Lake Killarney Hydrologic / Nutrient Budget Evaluation

Final Report

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Prepared for:

City of Winter Park, Florida

Orange County, Florida

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EXECUTIVE SUMMARY

Introduction

Lake Killarney is a 239-acre lake in north-central Orange County with watershed areas located primarily within the City of Winter Park and unincorporated Orange County. The lake consists of interconnected eastern and western lobes, along with a somewhat hydrologically isolated northern lobe. Lake Killarney is located in the larger Howell Branch Creek Basin which discharges to Lake Jesup and the St. Johns River. Watershed areas surrounding Lake Killarney are highly developed, with a mixture of residential, commercial, and professional office land use activities. Much of the existing development was constructed prior to implementation of regulations requiring stormwater treatment and discharges untreated runoff directly into the lake. Historical water quality within Lake Killarney has been highly variable, ranging from oligotrophic to hypereutrophic conditions. Lake Killarney is currently listed as an Impaired Waterbody by FDEP, with nutrients assumed to be the causative factor.

Development within the Lake Killarney drainage basin was initiated during the early 1900s and began to expand significantly during the 1940s and 1950s. During that time, Lake Killarney was renowned for clear water and excellent fishing. Currently, virtually all available parcels within the drainage basin have been developed with single-family, commercial, and office uses. Since the late 1960s, Lake Killarney has experienced periodic problems with excessive growth of aquatic submerged macrophytes and has exhibited highly variable water quality characteristics.

During July 2010, Environmental Research & Design, Inc. (ERD) began work on a project, funded jointly by the City of Winter Park and Orange County, to quantify and rank hydrologic and pollutant loadings to Lake Killarney. A field monitoring program was conducted by ERD from August 2010-July 2011 to collect hydrologic and water quality data for use in developing hydrologic and nutrient budgets for the lake. A detailed evaluation of sediment characteristics was also conducted which included physical and chemical characterization of surficial sediments and evaluation of internal phosphorus recycling. In addition, samples of groundwater seepage collected from Lake Killarney were submitted to the Colorado Plateau Isotope Laboratory to assist in source identification of nutrient inputs through groundwater seepage.

Bathymetric contour maps of water and muck depths were also developed by ERD as part of this project. Lake Killarney contains approximately 3,545 ac-ft of water which corresponds to a mean water depth of 10.7 ft. Based on the muck depth survey, Lake Killarney contains approximately 383.5 ac-ft of organic muck sediments which is sufficient to cover the entire lake bottom to a depth of 1.6 ft.

Water levels in Lake Killarney are controlled by an outfall structure located on the north side of the lake, which discharges to Lake Gem and ultimately Lake Maitland, as well as two drainage wells maintained by Orange County. Discharges rarely occur through the outfall structure with no significant discharges since 1996. Virtually all excess water in Lake Killarney discharges into the two drainage wells.

Drainage Basin Characteristics

A delineation of contributing drainage basin areas to Lake Killarney was conducted by ERD as part of this project. A total of 37 separate sub-basin areas, with a total combined watershed area of approximately 561.6 acres (each ranging in size from 0.89-110 acres), were delineated which discharge into Lake Killarney through individual stormsewers or channels. In addition, Lake Killarney receives intermittent inputs from four interconnected waterbodies along with a large wetland system, occupying an additional watershed area of 892.26 acres. Land use within the Lake Killarney drainage basin consists primarily of medium-density residential (52.8%), commercial (28.7%), institutional (8.6%), high-density residential (6.8%), transportation (2.6%), along with miscellaneous other land use categories. Soils within the drainage basin consist primarily of deep sandy soils with a very low runoff potential and a high rate of infiltration for rainfall into the soil.

A number of water quality retrofit projects have been conducted on Lake Killarney by the City of Winter Park and Orange County. The City of Winter Park has constructed leaf/debris traps on 10 of the 13 stormwater outfalls on the Winter Park side of Lake Killarney. In addition, the City of Winter Park has installed treatment systems on 2 of the 3 largest outfalls to the lake. Orange County has installed 39 curb and grate inlet baskets on the southern and western sides of Lake Killarney in areas within unincorporated Orange County.

Virtually all areas adjacent to Lake Killarney, with the exception of the east end of the east lobe adjacent to Orlando Avenue, use septic tanks for sanitary sewage disposal. Approximately 1376 individual septic tanks are located in the Lake Killarney drainage basin.

Hydrologic Budget

A hydrologic budget was developed by ERD for Lake Killarney which includes inputs from precipitation, stormwater runoff, inflow from interconnected lakes, and groundwater seepage. Inputs from groundwater seepage were monitored directly by ERD using 30 underwater seepage meters installed throughout the lake which were monitored over a period of 12 months. Hydrologic inputs from precipitation, stormwater runoff, and inflow from interconnected lakes were estimated using modeling techniques.

The largest hydrologic input to Lake Killarney is direct precipitation which contributes 36% of the total annual hydrologic inputs to the lake. Approximately 23% of the average annual hydrologic inputs originate as a result of stormwater runoff. Interconnected lake inflows from Lake Bell contribute approximately 17%, with 13% of the annual hydrologic inputs contributed by inflows from Lake Mendson. Groundwater seepage contributes approximately 9% of the annual hydrologic inputs, with 2% contributed by direct overland flow. The mean annual residence time in Lake Killarney is approximately 406 days.

Nutrient Loadings

Lake Killarney receives nutrient inputs from a variety of sources which include bulk precipitation, stormwater runoff, interconnected lake inflow, shallow groundwater seepage, and internal recycling. Nutrient loadings from bulk precipitation, stormwater runoff, shallow groundwater seepage, and internal recycling were measured directly by ERD as part of this project. During the field monitoring program, ERD collected a total of 12 composite bulk precipitation samples for use in quantifying the characteristics of wet and dry fallout onto Lake Killarney. A stormwater monitoring project was conducted by ERD at 7 separate monitoring locations, representing significant inflows into the lake, and a total of 37 separate composite inflow samples was collected during the field monitoring program. A total of 30 groundwater seepage meters was installed in Lake Killarney, with 8 monitoring events conducted over a period of 12 months. This information is used to estimate nutrient inputs into Lake Killarney from groundwater seepage. Large diameter core samples were collected at 4 separate locations within the lake and incubated under aerobic and anoxic conditions to estimate sediment nutrient release within the lake.

On an average annual basis, approximately 51% of the total nitrogen loadings to Lake Killarney originate from internal recycling, with 16% contributed by groundwater seepage, 12% by bulk precipitation, 10% by stormwater runoff, 5% each by inflows from Lake Mendson and Lake Bell, and 1% by overland flow.

Internal recycling appears to be the largest phosphorus input to Lake Killarney on an annual basis, contributing 63% of the estimated annual loading. Approximately 17% is contributed by stormwater runoff, with 8% each by bulk precipitation and groundwater seepage. Phosphorus loadings from direct overland flow and inflows from Lake Mendson and Lake Bell are relatively minimal. Approximately 82% of the total nitrogen which enters Lake Killarney each year is retained within the sediments, along with 96% of the total phosphorus and 84% of the suspended solids (TSS). Lake Killarney has historically been a phosphorus-limited lake which indicates that inputs of phosphorus should be controlled to improve water quality within the lake.

Isotope Analyses

Sub-samples of the groundwater seepage collected by ERD were shipped to the Colorado Plateau Stable Isotope Laboratory of Northern Arizona University for analysis of stable isotopes of nitrogen and oxygen in nitrate ions captured in the seepage samples. This process can partition the sources of the nitrogen and oxygen and assist in identifying the significance of external inputs into the lake. Approximately 60% of the collected samples indicated the presence of manure or sewage in the nitrogen and oxygen contained within the samples. The presence of sewage signatures in the seepage samples is limited exclusively to areas with existing septic tanks, with no sewage signature observed in areas served by central sewer systems. However, even though a sewage signature is present in the groundwater seepage entering Lake Killarney, nutrient loadings from groundwater seepage, particularly for phosphorus, are relatively minimal and can be addressed as part of a sediment inactivation project to control internal recycling.

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SECTION 1

INTRODUCTION

1.1 General Description

This report provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the City of Winter Park Lake Management Division (City) and the Orange County Environmental Protection Division (OCEPD) to develop hydrologic and nutrient budgets for Lake Killarney. Lake Killarney is a 239-acre lake located in north-central Orange County with watershed areas located primarily within the City of Winter Park and unincorporated Orange County. A general location map for Lake Killarney is given on Figure 1-1.

An overview of Lake Killarney is given on Figure 1-2. Lake Killarney is bounded on the west by I-4, on the north by Lee Road, on the east by Orlando Avenue (US 17-92), and on the south by Fairbanks Avenue. The lake consists of interconnected eastern and western lobes along with a somewhat hydrologically isolated northern lobe. Discharges from Lake Killarney occur from the northern lobe to Lake Gem and ultimately to Lake Maitland. Lake Killarney is located in the larger Howell Branch Creek Basin which discharges to Lake Jesup and the St. Johns River.

As indicated on Figure 1-2, watershed areas surrounding Lake Killarney are highly developed, with a mixture of residential, commercial, and professional office land use activities. Much of the existing development was constructed prior to implementation of regulations requiring stormwater treatment and discharges untreated runoff directly into the lake. Historical water quality within Lake Killarney has been highly variable, ranging from oligotrophic to hypereutrophic conditions.

1.2 Impaired Waters Designation

Section 303(d) of the Clean Water Act (CWA) requires states to submit lists of surface waterbodies that do not meet applicable water quality standards. These waterbodies are defined as “impaired waters” and Total Maximum Daily Loads (TMDLs) must be established for these waters on a prioritized schedule. The Florida Department of Environmental Protection (FDEP) has established a series of guidelines to identify impaired waters which may require the establishment of TMDLs. Waterbodies within the State of Florida have been divided into five separate groups for planning purposes, with Lake Killarney located in the Lake Jesup Planning Unit of the Middle St. Johns Basin in Group 2.

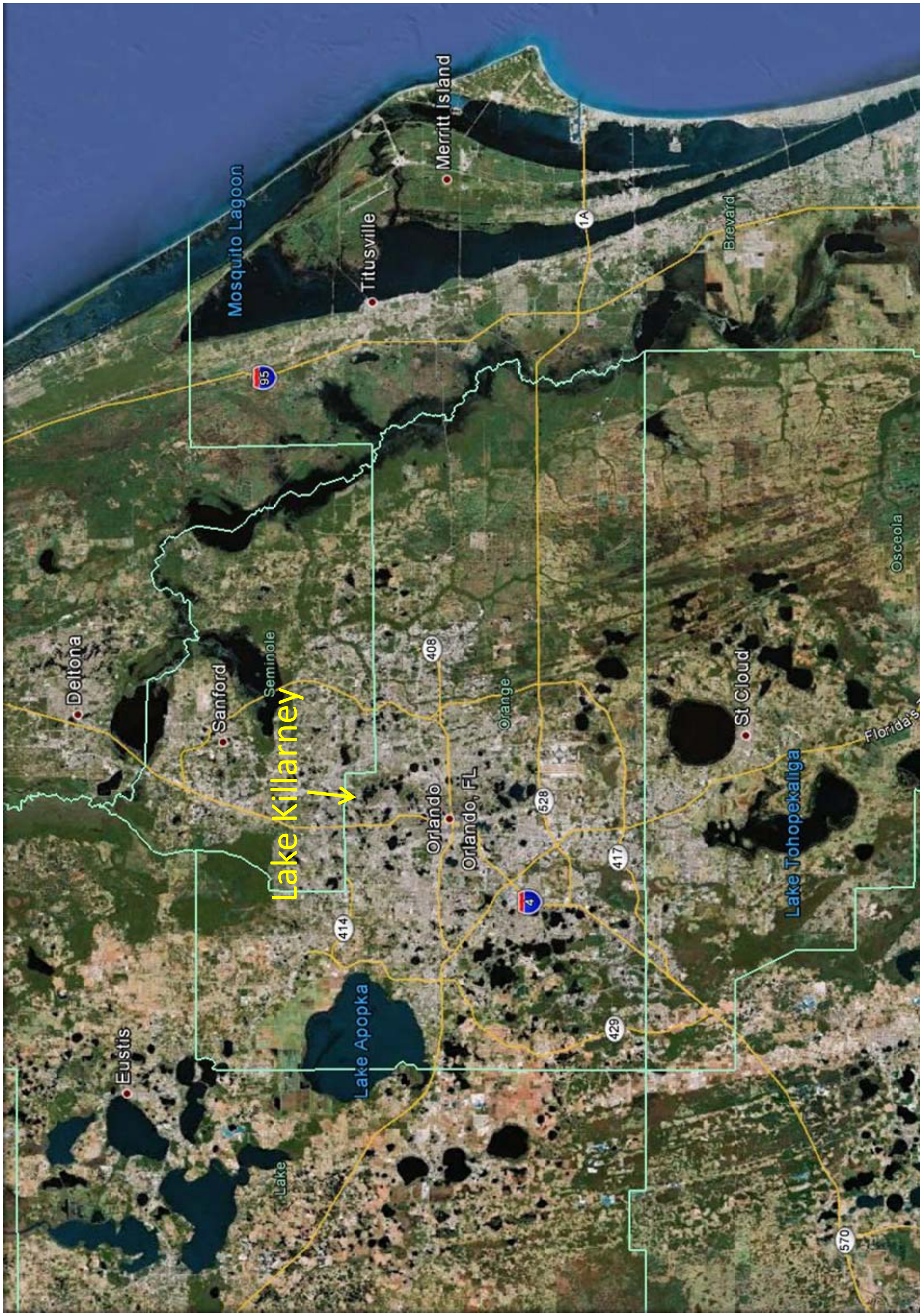


Figure 1-1. Location Map for Lake Killarney.

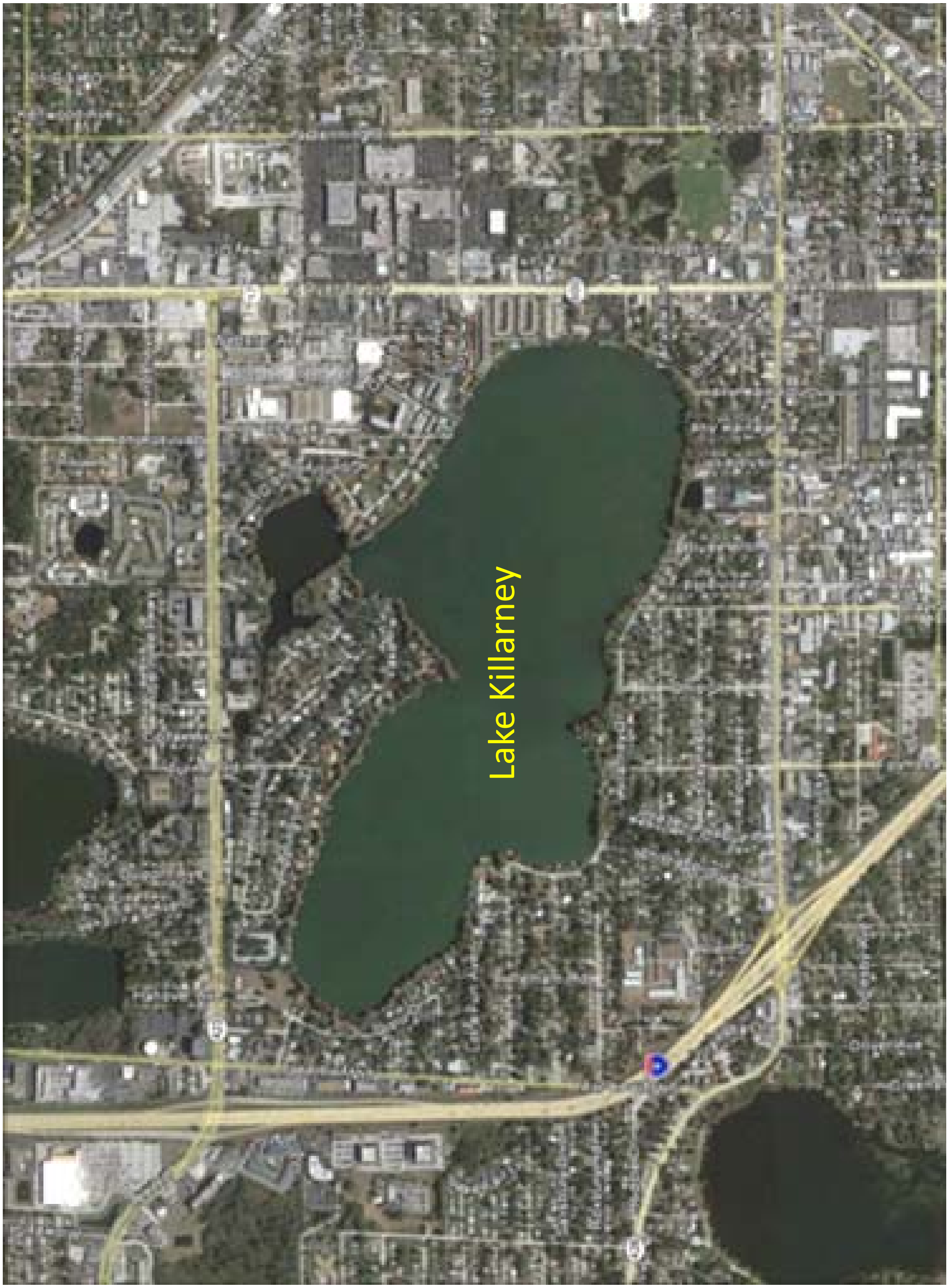


Figure 1-2. Overview of Lake Killarney.

During May 2009, the revised and re-adopted verified list of impaired waterbodies for the Middle St. Johns Basin was released by FDEP and includes Lake Killarney. Lake Killarney (WBID 2997X) is listed as impaired for nutrients based upon a mean TSI value exceeding 40 during 2007. Total phosphorus is stated to be the limiting nutrient within the lake. Lake Killarney is listed as a "medium" priority for TMDL development.

1.3 Current Conditions

Development within the Lake Killarney drainage basin was initiated during the early-1900s and began to expand significantly during the 1940s and 1950s. During that time, Lake Killarney was renowned for clear water and excellent fishing. Currently, virtually all available parcels within the drainage basin have been developed with single-family, commercial, and office uses. Since the late-1960s, Lake Killarney has experienced periodic problems with excessive growth of aquatic submerged macrophytes and exhibited highly variable water quality characteristics.

1.4 Work Efforts Performed by ERD

Work efforts were initiated on this project by ERD during July 2010. The primary objective of this project is to quantify and rank hydrologic and pollutant loadings to Lake Killarney. A field monitoring program was conducted by ERD from August 2010-July 2011 to collect hydrologic and water quality data for use in developing hydrologic and nutrient budgets for the lake. The hydrologic budget includes estimated inputs from precipitation, stormwater runoff, inflow from interconnected lakes, and groundwater seepage. The nutrient budget includes inputs from bulk precipitation, stormwater runoff, inflow from interconnected lakes, groundwater seepage, and internal recycling. A detailed evaluation of sediment characteristics in Lake Killarney was also conducted which included physical and chemical characterization of surficial sediments and evaluation of internal phosphorus recycling. In addition, samples of groundwater seepage collected from Lake Killarney were submitted to the Colorado Plateau Isotope Laboratory to assist in source identification of nutrient inputs through groundwater seepage.

This report has been divided into 7 separate sections for presentation of the work efforts performed by ERD. Section 1 contains an introduction to the report and provides a general overview of the work efforts performed by ERD. Current characteristics of Lake Killarney are discussed in Section 2, including lake bathymetry, sediment accumulation and characteristics, and water quality. A discussion of the drainage basin area is given in Section 3, and the hydrologic budget is presented in Section 4. A nutrient budget, which includes inputs from total nitrogen, total phosphorus, and TSS, is given in Section 5. A discussion of the results of the isotope monitoring on groundwater seepage samples is given in Section 6 with cited references listed in Section 7. Appendices are also attached which contain technical data and analyses used to support the information contained within the report.

SECTION 2

PHYSICAL AND CHEMICAL CHARACTERISTICS OF LAKE KILLARNEY

2.1 Physical Characteristics

A hydrographic survey of Lake Killarney was conducted by ERD on November 4, 2011 to evaluate water column depth as well as thickness of unconsolidated sediments within the lake. Measurements of water depth and sediment thickness were conducted at 307 individual sites in Lake Killarney. Probing locations used for the bathymetric study are indicated on Figure 2-1. Each of the data collection sites was identified in the field by longitude and latitude coordinates using a portable GPS device. The water level elevation in Lake Killarney on April 8, 2011 was 82.92 ft.

Water depth at each of the sites was determined by lowering a 20-cm diameter Secchi disk attached to a graduated line until resistance from the sediment layer was encountered. The depth on the graduated line corresponding to the water surface was recorded in the field and is defined as the water depth at each site. After measurement of the water depth at each site, a 1.5-inch graduated aluminum pole was then lowered into the water column and forced into the sediments until a firm bottom material, typically sand or clay, was encountered. The depth corresponding to the water surface is defined as the depth to the firm lake bottom. The difference between the depth to the firm lake bottom and the water depth at each site is defined as the depth of unconsolidated sediments.

The generated field data was converted into bathymetric maps for both water depth and unconsolidated sediment depth in Lake Killarney using AutoCAD 2007. Estimates of water volume and unconsolidated sediment volume within Lake Killarney were generated using the Autodesk Land Desktop 2007 Module.

A water depth contour map for Lake Killarney, based upon the field monitoring program performed by ERD, is given in Figure 2-2. Lake Killarney consists of two interconnected lobes. The larger lobe, which comprises the larger eastern portion of the lake, is characterized by relatively modest side slopes which extend to a deep central area at water depths ranging from 20-25 ft. The smaller lobe, comprising the western portion of the lake, is characterized by steeper slopes which extend rapidly to a maximum depth of approximately 25-27 ft. A small northern lobe is connected to the eastern lobe by a small channel. The northern lobe is characterized by relatively steep side slopes extending to a maximum water depth of 16 ft. Several other depressional areas are evident along the southern, eastern, and northeastern shoreline areas. The bathymetric signatures indicated on Figure 2-2 suggest that Lake Killarney originated as a result of multiple independent sinkhole features which became interconnected.

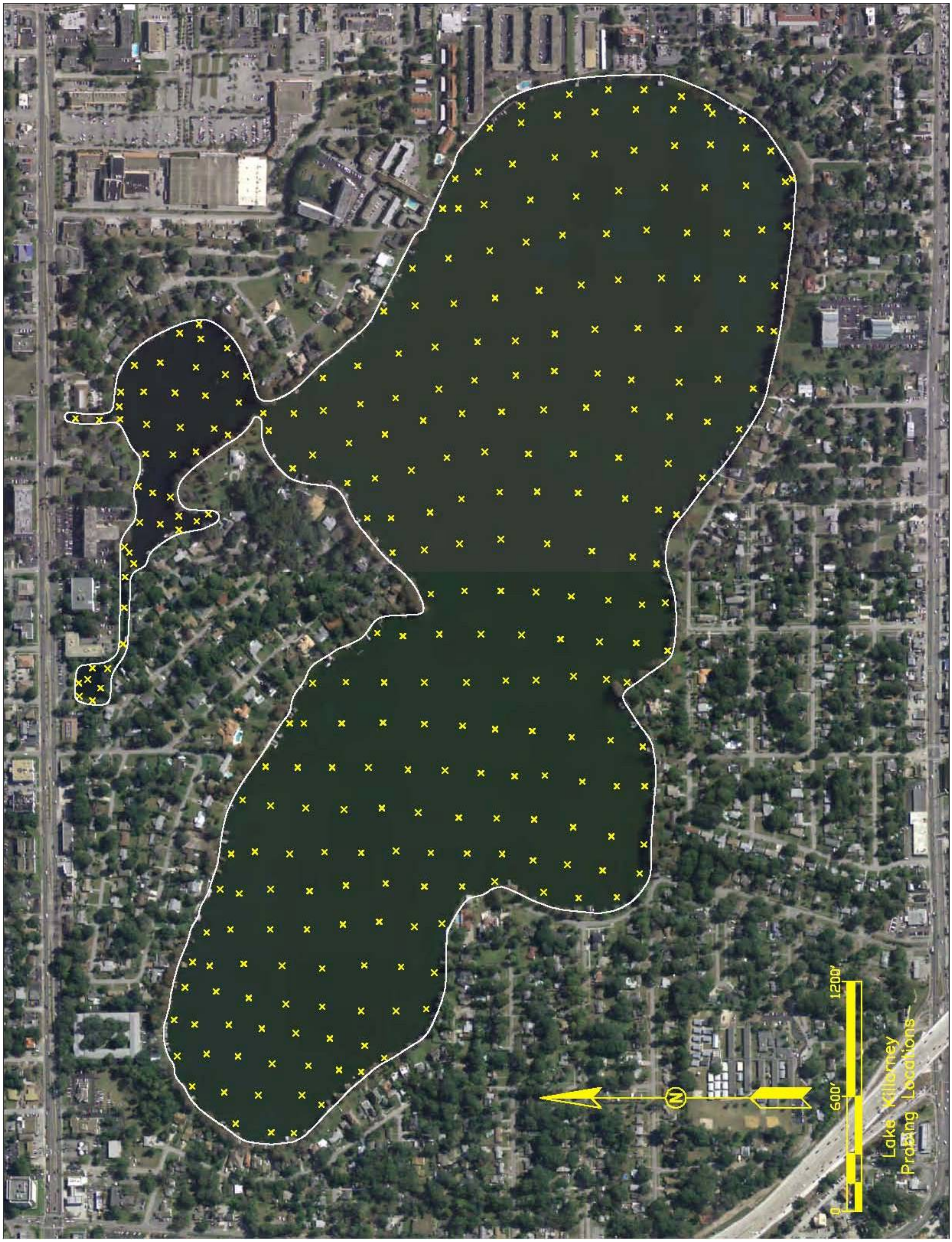


Figure 2-1. Probing Locations for Water and Muck Depth in Lake Killarney (November 4, 2011).

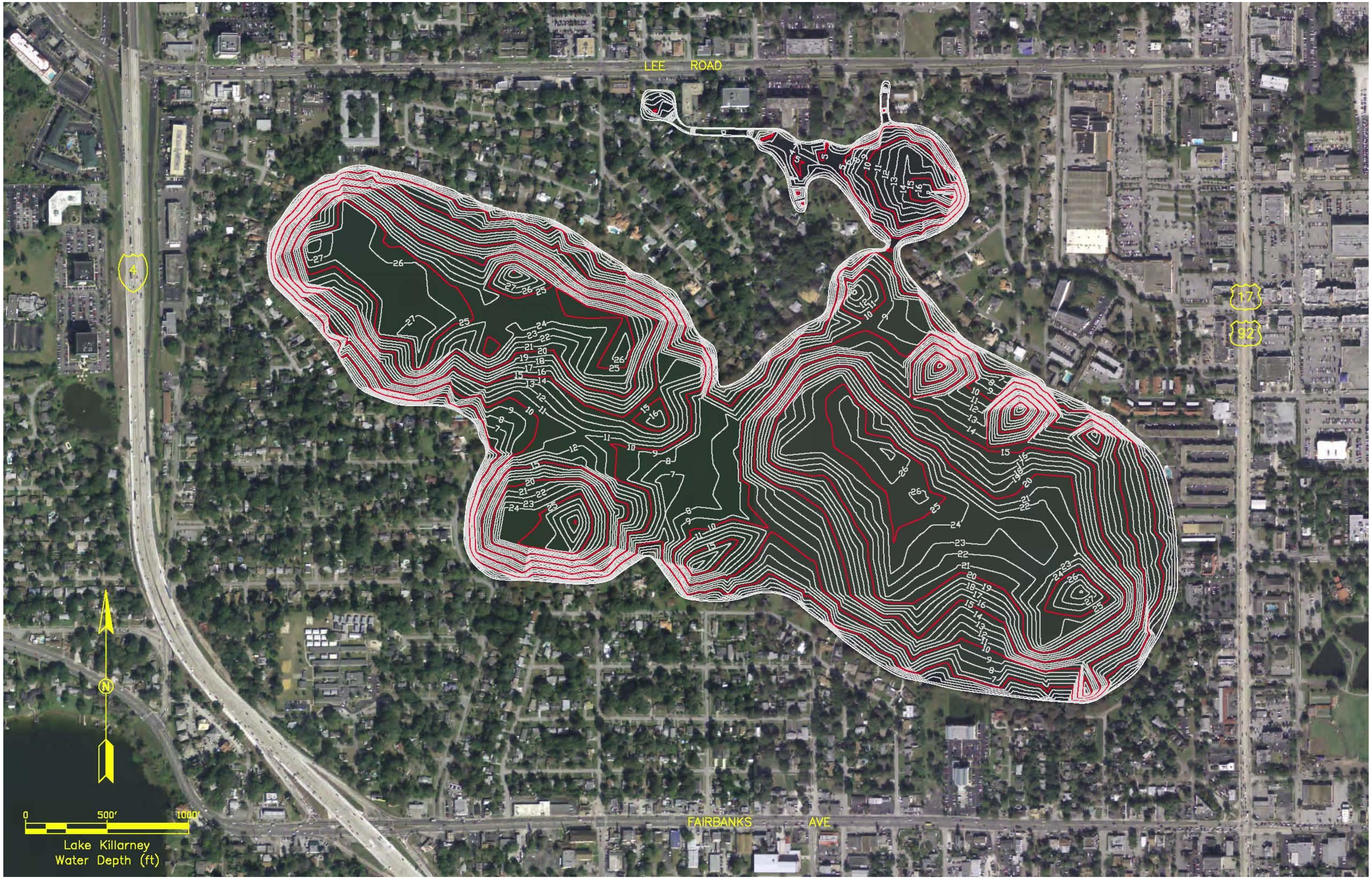


Figure 2-2. Water Depth Contours (ft) for Lake Killarney on November 4, 2011. (Water Elevation = 82.92 ft)

The water level in Lake Killarney is regulated by an outfall structure on the north side of the lake with a control discharge elevation of 83.86 ft (Orange County). This structure is discussed in more detail in a subsequent section. As indicated previously, the water surface elevation in Lake Killarney at the time of the bathymetric survey conducted by ERD was approximately 82.92 ft which is 0.94 ft lower than the control elevation for the lake.

Stage-area-volume relationships for Lake Killarney are summarized in Table 2-1 based on the bathymetric survey performed by ERD. At the water surface elevation of 82.92 ft present on April 8, 2011, the lake surface area is approximately 239.6 acres. The lake volume at this surface area is 3,545 ac-ft which corresponds to a mean water depth of approximately 14.8 ft which is relatively deep for a Central Florida lake. A summary of bathymetric characteristics of Lake Killarney is given in Table 2-2.

TABLE 2-1

DEPTH-AREA-VOLUME RELATIONSHIPS FOR LAKE KILLARNEY
(Elev. 82.92 ft)

ELEVATION (ft)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)	ELEVATION (ft)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)
0	239.6	3,545	16	104.8	646.7
1	235.3	3,307	17	97.0	545.9
2	229.8	3,075	18	89.9	452.4
3	224.3	2,848	19	83.0	366.0
4	218.3	2,626	20	76.1	286.4
5	212.1	2,411	21	68.0	214.3
6	206.4	2,202	22	58.9	150.9
7	199.8	1,999	23	48.1	97.4
8	188.6	1,805	24	36.3	55.2
9	176.7	1,622	25	22.0	26.0
10	165.6	1,451	26	11.6	9.24
11	154.6	1,291	27	2.50	2.18
12	143.8	1,142	28	0.77	0.54
13	133.7	1,003	29	0.16	0.08
14	123.4	874.2	30	0.0	0
15	113.4	755.8			

A bathymetric contour map of the depth of unconsolidated organic sediments in Lake Killarney is given in Figure 2-3. Deep pockets of organic muck are apparent in the center of the eastern and western lobes where muck depths range from 1-9 ft. Substantial accumulations of organic muck are also apparent in the areas associated with the smaller sinkhole features, with muck depths also ranging from 1-9 ft. Several other pockets of organic muck are scattered throughout the lake which range in depth from 1-6 ft.

