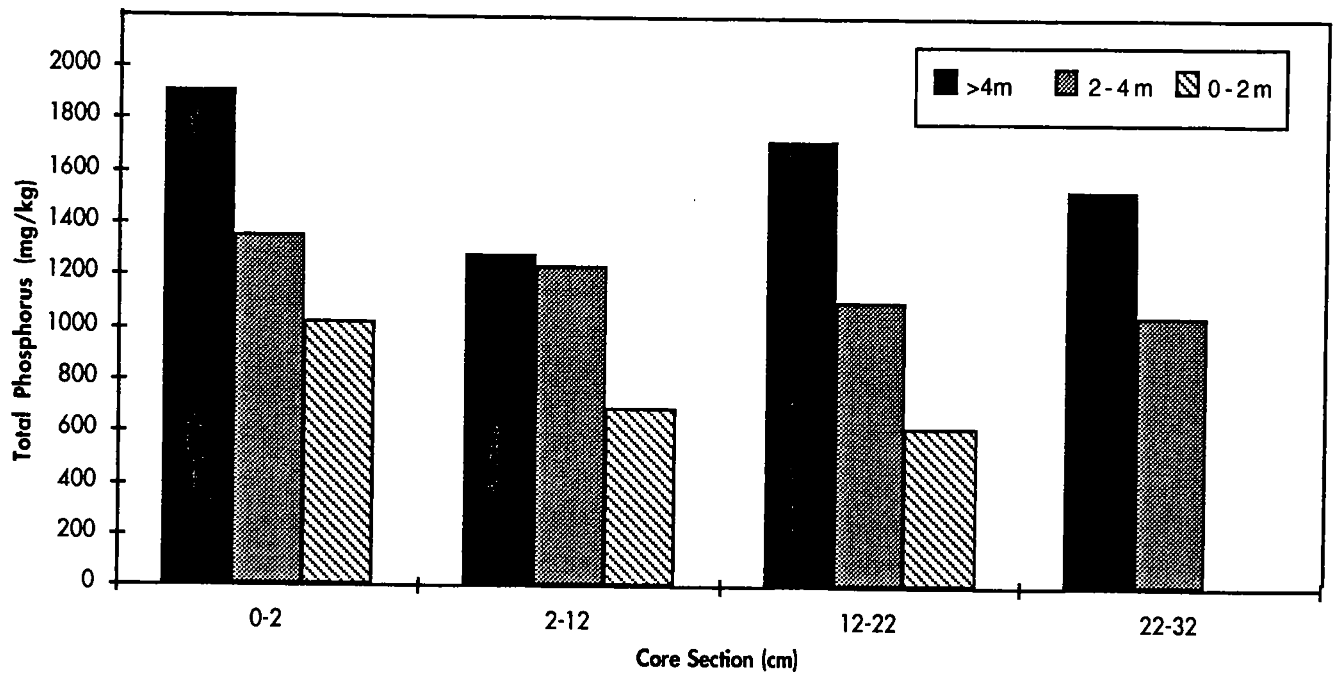


Figure 4–10 Lake Desire Lead and Zinc Sediment Profile

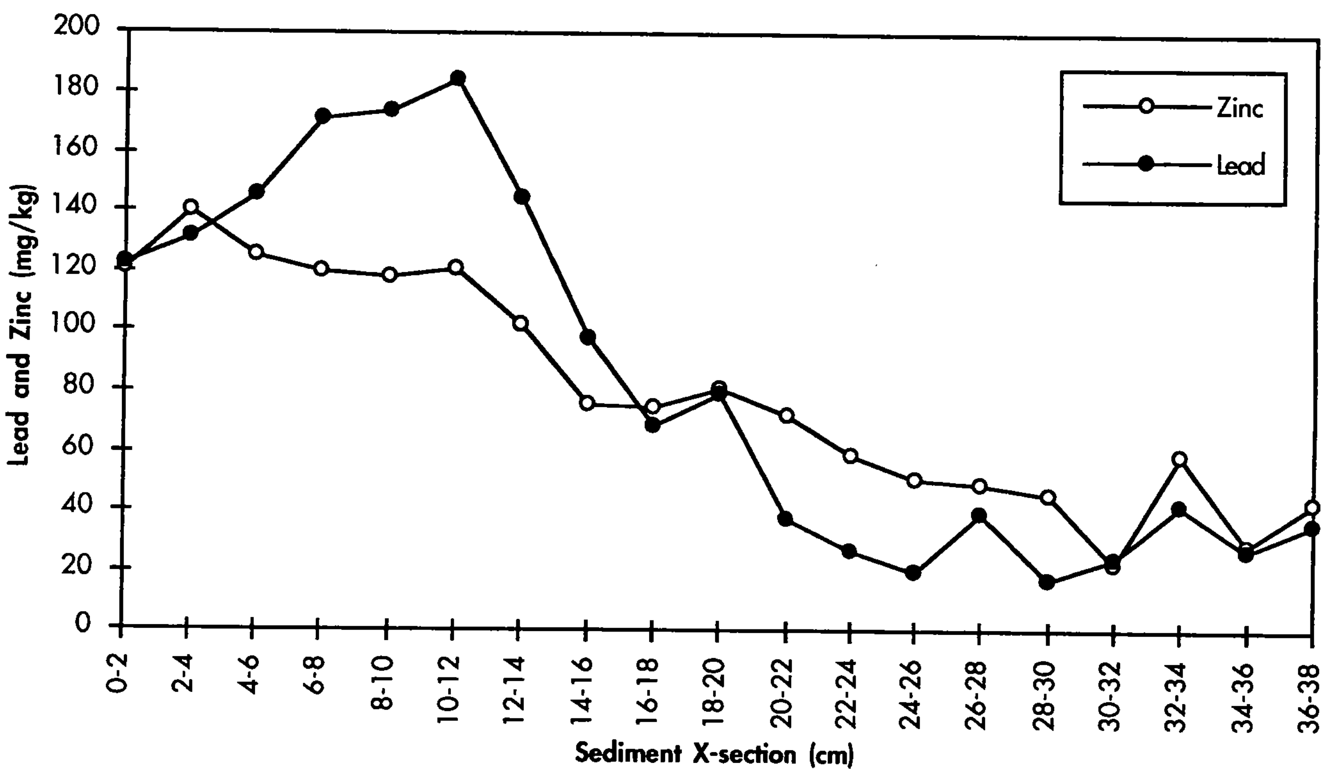


Table 4-5: Inflow and Outlet Water Quality

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

Parameter	Units	LDW1 (Wetland 14 outflow1) n=3			LDW2 (Wetland 14 outflow2) n=3			LDW4 (Wetland 14 inflow1) n=3		
		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

Parameter	Units	LDSRP1 (R/D Pond1) n=3			LDSRP2 (R/D Pond2) n=3		
		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

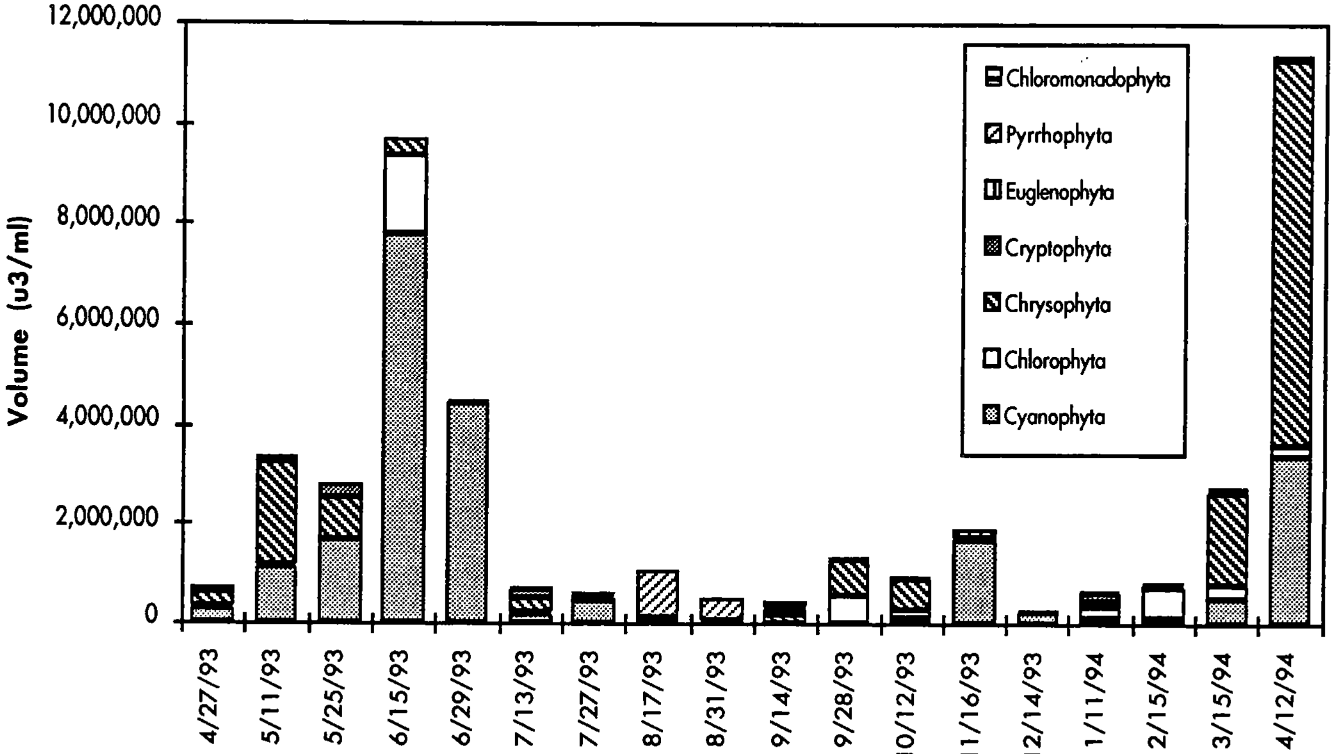


Figure 4–12 Lake Desire Chlorophyll *a* Concentrations