TABLE 2-2

BATHYMETRIC CHARACTERISTICS OF LAKE KILLARNEY

BATHYMETRIC PARAMETER[1]	VALUE
Surface Area	239.6 acres
Total Volume	3,545 ac-ft
Mean Depth	14.8 ft
Maximum Depth	> 30 ft
Shoreline Length	21,613 ft (4.09 miles)

1. Based upon a water surface elevation of 82.92 ft (NGVD) on April 8, 2011

Estimates of area-volume relationships for organic muck accumulations in Lake Killarney are given in Table 2-3. Approximately 157.6 acres (66%) of the lake area has existing muck accumulations ranging from 0-1 ft in depth, with 10% of the lake bottom covered by muck accumulations ranging from 1-2 ft in depth, and 7% ranging from 2-3 ft in depth. Overall, Lake Killarney contains approximately 383.5 ac-ft (16,705,260 ft^3) of unconsolidated organic sediments. The volume of unconsolidated sediment in Lake Killarney is sufficient to cover the entire lake bottom to a depth of approximately 1.60 ft. The mean muck depth in Lake Killarney is similar to the mean muck depth of 1.5 ft measured by ERD in Lake Holden during 2004 and the mean muck depth of 1.97 ft measured in Lake Pineloch during 2008.

TABLE 2-3

DEPTH-AREA-VOLUME RELATIONSHIPS FOR ORGANIC MUCK IN LAKE KILLARNEY

MUCK DEPTH (ft)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)	MUCK DEPTH (ft)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)
0	239.6	383.5	5	21.8	37.8
1	82.0	222.7	6	14.6	19.7
2	59.2	152.1	7	8.4	8.2
3	43.1	100.9	8	3.7	2.2
4	30.7	64.1	9	0.7	0

2.2 Sediment Characteristics

Sediment core samples were collected in Lake Killarney by ERD to evaluate the characteristics of existing sediments and potential impacts on water quality within the lake. Sediment core samples were collected at 45 separate locations within the lake on March 24, 2011 by ERD personnel. Locations of sediment sampling sites in Lake Killarney are illustrated on Figure 2-4. Based on the lake surface area of 239.6 acres, sediment samples were collected at a rate of one sample for every 5.3 acres of lake area.

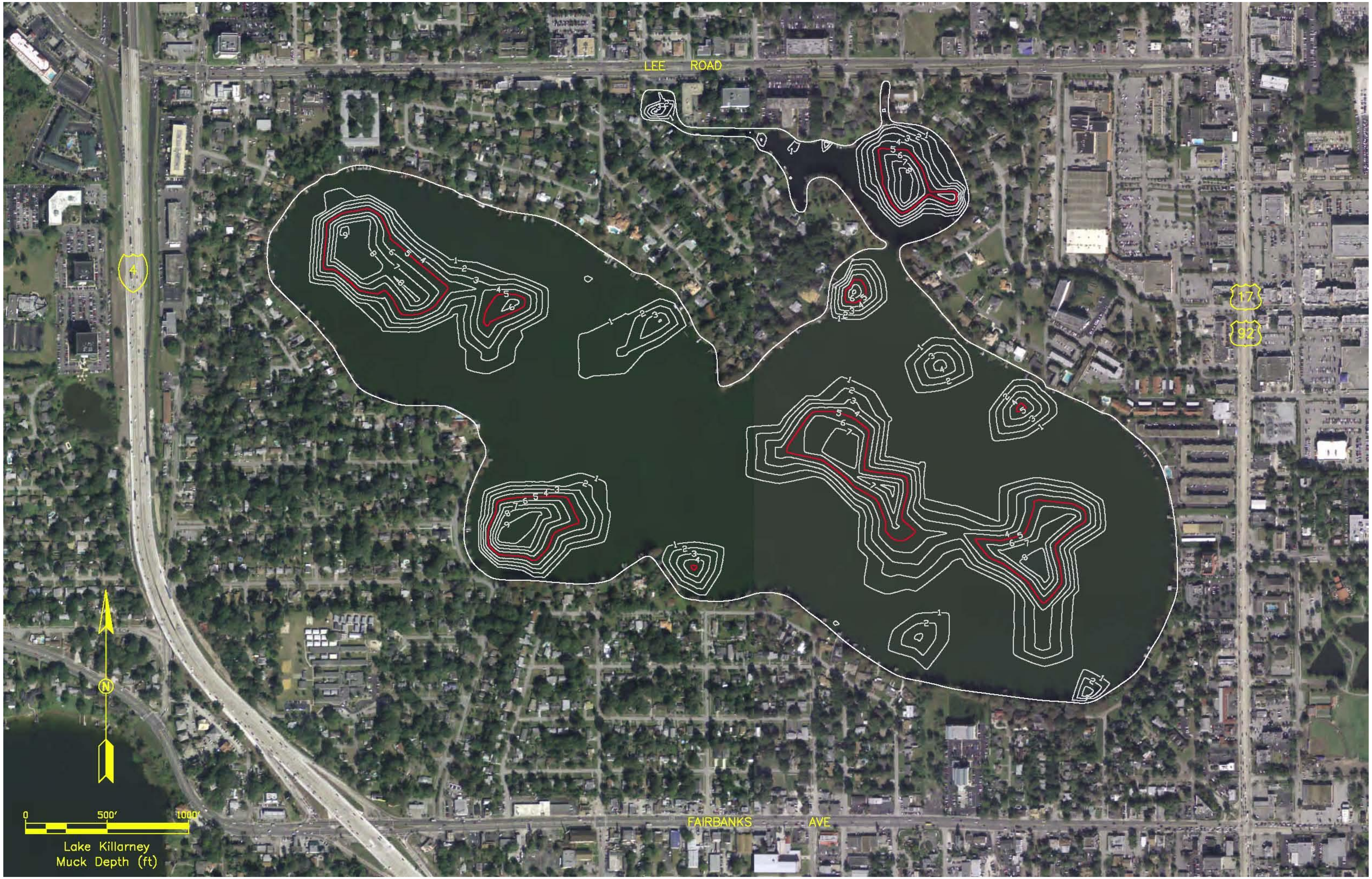


Figure 2-3. Muck Depth Contours (ft.) in Lake Killarney on April 8, 2011.

2.2.1 Sampling Techniques

Sediment samples were collected at each of the 45 monitoring sites using a stainless steel split-spoon core device, which was penetrated into the sediments at each location to a minimum distance of approximately 0.5 m. After retrieval of the sediment sample, any overlying water was carefully decanted before the split-spoon device was opened to expose the collected sample. Visual characteristics of each sediment core sample were recorded, and the 0-10 cm layer was carefully sectioned off and placed into a polyethylene container for transport to the ERD laboratory. Duplicate core samples were collected at each site, and the 0-10 cm layers were combined together to form a single composite sample for each of the 45 monitoring sites. The polyethylene containers utilized for storage of the collected samples were filled completely to minimize air space in the storage container above the composite sediment sample. Each of the collected samples was stored on ice and returned to the ERD laboratory for physical and chemical characterization.

2.2.2 Sediment Characterization and Speciation Techniques

Each of the 45 collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-4.

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on each of the 45 collected sediment samples. A modified version of the Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), was used for phosphorus fractionation. The Chang and Jackson Procedure allows the speciation of sediment phosphorus into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable sediment phosphorus), iron-bound phosphorus, and aluminum-bound phosphorus. Although not used in this project, subsequent extractions of the Chang and Jackson procedure also provide calcium-bound and residual fractions.

The Chang and Jackson procedure was originally developed at the University of Wisconsin to evaluate phosphorus bonding in dried agricultural soils. However, drying of wet sediments will significantly impact the phosphorus speciation, particularly the soluble and iron-bound associations. Therefore, the basic Chang and Jackson method was adapted and modified by ERD for wet sediments by adjusting solution concentrations and extraction timing to account for the liquid volume in the wet sediments and the reduced solids mass. This modified method has been used as the basis for all sediment inactivation projects which have been conducted in the State of Florida.

Saloid-bound phosphorus is considered to be available under all conditions at all times. Iron-bound phosphorus is relatively stable under aerobic environments, generally characterized by redox potentials greater than 200 mv (E_h), while unstable under anoxic conditions, characterized by redox potential less than 200 mv. Aluminum-bound phosphorus is considered to be stable under all conditions of redox potential and natural pH conditions. A schematic of the Chang and Jackson Speciation Procedure for evaluating soil phosphorus bounding is given in Figure 2-5.

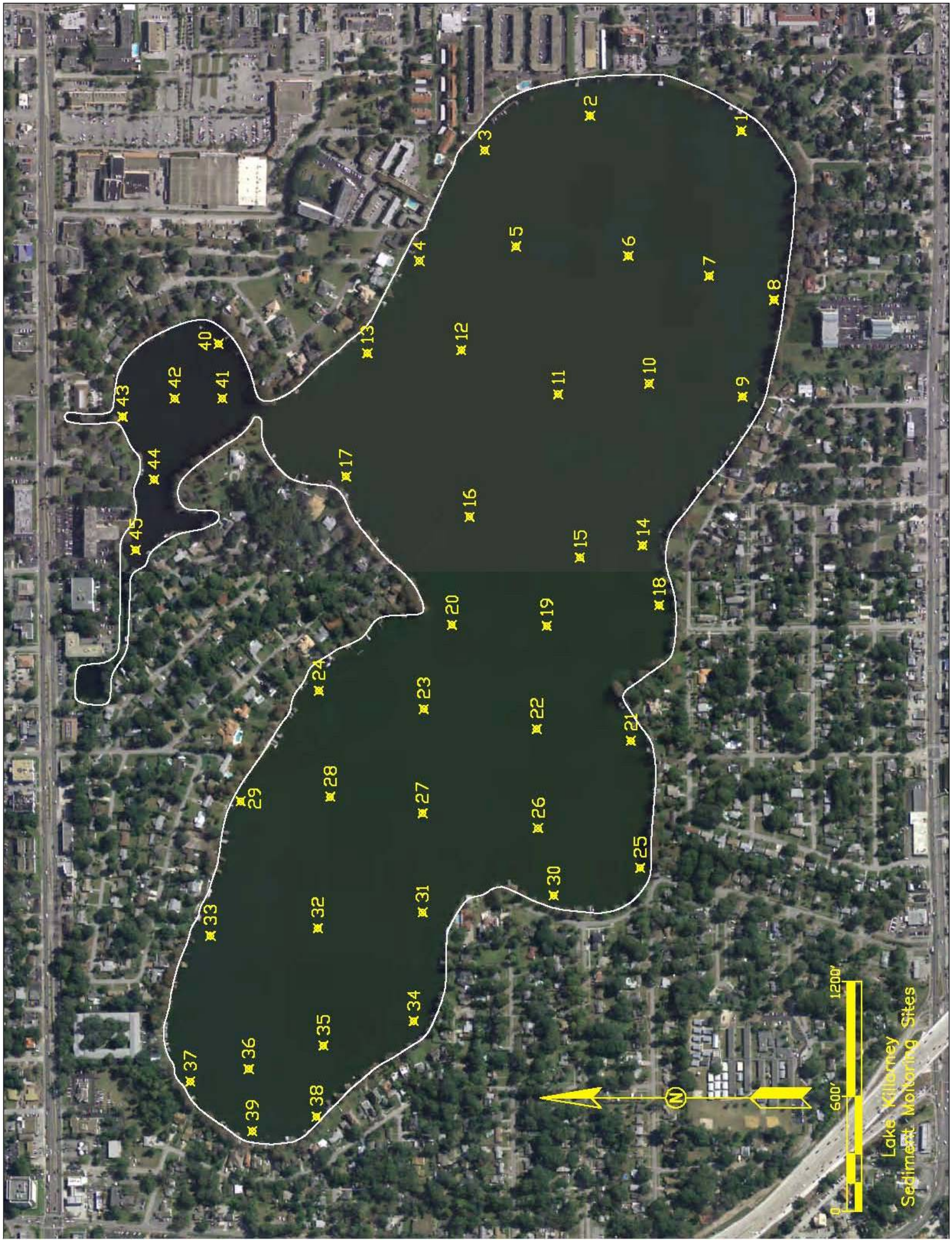


Figure 2-4. Location of Sediment Monitoring Sites in Lake Killarney.

TABLE 2-4

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

MEASUREMENT PARAMETER	SAMPLE PREPARATION	ANALYSIS REFERENCE	REFERENCE PREP./ANAL.*	METHOD DETECTION LIMITS (MDLs)
pH	EPA 9045	EPA 9045	3 / 3	0.01 pH units
Moisture Content	p. 3-54	p. 3-58	1 / 1	0.1%
Organic Content (Volatile Solids)	p. 3-52	pp. 3-52 to 3-53	1 / 1	0.1%
Total Phosphorus	pp. 3-227 to 3-228 (Method C)	EPA 365.4	1 / 2	0.005 mg/kg
Total Nitrogen	p. 3-201	pp. 3-201 to 3-204	1 / 1	0.010 mg/kg
Specific Gravity Density)	p. 3-61	pp. 3-61 to 3-62	1 / 1	NA

*REFERENCES:

1. Procedures for Handling and Chemical Analysis of Sediments and Water Samples, EPA/Corps of Engineers, EPA/CE-81-1, 1981.

2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.

3. Test Methods for Evaluating Solid Wastes, Physical-Chemical Methods, Third Edition, EPA-SW-846, Updated November 1990.

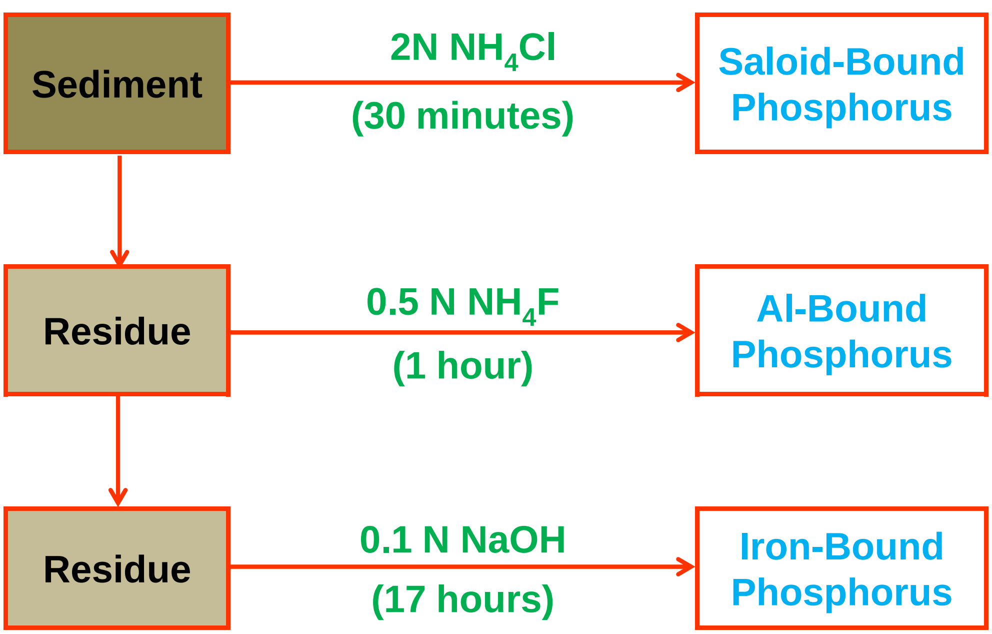


Figure 2-5. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

For purposes of evaluating release potential, ERD typically assumes that potentially available inorganic phosphorus in soils/sediments, particularly those which exhibit a significant potential to develop reduced conditions below the sediment-water interface, is represented by the sum of the soluble inorganic phosphorus and easily exchangeable phosphorus fractions (collectively termed saloid-bound phosphorus), plus iron-bound phosphorus which can become solubilized under reduced conditions. Aluminum-bound phosphorus is generally considered to be unavailable in the pH range of approximately 5.5-7.5 under a wide range of redox conditions.

2.2.3 Sediment Characteristics

2.2.3.1 Visual Characteristics

Visual characteristics of sediment core samples were recorded for each of the 45 sediment samples collected in Lake Killarney during March 2011. A summary of visual characteristics of sediment core samples is given in Table 2-5. In general, a surficial layer of unconsolidated organic muck was observed in Lake Killarney at 13 of the 45 monitoring sites, with measured depths ranging from 0-8 cm. This unconsolidated surficial layer is comprised primarily of fresh organic material (such as dead algal cells) and detritus which has recently accumulated onto the bottom of the lake. This organic material is easily disturbed by wind action or boating activities. In deeper portions of the lake, characterized by thick muck deposits, the organic muck becomes more consolidated beneath the surficial layer, with a consistency similar to pudding. These layers reflect older organic deposits which are resistant to further degradation. These layers typically do not resuspend into the water column except during relatively vigorous wind activity on the lake. Shallow and shoreline areas of the lake are characterized by a mixture of brown fine sand and muck. Photographs of typical sediment characteristics in Lake Killarney are given on Figure 2-6.

2.2.3.2 General Sediment Characteristics

After return to the ERD Laboratory, the collected sediment core samples were evaluated for general sediment characteristics, including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphorus. A summary of general characteristics measured in each of the 45 collected sediment core samples is given in Table 2-6. In general, sediments in Lake Killarney were found to be slightly acidic in pH, with measured pH values ranging from 5.45-6.87 and an overall geometric mean of 6.39. These values are typical of pH measurements commonly observed in eutrophic urban lakes.

Isopleths of pH in the top 10 cm of sediments in Lake Killarney are illustrated on Figure 2-7, based upon the information provided in Table 2-6. The majority of areas within Lake Killarney are characterized by pH values ranging from approximately 6.0-6.6. In general, pH values of approximately 6.2 or less were observed in areas of deep organic muck within the lake, although pH values equal to this or less were also observed in shoreline areas along the southwestern and northeastern portions of the lake.

TABLE 2-5

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE KILLARNEY ON MARCH 24, 2011

SITE NUMBER	LAYER (cm)	VISUAL APPEARANCE
1	0 - >12	Brown fine sand with organics
2	0 - >8	Brown fine sand with organics
3	0 - >11	Brown fine sand with organics
4	0 - >13	Brown fine sand with organics
5	0 - >28	Brown fine sand with organics
6	0 - 5 5 - >42	Dark brown unconsolidated organic muck Dark brown consolidated organic muck
7	0 - >14	Brown fine sand with organics
8	0 - >17	Brown fine sand with organics
9	0 - >14	Brown fine sand with organics
10	0 - 8 8 - >24	Dark brown unconsolidated organic muck Dark brown consolidated organic muck
11	0 - 6 6 - >43	Dark brown unconsolidated organic muck Dark brown consolidated organic muck
12	0 - >12	Light brown fine sand
13	0 - >11	Brown fine sand with organics
14	0 - >13	Brown fine sand with organics
15	0 - 6 6 - >11	Light brown fine sand Brown fine sand with organics
16	0 - 3 3 - 39 39 - >44	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Brown fine sand with organics
17	0 - >14	Brown fine sand with organics
18	0 - >18	Brown fine sand with organics
19	0 - >12	Brown fine sand with organics
20	0 - 1 1 - >13	Brown fine sand with organics Light brown fine sand
21	0 - >14	Brown fine sand with organics
22	0 - >11	Brown fine sand with organics
23	0 - >10	Brown fine sand with organics
24	0 - >14	Brown fine sand with organics
25	0 - >14	Brown fine sand with organics
26	0 - 3 3 - 22 22 - >69	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Dark brown consolidated organic muck
27	0 - 1 1 - >12	Brown fine sand with organics Light brown fine sand
28	0 - >7	Brown fine sand with organics
29	0 - >12	Brown fine sand with organics
30	0 - >14	Brown fine sand with organics
31	0 - 4 4 - >16	Light brown fine sand Brown fine sand with organics
32	0 - 3 3 - 19 19 - >44	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Dark brown consolidated organic muck
33	0 - >16	Brown fine sand with organics

TABLE 2-5 -- CONTINUED

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE KILLARNEY ON MARCH 24, 2011

SITE NUMBER	LAYER (cm)	VISUAL APPEARANCE
34	0 - >7	Brown fine sand with organics
35	0 - >16	Brown fine sand with organics
36	0 - 4	Dark brown unconsolidated organic muck
	4 - >39	Dark brown consolidated organic muck
37	0 - >7	Brown fine sand with organics
38	0 - >14	Brown fine sand with organics
39	0 - >6	Brown fine sand with organics
40	0 - 4	Dark brown unconsolidated organic muck
	4 - 36	Dark brown consolidated organic muck
	36 - >57	Brown fine sand with organics
41	0 - 5	Dark brown unconsolidated organic muck
	5 - 36	Dark brown consolidated organic muck
	36 - >44	Brown fine sand with organics
42	0 - 6	Dark brown unconsolidated organic muck
	6 - >48	Dark brown consolidated organic muck
43	0 - 3	Dark brown unconsolidated organic muck
	3 - 17	Dark brown consolidated organic muck
	17 - >26	Brown fine sand with organics
44	0 - >27	Dark brown unconsolidated organic muck
45	0 - 1	Dark brown unconsolidated organic muck
	1 - >18	Brown fine sand with organics

Measurements of sediment moisture content and organic content in Lake Killarney were found to be highly variable throughout the lake. Many of the collected sediment samples are characterized by a relatively low moisture content and low organic content, suggesting that these surficial sediments are comprised primarily of fine sand. In contrast, other sediment core samples are characterized by elevated values for both moisture content and organic content, suggesting areas of accumulated organic muck. Measured sediment moisture contents ranged from 24.6-90.4% with an overall geometric mean of 40.5%.

Isopleths of sediment moisture content in Lake Killarney are summarized in Figure 2-8 based upon the information provided in Table 2-6. Areas of elevated moisture content are present in portions of the eastern and western lobes, along with the south-central and northern lobe. Sediment moisture contents in excess of 50% are often indicative of highly organic sediments, while moisture contents less than 50% reflect mixtures of sand and muck. These areas correspond well with the areas of accumulated muck indicated on Figure 2-3.

a. Sandy sediments

b. Organic muck overlying sand

c. Deep organic muck sediments

d. Organic muck with shell fragments

Figure 2-6. Photographs of Typical Sediment Characteristics in Lake Killarney.

TABLE 2-6

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE KILLARNEY DURING MARCH 2011

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	WET DENSITY (g/cm^3)	TOTAL NITROGEN (µg/cm^3)	TOTAL PHOSPHORUS (µg/cm^3)
1	6.51	37.8	3.0	1.90	7,435	1,355
2	6.73	24.6	0.7	2.12	4,591	581
3	5.56	31.3	1.2	2.02	5,320	550
4	6.23	30.9	1.4	2.02	5,549	905
5	6.36	29.5	0.8	2.05	2,937	814
6	5.89	87.0	36.3	1.12	5,294	1,493
7	6.51	26.5	0.9	2.09	4,530	621
8	6.53	40.9	2.2	1.87	7,556	850
9	6.51	29.3	11.4	1.94	5,719	1,663
10	6.12	90.0	36.1	1.10	4,934	1,187
11	5.96	87.2	30.6	1.13	4,648	1,575
12	6.74	26.9	0.6	2.09	3,257	513
13	6.66	28.8	18.9	1.87	5,256	718
14	6.50	31.0	1.5	2.02	4,599	619
15	6.69	29.2	0.7	2.05	2,946	642
16	5.83	83.5	27.5	1.18	5,126	1,490
17	6.69	42.3	2.2	1.85	6,492	1,062
18	6.56	33.3	1.2	1.99	4,143	434
19	6.59	32.7	1.1	2.00	5,766	655
20	6.87	28.1	0.8	2.07	2,218	346
21	6.69	25.0	0.9	2.12	2,592	374
22	6.71	36.5	1.0	1.94	4,367	516
23	6.46	26.8	0.8	2.09	3,403	1,044
24	6.64	25.9	1.0	2.10	2,613	1,172
25	6.15	34.3	3.0	1.96	4,425	1,357
26	5.98	89.8	35.2	1.10	4,864	1,152
27	6.49	32.7	0.6	2.00	1,814	522
28	6.39	32.3	1.2	2.00	3,739	861
29	6.72	37.1	2.1	1.92	4,822	921
30	6.04	31.2	1.2	2.02	4,204	1,068
31	6.55	30.3	0.7	2.04	4,605	770
32	6.05	86.9	32.8	1.13	4,370	1,438
33	6.56	33.5	1.3	1.98	4,896	682
34	6.69	31.9	1.2	2.01	4,155	821
35	6.77	28.8	1.2	2.06	4,453	741
36	6.08	90.4	35.5	1.09	5,105	1,050
37	6.52	38.1	2.8	1.90	5,148	658
38	5.45	36.1	2.0	1.94	6,162	913
39	5.99	32.3	1.3	2.00	4,787	981
40	6.23	84.6	25.7	1.17	5,748	1,694
41	6.33	76.2	13.8	1.31	6,798	2,357
42	6.23	85.6	31.4	1.15	4,691	1,528
43	6.78	74.9	23.9	1.29	5,357	1,097
44	6.75	30.7	2.1	2.02	3,466	1,166
45	6.81	50.2	5.6	1.71	4,460	4,300
Minimum	**5.45**	**24.6**	**0.6**	**1.09**	**1,814**	**356**
Maximum	**6.87**	**90.4**	**36.3**	**2.12**	**7,556**	**4,300**
Geometric Mean	**6.39**	**40.5**	**3.1**	**1.74**	**4,470**	**923**

Figure 2-7. Isopleths of pH in the Top 10 cm of Sediments in Lake Killarney.

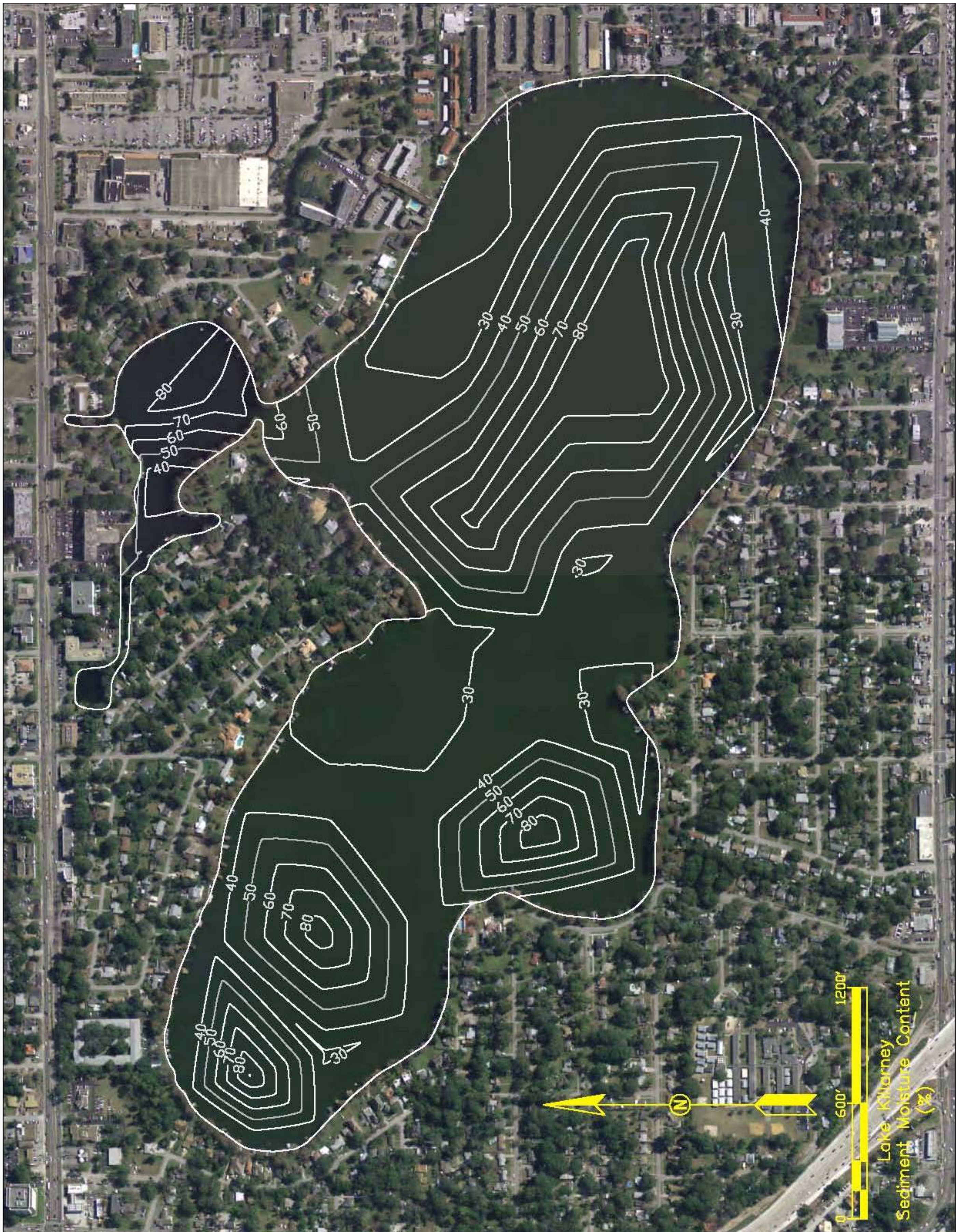


Figure 2-8. Isopleths of Moisture Content (%) in the Top 10 cm of Sediments in Lake Killarney.

Isopleths of sediment organic content in Lake Killarney are illustrated on Figure 2-9 based upon the information provided in Table 2-6. In general, sediment organic content values in excess of 20-30% are often indicative of organic muck type sediments, with values less than 20-30% representing either sand or mixtures of muck and sand. Based upon these criteria, areas of concentrated organic muck are apparent in central portions of the eastern and western lobes along with the south-central and northern lobe. These areas of high organic content correspond closely with the areas of accumulated organic muck deposits illustrated on Figure 2-3. Measured sediment organic content within Lake Killarney ranges from 0.6-36.3%, with an overall mean of 3.1%. The mean sediment organic content of 3.1% in Lake Killarney is less than the mean organic content of 8.4% in measured Lake Holden sediments and the mean of 11.3% measured in Lake Pineloch.

Measured sediment density values are also useful in evaluating the general characteristics of sediments within a lake. Sediments with calculated wet densities between 1.0 g/cm^3 and 1.25 g/cm^3 are indicative of highly organic muck type sediments, while sediment densities of approximately 2.0 or greater are indicative of sandy sediment conditions. Values between 1.25 g/cm^3 and 2.0 g/cm^3 indicate mixtures of sand muck. Measured sediment density values in Lake Killarney range from 1.09-2.12 g/cm^3, with an overall mean of 1.74 g/cm^3.

Isopleths of wet density in Lake Killarney sediments are given in Figure 2-10. Areas of low density sediments are apparent in the eastern and western lobes, the south-central area, and the northern lobe. Sediments characterized by densities indicative of sandy sediments are located primarily around the perimeter of the shoreline and central portions of the lake.

Measured concentrations of total phosphorus in Lake Killarney sediments were found to be highly variable throughout the lake, ranging from 346-4,300 μg/cm^3, with an overall mean of 923 μg/cm^3. In general, sandy sediments are often characterized by low total phosphorus concentrations, while highly organic muck type sediments are characterized by elevated total phosphorus concentrations. The mean sediment phosphorus concentration of 923 μg/cm^3 in Lake Killarney is substantially greater than the sediment phosphorus concentration of 439 μg/cm^3 measured in Lake Holden and the concentration of 502 μg/cm^3 measured in Lake Pineloch.

Isopleths of sediment phosphorus concentrations in Lake Killarney are presented on Figure 2-11, based on information contained in Table 2-6. Areas of elevated sediment phosphorus concentrations are present in the central and southeastern portions of the lake, similar to the areas of elevated moisture and organic content illustrated on Figures 2-8 and 2-9, respectively. In general, overall total phosphorus concentrations observed in Lake Killarney appear to be somewhat elevated compared with phosphorus sediment concentrations typically observed in urban lakes.