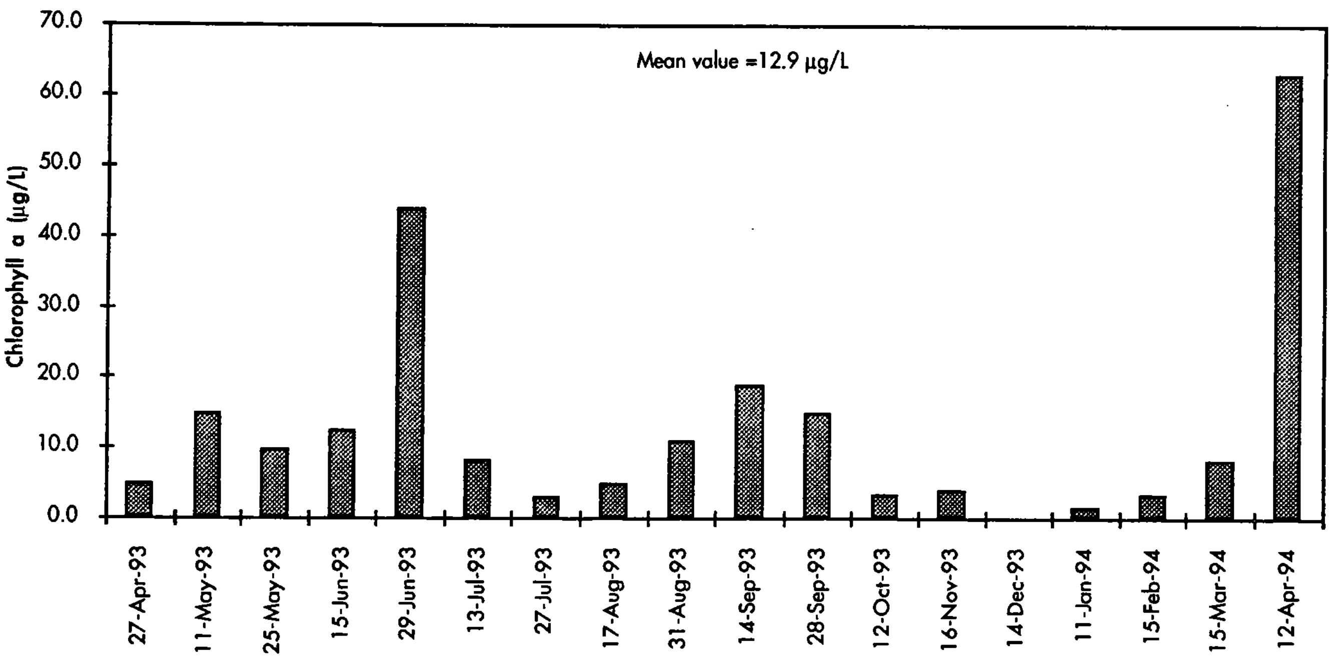


Figure 4–13 Lake Desire Zooplankton Densities