Similar to the trends observed for sediment phosphorus concentrations, sediment nitrogen concentrations are also highly variable throughout Lake Killarney. Measured sediment nitrogen concentrations in the lake range from 1,814-7,556 μg/cm^3, with an overall mean of 4,470 μg/cm^3. Measured sediment nitrogen concentrations in Lake Killarney appear to be elevated compared with values normally observed in urban lakes. The mean sediment nitrogen concentration of 4,470 μg/cm^3 in Lake Killarney is substantially greater than the mean of 1198 μg/cm^3 measured by ERD in Lake Holden during September 2003. Isopleths of sediment nitrogen concentrations in Lake Killarney are illustrated on Figure 2-12. In general, areas of elevated nitrogen concentrations are present in eastern, north-central, and western portions of the lake.

Figure 2-9. Isopleths of Organic Content (%) in the Top 10 cm of Sediments in Lake Killarney.

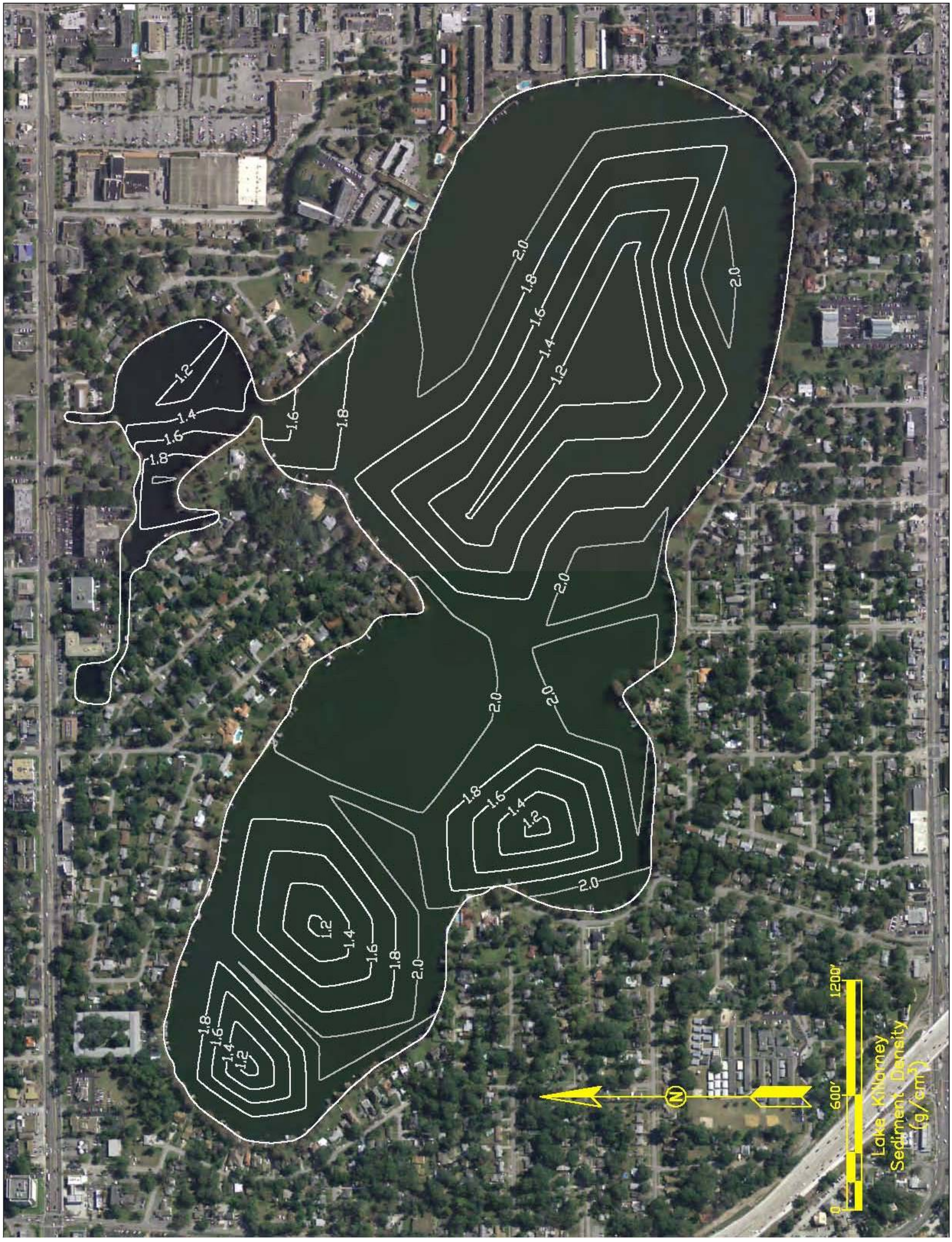


Figure 2-10. Isopleths of Wet Density (g/cm^3) in the Top 10 cm of Sediments in Lake Killarney.

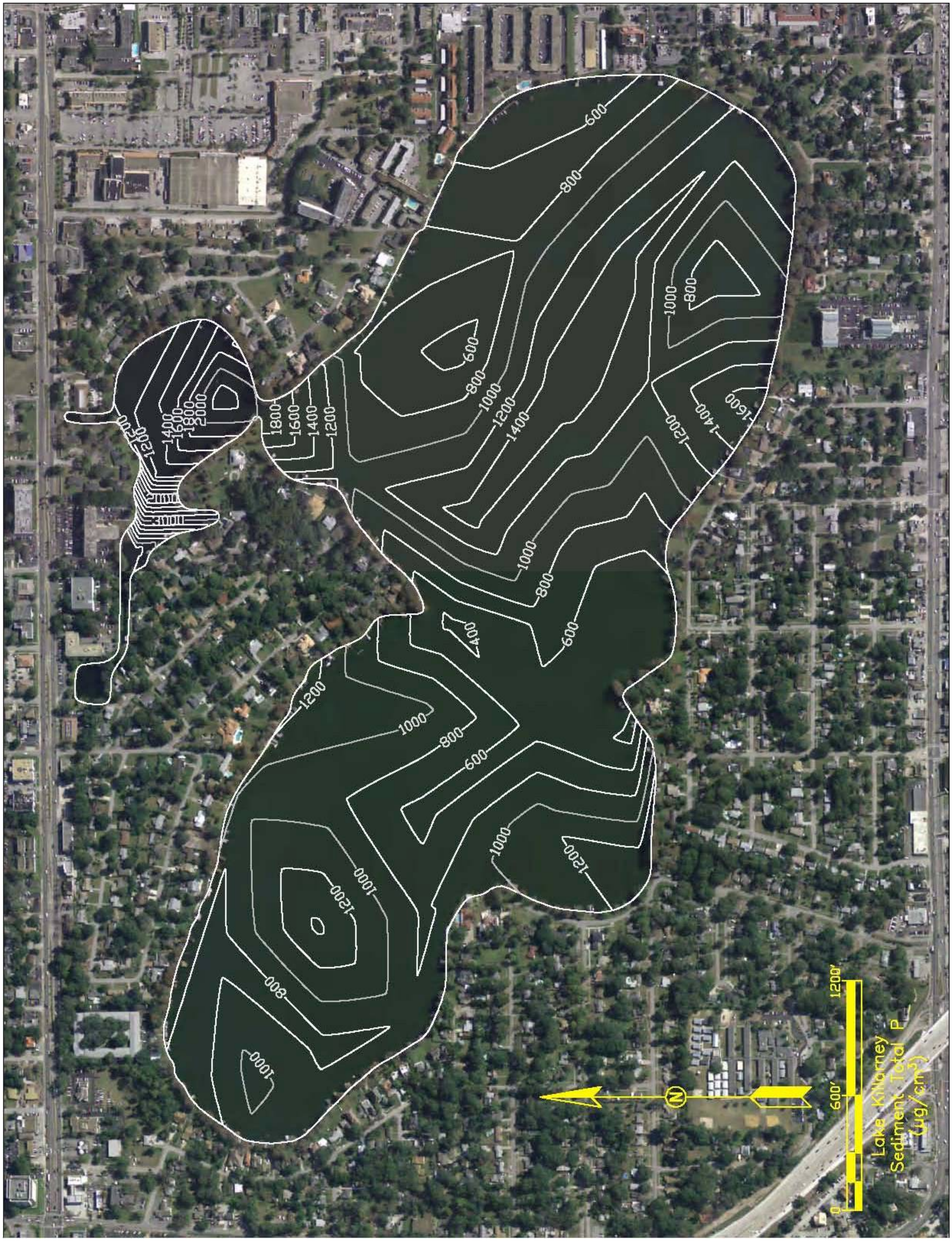


Figure 2-11. Isopleths of Total Phosphorus ($\mu g/cm^3$) in the Top 10 cm of Sediments in Lake Killarney.

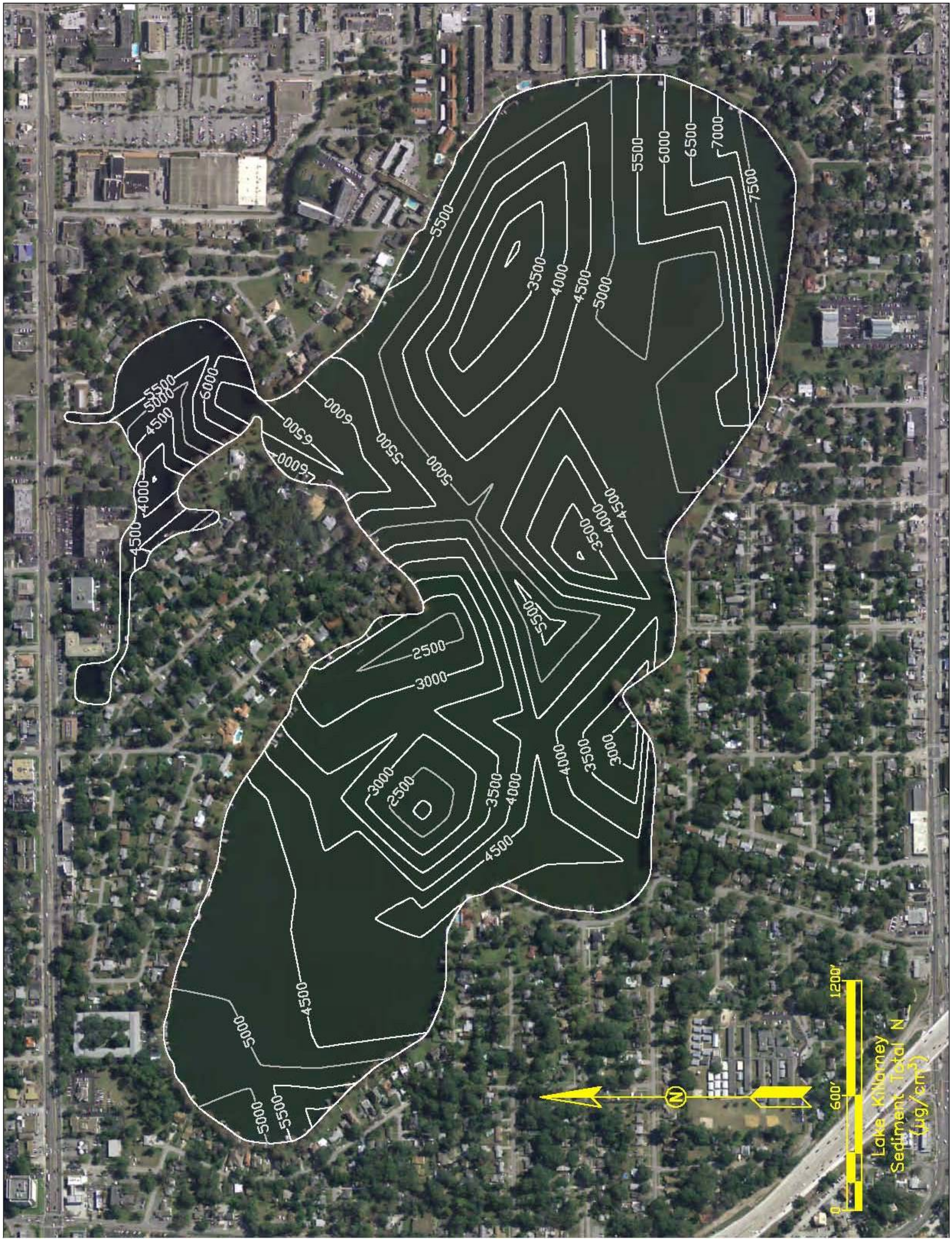


Figure 2-12. Isopleths of Total Nitrogen (μg/cm^3) in the Top 10 cm of Sediments in Lake Killarney.

2.2.3.3 Phosphorus Speciation

As discussed in Section 2.2.2, each of the collected sediment core samples was evaluated for phosphorus speciation based upon the Chang and Jackson speciation procedure. This procedure allows phosphorus within the sediments to be speciated with respect to bonding mechanisms within the sediments. This information is useful in evaluating the stability of phosphorus in the sediments and the potential for release of phosphorus from the sediments under anoxic or other conditions.

A summary of phosphorus speciation in sediment core samples collected from Lake Killarney during March 2011 is given in Table 2-7. Saloid-bound phosphorus represents sediment phosphorus which is either soluble or easily exchangeable and is typically considered to be readily available for release from the sediments into the overlying water column. As seen in Table 2-7, saloid-bound phosphorus concentrations appear to be fairly uniform throughout the sediments of Lake Killarney. Measured values for saloid-bound phosphorus range from 1-29 $\mu g/cm^3$, with an overall mean of 4.1 $\mu g/cm^3$. This value is 2 times greater than the saloid phosphorus concentration of 1.9 $\mu g/cm^3$ measured by ERD in Lake Holden.

In general, iron-bound phosphorus associations in the sediments of Lake Killarney appear to be somewhat elevated in value. Iron-bound phosphorus is relatively stable under oxidized conditions, but becomes unstable under a reduced environment, causing the iron-phosphorus bonds to separate, releasing the bound phosphorus directly into the water column. Iron-bound phosphorus concentrations in the sediments of Lake Killarney range from 5-220 $\mu g/cm^3$, with an overall mean of 64 $\mu g/cm^3$. Since iron-bound phosphorus can be released under anoxic conditions, large portions of Lake Killarney may have conditions favorable for release of iron-bound sediment phosphorus into the water column throughout much of the year. The iron-bound phosphorus concentrations summarized in Table 2-7 appear to be somewhat elevated compared with values commonly observed in urban lake systems.

Isopleths of iron-bound phosphorus in the top 10 cm of sediments in Lake Killarney are illustrated on Figure 2-13. Areas of elevated iron-bound phosphorus are located primarily in deeper portions of the eastern and western lobes, along with the northern lobe, and correspond closely to the areas of accumulated organic muck.

Total available phosphorus represents the sum of the saloid-bound phosphorus and iron-bound phosphorus associations in each sediment core sample. Since the saloid-bound phosphorus is immediately available, and the iron-bound phosphorus is available under reduced conditions, the sum of these speciations represents the total phosphorus which is potentially available within the sediments. This information can be utilized as a guide for future sediment inactivation procedures. A summary of total available phosphorus in each of the 45 collected sediment core samples is given in Table 2-7. Total available phosphorus concentrations within the lake range from 14-224 $\mu g/cm^3$, with an overall mean of 72 $\mu g/cm^3$. The mean sediment total available phosphorus in Lake Killarney is similar to the mean sediment available phosphorus measured in Lake Holden and Lake Pineloch by ERD.

TABLE 2-7

PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE KILLARNEY DURING MARCH 2011

SITE	SALOID-BOUND P (µg/cm^3 wet wt.)	Fe-BOUND P (µg/cm^3 wet wt.)	AVAILABLE P (µg/cm^3 wet wt.)	PERCENT OF SEDIMENT P WHICH IS AVAILABLE (%)	Al-BOUND P (µg/cm^3 wet wt.)
1	7	98	105	8	102
2	8	20	28	5	28
3	4	33	37	7	28
4	8	76	84	9	63
5	8	100	108	13	56
6	2	175	178	12	106
7	5	46	52	8	36
8	17	43	60	7	46
9	3	220	224	13	133
10	1	134	135	11	78
11	1	213	214	14	105
12	13	33	46	9	27
13	7	49	56	8	35
14	2	48	50	8	61
15	4	56	60	9	39
16	2	175	177	12	102
17	14	73	87	8	46
18	3	24	27	6	20
19	3	33	35	5	27
20	2	28	30	9	24
21	1	35	37	10	21
22	5	25	30	6	25
23	2	120	122	12	55
24	1	94	95	8	51
25	2	99	101	7	78
26	3	93	95	8	78
27	1	71	72	14	32
28	2	69	70	8	48
29	3	48	52	6	51
30	2	112	114	11	41
31	3	62	66	9	42
32	1	220	221	15	111
33	2	59	61	9	44
34	2	67	69	8	62
35	4	58	61	8	45
36	5	68	73	7	70
37	4	47	51	8	37
38	1	72	73	8	41
39	2	73	75	8	46
40	8	57	64	4	110
41	5	65	117	5	91
42	1	113	115	7	113
43	5	78	82	7	98
44	9	5	14	1	89
45	29	82	111	3	193
Minimum	1	5	14	1	**20**
Maximum	**29**	**220**	**224**	**15**	**193**
Geometric Mean	**4**	**64**	**72**	**8**	**54**

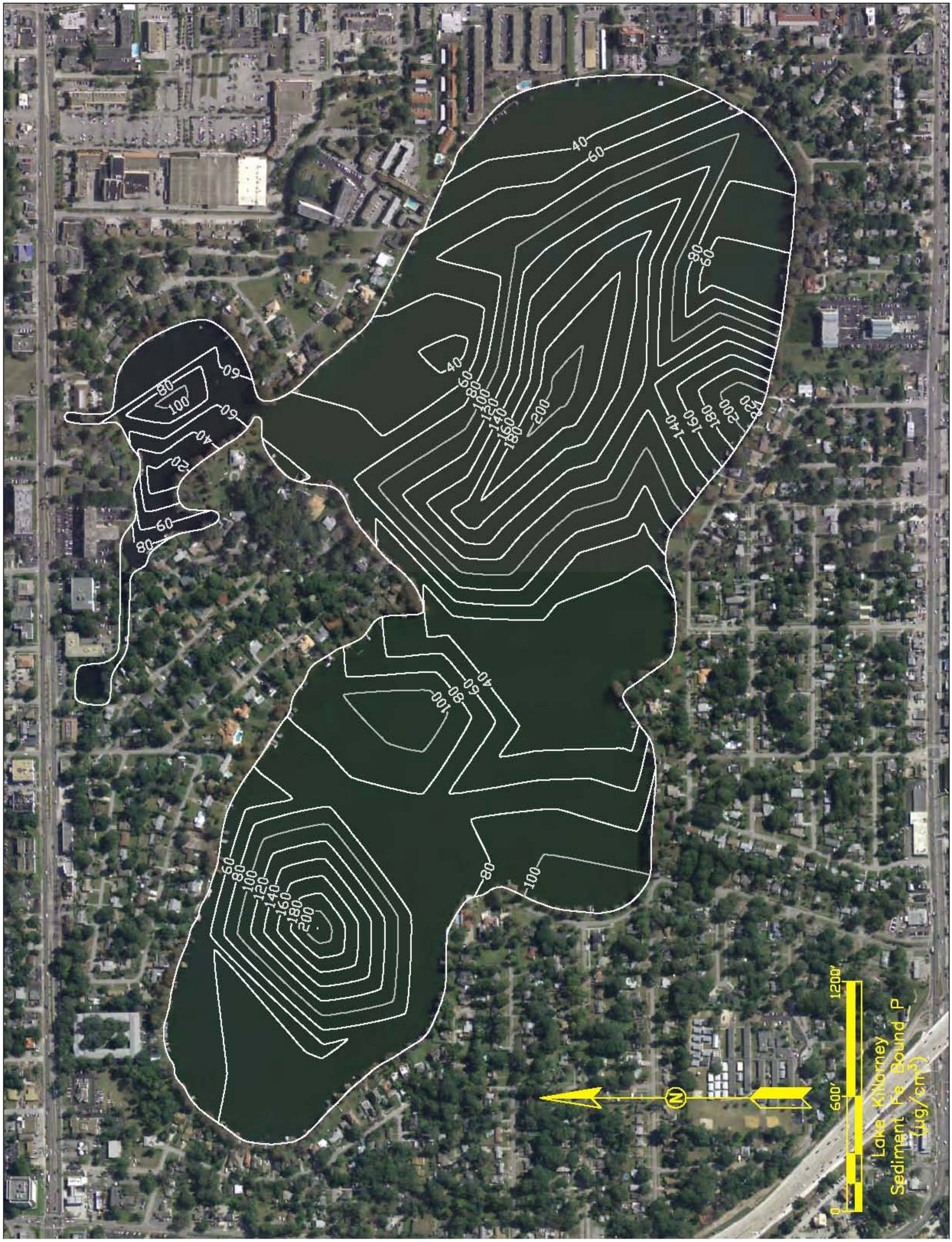


Figure 2-13. Isopleths of Iron-Bound Phosphorus (µg/cm^3) in the Top 10 cm of Sediments in Lake Killarney.

Isopleths of total available phosphorus in the top 10 cm of sediments in Lake Killarney are illustrated on Figure 2-14. Areas of elevated total available phosphorus are apparent in the eastern and western lobes along with the central lobe and corresponds closely to the areas of accumulated organic muck. The isopleths presented on Figure 2-14 can be utilized directly as a guide for future sediment inactivation activities.

Available sediment phosphorus is also expressed as a percentage of total phosphorus concentrations within the sediments. The percentage of available phosphorus within the sediments of Lake Killarney ranges from approximately 1-15%, with an overall mean of 17%. This suggests that approximately 17% of the existing accumulation of phosphorus within the lake is potentially available for release into the overlying water column as a result of sediment agitation or anoxic conditions.

Isopleths of the percentage of available sediment phosphorus in the top 10 cm of sediments in Lake Killarney are illustrated on Figure 2-15. The highest percentages of available sediment phosphorus occur in central portions of the eastern and western lobes of the lake where the percentage of available phosphorus ranges from approximately 13-15%.

Aluminum-bound phosphorus represents an unavailable species of phosphorus within the sediments. Phosphorus bound with aluminum is typically considered to be inert under a wide range of pH and redox conditions within the sediments. Aluminum-bound phosphorus concentrations range from 20-193 $\mu g/cm^3$, with an overall mean of 54 $\mu g/cm^3$. These values appear to be somewhat lower than aluminum-bound phosphorus concentrations commonly observed in urban lake systems. These values suggest that approximately 6% of the existing phosphorus within the sediments is bound in sediment associations which are considered to be unavailable.

2.3 Water Quality Characteristics of Lake Killarney

2.3.1 Historical Water Quality Data Availability

Relatively extensive historical water quality monitoring has been conducted in Lake Killarney by the City of Winter Park (City), the Orange County Environmental Protection Division (OCEPD), and the LAKEWATCH volunteer program sponsored by the University of Florida. A summary of available historical water quality data for Lake Killarney is given in Table 2-8. Water quality monitoring by Orange County is conducted at a single location near the center of the eastern lobe. This monitoring was initiated during 1967, with one monitoring event conducted during the initial year. Three separate monitoring events were conducted during 1968, with one event during 1969, two events each year from 1970-1974, and one event during 1975. Monitoring has been conducted on approximately a quarterly basis from 1977 to the present. Monitoring conducted by OCEPD include measurement of field parameters and laboratory analyses for general parameters, nutrients, microbiological parameters, and metals. A total of 145 water quality samples have been collected as part of the OCEPD monitoring program.

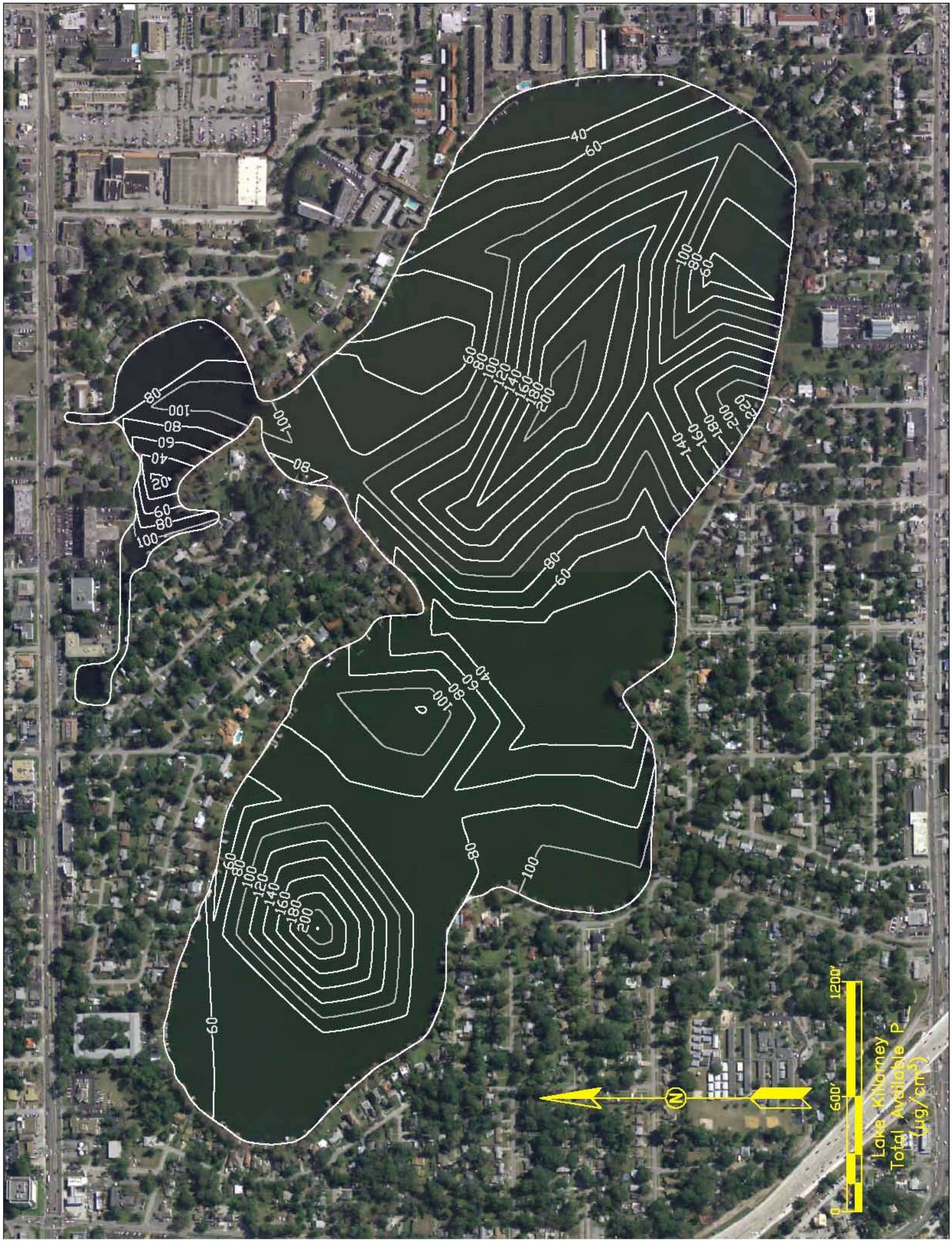


Figure 2-14. Isopleths of Total Available Phosphorus (µg/cm^3) in the Top 10 cm of Sediments in Lake Killarney.

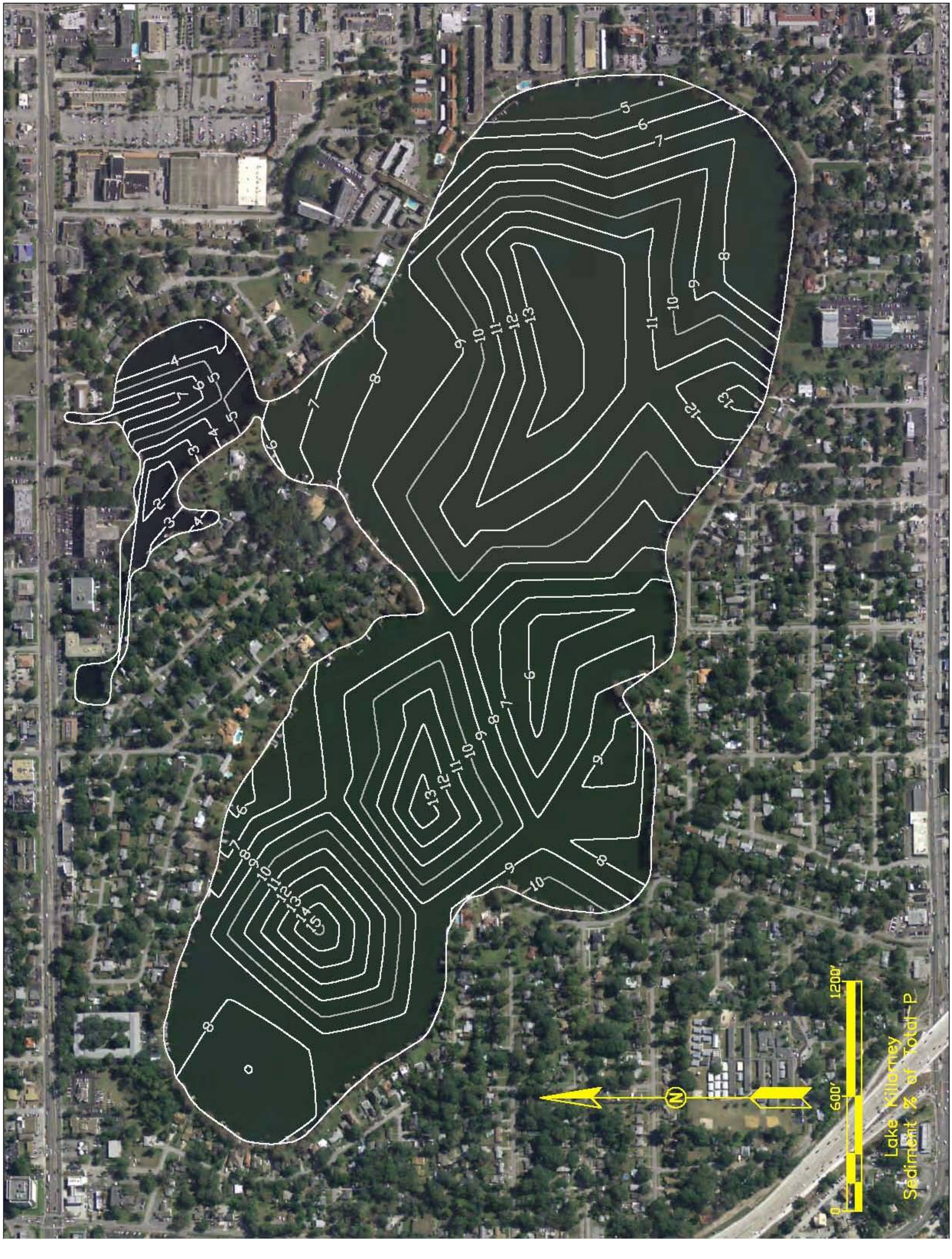


Figure 2-15. Isopleths of the Percentage of Available Sediment Phosphorus in the Top 10 cm of Sediments in Lake Killarney.

TABLE 2-8

SUMMARY OF AVAILABLE HISTORICAL WATER QUALITY DATA FOR LAKE KILLARNEY

AGENCY	STATION I.D.	COLLECTION DATES	MONITORING FREQUENCY		NUMBER OF EVENTS	TYPE OF DATA	
OCEPD	HB-21	2/67-Present	1967-1975:	1-5 events/year	145	Field parameters, general parameters, nutrients, microbiological parameters, metals	
			1977-present:	quarterly			
Winter Park	Killarney-29	2/98-Present	Monthly		163	2/98-8/03:	Secchi depth, turbidity
						9/03-1/09:	pH, Secchi depth, turbidity
						2/09-present:	General parameters, nutrients, chlorophyll
LAKEWATCH	Killarney-Orange	8/87-5/95	Monthly to Bi-monthly		26	Total phosphorus, chlorophyll, Secchi depth	

Surface water monitoring by the City of Winter Park was initiated in Lake Killarney during February 1998 at a single site located near the geographic center of the lake. Routine surface water monitoring has continued on approximately a monthly basis. During the period from February 1998-August 2003, monitoring conducted by the City included only measurements of Secchi depth and turbidity. Beginning in September 2003 and continuing to January 2009, monitoring included measurements of pH, Secchi depth, and turbidity. From February 2009 to the present, monitoring conducted by the City has included laboratory analysis of general parameters, nutrients, and chlorophyll. A total of 163 separate samples has been collected as part of the City of Winter Park monitoring program.