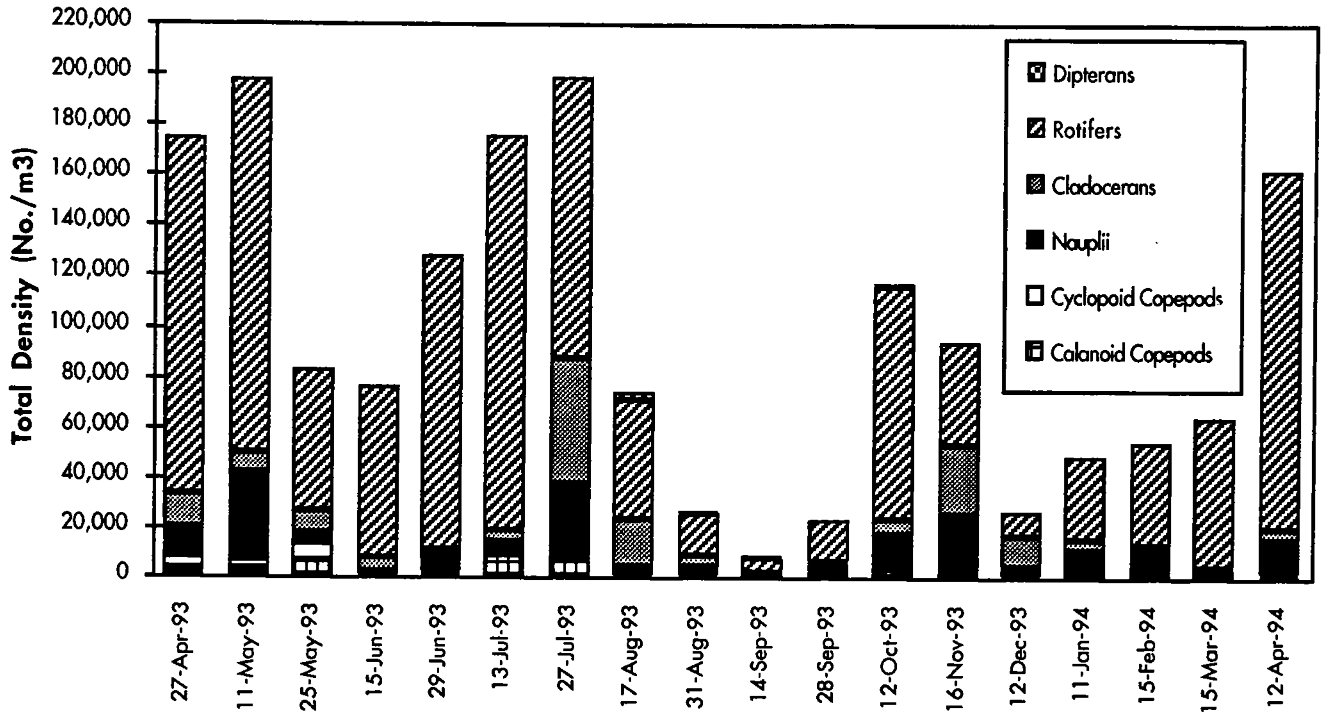
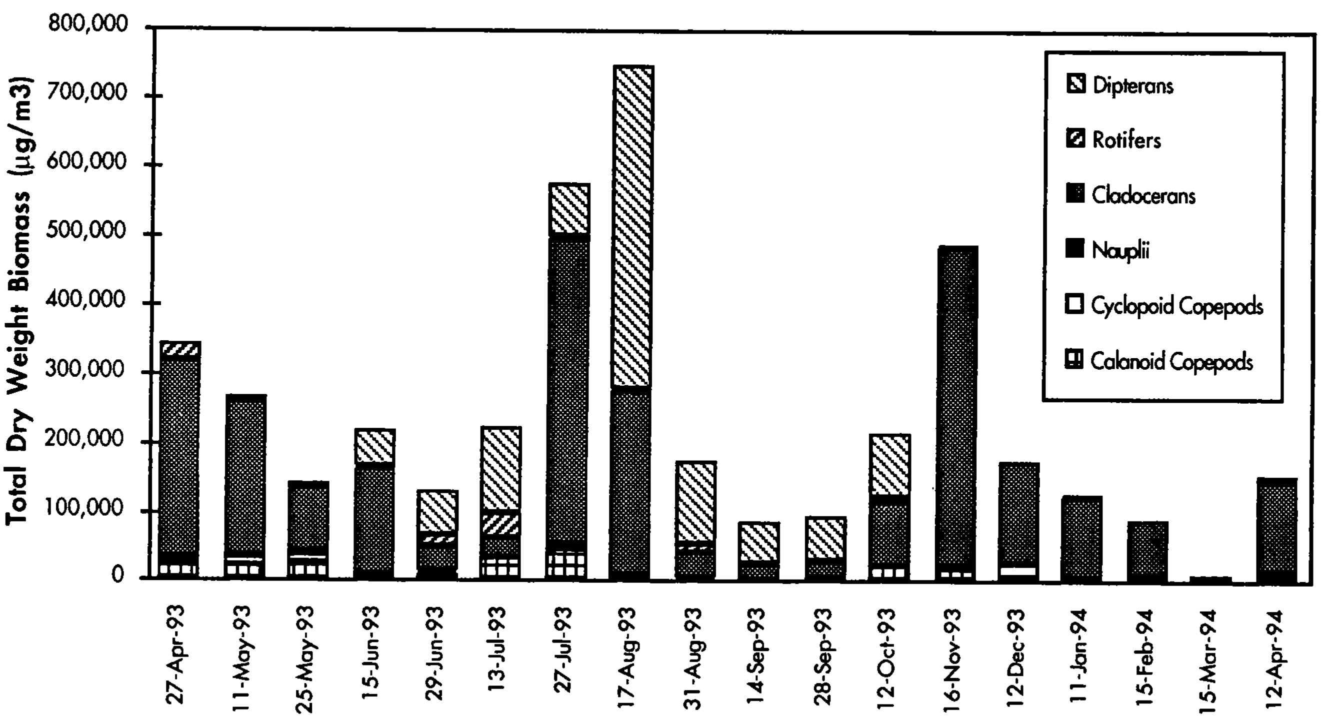