In addition to monitoring conducted by OCEPD and the City of Winter Park, surface water monitoring was also conducted by the LAKEWATCH volunteer program on approximately a monthly to bi-monthly basis from August 1987-May 1995, with a total of 26 separate monitoring events. The collected samples were shipped to the University of Florida for analysis of total phosphorus and chlorophyll-a. A measurement of Secchi depth was also conducted at the time of each monitoring event. A complete listing of historical water quality data collected in Lake Killarney by the City, OCEPD, and the LAKEWATCH program is given in Appendix A.

A historical data set for Lake Killarney was developed by ERD by combining the available data collected by OCEPD, the City of Winter Park, and the LAKEWATCH volunteer monitoring program. Although water quality data for Lake Killarney are available as far back as 1967, much of this earlier data suffers from poor detection limits and contains a number of potentially questionable data points. Therefore, for purposes of discussing historical water quality in Lake Killarney, only data collected from 1985-present are included in this discussion. This provides a usable data period of more than 25 years from 1985-present for evaluation of historical water quality and water quality trends.

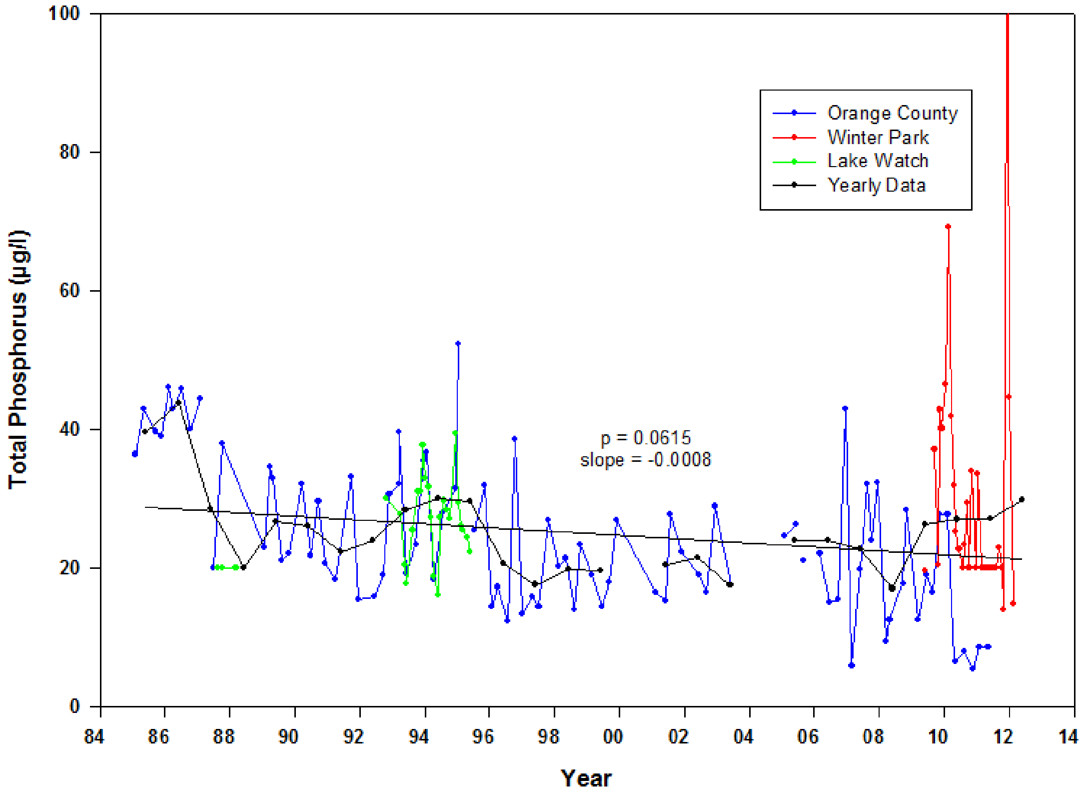
Historical water quality characteristics in Lake Killarney were evaluated by ERD based upon an examination of the results of individual monitoring events as well as mean annual concentrations for total phosphorus, total nitrogen, chlorophyll-a, Secchi disk depth, TN/TP ratio, and TSI. A summary of historical trends in total phosphorus and total nitrogen in Lake Killarney from 1985-2011 is given in Figure 2-16. Mean annual average values for these parameters are also superimposed over the historical data to provide a less cluttered view of potential water quality trends within the lake. A trend line is also provided to assist in identifying significant water quality trends which is obtained using linear regression techniques on the annual average values. The calculated probability value (p value) is also provided which indicates the level of significance associated with each regression model. A model which is significant at a 95% confidence level would be associated with a p value of 0.05. However, lakes exhibit normal seasonal cyclic variations in water quality which can reduce the statistical significance of the regression model. For evaluating water quality trends in lakes, a p value of 0.1 or less is generally considered to indicate a significant statistical trend, while p values greater than 0.1 suggest an insignificant trend.

Measured total phosphorus concentrations in Lake Killarney from 1985-2011 ranged from approximately 5-115 μg/l, although the majority of values appear to range from approximately 10-40 μg/l. Total phosphorus concentrations measured by Orange County and LAKEWATCH appear to be relatively similar in value. Phosphorus concentrations measured by Winter Park appear to be highly variable, with substantially higher values during some events. A general trend of decreasing phosphorus concentrations has been observed in Lake Killarney over the period of record. Based on the calculated p value of 0.0615, this trend is statistically significant.

A summary of measured total nitrogen concentrations in Lake Killarney is also provided in Figure 2-16. Measured concentrations of total nitrogen have ranged from approximately 100-1500 μg/l, although the majority of values appear to be in the range of 400-1200 μg/l. Total nitrogen concentrations measured by Orange County and LAKEWATCH appear to be relatively similar in value, with somewhat lower values reported by Winter Park. In contrast to the trends exhibited by total phosphorus, total nitrogen does not appear to exhibit a trend of either increasing or decreasing concentrations within the lake. The calculated p value of 0.7895 confirms the lack of a significant trend.

Variations in measured concentrations of chlorophyll-a (corrected) and Secchi disk depth in Lake Killarney from 1985-2011 are illustrated on Figure 2-17. Measured chlorophyll-a concentrations in the lake have ranged from 1-55 mg/m^3 over the monitoring period, although the majority of values range from approximately 5-40 mg/m^3. Measured chlorophyll-a concentrations by Orange County, LAKEWATCH, and the City of Winter Park appear to be relatively similar. Mean annual concentrations of chlorophyll-a in Lake Killarney exhibit a trend similar to that observed for total phosphorus, with a slow decline over time. More recent chlorophyll-a concentrations in the lake have been highly variable. The calculated p value of 0.0018 indicates a highly significant downward trend.

Variability in measured Secchi disk depths in Lake Killarney are also illustrated on Figure 2-17. Measurements have ranged from near zero to 5.5 m, although both of these extreme values appear unlikely. The majority of the measured values appear to fall in the range of 0.5-2 m. A trend of increasing Secchi disk depth is apparent over time, and the calculated p value of 0.0028 indicates that the trend is highly significant.



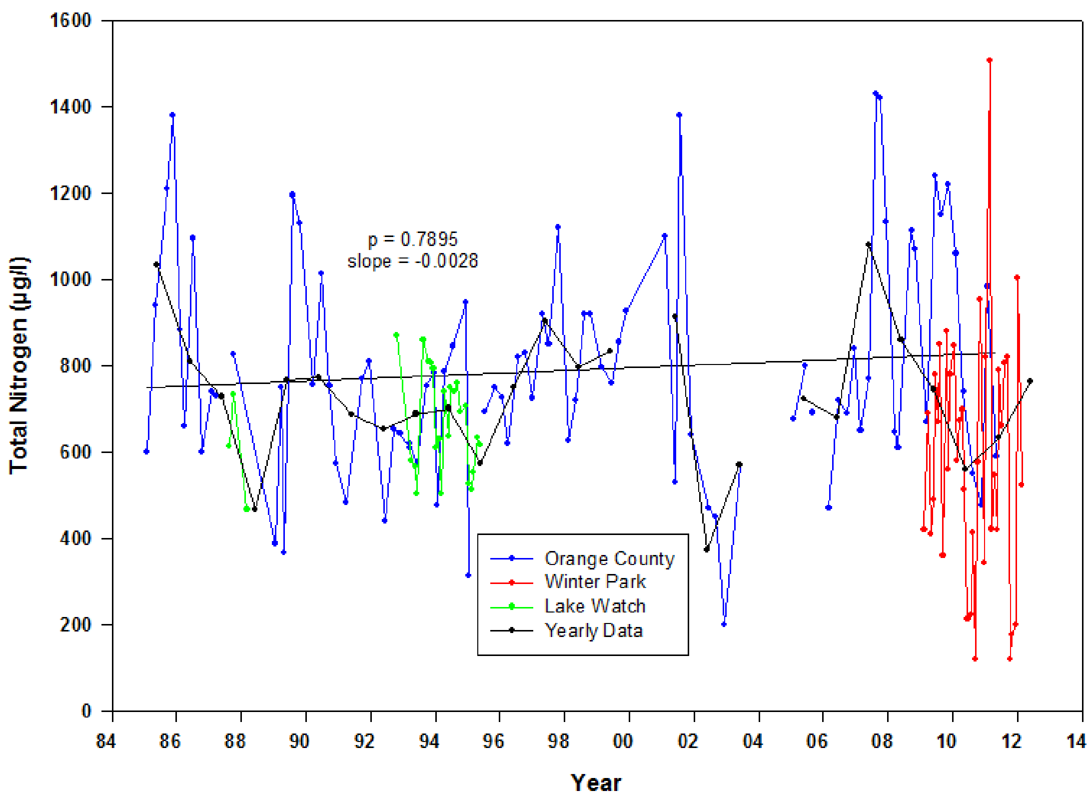
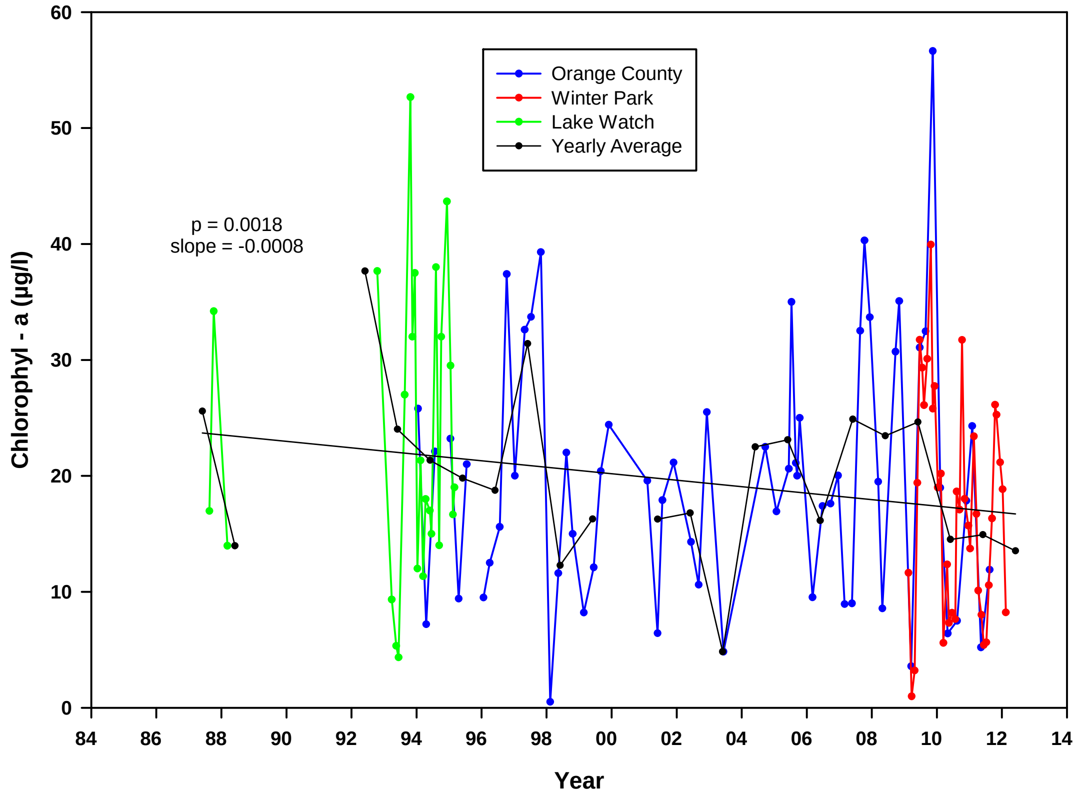


Figure 2-16. Summary of Trends in Total Phosphorus and Total Nitrogen in Lake Killarney from 1985-2011.



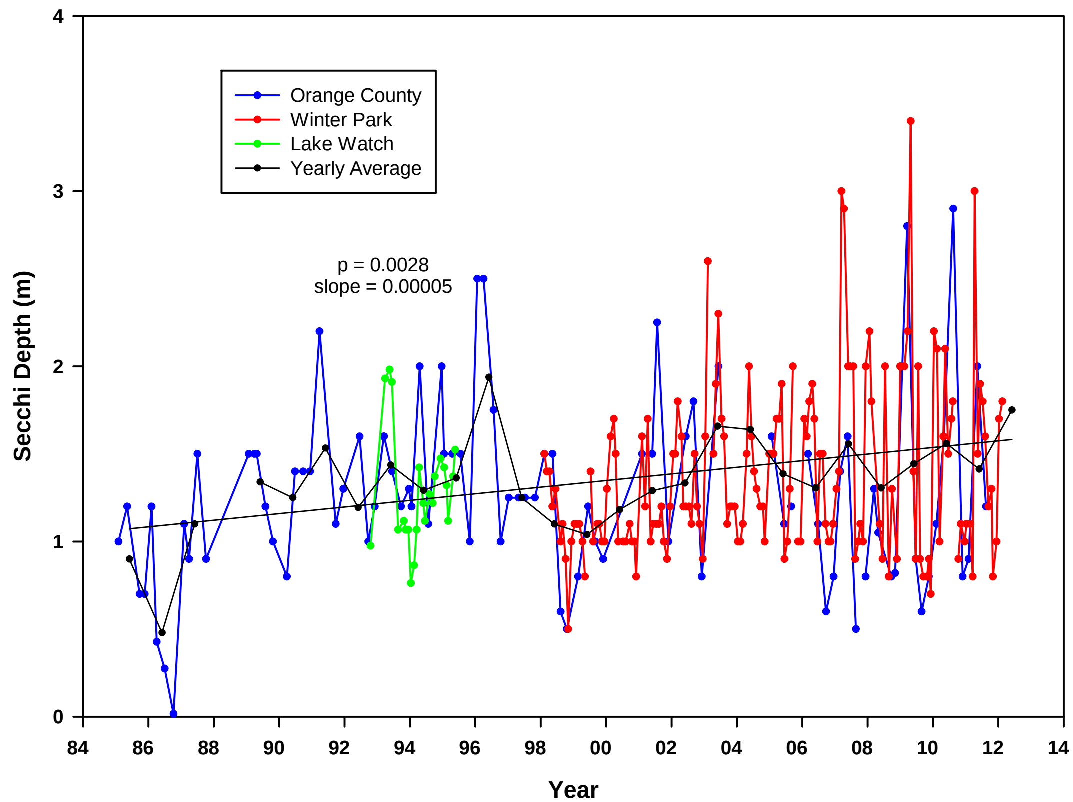


Figure 2-17. Summary of Trends in Chlorophyll-a and Secchi Disk Depth in Lake Killarney from 1985-2011.

Nutrient limitation in a waterbody is often evaluated using the total nitrogen/total phosphorus (TN/TP) ratio. The calculated TN/TP ratio is a numerical ratio of the measured water column concentrations of total nitrogen and total phosphorus. This ratio is useful in evaluating the relative significance of nitrogen and phosphorus in regulating primary productivity (algal growth) in a waterbody. Measured TN/TP ratios less than 10 are considered to indicate nitrogen-limited conditions, suggesting that phosphorus is relatively abundant and nitrogen is the element which regulates primary productivity and the growth of algae within the lake system. Calculated TN/TP ratios between 10-30 indicate nutrient-balanced conditions, with both nitrogen and phosphorus considered important for limiting aquatic growth. Calculated TN/TP ratios in excess of 30 indicate phosphorus-limited conditions, which suggests that nitrogen is abundant within the system and algal growth is limited by the availability of phosphorus. This is the typical situation observed in many lakes in the Central Florida area. This condition indicates that inputs of phosphorus into the lake system should be controlled to regulate the growth of algal biomass within the lake.

A summary of mean annual total nitrogen/total phosphorus (TN/TP) ratios in Lake Killarney from 1985-2011 is given in Figure 2-18. Based on the mean annual TN/TP ratios indicated on Figure 2-18, it appears Lake Killarney exists in either a nutrient-balanced or phosphorus-limited condition much of the time. The data appear to suggest that Lake Killarney is becoming more phosphorus-limited over time, although recent monitoring by Orange County indicates phosphorus-limited conditions presently while the Winter Park data suggest nitrogen-limited conditions. A trend line for changes in TN/TP ratios is also shown on Figure 2-18 which indicates a general trend toward increasing phosphorus limitation within the lake. The p value of 0.0179 suggests that the trend is highly significant.

Florida Trophic State Index (TSI) values were also calculated for each monitoring event in Lake Killarney over the available period of historical data. TSI is a summary statistic which incorporates measured concentrations of significant parameters in lake systems and is often considered the best overall indicator of the health of a lake system. Calculated TSI values less than 50 indicate oligotrophic conditions, representing lakes with low nutrient loadings and good to excellent water quality characteristics. Calculated TSI values from 50-60 indicate mesotrophic or fair water quality characteristics. Calculated TSI values between 60-70 indicate eutrophic or poor water quality characteristics, with hypereutrophic conditions, reflecting very poor water quality, indicated by TSI values in excess of 70.

The trophic state index was developed by Carlson (1977) as a relative measure of the degree of biological productivity in lakes. The TSI concept incorporates forcing functions such as nutrient supplies, light availability, seasonality, and other factors. Since the TSI value is intended to reflect the level of biological productivity, the best estimator for productivity is chlorophyll-a. Some calculations also incorrectly include concentrations of nutrients and Secchi disk depth in addition to chlorophyll-a. However, nutrients and Secchi disk depth should only be included as surrogates for biological productivity when chlorophyll data are not available. Therefore, TSI calculations were conducted for Lake Killarney using measured concentrations of chlorophyll-a only according to the following relationship:

$$\text{TSI (chl-a)} = 16.8 + 14.4 \ln \text{chl-a} \ (\text{mg/m}^3)$$

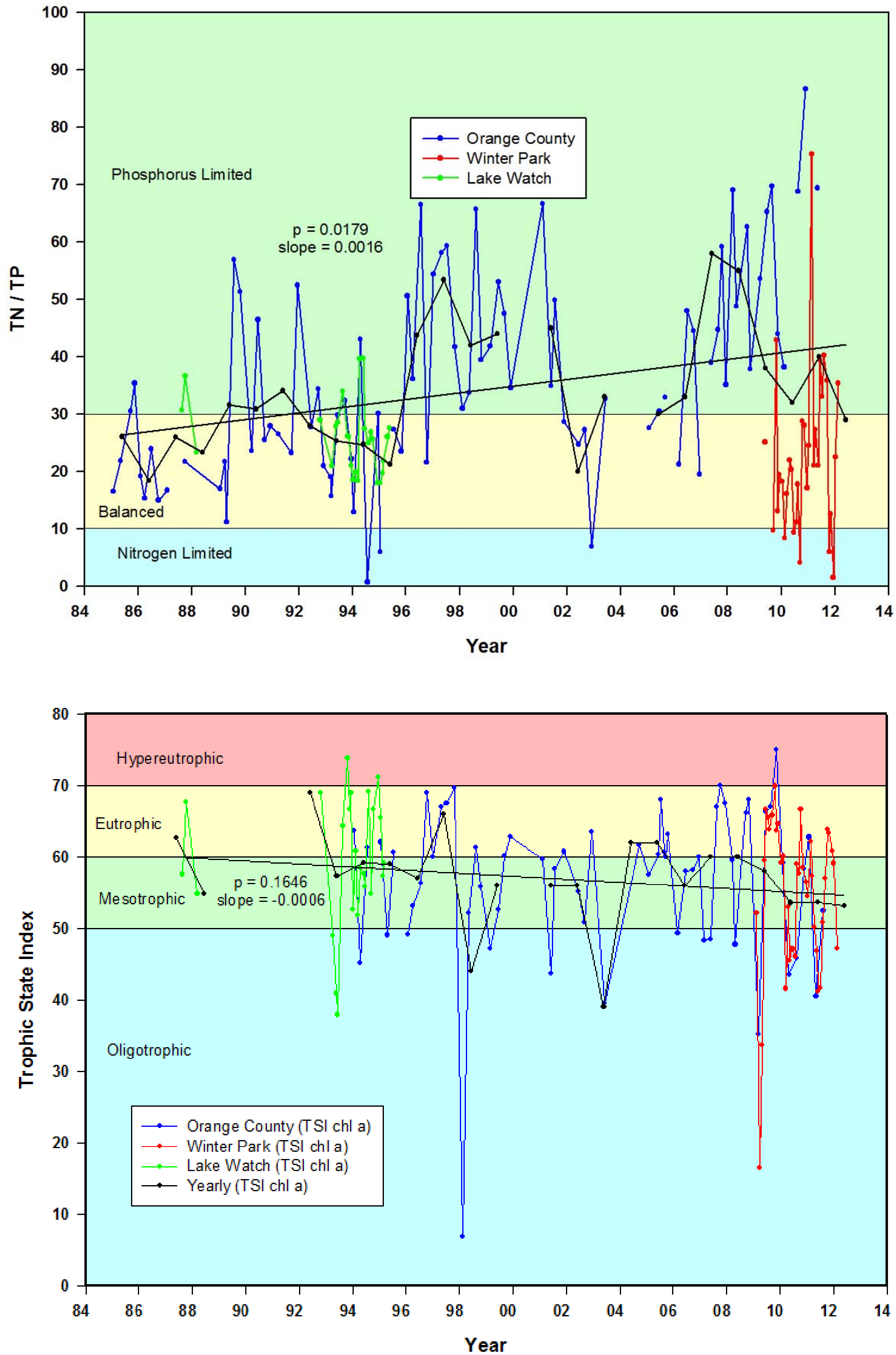


Figure 2-18. Summary of Trends in TN/TP Ratio and TSI Values in Lake Killarney from 1985-2011.

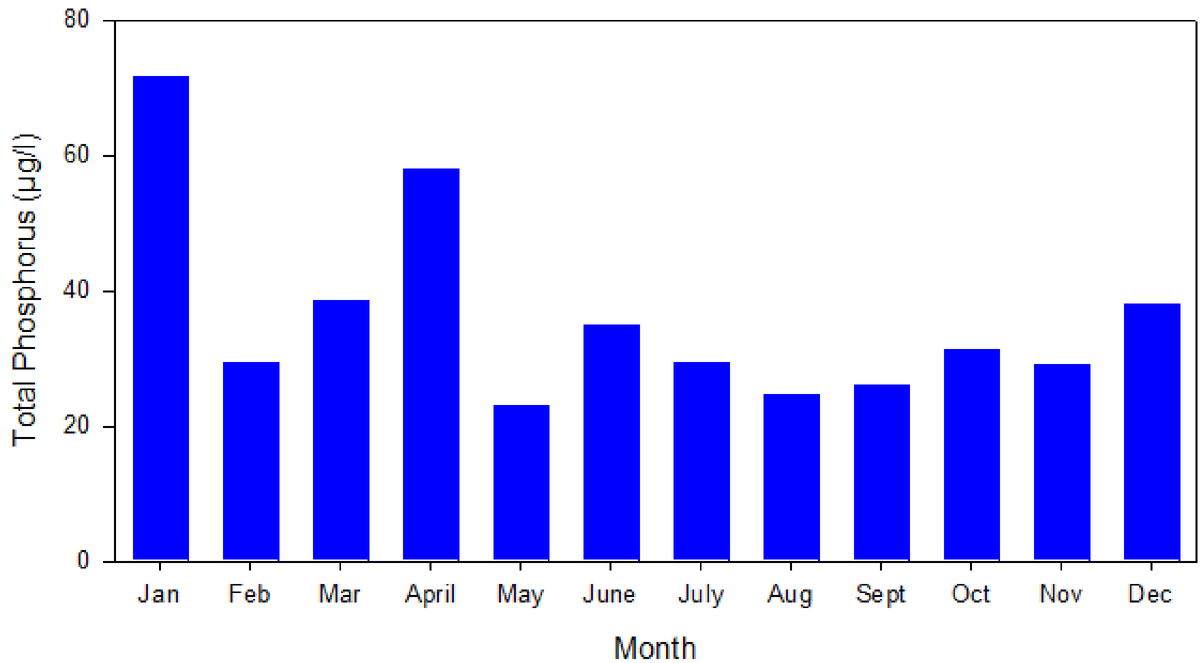
Mean annual TSI values in Lake Killarney from 1985-2011 are also summarized on Figure 2-18. Mean annual TSI conditions in Lake Killarney have ranged from oligotrophic to borderline eutrophic-hypereutrophic conditions, with most values reflecting mesotrophic to eutrophic conditions, and the calculated p value of 0.1646 indicates that the trend is not statistically significant.

Additional evaluations were performed by ERD to examine seasonal variations in water quality in Lake Killarney. For this evaluation, mean monthly concentrations were calculated for total phosphorus, total nitrogen, and chlorophyll-a over the period of record from 1985-2011 using the combined data set. A comparison of mean monthly concentrations of total phosphorus in Lake Killarney from 1985-2011 is given in Figure 2-19. In general, it appears that mean monthly phosphorus concentrations in Lake Killarney are generally lowest during June-September and highest in value during the fall, winter, and spring months, although a lot of variability is apparent in the data. Since the fall, winter, and spring months are generally characterized by low rainfall and reduced runoff inputs, the increases in phosphorus concentrations observed during this period suggests that phosphorus sources in addition to stormwater runoff are impacting water quality in Lake Killarney.

The general pattern of monthly phosphorus concentrations exhibited in Figure 2-19 suggests that significant internal recycling may be occurring in Lake Killarney. During late-spring through early-fall, lakes in Central Florida typically become stratified, with anoxic conditions developing in lower portions of the lake. These anoxic conditions accelerate the release of phosphorus from the bottom sediments which begin to accumulate in the lower isolated portions of the waterbody. When water temperatures cool during late-fall and winter, the water column begins to circulate, and accumulated phosphorus concentrations in lower layers of the lake are distributed throughout the entire water column, resulting in increases in phosphorus levels within the lake. The trend exhibited by total phosphorus for Lake Killarney suggests that significant internal recycling, fueled by upwelling of high phosphorus water during circulating events, may be occurring within the lake.

Average monthly concentrations of total nitrogen in Lake Killarney from 1985-2011 are also included on Figure 2-19. No significant seasonal trend is apparent for total nitrogen, suggesting that multiple sources of nitrogen are impacting Lake Killarney on an annual basis.

A comparison of mean monthly concentrations of chlorophyll-a in Lake Killarney from 1985-2011 is given in Figure 2-20. The monthly chlorophyll-a concentrations within the lake appear to exhibit a pattern similar to that observed for total phosphorus, with the most elevated concentrations observed during fall, winter, and spring conditions, and lower concentrations observed during June-September. This pattern suggests that significant nutrient loadings are impacting Lake Killarney other than runoff.



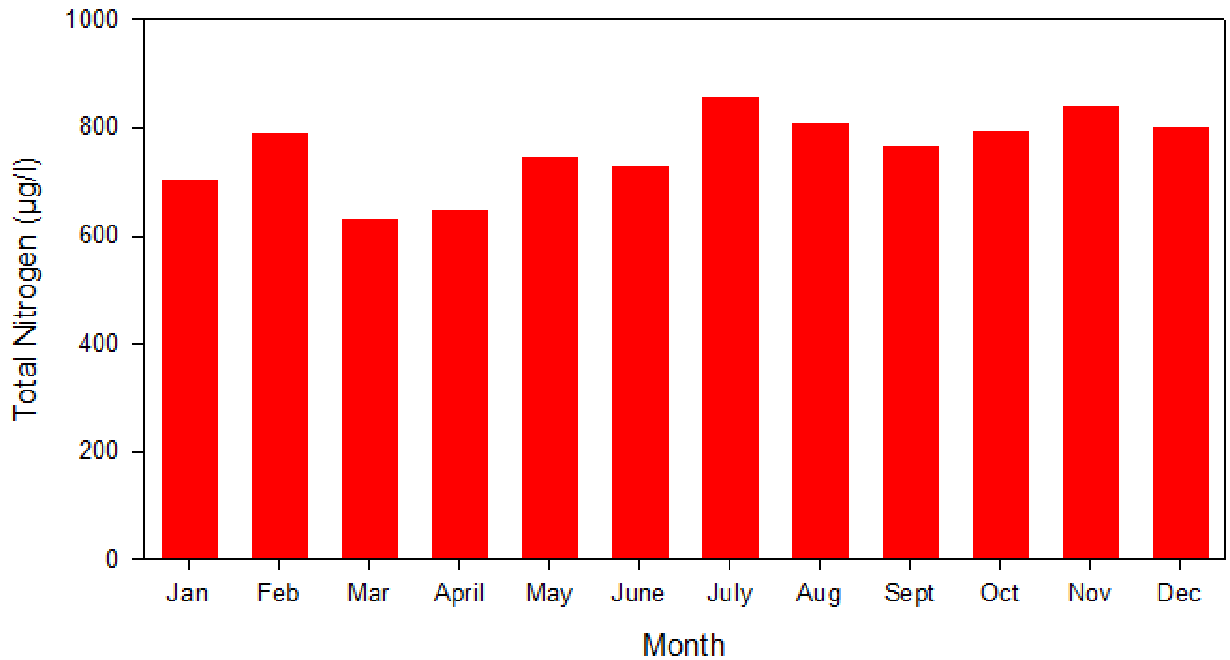


Figure 2-19. Mean Monthly Concentrations of Total Phosphorus and Total Nitrogen in Lake Killarney from 1985-2011.

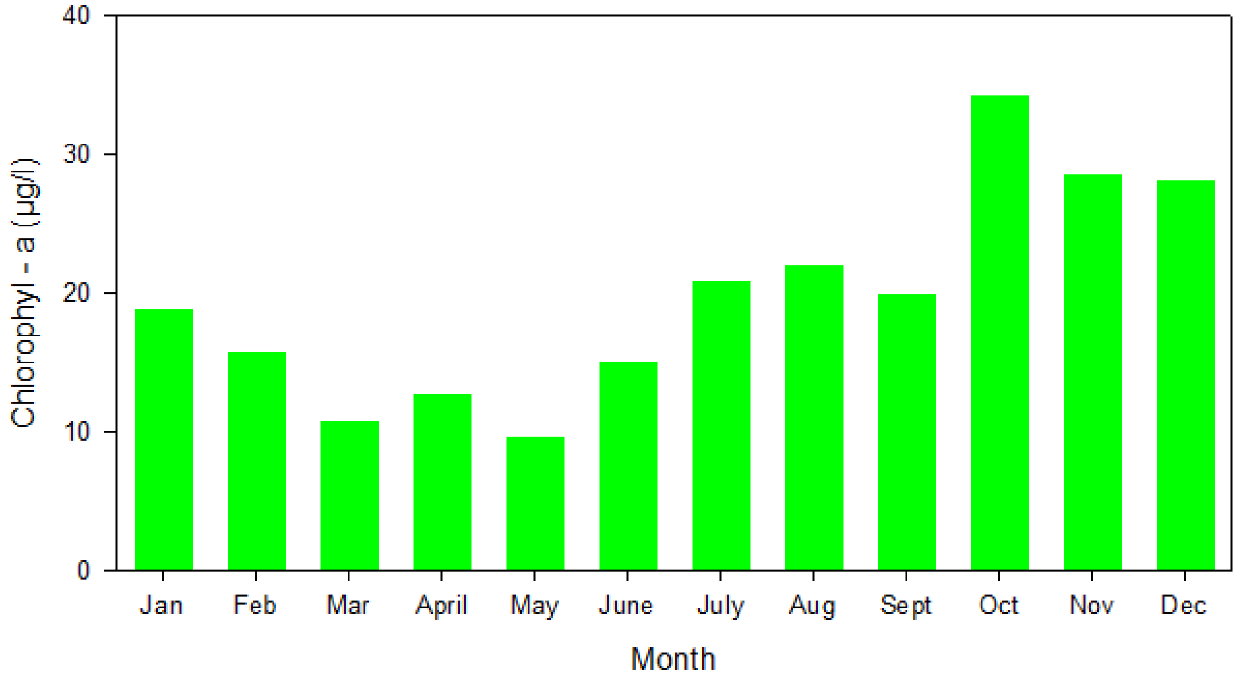


Figure 2-20. Mean Monthly Concentrations of Chlorophyll-a in Lake Killarney from 1985-2011.

A tabular summary of historical water quality characteristics of Lake Killarney from 1985-2011 is given on Table 2-9. The historical data from 1985-2011 are divided into three separate intervals for comparison purposes including the period from 1985-1990, 1991-2000, and 2001-2011. Mean values are provided for each of the three interval periods, along with the number of measurements conducted for each listed parameter. The means provided in Table 2-9 reflect geometric mean values since the data exhibit a log-normal distribution.

In general, historical measured values for pH, alkalinity, conductivity, ammonia, and NO_x are similar to values commonly observed in urban lakes. However, measured values for total nitrogen, total phosphorus, chlorophyll-a, and organic nitrogen appear to be lower than average for most urban lakes. A general trend of decreasing mean concentrations over time is apparent for total nitrogen, SRP, ammonia, NO_x, total nitrogen, total phosphorus, color, chlorophyll-a, and TSI value, although it is not known if the trends are statistically significant. However, based upon the data summarized in Table 2-9, it appears that water quality in Lake Killarney has remained relatively constant or actually improved over the past 25 years.

In general, Lake Killarney has exhibited low levels of inorganic nitrogen (ammonia + NO_x) as well as moderate to low values of SRP. It appears that algal productivity in Lake Killarney has been limited historically by a lack of available nutrients. Measured Secchi disk depths in Lake Killarney appear to have improved from a mean of 2.7 ft during 1985-1990 to a mean of 4.4 ft during the period from 2001-2011. The lake has also exhibited a decrease in TSI from mesotrophic to oligotrophic conditions over the same period. Calculated TN/TP ratios in Lake Killarney indicate the lake has historically been a phosphorus-limited waterbody and appears to be becoming even more phosphorus-limited over time.

TABLE 2-9

SUMMARY OF HISTORICAL WATER QUALITY CHARACTERISTICS OF LAKE KILLARNEY FROM 1985-2011

PARAMETER	UNITS	1985-1990		1991-2000		2001-2011	
		Mean	No. of Samples	Mean	No. of Samples	Mean	No. of Samples
pH	s.u.	7.77	24	7.93	32	8.21	130
Alkalinity	mg/l	64.1	24	61.2	32	76.3	33
Conductivity	µmho/cm	221	24	188	34	217	30
Ammonia	µg/l	61	21	18	35	14	33
NO_x	µg/l	35	21	17	34	16	56
Organic Nitrogen	µg/l	641	19	679	34	630	33
Total Nitrogen	µg/l	822	19	732	18	729	24
SRP	µg/l	11	19	7	18	3	24
Total Phosphorus	µg/l	26	23	19	57	18	62
Color	Pt-Co	17	5	16	23	8	29
Chlorophyll-a	mg/m^3	20.1	3	17.2	43	15.7	74
Secchi Disk	ft	2.7	21	4.0	90	4.4	156
TSI	--	52.2	3	51.6	30	48.0	55
TN/TP Ratio	--	32	19	39	18	41	33

2.3.2 Current Water Quality Characteristics

2.3.2.1 Monitoring Activities

A monthly surface water quality monitoring program was conducted in Lake Killarney by ERD from August 2010-July 2011 at three fixed monitoring locations within the lake. Approximate locations of the surface water monitoring sites in Lake Killarney are indicated on Figure 2-21. Surface water monitoring sites were located near the center of the east lobe, west lobe, and north lobe of the lake. The water quality monitoring sites were selected to allow evaluation of vertical water quality in the deepest areas of the lake, provide general information on ambient water quality characteristics, and evaluate both horizontal and vertical water quality variability. Water quality monitoring was conducted on a monthly basis, with a total of 12 monitoring events conducted during the 12-month monitoring program.

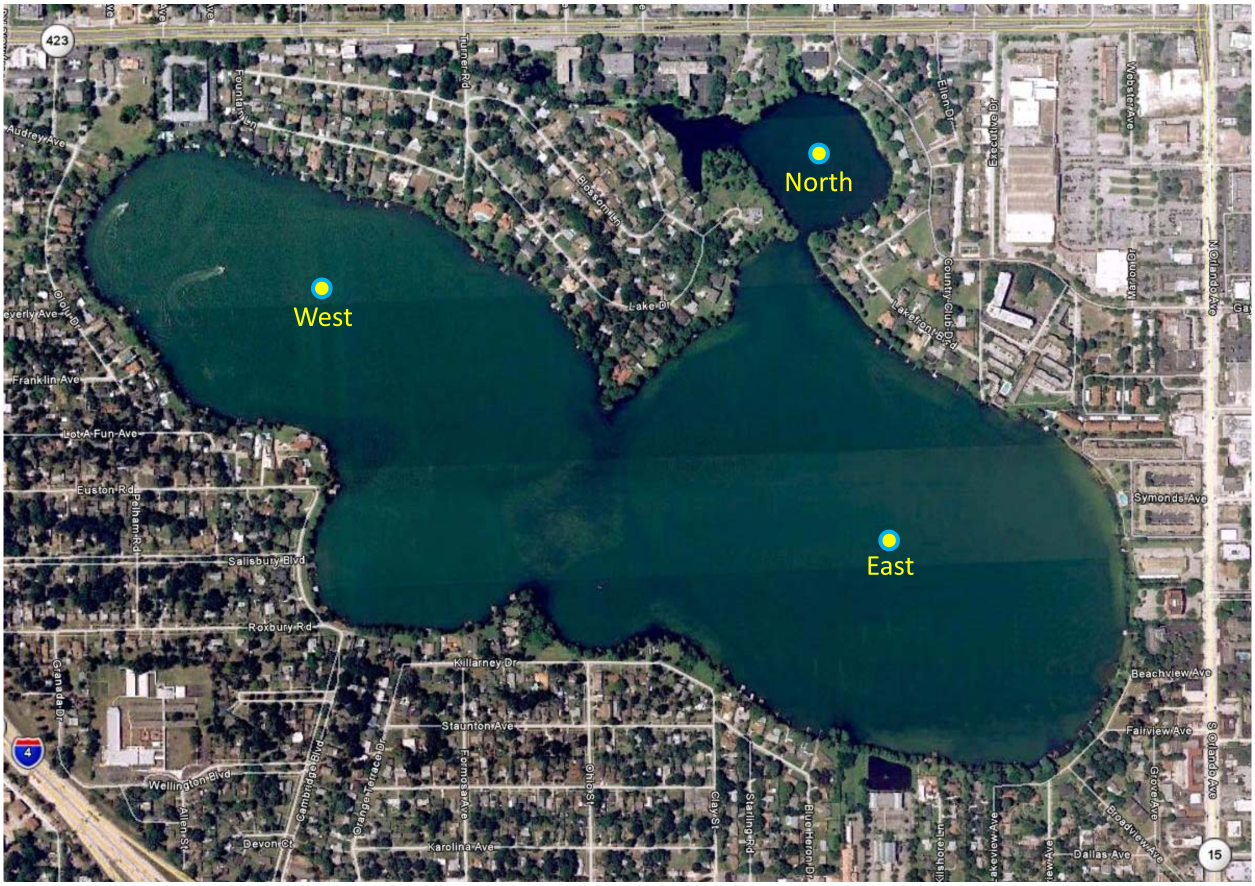


Figure 2-21. Surface Water Monitoring Sites in Lake Killarney Used by ERD.

Sample collection procedures generally followed methods outlined in DEP-SOP-001/01 titled "Department of Environmental Protection Standard Operating Procedures for Field Activities" dated February 1, 2004. Surface water samples were collected using a battery-powered peristaltic pump constructed of plastic and stainless steel. Two separate samples were collected at each site during each monitoring event. The first sample was collected at a depth equal to 50% of the Secchi disk depth at the time of sample collection. The second sample was collected at a depth of 0.5 m above the sediment/water interface. Each of the collected samples was preserved as appropriate for the parameter to be analyzed, stored on ice, and returned to the ERD Laboratory for chemical analyses. A listing of laboratory measurements performed on the collected samples is given in Table 2-10, along with a summary of analytical methods and laboratory detection limits.

During each monitoring event, vertical profiles of pH, temperature, conductivity, dissolved oxygen, oxidation reduction potential (ORP), and turbidity were conducted at each site. Field measurements were collected at water depths of 0.25 m and at 0.5 m, and at 0.5 m intervals to the bottom at each site. All field measurements were performed using Hydrolab Data Sonde H2O and Data Sonde 4a units. A measurement of Secchi disk depth was also performed at each site.

TABLE 2-10

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES CONDUCTED BY ENVIRONMENTAL RESEARCH AND DESIGN, INC.

MEASUREMENT PARAMETER		METHOD	METHOD DETECTION LIMITS (MDLs)[1]
General Parameters	Hydrogen Ion (pH)	SM-21[2], Sec. 4500-H^+ B	N/A
	Alkalinity	SM-21, Sec. 2320 B	0.7 mg/l
	TSS	SM-21, Sec. 2540 D	0.7 mg/l
	Color	SM-21, Sec. 2120 C	0.9 Pt-Co Unit
	Specific Conductivity	SM-21, Sec. 2510 B	2 μmho/cm
	Turbidity	SM-21, Sec. 2130 B	0.4 NTU
Nutrients	Ammonia-N (NH_3-N)	SM-21, Sec. 4500-NH_3 G	0.005 mg/l
	Nitrate + Nitrite (NO_x-N)	SM-21, Sec. 4500-NO_3 F	0.005 mg/l
	Total Nitrogen	SM-21, Sec. 4500-N C	0.025 mg/l
	Orthophosphorus	SM-21, Sec. 4500-P F	0.001 mg/l
	Total Phosphorus	SM-21, Sec. 4500-P B.5	0.001 mg/l
Biological Parameters	Chlorophyll-a	SM-21, Sec. 10200 H.1.3	1 mg/m^3

1. MDLs are calculated based on the EPA method of determining detection limits.
2. Standard Methods for the Examination of Water and Wastewater, 21st Ed., 2005.

2.3.2.2 Field Profiles

A complete listing of vertical field profiles collected in Lake Killarney from August 2010-July 2011 is given in Appendix B.1. A compilation of vertical depth profiles collected at the east lobe monitoring site during each of the 12 monthly monitoring events is given on Figure 2-22. In general, significant thermal stratification at the east lobe monitoring site was observed only during the April 2011 monitoring event, with relatively uniform temperature profiles observed during each of the remaining monitoring events. Typical temperature differences between top and bottom measurements at this site range from approximately 0-4°C for most events. During the April 2011 event, a temperature difference of approximately 6°C was observed between top and bottom measurements.

Field measured surface pH values at the east lobe monitoring site ranged from approximately 7.6-8.5 during the field monitoring program. Relatively isograde pH conditions were observed in the top 3-4 m of the water column during most events, followed by a relatively rapid decrease in pH with increasing water depth, with bottom pH measurements ranging from approximately 6.4-7.0. The vertical patterns for pH exhibited in the eastern lobe are typical of eutrophic urban lakes.

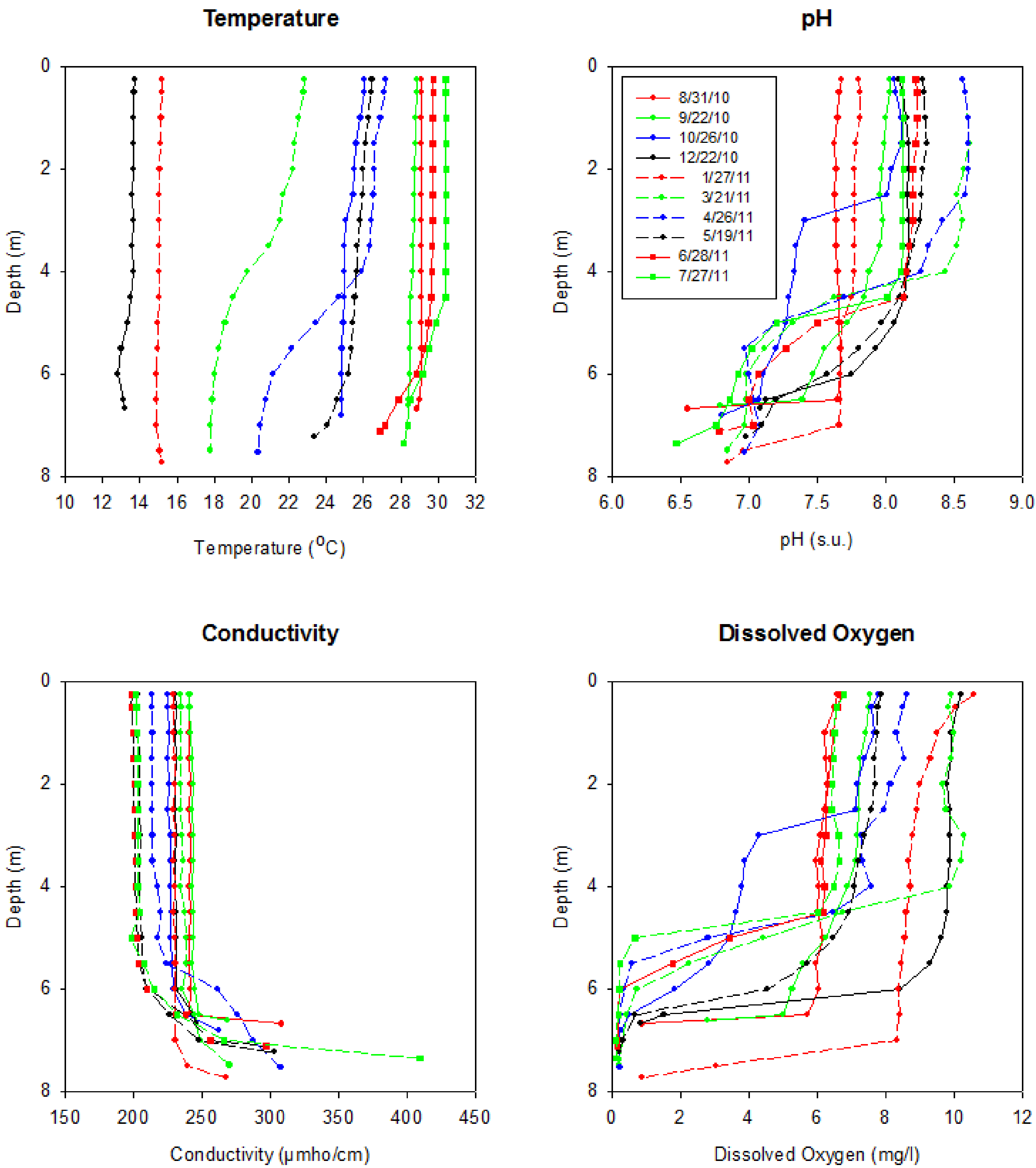


Figure 2-22. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen at the East Lobe Site in Lake Killarney from August 2010-July 2011.

Specific conductivity values in the east lobe of Lake Killarney ranged from approximately 200-250 µmho/cm near the water surface. Relatively isograde conductivity values were observed to a water depth of approximately 6 m during virtually all monitoring events. At depths in excess of 6 m, increases in specific conductivity were observed which ranged from approximately 15-100% depending upon the monitoring date. The observed increases in conductivity near the water-sediment interface are an indication of internal recycling from the sediments in anoxic lower portions of the water column.

In general, surface dissolved oxygen concentrations at the east lobe were relatively good, ranging from approximately 6-10 mg/l depending upon the monitoring date. Relatively uniform dissolved oxygen concentrations were maintained in the water column to depths ranging from approximately 3-6 m, depending upon time of year. However, substantial decreases in dissolved oxygen were observed in lower portions of the water column during each of the 12 monitoring events, with anoxic conditions present near the water-sediment interface throughout virtually all of the year. The presence of anoxic conditions in lower portions of the water column is verified by the measurements of oxidation-reduction potential (ORP) included in Appendix B. In general, measured ORP values less than 200 mV suggest the presence of anoxic conditions which was observed in lower portions of the water column in the east lobe during virtually all monitoring events.

A compilation of vertical depth profiles collected at the west lobe monitoring site from August 2010-July 2011 is given on Figure 2-23. In general, vertical profiles collected at the west lobe site appear to be relatively similar to measurements conducted at the east lobe site, with a few exceptions. In general, the west lobe location appears to exhibit a higher degree of thermal stratification than observed at the eastern lobe site, with significant thermal stratification observed during 4 of the 12 monitoring events. However, vertical profiles for pH are virtually identical between the eastern and western lobes, with surface pH values at the western lobe ranging from approximately 7.6-8.5, decreasing to bottom measurements ranging from 6.4-7.0.

Relatively isograde conductivity measurements occur within the water column to a depth of approximately 6 m, followed by a relatively rapid increase in conductivity near the water-sediment interface. The degree of increases in conductivity in bottom portions of the water column appears to be slightly greater at the west lobe than observed at the east lobe. Relatively good surface dissolved oxygen concentrations were maintained at the west lobe, with values ranging from approximately 7-11 mg/l. Uniform dissolved oxygen concentrations were maintained during most events to a water depth of approximately 4 m, followed by a relatively rapid decrease in concentration with increasing water depth. Anoxic conditions near the water-sediment interface were observed during 9 of the 12 monitoring events at the west lobe site, with near-anoxic conditions observed during the remaining 3 events. The observed patterns of decreasing pH, decreasing dissolved oxygen, and increasing specific conductivity near the water-sediment interface are all indicative of internal recycling within the lake.

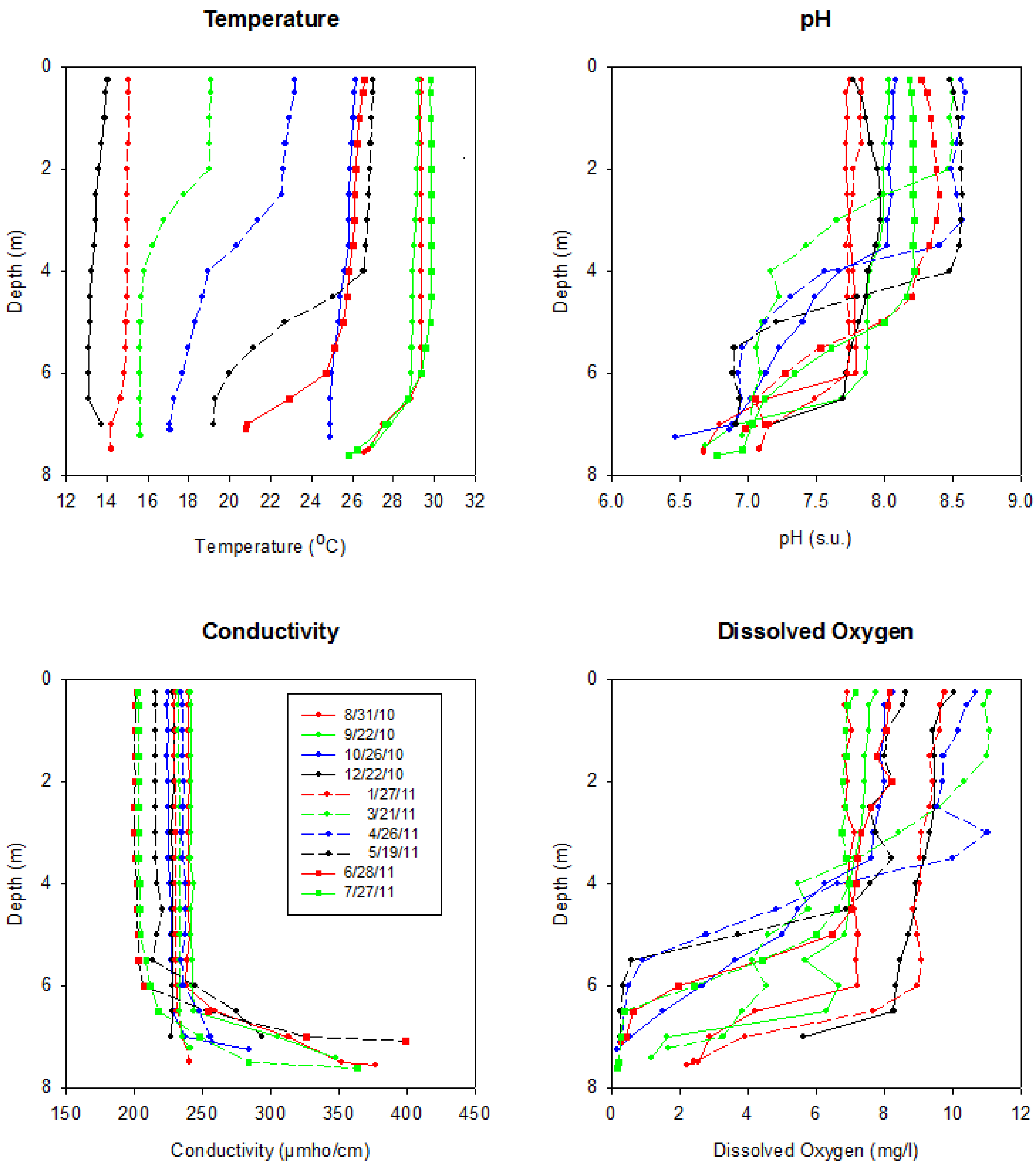


Figure 2-23. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen at the West Lobe Site in Lake Killarney from August 2010-July 2011.

A compilation of vertical depth profiles collected at the northern lobe monitoring site from August 2010-July 2011 is given on Figure 2-24. Vertical profiles collected at the north lobe site appear to be impacted somewhat due to the substantially shallower water column at this site. Relatively isograde temperature profiles were observed during each of the monitoring events, with no significant thermal stratification observed during the field monitoring program. Surface pH values at the north lobe site ranged from approximately 7.3-8.7, decreasing to bottom measurements ranging from approximately 6.6-7.5. Relatively isograde conductivity measurements occurred in upper portions of the water column to a depth of approximately 3 m, followed by increases in conductivity near the water-sediment interface. However, the degree of observed conductivity increases appears to be less than observed in either the east or west lobes. Measured surface dissolved oxygen concentrations in the north lobe ranged from 4-12 mg/l during the field monitoring program. Relatively uniform dissolved oxygen measurements were maintained in upper portions of the water column followed by a rapid decrease near the water-sediment interface. Anoxic conditions were observed near the water-sediment interface at this site during 10 of the 12 monitoring events. The vertical field profiles collected at the north lobe site are also indicative of the presence of internal recycling, although the level of significance may be less than occurs at the east and west lobe sites.

2.3.2.3 Water Quality Characteristics

A complete listing of the results of laboratory analyses conducted on the monthly surface water samples collected from Lake Killarney is given in Appendix B.2. A summary of water quality characteristics at the three monitoring sites in Lake Killarney from August 2010-July 2011 is given in Table 2-11. Water samples collected in the east and west lobes were moderately well buffered, with mean alkalinity values ranging from 81.4-85.7 mg/l. However, a substantially higher mean alkalinity value of 108 mg/l was measured in surface water samples collected in the north lobe. This value suggests inputs into the north lobe of a relatively high alkalinity source. Measured conductivity values in the east and west lobes were relatively similar, ranging from 219-221 μmho/cm. However, a substantially higher mean conductivity value of 261 μmho/cm was observed in the north lobe, indicating a higher influx of dissolved ions into this portion of the lake.

Measured concentrations of ammonia and NO_x were relatively similar and low in value at each of the three monitoring sites. A similar pattern is also apparent for dissolved organic nitrogen and particulate nitrogen, all of which are relatively low in value and relatively consistent between the three lobes. Mean total nitrogen concentrations ranged from 579-681 μg/l within the three lobes, indicating values which are somewhat lower than concentrations for total nitrogen commonly observed in urban lakes. The dominant nitrogen species observed at each of the three sites appears to be particulate nitrogen which comprises more than 50% of the total nitrogen measured at each site.

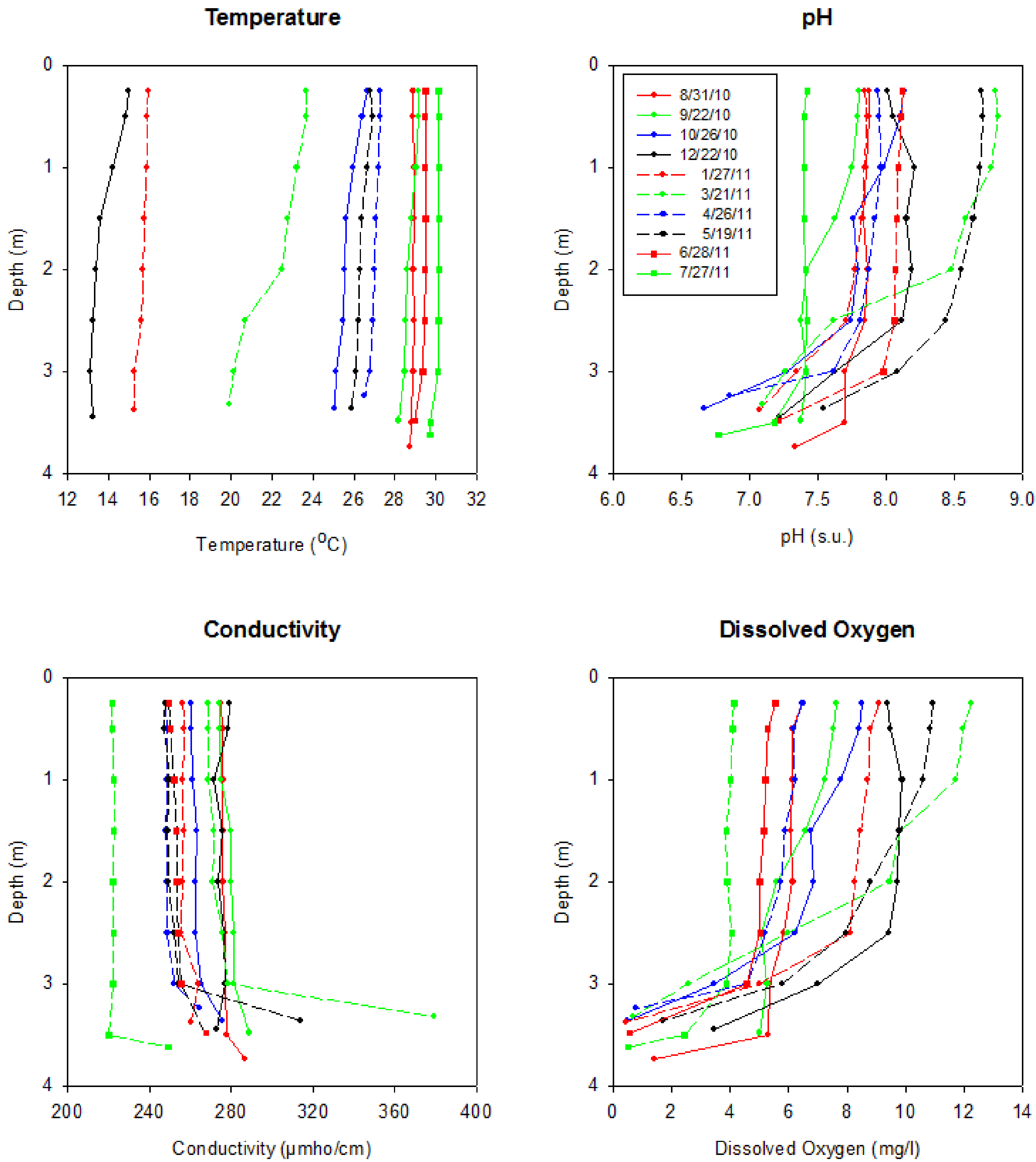


Figure 2-24. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen at the North Lobe Site in Lake Killarney from August 2010-July 2011.

TABLE 2-11

SUMMARY OF WATER QUALITY CHARACTERISTICS OF LAKE KILLARNEY FROM AUGUST 2010-JULY 2011 (n = 12 samples)

PARAMETER	UNITS	EAST LOBE		WEST LOBE		NORTH LOBE	
		Top	Bottom	Top	Bottom	Top	Bottom
pH	s.u.	7.78	7.46	7.57	7.16	7.55	7.44
Alkalinity	mg/l	85.7	90.2	81.4	86.2	108	110
Conductivity	μmho/cm	221	231	219	229	261	247
NH_3	μg/l	31	109	37	93	24	28
NO_x	μg/l	1	1	1	1	1	1
Diss. Org. N	μg/l	189	378	234	188	216	185
Particulate N	μg/l	329	385	373	431	328	269
Total N	μg/l	579	959	681	765	611	518
SRP	μg/l	1	1	1	1	10	12
Diss. Org. P	μg/l	3	4	4	3	6	4
Particulate P	μg/l	16	32	12	23	47	49
Total P	μg/l	21	39	17	28	64	68
Turbidity	NTU	4.3	7.3	4.1	6.8	3.7	4.1
Color	Pt-Co	11	11	10	10	16	16
Chlorophyll-a	mg/m^3	15.3	--	9.5	--	25.9	--

Measured concentrations of SRP, dissolved organic phosphorus, particulate phosphorus, and total phosphorus were all relatively low in value in surface water samples collected at the east and west lobes. Particulate phosphorus appears to be the dominant phosphorus species at these sites, comprising approximately 75% of the total phosphorus measured. However, substantially higher phosphorus concentrations were observed for each measured species of phosphorus at the north lobe site. The overall mean total phosphorus concentration of 64 μg/l measured at the north lobe site is approximately 3-4 times greater than concentrations measured at the east and west lobe sites.

Measured concentrations of turbidity and color were relatively low in value at each of the three monitoring sites throughout the field monitoring program. Moderate levels of chlorophyll-a were observed at the east and west lobe sites, with mean concentrations of 15.3 mg/m^3 and 9.5 mg/m^3, respectively. A somewhat higher mean chlorophyll-a concentration of 25.9 mg/m^3 was measured in the north lobe which is consistent with the more elevated levels of total phosphorus observed at this site.

Mean concentrations for samples collected near the lake bottom at each of the monitoring sites are also provided in Table 2-11. In general, samples collected near the lake bottom were characterized by lower levels of pH but higher alkalinity values, suggesting that influx of groundwater may occur in deeper portions of the lake. Bottom samples at the east and west lobes were also characterized by higher levels of total nitrogen, primarily as a result of increases in measured concentrations of ammonia and particulate nitrogen. In contrast, a lower total nitrogen concentration was measured in bottom samples collected from the north lobe.

Samples collected near the lake bottom were also characterized by higher levels of particulate phosphorus and total phosphorus compared with samples collected near the water surface. Bottom samples also had more elevated levels of turbidity, although color concentrations were relatively the same in the top and bottom samples.

In general, water quality characteristics appear to be relatively similar between the east and west lobes of Lake Killarney. The lake is characterized in general by relatively low levels of total nitrogen and low to moderate levels of total phosphorus and chlorophyll-a. However, the north lobe appears to have substantially different water quality characteristics, with higher levels for alkalinity, conductivity, SRP, particulate phosphorus, total phosphorus, and chlorophyll-a. It appears that the north lobe experiences impacts from inputs which are not present in the east and west lobes.