Figure 4–14 Lake Desire Zooplankton Biomass



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]

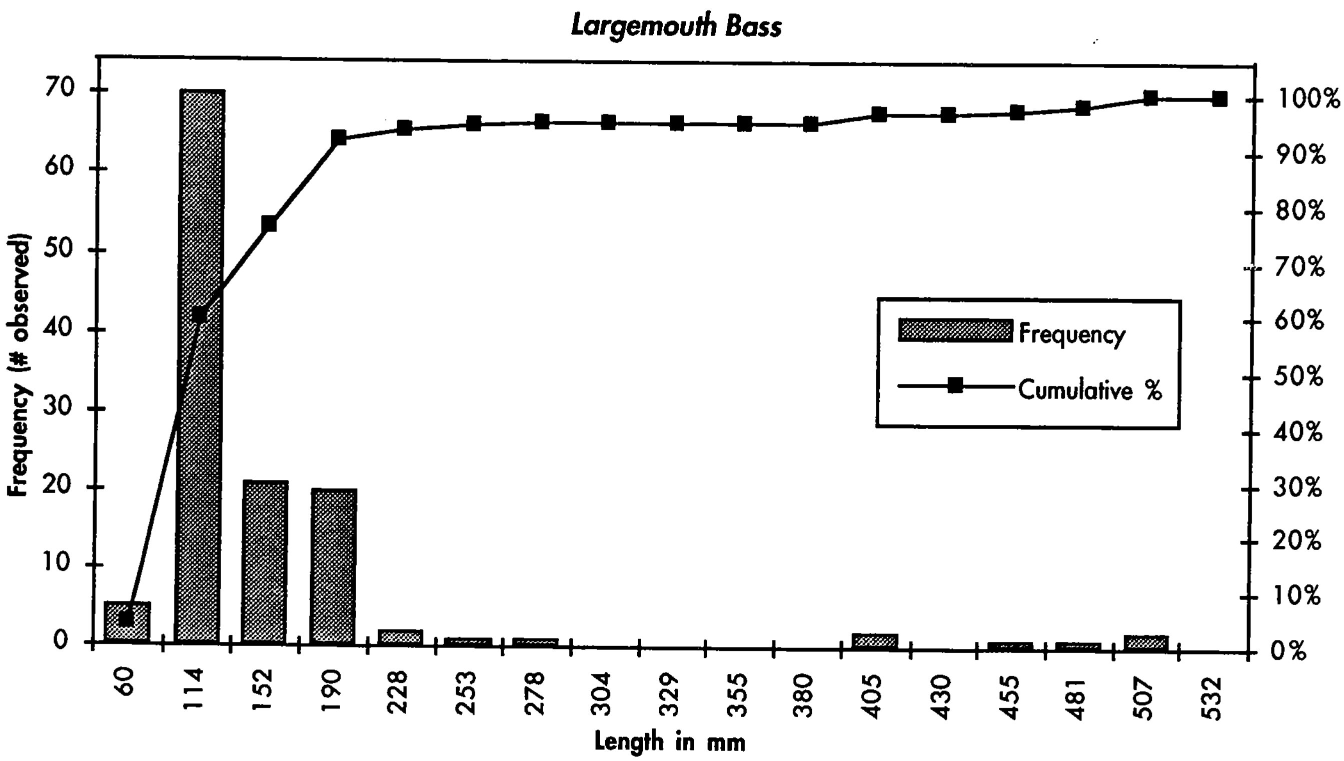
Species	Number of Fish Caught Electrofishing	Fyke Trap	% of Total
Largemouth Bass	114	13	62
Crappie	1	1	1
Yellow Perch	47	14	30
Sunfish	5	2	3.5
Brown Bullhead	3	2	2.5
Rainbow Trout	2	0	1
Total	172	32	100