A comparison of variability in measured concentrations of total nitrogen and total phosphorus in Lake Killarney, based upon the field monitoring program conducted by ERD from September 2010-August 2011, is given in Figure 2-25. Separate plots are provided for each of the three surface water monitoring sites within the lake, as well as comparative plots for samples collected near the top and bottom of the water column at each site. In general, measured total nitrogen concentrations in the surface samples ranged from approximately 300-1100 μg/l. Total nitrogen concentrations measured at the east lobe monitoring site appear to be lower in value throughout much of the year and also exhibit a lower degree of variability than observed for nitrogen concentrations measured at the west lobe and north lobe sites. The most elevated surface concentrations of total nitrogen appear to occur throughout much of the year at the west lobe monitoring site, although higher concentrations were observed in the north lobe during several monitoring events. Nitrogen concentrations measured in the west lobe and north lobe were characterized by a much higher degree of variability throughout the year than occurred at the east lobe site.

In general, measured total nitrogen concentrations in the bottom samples exhibited a high degree of variability throughout the monitoring program. At the east monitoring site, total nitrogen concentrations in the bottom samples were equal to or greater than the surface sample concentrations throughout the entire 12-month monitoring program. Differences in nitrogen concentrations between surface and bottom samples were particularly pronounced during the period from February-August 2011 when bottom nitrogen concentrations were roughly 2 times greater than surface water concentrations at this site. However, this pattern was not observed at the north and west lobe monitoring sites where surface and bottom samples were generally closer in value throughout most of the year.

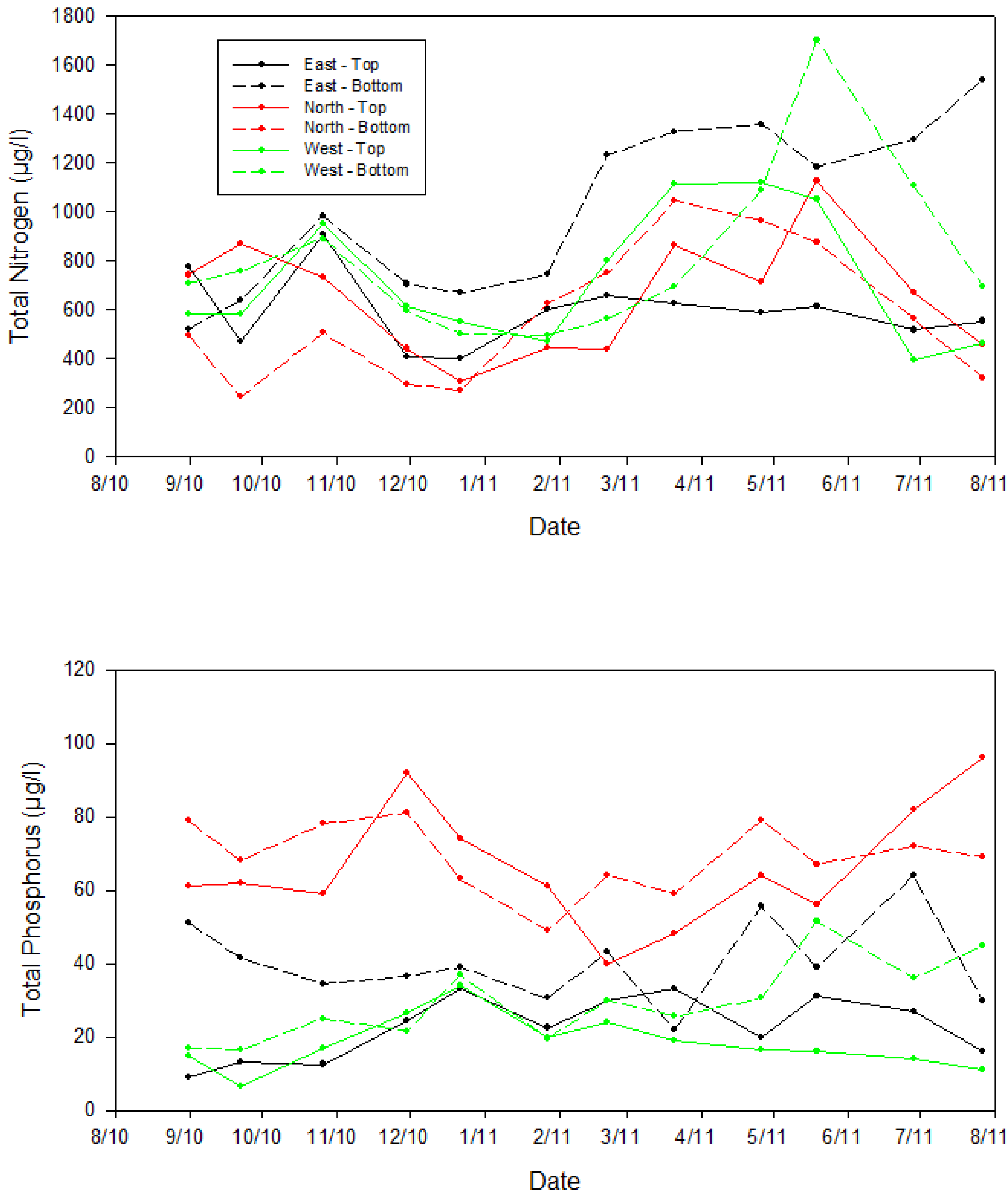


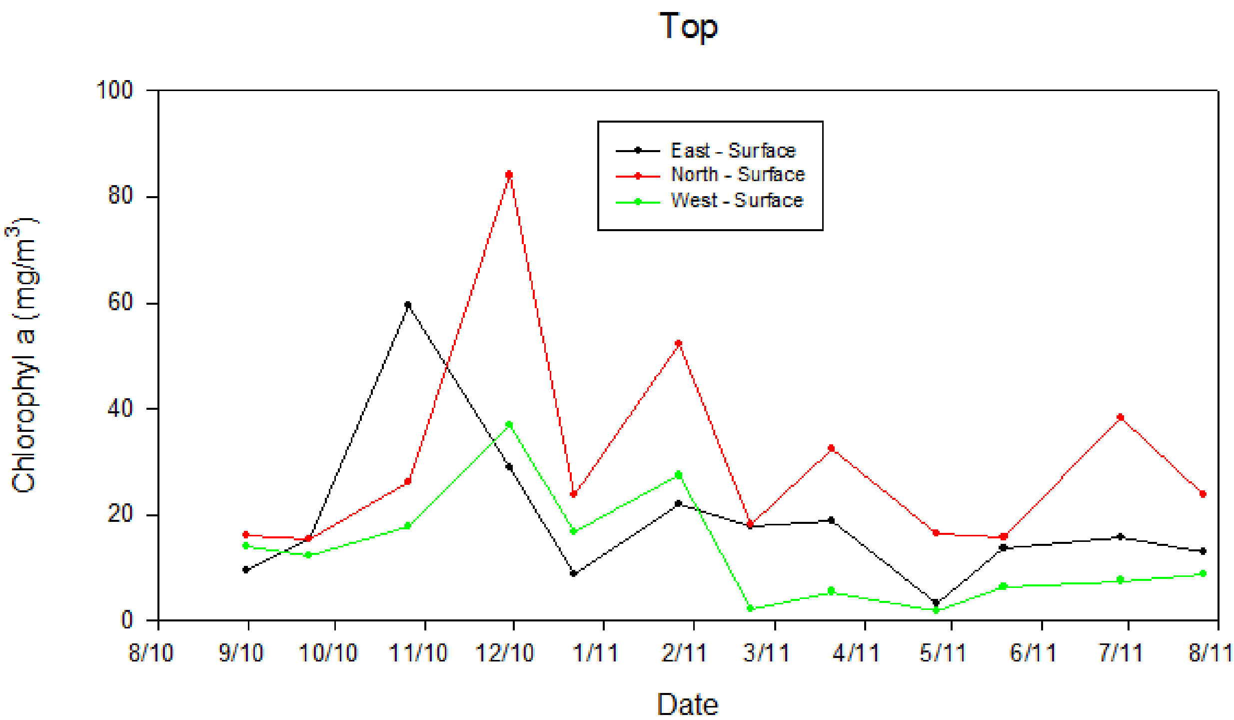
Figure 2-25. Variability in Measured Concentrations of Total Nitrogen and Total Phosphorus in Lake Killarney from September 2010-August 2011.

A graphical comparison of variability in measured concentrations of total phosphorus in Lake Killarney, based upon the field monitoring program conducted by ERD from September 2010-August 2011, is also given on Figure 2-25. Total phosphorus concentrations in surface samples collected at the east and west lobe monitoring sites were relatively similar throughout the monitoring program. However, substantially higher and more variable total phosphorus concentrations were measured in surface samples collected within the north lobe. These data suggest that the north lobe is impacted by significant additional phosphorus loadings which are not present in the east or west lobes. Phosphorus concentrations in bottom samples at the east and west lobes were generally higher than concentrations measured in the surface samples throughout much of the field monitoring program, particularly during fall and spring conditions. These differences in concentrations between surface and bottom samples provide additional evidence that internal recycling of phosphorus from the bottom sediments may be significant. In contrast, no significant trend of higher phosphorus concentrations in bottom samples was observed in the north lobe, with alternating trends of the highest phosphorus concentrations in the top and bottom samples.

A graphical comparison of variability in measured concentrations of chlorophyll-a and TN/TP ratio in Lake Killarney, based upon the field monitoring program conducted by ERD from September 2010-August 2011, is given on Figure 2-26. Measured chlorophyll-a values were highly variable at the three monitoring sites throughout the monitoring program. The most elevated chlorophyll-a values appeared to occur during fall and winter conditions, with the lowest concentrations observed during spring and summer conditions. In general, chlorophyll-a concentrations measured at the east and west lobes were lower in value on virtually all monitoring dates than chlorophyll-a concentrations measured in the northern lobe. Measured chlorophyll-a concentrations in the west lobe were lower in value than concentrations measured in the east lobe during the final 6 months of the monitoring program.

A graphical comparison of variability in TN/TP ratios at each of the three monitoring sites during the field monitoring program conducted by ERD is also provided in Figure 2-26. Calculated TN/TP ratios at the east and west lobe monitoring sites indicated either nutrient-balanced or phosphorus-limited conditions throughout virtually all of the field monitoring program. However, calculated ratios at the north lobe monitoring site suggests nutrient-balanced or nitrogen-limited conditions at this site. The apparent nitrogen-limited conditions at this site are likely a result of the more elevated total phosphorus concentrations observed at this site rather than a true nitrogen limitation.

A graphical comparison of variability in calculated TSI values, based upon chlorophyll-a, is given in Figure 2-27. During the first 6 months of the field monitoring program, each of the three monitoring sites appear to exhibit primarily mesotrophic or eutrophic conditions. However, during the final 6 months of the field monitoring program, primarily oligotrophic characteristics were observed at the west lobe site, with a combination of oligotrophic and mesotrophic characteristics at the east lobe site. TSI values at the northern lobe suggest primarily mesotrophic and eutrophic conditions at this site.



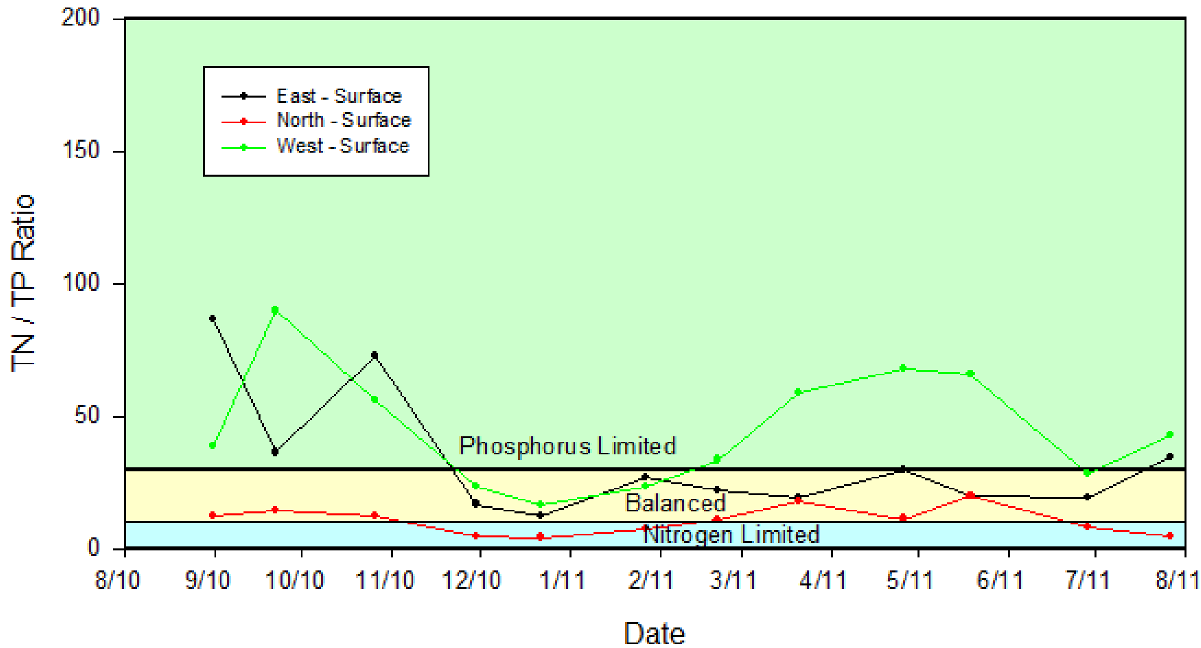


Figure 2-26. Variability in Measured Concentrations of Chlorophyll-a and TN/TP Ratio in Lake Killarney from September 2010-August 2011.

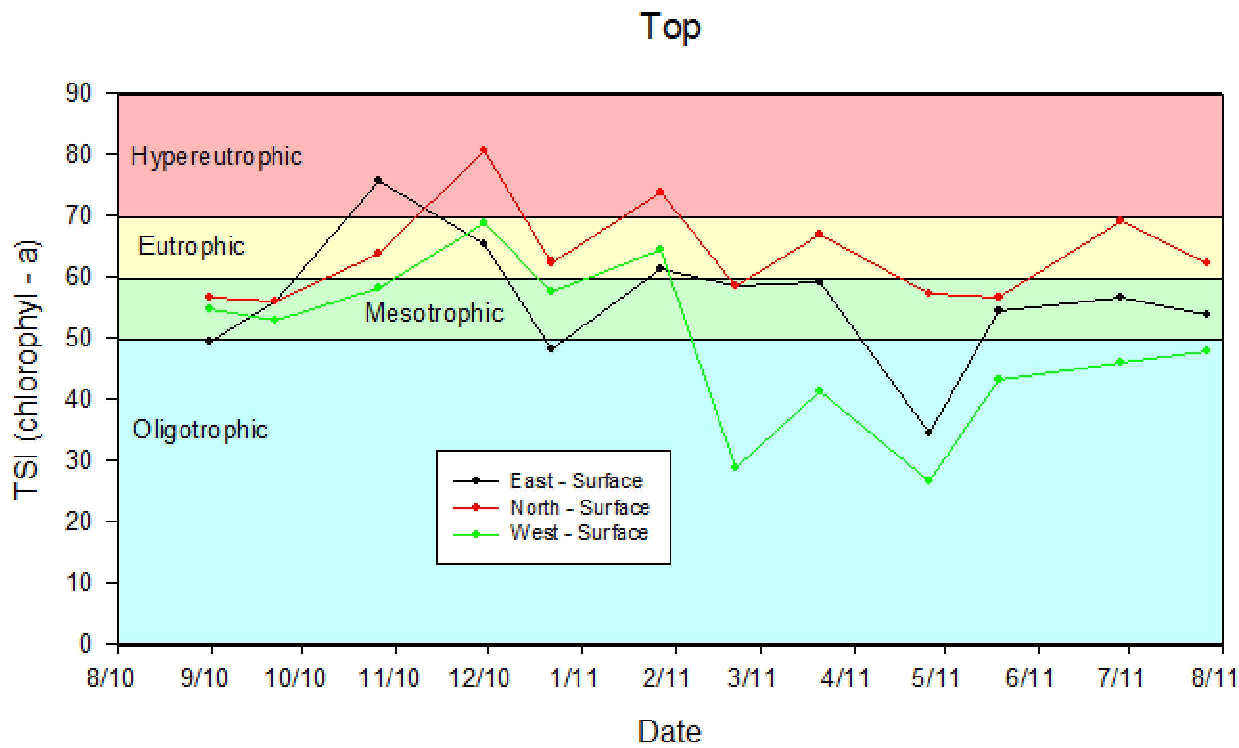


Figure 2-27. Variability in Measured Concentrations of TSI in Lake Killarney from September 2010-August 2011.

2.3.2.4 <u>Summary</u>

In general, Lake Killarney exhibits water quality characteristics which are typical of impacted urban lakes. Upper portions of the water column appear to be relatively well mixed during much of the year to water depths of 3-4 m or more. Water quality in these upper layers of the lake typically ranges from moderately good to poor. Historical water quality monitoring conducted in Lake Killarney suggests that water column concentrations of total nitrogen and total phosphorus may be improving over time, with a corresponding increase in Secchi disk depth, particularly in recent years. However, it is likely that much of this apparent improvement in total nitrogen and total phosphorus in the water column of the lake is a result of the extensive and expanding crop of aquatic vegetation within the lake which is removing nutrients from the water column and may be masking actual water quality trends within the lake. Both historical and current water quality data suggest that Lake Killarney becomes stratified both physically and chemically during at least portions of the year. These lower portions of the water column are often anoxic and create conditions favorable for release of ammonia and phosphorus from the sediments into the hypolimnetic layer. Periodic episodes of circulation cause these accumulated nutrients to be redistributed into other portions of the water column, particularly during fall, winter, and spring conditions. This type of behavior is characteristic of eutrophic lake systems.

Sediment and bathymetric monitoring conducted by ERD indicate the presence of deep accumulations of organic muck in the historically deeper portions of the lake. These sediments contain a substantial amount of accumulated organic matter which contributes to creating the anoxic conditions observed in deeper portions of the lake and creates ideal conditions for sediment release of nutrients, particularly ammonia and phosphorus. The historical data, as well as the current evaluation conducted by ERD, suggest that Lake Killarney is impacted by both external and internal nutrient sources.

Both the historical and current water quality monitoring programs suggest the east and west lobes have similar water quality characteristics throughout much of the year. However, water quality within the north lobe appears to be substantially different, with higher concentrations of total nitrogen, total phosphorus, and chlorophyll-a. It appears that this area is impacted by higher areal nutrient loading rates than occur in the main portions of the lake. The outfall structure for the lake is also located in the north lobe, and the elevated water quality characteristics present in this lobe result in downstream discharges from the lake which may not be truly indicative of the overall water quality in Lake Killarney.

2.4 Water Level

Water level elevations in Lake Killarney are regulated by a combination of drainage wells and an outfall structure located in the northern lobe of the lake. Two separate drainage well structures are located on the southeast side of Lake Killarney in unincorporated Orange County, designated as H-34 and H-35. Physical characteristics of the drainage well structures are given in Table 2-12. Each of the drainage wells are 18 inches in diameter and extend 390-400 ft below ground. The overflow elevation of each well is 82.5 ft.

TABLE 2-12

CHARACTERISTICS OF DRAINAGE WELL STRUCTURES ON LAKE KILLARNEY

WELL I.D. NO.	WELL DEPTH (ft)	BOTTOM OF CASING (ft)	WELL DIAMETER (inches)	OVERFLOW ELEVATION (ft)
H-34	390	181	18	82.5
H-35	400	200	18	82.5

An overview of the outfall structure is given on Figure 2-28. The structure was constructed in the mid-1970s to regulate water level elevations in Lake Killarney and increase available water storage. Water levels are controlled by a downward operating aluminum weir gate which can regulate water level elevations between 81.91 ft and 83.86 ft. Operation of the outfall structure is conducted by Orange County. According to Orange County, the weir gate has been maintained at an elevation of 83.86 ft since the time of installation. Discharges from Lake Killarney travel northward through underground stormsewers to Lake Gem. Lake Gem discharges through an open channel to Park Lake which ultimately outfalls to Lake Maitland.

Figure 2-28. Photograph of Outfall Structure.

Historical water level elevations in Lake Killarney have been recorded by Orange County on approximately a monthly basis from 1960-present. A graphical summary of water surface elevations in Lake Killarney over the available period of record is given on Figure 2-29. During this period, water surface elevations in Lake Killarney have ranged from approximately 81-86 ft, a difference of approximately 5 ft, although the vast majority of measured elevations within the lake have ranged from approximately 82.5-83.5 ft. Minimum water levels in Lake Killarney appear to have increased in the mid-1970s following construction of the outfall structure. The normal high water elevation in Lake Killarney is 83.0 ft (Source: Orange County). Water levels in Lake Killarney have been above the outfall control elevation of 83.86 ft on only 8 occasions over the 37-year period from 1960-1996, with no water elevations above the outfall control elevation over the most recent 15-year period from 1997-2011.

2.5 Vegetation Control

Lake Killarney has a long history of management efforts to control aquatic vegetation within the lake. During the 1970s, hydrilla expanded throughout much of the lake, and according to the City of Winter Park, a "high" rate of grass carp was stocked for vegetation control, although the specific number of fish added is not known. The large number of grass carp removed much of the vegetation from the lake, and a re-vegetation project was conducted by lakefront residents during 1999-2000.

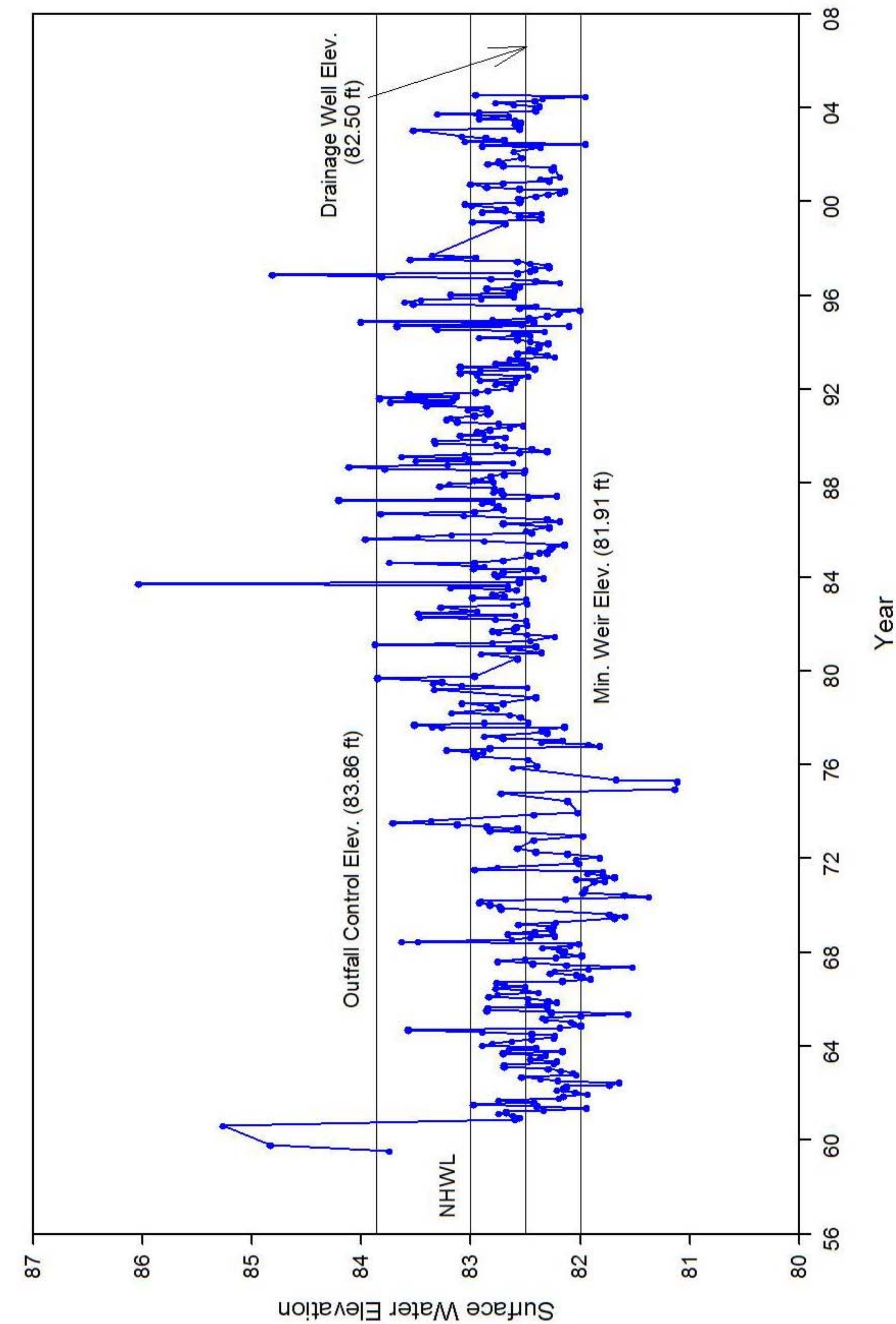


Figure 2-29. Historical Water Level Elevations in Lake Killarney. (Source: Orange County)

Around 2000, noticeable regrowth of hydrilla was observed within the lake, and in 2001 the City of Winter Park began doing spot treatments for hydrilla control. The spot treatments were relatively minimal in scope and frequency until 2006 when a whole-lake treatment was conducted using Fluridone. The whole-lake treatment was followed by spot treatments of Endothal in areas that were particularly infested with hydrilla. In 2007, the City of Winter Park concluded that the hydrilla in the lake was becoming tolerant to Fluridone, and Lake Killarney was subsequently stocked with approximately 500 grass carp, equivalent to a stocking rate of approximately 2-2.5 fish/acre. This stocking rate is in line with stocking rates typically recommended by many limnologists and fish control experts. Grass carp are commonly used for control of exotic or nuisance vegetation such as hydrilla and Illinois pond weed. Introduction of grass carp often leads to a relative monoculture of species such as eelgrass which is a native beneficial species that grass carp eat only when more desirable vegetation is not present.

Photographs of submerged aquatic vegetation in Lake Killarney under existing conditions are given in Figure 2-30. Abundant growth of eelgrass occurs in virtually all shoreline areas of the lake, often extending to water depths of 8-10 ft. In some areas, the dense growth of eelgrass interferes with navigation and boating activities, and floating eelgrass cut by boating activities can be seen along lakefront shorelines on virtually any day.

a. Eelgrass in shoreline areas

b. Floating eelgrass cut by boating activities

Figure 2-30. Photographs of Submerged Aquatic Vegetation Under Existing Conditions.

Since 2007, a few minimal hydrilla treatments have occurred which have been mostly confined to the cove and canal areas of the lake. However, in the summer of 2012, Lake Killarney experienced a growth of hydrilla in the main section of the lake, and the City of Winter Park treated about 15 acres of open water for hydrilla control. The City currently plans to add additional grass carp to Lake Killarney in the fall of 2012 at an additional stocking rate of approximately one fish per acre, as recommended by the Florida Wildlife Commission (FWC).

SECTION 3

CHARACTERISTICS OF THE LAKE KILLARNEY DRAINAGE BASIN

Characteristics of the drainage basin area for Lake Killarney are summarized in this section, including information on drainage basin delineations, governmental jurisdictions, land use characteristics, soil types, basin topography, stormwater treatment areas, and sewage disposal. A discussion of each of these elements is given in the following sections.

3.1 Watershed Characteristics

A delineation of contributing drainage basin areas to Lake Killarney was conducted by ERD as part of this project. Preliminary drainage basin boundaries were established based upon a previous study conducted by ERD during 1996 for the City of Winter Park which provided approximate drainage basin delineations for Lake Killarney as part of a loading evaluation project. The 1996 ERD basin boundaries were modified, as appropriate, by reviewing one foot LIDAR contour elevation maps, provided to ERD by Orange County (2008), for the Lake Killarney drainage basin, a review of environmental resource permits (ERPs) for recent constructed projects within the drainage basin, 2008 aerial photography obtained from FDEP, field reconnaissance, and observation of drainage patterns during significant rain events. Individual sub-basin areas were delineated to identify areas which discharge through individual stormsewer inflows into Lake Killarney.

An overview of the overall drainage basin delineation and individual sub-basin areas discharging into Lake Killarney is given on Figure 3-1. Contributing drainage basins to Lake Killarney are divided into areas which discharge to the lake on a routine basis and areas which discharge only periodically. Areas which discharge to Lake Killarney on a routine basis are identified as the "Lake Killarney" drainage basin which consists of areas surrounding the lake that discharge into the lake through unique stormsewer systems. A total of 47 separate sub-basin areas were delineated which discharge into the lake through individual storm sewers or channels. In addition, areas located around the perimeter of Lake Killarney which discharge into the lake through overland flow are referred to as "overland flow" sub-basins. A tabular summary of sub-basin areas included in the Lake Killarney drainage basin is given on Table 3-1. The identified sub-basins range in size from 0.89-110 acres, with a total combined area of approximately 561.50 acres. The largest sub-basin areas are Sub-basin 31, located south of Fairbanks Avenue, and the direct overland flow sub-basin which comprise 19.6% and 13.7%, respectively, of the overall basin area. Approximately 6.7% of the overall basin area is contributed by Sub-basin 24, with 6.6% contributed by Sub-basin 34, 5.6% by Sub-basin 1, and 5.4% by Sub-basin 35. Each of the remaining sub-basin areas contributes approximately 4% or less of the total drainage basin area.

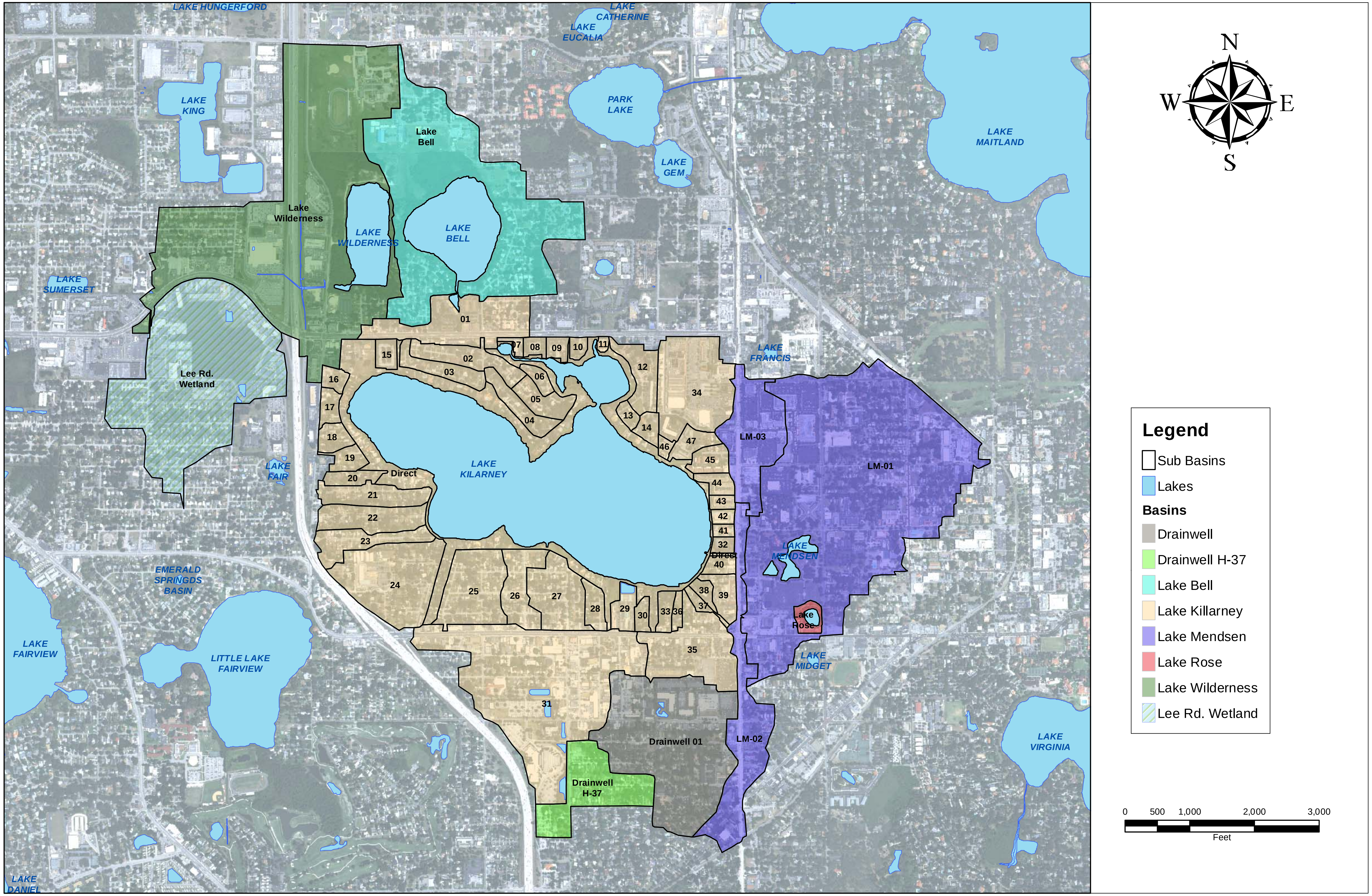


Figure 3-1. Delineation of Sub-basin Areas Discharging to Lake Killarney.