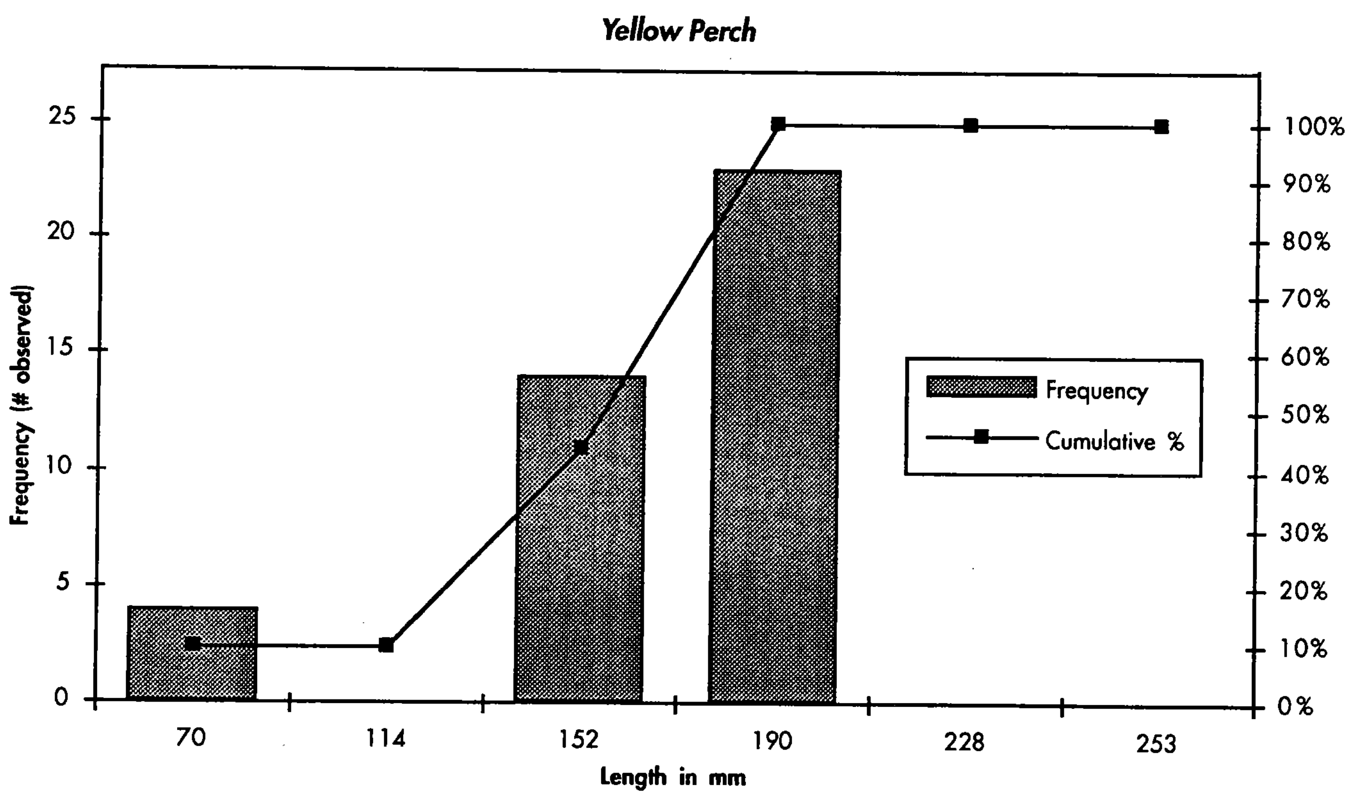
[a]*Data from KCM, 1994a.*

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).

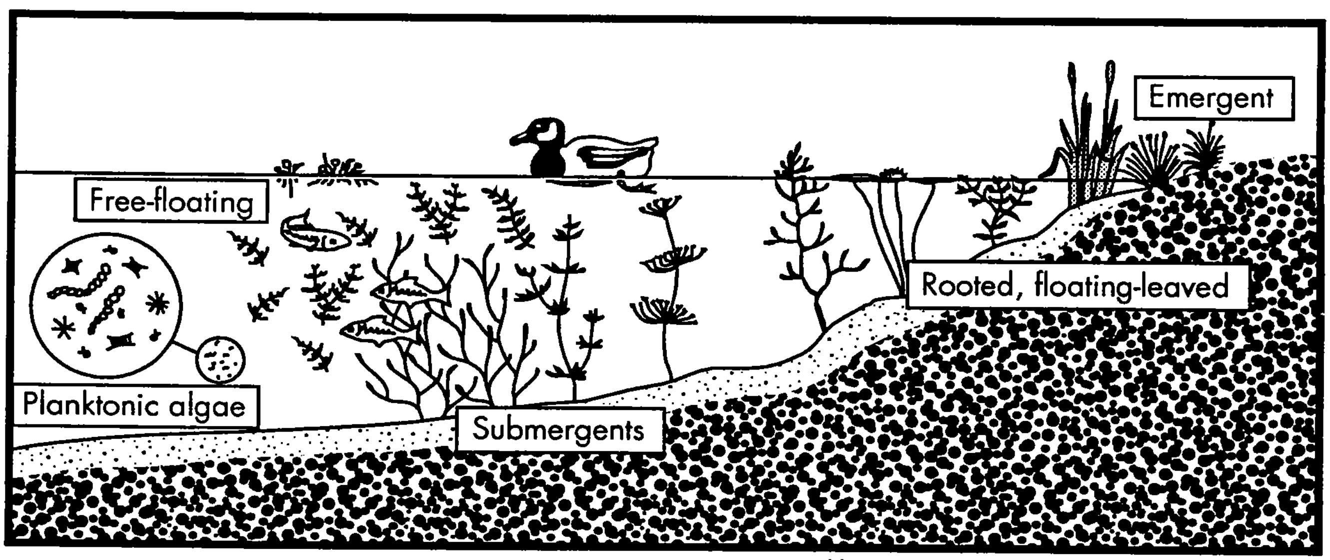
A lack of bass in the 290-400 mm range was consistent throughout the fisheries assessment. This size range represents 4-5 year old fish. It is possible that intermittent, poor lake water quality (e.g., extended low oxygen, high temperatures, toxicity, or turbidity) could have adversely affected this 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

King County Surface Water Management

Everyone lives downstream

CARTOGRAPHY & GRAPHICS

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.