TABLE 3-1

SUMMARY OF SUB-BASIN AREAS IN THE LAKE KILLARNEY DRAINAGE BASIN

SUB-BASIN I.D.	TOTAL (acres)	PERCENT OF TOTAL	SUB-BASIN I.D.	TOTAL (acres)	PERCENT OF TOTAL
01	31.69	5.6	25	24.33	4.3
02	11.76	2.1	26	13.47	2.4
03	8.18	1.5	27	19.28	3.4
04	7.77	1.4	28	4.90	0.9
05	7.63	1.4	29	4.71	0.8
06	2.84	0.5	30	2.52	0.4
07	1.37	0.2	31	110.11	19.6
08	2.34	0.4	32	1.97	0.4
09	2.73	0.5	33	3.52	0.6
10	1.99	0.4	34	36.94	6.6
11	0.89	0.2	35	30.14	5.4
12	10.63	1.9	36	1.89	0.3
13	2.29	0.4	37	2.03	0.4
14	3.46	0.6	38	2.41	0.4
15	3.48	0.6	39	6.15	1.1
16	2.97	0.5	40	3.08	0.5
17	3.77	0.7	41	1.57	0.3
18	4.57	0.8	42	1.86	0.3
19	4.25	0.8	43	2.02	0.4
20	4.25	0.8	44	3.65	0.7
21	12.14	2.2	45	5.47	1.0
22	14.64	2.6	46	1.44	0.3
23	12.18	2.2	47	5.38	1.0
24	37.75	6.7	Overland Flow	77.08	13.7
			Total:	**561.50**	**100.0**

Also included in Figure 3-1 are sub-basins which discharge to Lake Killarney on an intermittent basis. The largest of these additional sub-basin areas is the Lake Mendsen basin which consists primarily of areas east of US 17-92 and includes a combination of commercial, office space, and residential land use which discharge ultimately into Lake Mendsen. This basin also contains a large number of constructed projects which provide stormwater treatment primarily through infiltration of runoff into the ground which reduces the overall runoff volume generated within the basin. Portions of the runoff discharging to Lake Mendsen are used for irrigation purposes on city-owned property adjacent to the lake. The excess runoff volume is discharged into an underground storm sewer system which enters the east side of Lake Killarney. Also included in the Lake Mendsen drainage basin is Lake Rose, formerly known as the Winter Park sinkhole. The Lake Rose basin is a land-locked basin with no outfall and is assumed to be a closed basin for purposes of this analysis.

Two additional intermittent sub-basins are located south of Lake Killarney and are referred to as Drainwell 01 and Drainwell H-37 basins. Runoff generated within these basins is discharged primarily into a drainwell structure in each of the two basins. Discharges from these areas to Lake Killarney would occur only under extreme flooding conditions, and for purposes of this analysis, these basins are also considered to be closed basins with no significant contribution to Lake Killarney.

Three relatively large intermittent sub-basin areas are located on the northwest side of Lake Killarney. The most southern of these sub-basins is referred to as the Lee Road Wetland which consists of areas of commercial and residential land use which discharge into a large wetland system located near the center of the basin. Excess water from the wetland discharges north into the Lake Wilderness drainage basin when water levels exceed the control elevation. The Lake Wilderness drainage basin consists of a combination of commercial and residential land use which is bisected in a north-south direction by I-4. Runoff generated within this basin combines with excess water from the Lee Road Wetland sub-basin and discharges from west to east beneath I-4, ultimately entering Lake Wilderness.

When water levels in Lake Wilderness exceed the control elevation, discharges occur from Lake Wilderness into Lake Bell. Lake Bell also receives runoff from a primarily residential drainage basin which surrounds the lake. Excess water from Lake Bell can then discharge beneath Lee Road and enter the western end of the northern lobe of Lake Killarney. Due to the large amount of wetland and water surface within these three basins, only a portion of the generated runoff volume from each basin actually reaches Lake Killarney. A tabular summary of the intermittent sub-basins discharging to Lake Killarney is given on Table 3-2. Overall, the intermittent sub-basins occupy an area of approximately 892.26 acres. If the land-locked basins are excluded from the total, the area of the intermittent drainage sub-basin areas is reduced to approximately 773.48 acres.

TABLE 3-2

SUMMARY OF INTERMITTENT SUB-BASINS DISCHARGING TO LAKE KILLARNEY

BASIN	SUB-BASIN	TOTAL acres)
Lake Mendsen	LM-01 LM-02 LM-03	236.73 40.27 32.74
Drainwell 01	Drainwell 01	86.07
Drainwell H-37	Drainwell H-37	29.14
Lake Bell	Lake Bell	125.35
Lake Rose	Lake Rose	2.94
Lake Wilderness	Lake Wilderness	217.60
Lee Road Wetland	Lee Road Wetland	121.42
	Grand Total	**892.26**
	Grand Total Excluding Land-locked Basins	**773.48**

3.2 Governmental Jurisdictions

An overview of governmental jurisdictions in the Lake Killarney drainage basin is given on Figure 3-2. Drainage basin boundaries are included for the directly discharging and intermittent sub-basin areas. City limits are provided for the cities of Eatonville, Maitland, Orlando, and Winter Park, along with areas located in unincorporated Orange County. Virtually the entire eastern portion of the drainage basin is located within the City of Winter Park, with western portions of the drainage basin located primarily in unincorporated Orange County. A small corner (0.24 acres) of the Lake Bell drainage basin is located within the City of Maitland, with approximately 40-50% of the Lake Bell and Lake Wilderness drainage basins located in the City of Eatonville.

A tabular summary of governmental jurisdictions in each of the direct and interconnected drainage basins is given in Table 3-3. Approximately 56% of the direct drainage basin (Lake Killarney Basin) is located within the City of Winter Park, with 37% located within Orange County, and the remaining 7% in the City of Orlando. In the interconnected drainage basins, approximately 54% is located within the City of Winter Park, 29% in unincorporated Orange County, 17% in Orlando, and 1% in Maitland and Eatonville.

TABLE 3-3

SUMMARY OF GOVERNMENTAL JURISDICTIONS IN THE LAKE KILLARNEY DIRECT AND INTERCONNECTED DRAINAGE BASINS

BASIN	TOTAL AREA (acres)	AREA BY GOVERNMENTAL JURISDICTION (acres)				
		Winter Park	Unincorporated Orange County	Maitland	Orlando	Eatonville
Lake Killarney	561.50	315.73	206.66	--	39.11	--
Lake Mendsen	309.74	309.74	--	--	--	--
Drainwell 01	86.07	64.12	21.95	--	--	--
Drainwell H-37	29.14	2.16	22.12	--	4.86	--
Lake Bell	125.35	63.80	0.03	0.24	--	61.28
Lake Rose	2.94	2.94	--	--	--	--
Lake Wilderness	217.60	36.18	95.25	--	--	86.17
Lee Road Wetland	121.42	0.47	120.95	--	--	--
Total:	**1453.76**	**795.14 (55%)**	**466.96 (32%)**	**0.24 (<1%)**	**43.97 (3%)**	**147.45 (10%)**

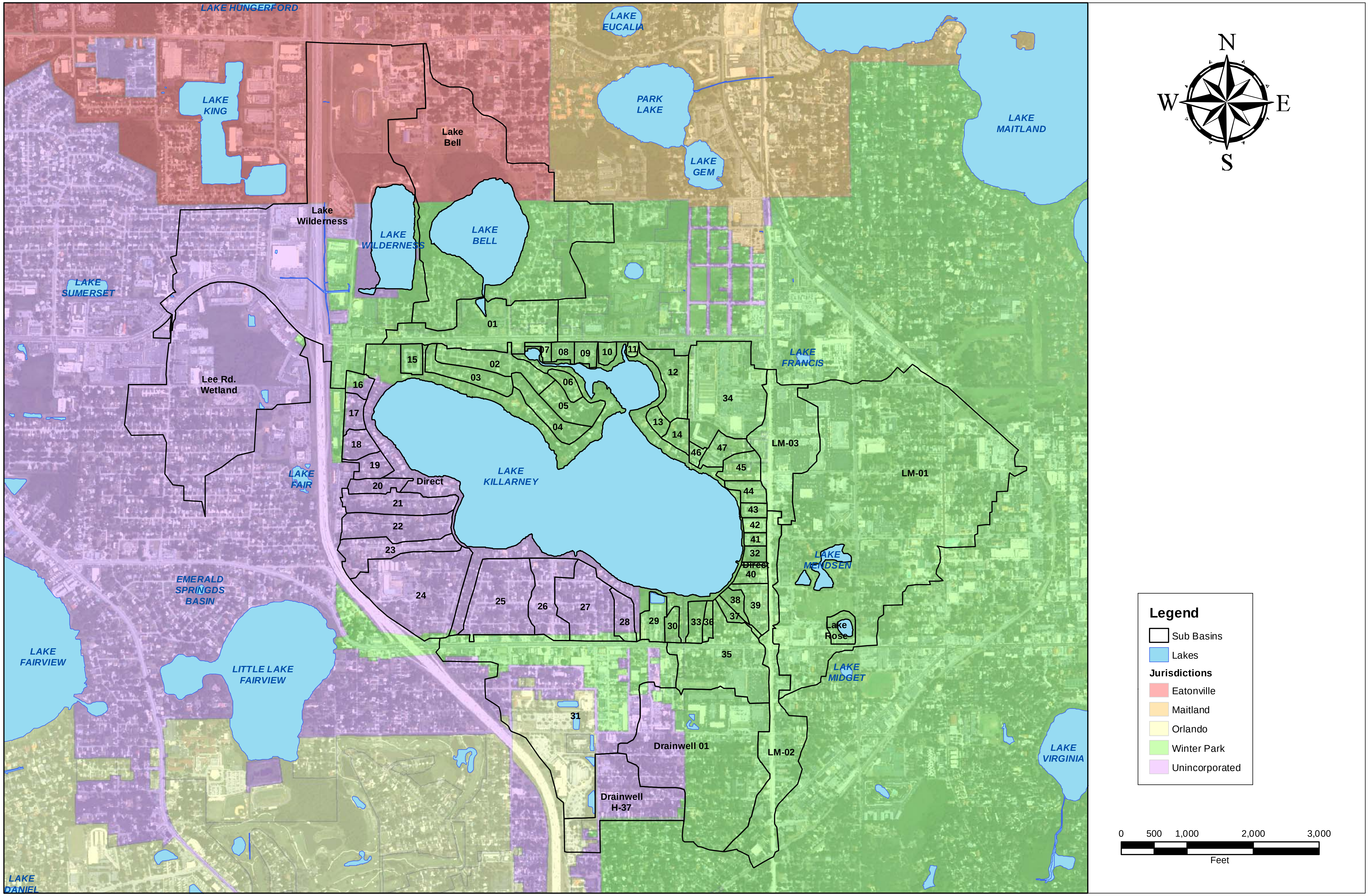


Figure 3-2. Governmental Jurisdictions in the Lake Killarney Drainage Basin.

3.3 Land Use

Land use information for the Lake Killarney drainage basin was obtained from the 2009 Land Use Inventory conducted by the SJRWMD. This land use information was initially obtained by ERD in a GIS format in the form of Level III FLUCCS (Florida Land Use Cover and Classification System) Codes. The Level III FLUCCS codes were condensed by ERD to a series of general land use categories to simplify presentation of the information. This information was utilized by ERD as a preliminary base map, and modifications to the land use characterization data were made using a combination of aerial photography and field reconnaissance to reflect land use under current conditions.

An overview of current land use in the Lake Killarney and intermittent drainage basins is given in Figure 3-3. The dominant land use categories within the basin appear to be medium-density residential, high-density residential, and commercial, with smaller areas of wetlands, recreational areas, and woods.

A summary of current land use in the Lake Killarney drainage basin, excluding the intermittent drainage basin areas, is given in Table 3-4. The largest land use categories within the basin are medium-density residential (which occupies 52.8% of the total land area), followed by commercial (28.7%), institutional (8.6%), high-density residential (6.8%), and transportation (2.6%). Each of the remaining land use categories comprises 0.3% or less of the total basin area.

A summary of current land use in the intermittent drainage basins is given in Table 3-5. Similar to the Lake Killarney drainage basin, the intermittent drainage basins are also primarily composed of medium-density residential (33.8%), commercial (35.6%), institutional (9.1%), and transportation (6.9%) uses. Each of the remaining land use categories comprises approximately 4% or less of the total basin area within the intermittent basins. The land-locked basin areas are highlighted in yellow.

3.4 Soil Characteristics

Information on soil types within the Lake Killarney drainage basin was obtained from the St. Johns River Water Management District GIS database. Soil information was extracted in the form of Hydrologic Soil Groups (HSG) which classifies soil types with respect to runoff-producing characteristics. Using this system, soils are classified into groups for evaluation and modeling purposes. The chief consideration in each of the soil group types is the inherent capacity of bare soil to permit infiltration. A summary of the characteristics of each hydrologic soil group is given in Table 3-6.

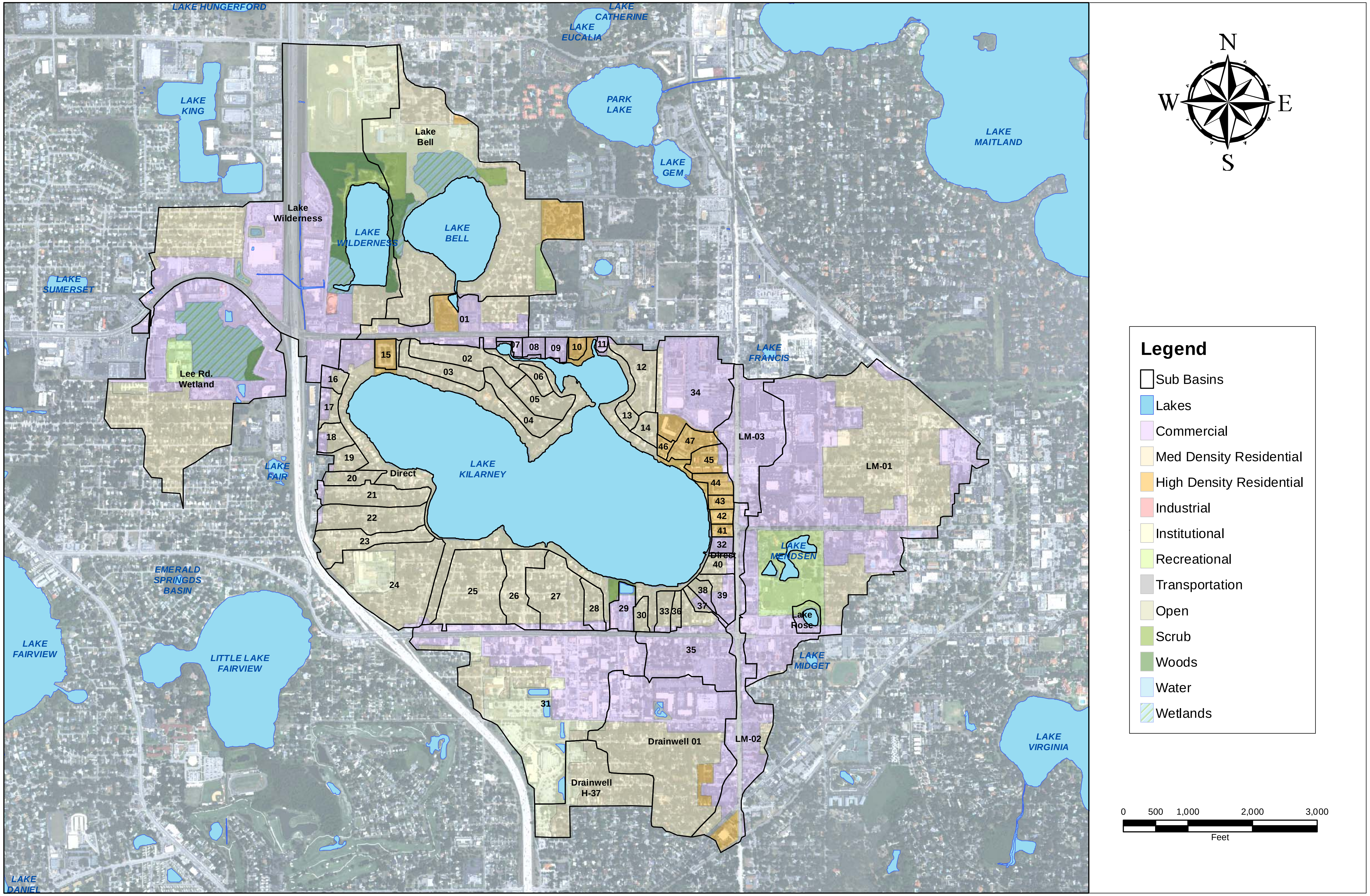


Figure 3-3. Current Land Use in the Lake Killarney and Intermittent Drainage Basins.

TABLE 3-4

SUMMARY OF CURRENT LAND USE IN THE LAKE KILLARNEY DRAINAGE BASIN

SUB-BASIN	LAND USE AREA (acres)												
	Commercial	High-Density Residential	Industrial	Institutional	Medium-Density Residential	Open	Recreational	Scrub	Transportation	Water	Wetlands	Woods	Total
01	13.12	4.48			9.06				5.00		0.03		**31.69**
02	0.31				11.46								**11.76**
03					8.18								**8.18**
04					7.77								**7.77**
05					7.63								**7.63**
06					2.84								**2.84**
07	1.37												**1.37**
08	2.34												**2.34**
09	2.69	0.04											**2.73**
10		1.99											**1.99**
11	0.89				0.00								**0.89**
12	0.42				10.21								**10.63**
13					2.29								**2.29**
14		0.07			3.39								**3.46**
15		3.47			0.01								**3.48**
16	1.33				1.64								**2.97**
17	1.72				2.05								**3.77**
18	1.06				3.51								**4.57**
19	0.32				3.94								**4.25**
20	0.11				4.14								**4.25**
21	0.74				11.40								**12.14**
22	0.42				14.22								**14.64**
23					11.85				0.33				**12.18**
24	0.57			9.68	26.83				0.67				**37.75**
25	0.44				23.89								**24.33**
26	0.74				12.73								**13.47**
27	2.06				17.23								**19.28**
28	0.93				3.97								**4.90**
29	4.49							0.22					**4.71**
30	0.08				2.44								**2.52**
31	51.29			38.80	13.50	0.63			5.90				**110.11**
32	1.97												**1.97**
33	0.55				2.95				0.02				**3.52**
34	31.09	3.58			2.27								**36.94**
35	24.05				3.63				2.47				**30.14**
36	0.18				1.71								**1.89**
37	1.04				0.99								**2.03**
38	0.98				1.43								**2.41**
39	4.33				1.52				0.29				**6.15**
40	0.78				2.21				0.08				**3.08**
41	0.09	1.48											**1.57**
42		1.86							0.00				**1.86**
43		2.01							0.01				**2.02**
44	0.12	3.53							0.00				**3.65**
45	1.29	4.18											**5.47**
46		1.44											**1.44**
47	0.07	5.31											**5.38**
Direct	7.29	4.71			63.59			1.49	0.00				**77.08**
Totals:	**161.26**	**38.16**	**0.00**	**48.48**	**296.46**	**0.63**	**0.00**	**1.71**	**14.78**	**0.00**	**0.03**	**0.00**	**561.50**
Percent of Totals:	**28.7**	**6.8**	**0.0**	**8.6**	**52.8**	**0.1**	**0.0**	**0.3**	**2.6**	**0.0**	**0.0**	**0.0**	**100.0**

TABLE 3-5

SUMMARY OF CURRENT LAND USE IN THE INTERMITTENT DRAINAGE BASINS

BASIN	SUB-BASIN	LAND USE AREA (acres)												
		Commercial	High-Density Residential	Industrial	Institutional	Medium-Density Residential	Open	Recreational	Scrub	Transportation	Water	Wetlands	Woods	Total
Lake Mendsen	LM-01	114.98			0.45	91.65		24.65		5.01				**236.73**
	LM-02	22.99	3.32			3.33				10.64				**40.27**
	LM-03	28.57	0.12							4.05				**32.74**
Lee Road Wetland	Lee Road Wetland	44.41			2.46	43.31		6.81				22.44	1.98	**121.42**
Lake Wilderness	Lake Wilderness	68.54		1.25	46.77	32.59	1.52		4.23	41.96	0.47	3.89	16.37	**217.60**
Lake Bell	Lake Bell	0.42	9.94		23.97	63.28		3.59	7.83			12.35	3.98	**125.35**
Drainwell	Drainwell 01	36.52	2.73		0.09	46.03	0.56			0.14				**86.07**
Drainwell H-37	Drainwell H-37				7.39	21.75								**29.14**
Lake Rose	Lake Rose	1.63						1.31						**2.94**
Totals		**318.05**	**16.10**	**1.25**	**81.14**	**301.93**	**2.08**	**36.36**	**12.06**	**61.81**	**0.47**	**38.68**	**22.33**	**892.26**
Percent of total:		**35.6**	**1.8**	**0.1**	**9.1**	**33.8**	**0.2**	**4.1**	**1.4**	**6.9**	**0.1**	**4.3**	**2.5**	**100.0**

TABLE 3-6

CHARACTERISTICS OF SCS HYDROLOGIC SOIL GROUP CLASSIFICATIONS

SOIL GROUP	DESCRIPTION	RUNOFF POTENTIAL	INFILTRATION RATE
A	Deep sandy soils	Very low	High
A / D	Deep sandy soils with high water table in undeveloped condition	Very high in undeveloped condition	Very low in undeveloped state
		Very low when developed and water table lowered	Very high when water table lowered with development
B / D	Shallow sandy soils over low permeability layer; high water table in undeveloped condition	High in undeveloped condition	Low in undeveloped condition
		Low when developed and water table lowered	Moderate when developed and water table lowered
C	Sandy soil with high clay or organic content	Medium to high	Low
D	Clayey soils	Very high	Low to none
W	Wetland or hydric soils	Very high	Low to none

A graphical summary of hydrologic soil groups in the Lake Killarney and intermittent drainage basins is given on Figure 3-4. The vast majority of soils within the overall drainage basin areas appear to be either in HSG A, which includes deep sandy soils with a very low runoff potential, and HSG A/D, which includes deep sandy soils with infiltration limited by high groundwater under undeveloped conditions but which have high permeability and low runoff generation when the water table is lowered under developed conditions. Therefore, virtually all of the soils within the overall drainage basin areas consists of deep sandy, well drained soils with high infiltration rates and low runoff potentials. Isolated pockets of HSG D soils are located in wetland areas associated with the Lee Road Wetland, Lake Wilderness, and Lake Bell sub-basin areas, with a small sliver of HSG B/D soil in the northwest corner of the Lake Wilderness basin. This information is used to generate input data for hydrologic modeling of runoff inputs from each of the sub-basin areas. A tabular summary of hydrologic soil groups in each sub-basin area within the Lake Killarney drainage basin is given on Table 3-7. Virtually 100% of the land area contained within the Lake Killarney drainage basin is categorized in HSG A or HSG A/D.

TABLE 3-7

HYDROLOGIC SOIL GROUPS IN
THE LAKE KILLARNEY DRAINAGE BASIN

BASIN	AREA BY HSG (acres)						BASIN	AREA BY HSG (acres)					
	A	A/D	B/D	D	W	Total		A	A/D	B/D	D	W	Total
01	31.25	0.42		0.03		**31.69**	26	12.03	1.45				**13.47**
02	11.62	0.14				**11.76**	27	17.54	1.75				**19.28**
03	8.18					**8.18**	28	3.96	0.94				**4.90**
04	7.77					**7.77**	29	1.30	3.41				**4.71**
05	7.39	0.24				**7.63**	30		2.52				**2.52**
06	1.07	1.77				**2.84**	31	61.74	48.37				**110.11**
07	0.91	0.45				**1.37**	32	1.97					**1.97**
08	2.12	0.22				**2.34**	33		3.52				**3.52**
09	1.96	0.77				**2.73**	34	36.94					**36.94**
10	1.03	0.97				**1.99**	35	28.12	2.02				**30.14**
11	0.89					**0.89**	36		1.89				**1.89**
12	10.63					**10.63**	37	2.00	0.03				**2.03**
13	1.89	0.40				**2.29**	38	2.41					**2.41**
14	3.27	0.19				**3.46**	39	6.15					**6.15**
15	3.48					**3.48**	40	3.08					**3.08**
16	2.97					**2.97**	41	1.57					**1.57**
17	3.77					**3.77**	42	1.86					**1.86**
18	4.57					**4.57**	43	2.02					**2.02**
19	4.25					**4.25**	44	3.65					**3.65**
20	4.25					**4.25**	45	5.47					**5.47**
21	12.14					**12.14**	46	1.44					**1.44**
22	13.91	0.73				**14.64**	47	5.38					**5.38**
23	12.18					**12.18**	Direct	53.57	23.51				**77.08**
24	37.75					**37.75**	**Totals:**	**465.79**	**95.68**	**0.00**	**0.03**	**0.00**	**561.60**
25	24.33					**24.33**	**% of Total:**	**83.0**	**17.0**	**0.0**	**0.0**	**0.0**	**100.0**

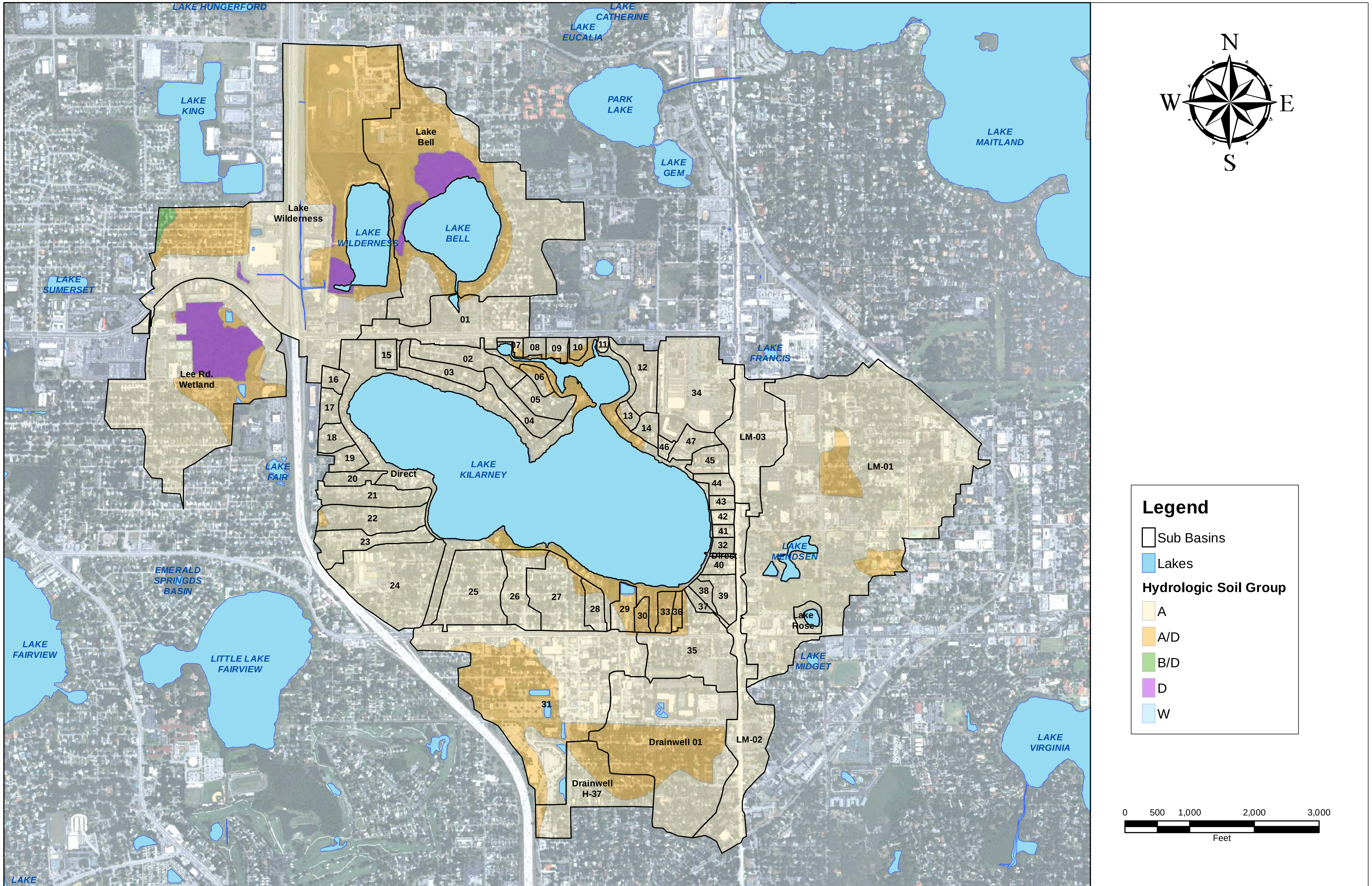


Figure 3-4. Hydrologic Soil Groups in the Lake Killarney and Intermittent Drainage Basins.

A tabular summary of hydrologic soil groups in the intermittent drainage basin areas is given in Table 3-8. Approximately 95% of the overall intermittent basin areas consist of either HSG A or HSG A/D, indicating highly permeable soils with a low runoff potential.

TABLE 3-8

HYDROLOGIC SOIL GROUPS IN THE INTERMITTENT DRAINAGE BASIN AREAS

BASIN	SUB-BASIN	AREA BY HSG (acres)					
		A	A/D	B/D	D	W	Total
Lake Mendsen	LM-01 LM-02 LM-03	220.78 40.27 32.74	15.96				236.73 40.27 32.74
Lee Rd. Wetland	Lee Rd. Wetland	78.74	20.18		22.49		121.42
Lake Wilderness	Lake Wilderness	107.88	102.38	2.15	4.71	0.47	217.60
Lake Bell	Lake Bell	55.43	57.57		12.35		125.35
Drainwell	Drainwell 01	53.02	33.05				86.07
Drainwell H-37	Drainwell H-37	16.10	13.04				29.14
Lake Rose	Lake Rose	2.94					2.94
Totals:		**607.90**	**242.18**	**2.15**	**39.55**	**0.47**	**892.26**
Percent of Total:		**68.1**	**27.1**	**0.2**	**4.4**	**0.1**	**100.0**

3.5 Basin Topography

Elevation contours in the vicinity of Lake Killarney are indicated on Figure 3-5 based upon one foot LIDAR data provided by Orange County. Land surface elevations within the drainage basin range from approximately 85 ft near Lake Killarney to approximately 100 ft in perimeter portions of the drainage basin. Contour elevations approach approximately 110 ft in portions of the basin associated with overpasses for I-4. The Lake Killarney drainage basin exhibits a relatively mild slope throughout most of the basin area.