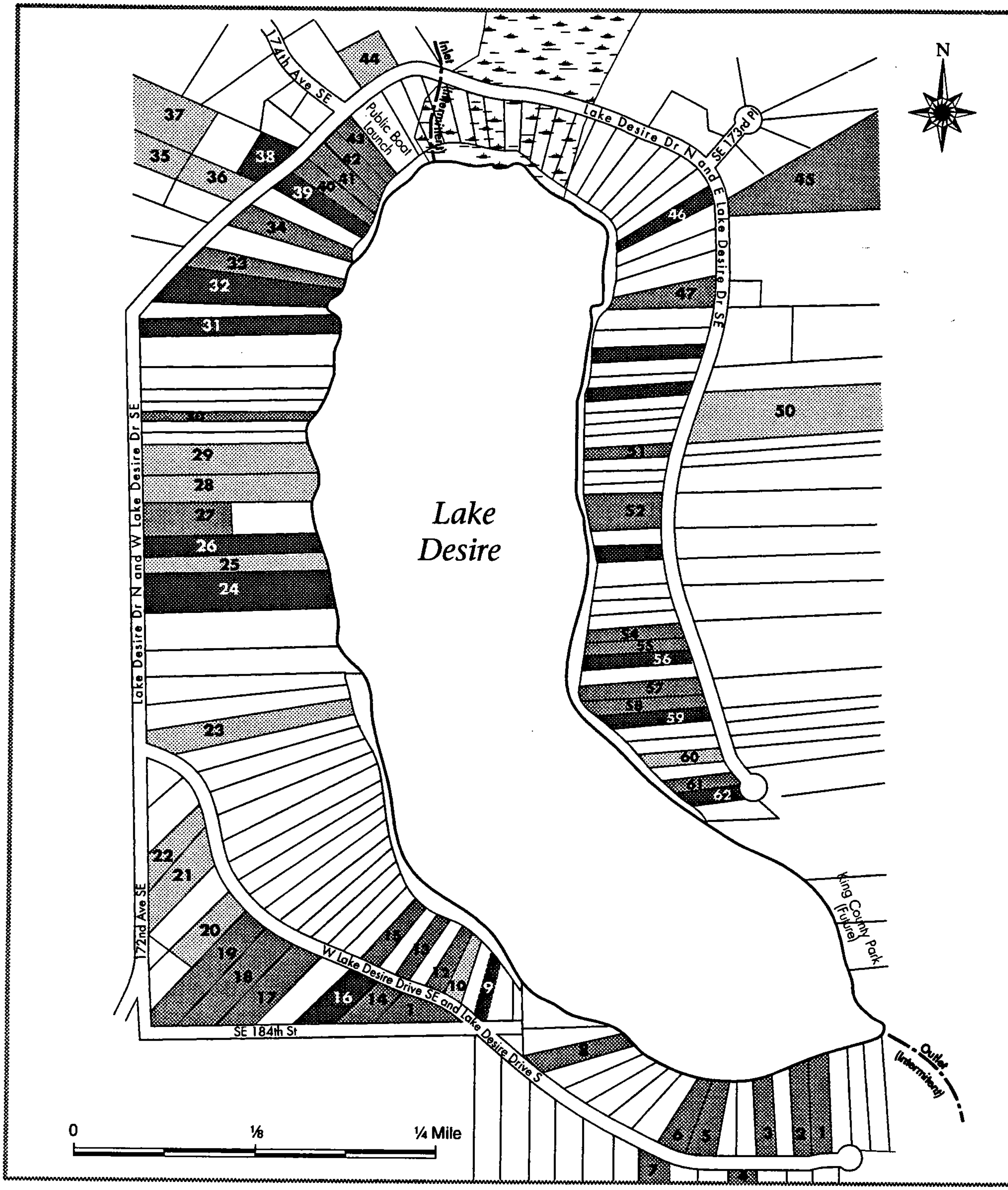


Figure 4-18: Possible Septic System Problem Sites

Wetland

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

Age of Septic System

10-20 years

>20 years

Unknown

King County Surface Water Management

Everyone lives downstream

CARTOGRAPHY & GRAPHICS

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]	Secchi (m)	Summer Chl. a (µg/L)	TP (µg/L)	Secchi (m)	Annual Chl. a (µg/L)	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 .*