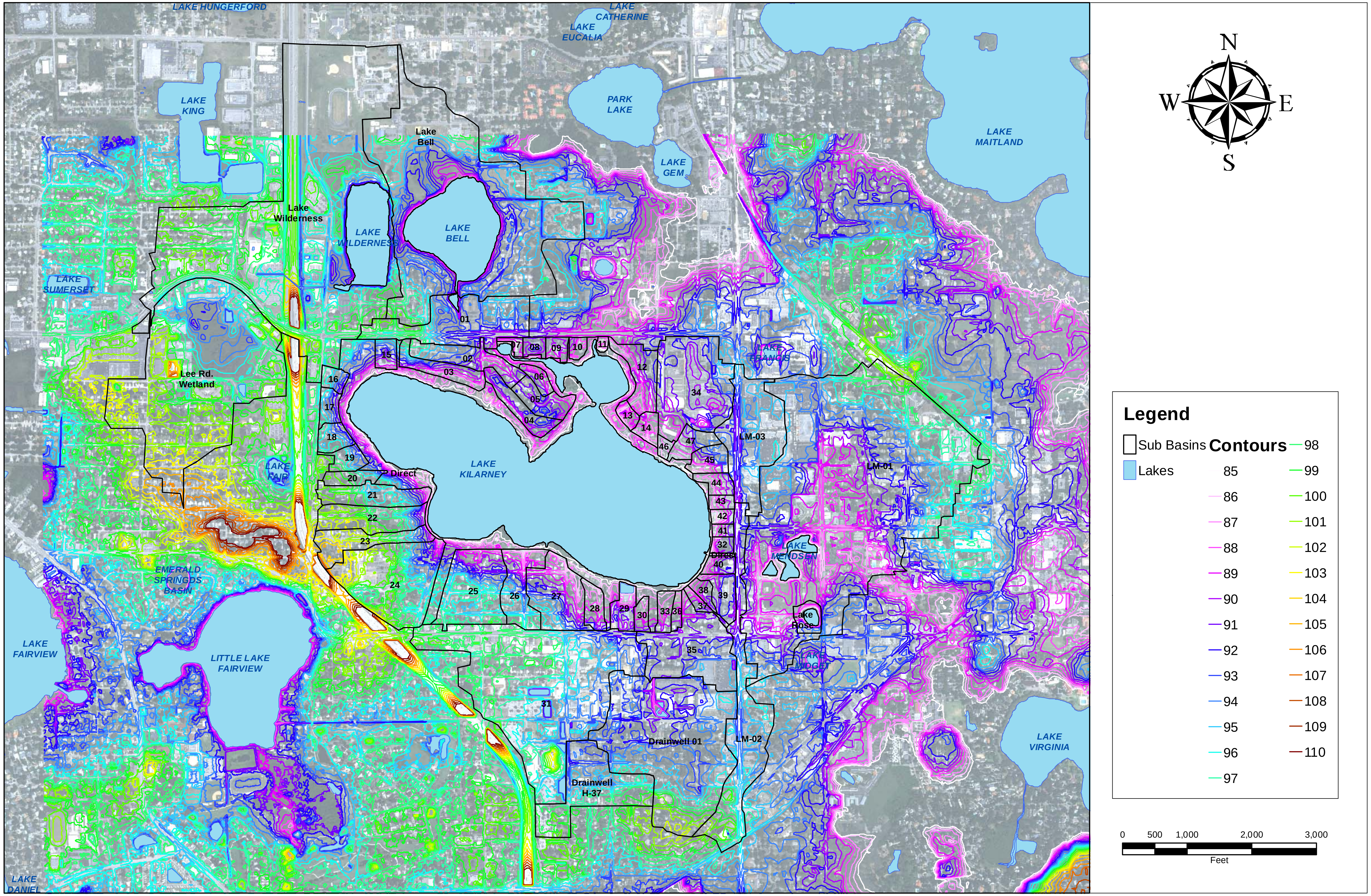


Figure 3-5. Topographic Contours in the Vicinity of Lake Killarney and Adjacent Watershed Areas.

3.6 Stormwater Treatment

3.6.1 Permitted and Natural Treatment Systems

Watershed areas which currently receive stormwater treatment were identified by ERD within the overall Lake Killarney drainage basin using a combination of aerial photography, field reconnaissance, and a review of historical permitting records in the possession of SJRWMD. A summary of the results of this evaluation is given on Figure 3-6. Permitted stormwater management systems using dry retention, which relies upon infiltration of runoff into the soil, are indicated by tan colored areas on Figure 3-6. Areas which provide stormwater treatment through wet detention systems are highlighted in blue. Also indicated on Figure 3-6 are wetland areas which receive stormwater runoff and provide some level of natural treatment, although these systems are not necessarily permitted systems. Lake Rose, which provides full retention for runoff generated in this relatively small basin, is also highlighted on the figure. In addition, the City of Winter Park's Stormwater Management and Reuse Technology (SMART) system is also highlighted which provides for stormwater treatment through on-site irrigation of runoff. The information summarized on Figure 3-6 is used in Sections 4 and 5 for estimation of hydrologic inputs and mass loadings from stormwater runoff reaching Lake Killarney.

3.6.2 Retrofit Projects

In addition to the permitted and natural stormwater treatment systems discussed previously, the City of Winter Park and Orange County have constructed a number of retrofit projects in the Lake Killarney drainage basin to reduce runoff loadings to the lake. The City of Winter Park has constructed leaf/debris traps on 10 of the 13 stormwater outfalls on the Winter Park side of Lake Killarney. A photograph of a typical leaf/debris trap is included on Figure 5-5b. The traps consist of a fenced area outside of the stormsewer outfall which uses a filter fabric to filter solids and other debris from the stormwater inflows and retain them within the leaf/debris trap.

The City of Winter Park has also installed additional treatment systems on 2 of the 3 largest outfalls to the lake. The Lee Road outfall, which is one of the larger outfalls discharging to Lake Killarney, has been retrofitted with a large baffle box structure to remove sediments and debris. The City of Winter Park also recently completed a stormwater project that directs first flush runoff from a section of US 17-92, which previously discharged directly to Lake Killarney through the Beachview Avenue outfall, into the ponds at Lake Island Park. The discharge from this treatment system is referred to as the Lake Mendsen outfall and was monitored directly by ERD as part of this project.

Orange County has installed 39 curb and grate baskets on southern and western sides of Lake Killarney in areas included in unincorporated Orange County. Locations of the curb and grate baskets installed by Orange County are given on Figure 3-7. The installed curb grate and inlet baskets are located primarily along Killarney Drive on the south side of Lake Killarney and Ololu Drive on the west side of Lake Killarney. Each of the curb and grate inlet baskets is emptied and cleaned on a monthly basis by a private subcontractor.

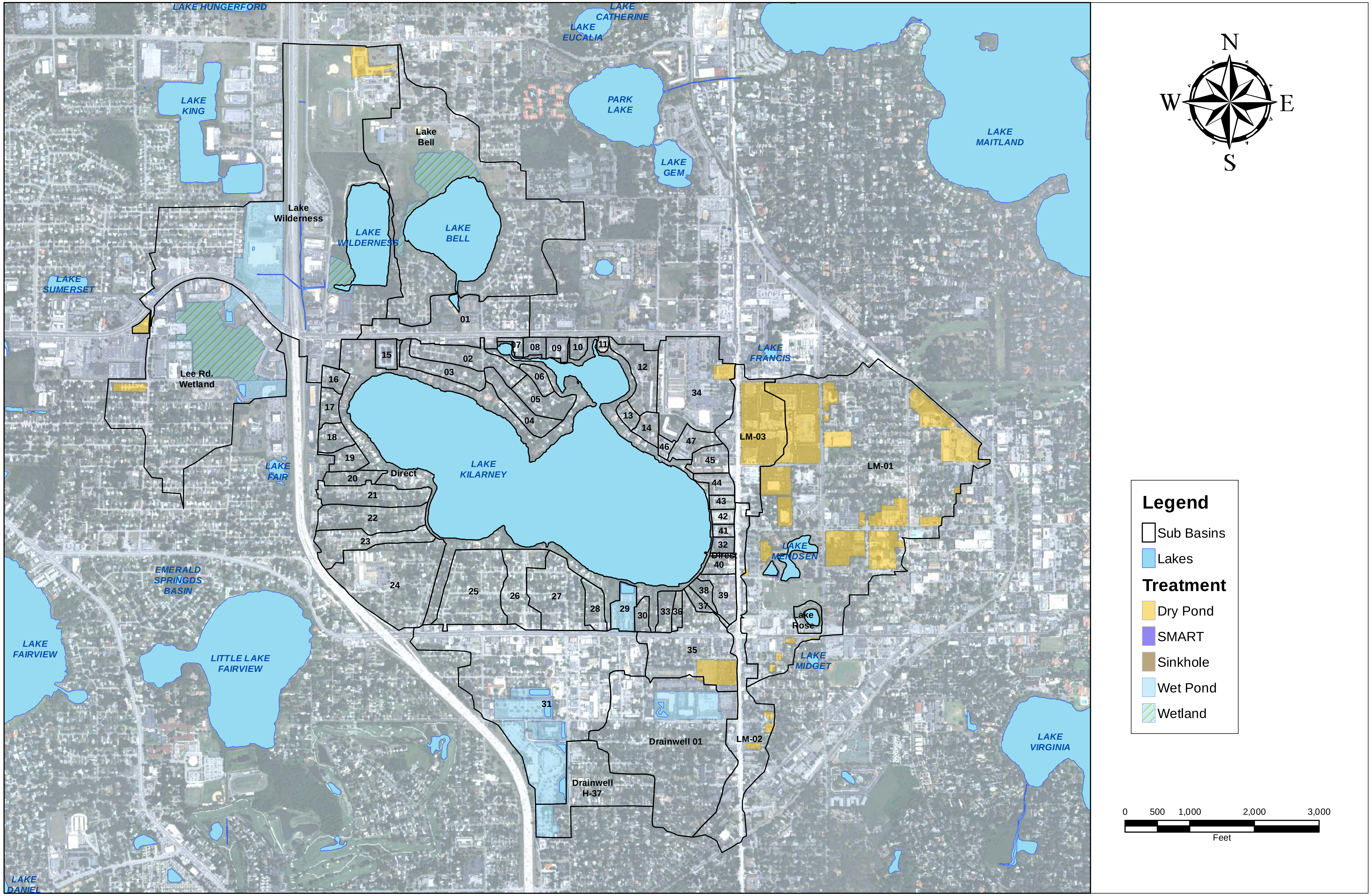


Figure 3-6. Areas with Stormwater Treatment in the Lake Killarney and Intermittent Basin Areas.

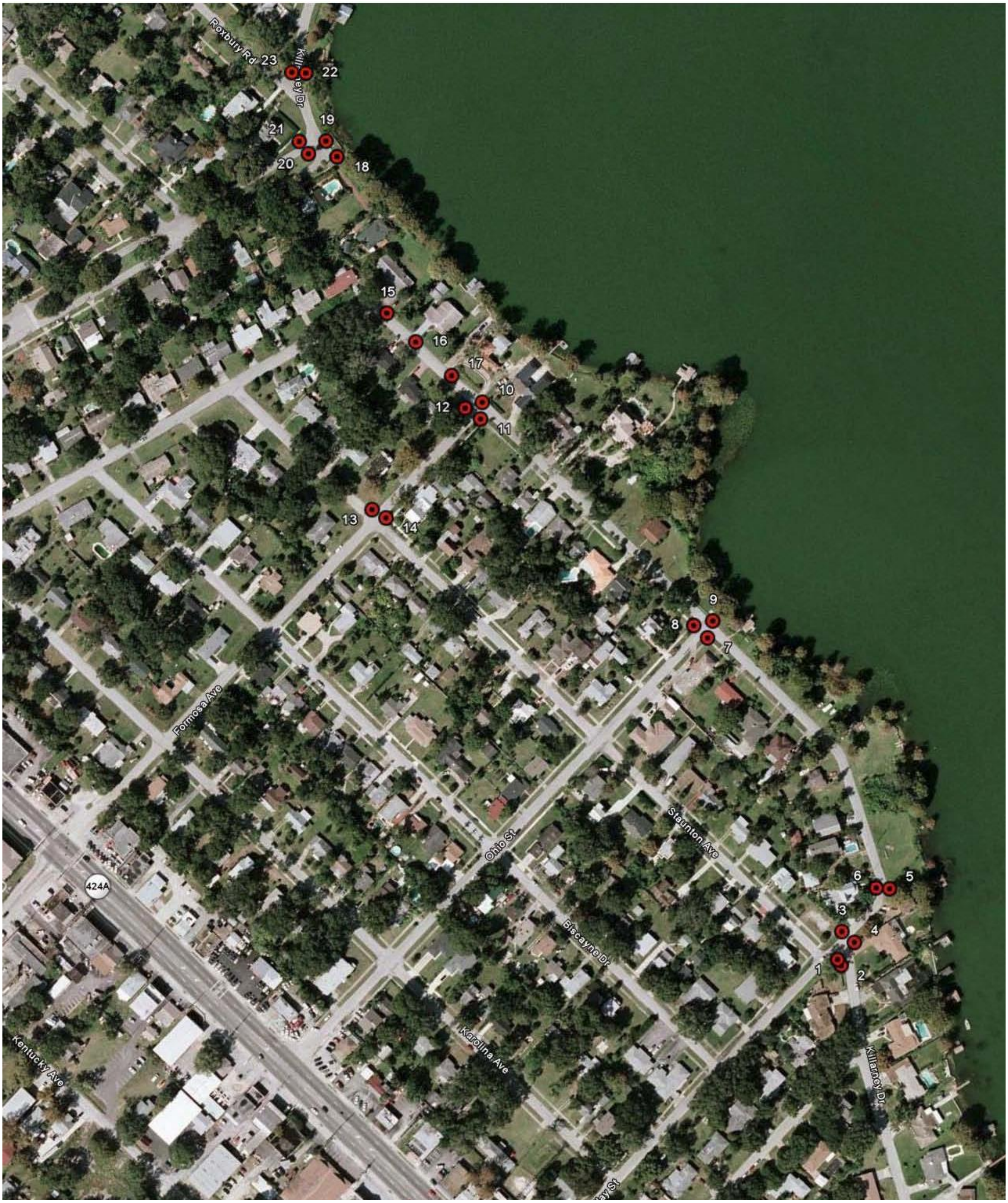


Figure 3-7. Locations of Curb and Grate Inlet Baskets Installed by Orange County.

Figure 3-7. Locations of Curb and Grate Inlet Baskets Installed by Orange County. (Continued)

3.7 Sewage Disposal

Disposal of sanitary sewage within the overall Lake Killarney drainage basin occurs using a combination of on-site septic tank systems and central sanitary sewer systems. Information on current septic tank systems for developed parcels in the overall Lake Killarney drainage basin was provided to ERD by Orange County. A graphical summary of developed parcels with septic tanks for sewage disposal in the overall Lake Killarney drainage basin is given on Figure 3-8. A large number of septic tank systems exist within the overall drainage basin area, located primarily within unincorporated Orange County. Only a few scattered permitted septic tank systems appear to exist within the City of Winter Park which provides central sewer throughout the urbanized area. With the exception of parcels located on the east side of Lake Killarney, virtually all of the developed parcels immediately adjacent to Lake Killarney use septic tanks for wastewater disposal. Based on the Orange County GIS layer, there are currently 1376 individual septic tanks in the Lake Killarney drainage basin, including the intermittent basins.

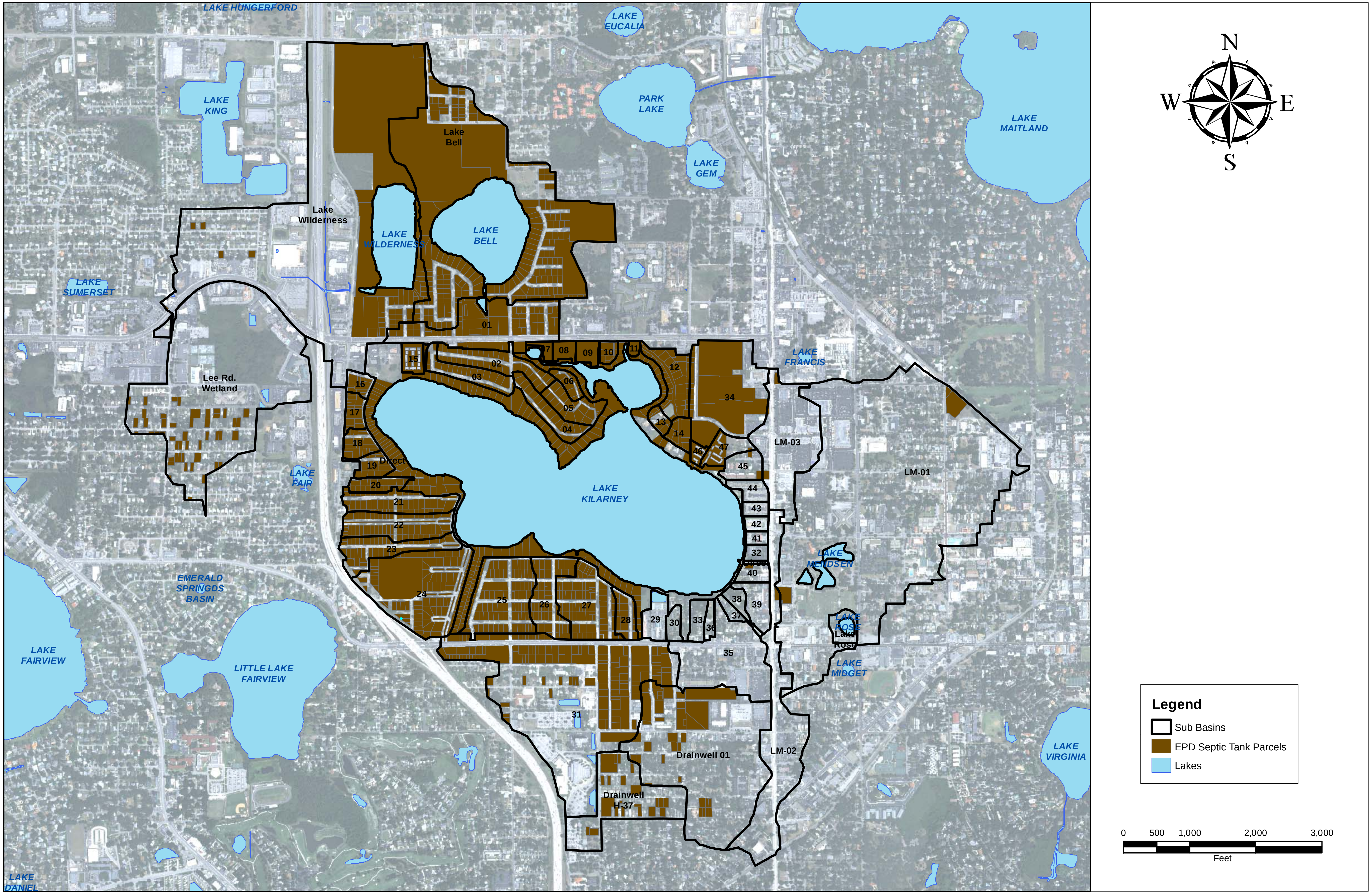


Figure 3-8. Developed Parcels Using Septic Tanks for Sewage Disposal in the Overall Lake Killarney Drainage Basin.

SECTION 4

HYDROLOGIC INPUTS AND LOSSES

An average annual hydrologic budget was developed for Lake Killarney which includes inputs from direct precipitation, stormwater runoff, and groundwater seepage. Hydrologic losses are estimated for evaporation, deep recharge, inflow from interconnected lakes, and discharges through the outfall structure. The hydrologic budget is used as input for development of nutrient budgets as well as estimation of hydraulic residence time. A conceptual schematic of evaluated hydrologic inputs and losses in Lake Killarney is given on Figure 4-1. A discussion of identified hydrologic inputs and losses for Lake Killarney is given in the following sections.

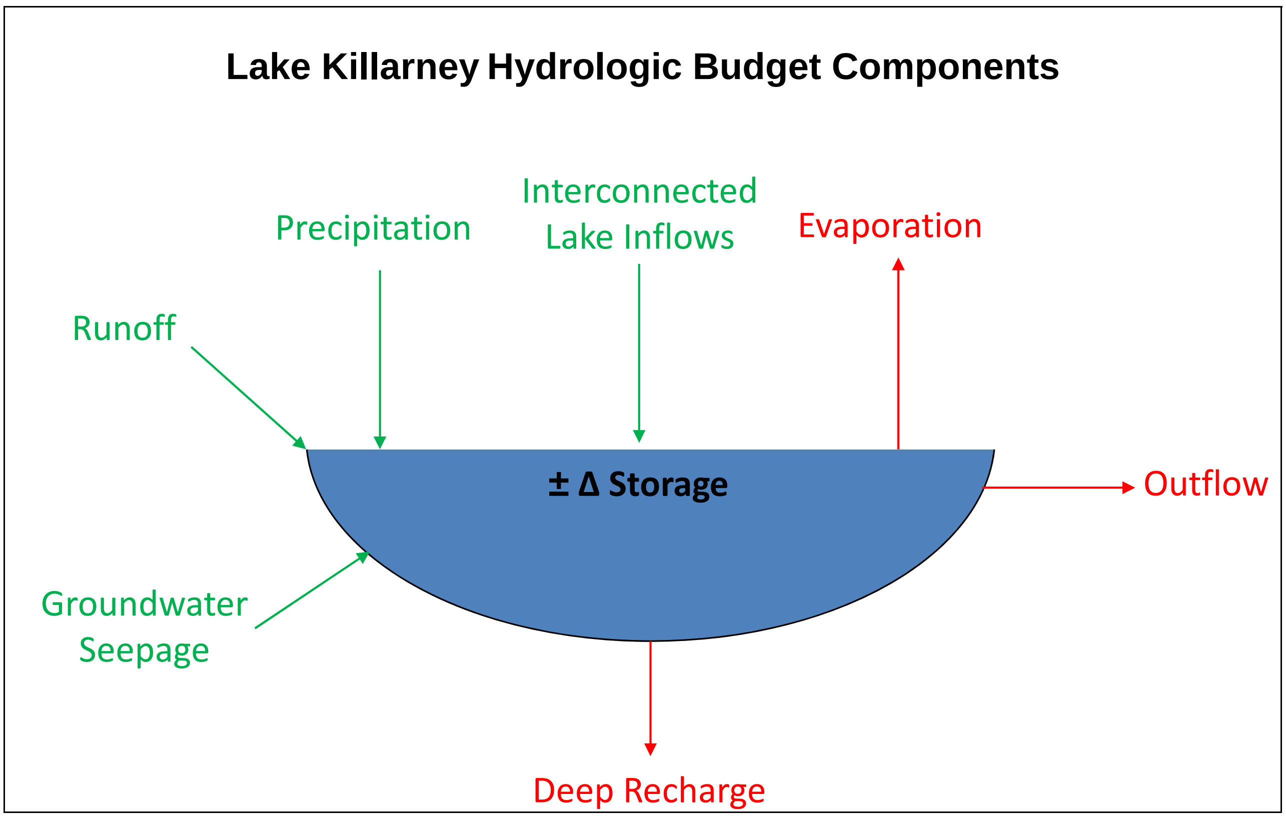


Figure 4-1. Conceptual Schematic of Evaluated Hydrologic Inputs and Losses to Lake Killarney.

4.1 Hydrologic Inputs

4.1.1 Direct Precipitation

4.1.1.1 Rainfall Characteristics

Hydrologic inputs from direct precipitation to Lake Killarney are calculated based upon historical mean monthly precipitation for the Central Florida area. Estimates of mean monthly precipitation were generated by ERD based upon historical monthly rainfall at the Orlando International Airport (OIA) meteorological station over the period from 1942-2005.

A summary of mean monthly rainfall at the OIA meteorological station is given in Table 4-1. Mean monthly rainfall depths range from a low of 2.04 inches during December to a high of 7.61 inches in July, with an annual total of approximately 50.03 inches.

TABLE 4-1

SUMMARY OF MEAN MONTHLY RAINFALL IN THE ORLANDO AREA FROM 1942-2010

MONTH	RAINFALL DEPTH (inches)	MONTH	RAINFALL DEPTH (inches)
January	2.53	July	7.61
February	2.46	August	6.16
March	3.62	September	6.27
April	2.82	October	2.60
May	3.82	November	2.61
June	7.49	December	2.04
		TOTAL:	**50.03**

4.1.1.2 Hydrologic Inputs

Estimated monthly hydrologic inputs from direct precipitation into Lake Killarney were calculated by multiplying the mean monthly rainfall measured at the OIA monitoring site (as summarized in Table 4-1) times the assumed lake surface area of 239.6 acres. A summary of estimated mean monthly hydrologic inputs to Lake Killarney from direct precipitation is given in Table 4-2. During an average annual rainfall year, direct precipitation contributes approximately 999 ac-ft of water to Lake Killarney.

TABLE 4-2

ESTIMATED MEAN MONTHLY HYDROLOGIC INPUTS TO LAKE KILLARNEY FROM DIRECT PRECIPITATION

MONTH	MONTHLY RAINFALL (inches)	HYDROLOGIC INPUTS (ac-ft/month)
January	2.53	50.5
February	2.46	49.1
March	3.62	72.3
April	2.82	56.3
May	3.82	76.3
June	7.49	149.6
July	7.61	151.9
August	6.16	123.0
September	6.27	125.2
October	2.60	51.9
November	2.61	52.1
December	2.04	40.7
TOTALS:	**50.03**	**999**

4.1.2 Stormwater Runoff

Estimates of hydrologic inputs to Lake Killarney from stormwater runoff were calculated for each of the identified direct and intermittent sub-basin areas based upon mean rainfall characteristics from 1942-2010. Individual estimates of runoff inputs were generated for each of the 48 sub-basin areas (direct + overland flow) discharging to Lake Killarney, along with sub-basin areas for each of the intermittent basins, and are utilized for development of both hydrologic and nutrient budgets. Details of evaluation methods and results of the runoff modeling efforts are given in the following sections.

4.1.2.1 Computational Methods

Estimates of volumetric inputs from direct stormwater runoff were generated for each of the identified sub-basin areas discharging to Lake Killarney and the intermittent basin areas. The estimated runoff volumes were calculated for average annual rainfall conditions based upon hydrologic modeling of individual rain events measured at the OIA meteorological station over the period from 1942-2010. A continuous runoff simulation model was developed, and the historical rainfall data were used as the precipitation input data. This model provides an estimate of runoff inputs from each sub-basin based on actual rainfall events over the period from 1942-2010.

The SCS curve number methodology was used to provide estimates of the runoff volumes generated within each delineated drainage sub-basin area for each historical rain event from 1942-2005. The SCS methodology utilizes the hydrologic characteristics of the drainage basin, including impervious area, directly connected impervious area, and soil curve numbers to estimate runoff volumes for modeled storm events. Hydrologic characteristics of the sub-basin areas were determined by ERD based upon aerial photography and a field reconnaissance of the watershed areas. This information was discussed previously in Section 3. Detailed hydrologic characteristics of the sub-basin areas are provided in Appendix C.

After estimating the hydrologic characteristics of each sub-basin area, the runoff volume for each rainfall event is calculated by adding the rainfall excess from the non-directly connected impervious area (non-DCIA) portion to the rainfall excess created from the DCIA portion for the basin. Rainfall excess from the non-DCIA areas is calculated using the following set of equations:

$$Soil\ \ Storage,\ S = \left(\frac{1000}{nDCIA\ \ CN} - 10 \right)$$

$$nDCIA\ \ CN = \frac{[CN\ *\ (100 - IMP)] + [98\ (IMP - DCIA)]}{(100 - DCIA)}$$

$$Q_{nDCIA_i} = \frac{(P_i - 0.2S)^2}{(P_i + 0.8S)}$$

where:

CN	=	curve number for pervious area
IMP	=	percent impervious area
DCIA	=	percent directly connected impervious area
nDCIA CN	=	curve number for non-DCIA area
P_i	=	rainfall event depth (inches)
Q_{nDCIAi}	=	rainfall excess for non-DCIA for rainfall event (inches)

For the DCIA portion, rainfall excess is calculated using the following equation:

$$Q_{DCIA_i} = (P_i - 0.1)$$

When P_i is less than 0.1, Q_{DCIAi} is equal to zero. This methodology is used to estimate the generated runoff volume within each of the delineated sub-basin areas for each rainfall event which occurred over the period from 1942-2005.

The methodology outlined above provides an estimate of the runoff volume "generated" from each of the individual rain events in each sub-basin over the 69-year period from 1942-2010. The sum of the total runoff was then divided by 69 years to obtain an estimate of the mean annual runoff volume. However, significant portions of the generated runoff volume may be attenuated during migration through stormwater management systems within each sub-basin area. If the stormwater management system provides dry retention treatment, a large portion of the runoff volume may be infiltrating into the ground and not reach the receiving water as a surface flow. If the stormwater system provides wet detention treatment, a portion of the generated runoff volume may be lost due to evaporation within the pond or infiltration through the pond bottom.

The watershed model includes estimates of the types of stormwater management systems utilized within each sub-basin area and the amount of developed area treated by each stormwater management type. The runoff volume discharging to wet or dry stormwater treatment systems is reduced or attenuated for likely volumetric removal processes in the wet or dry treatment systems. Estimates of the amount of generated runoff volume attenuated by each type of stormwater management system are included in the model, and the attenuated volume is subtracted from the generated volume within each sub-basin. The result is an estimate of the runoff volume which actually discharges into the receiving waterbody from each sub-basin area.

A summary of estimated volumetric removal efficiencies for stormwater management systems in the Lake Killarney and intermittent drainage sub-basins is given in Table 4-3. These volumetric removals are based on previous research performed by ERD on the performance efficiencies of stormwater management systems used in the State of Florida. Developed areas treated by dry retention are assumed to have a volumetric loss of approximately 80% for runoff inputs due to infiltration and evaporation within the pond. Wet detention ponds are assumed to have a volumetric loss of approximately 20%, due primarily to evaporation and infiltration through the pond bottom. The land-locked basin areas are assumed to retain 100% of the generated annual runoff in each basin. The information summarized in Table 4-3 is combined with information on stormwater management systems (Figure 3-6) to assist in calculation of estimated runoff inflow from each sub-basin area.

TABLE 4-3

ESTIMATED VOLUMETRIC REMOVAL EFFICIENCIES FOR STORMWATER MANAGEMENT SYSTEMS IN THE LAKE KILLARNEY DRAINAGE BASIN

SYSTEM TYPE	VOLUME REDUCTION (%)
Dry Retention Pond	80
Wet Detention Pond	20
Land-Locked Basins	100

A summary of estimated runoff volumes which discharge from each drainage sub-basin area into Lake Killarney on an average annual basis is given in Table 4-4. The generated runoff volume represents the modeled runoff volume within each sub-basin prior to volume reduction in stormwater management systems. Estimates of the volume removed in dry retention ponds, and wet detention ponds are also included, based upon the volumetric removal efficiencies summarized in Table 4-3. The resulting value represents the observed mean annual runoff volume which is actually discharged from each sub-basin to Lake Killarney. Estimates of the generated and observed runoff coefficients (C value) are also provided for each drainage sub-basin.

The generated and observed runoff coefficients are calculated as follows:

$$\textit{Generated C Value} = \frac{\textit{Generated Runoff Volume (ac-ft)}}{\textit{Total Basin Area (ac)} \times \textit{Rainfall Depth (ft)}}$$

$$\textit{Observed C Value} = \frac{\textit{Observed Runoff Volume (ac-ft)}}{\textit{Total Basin Area (ac)} \times \textit{Rainfall Depth (ft)}}$$

As indicated on Table 4-4, approximately 28.1% of the annual runoff inflow into Lake Killarney is generated within Sub-basin 31 which is located on the southern side of the lake, and includes Fairbanks Avenue and areas south of Fairbanks Avenue. Approximately 10.1% of the annual runoff inputs originate within Sub-basin 34 which includes the shopping complex near the corner of Lee Road and US 17-92. An additional 7.8% of the annual runoff inputs to Lake Killarney originate within Sub-basin 35 which includes commercial and residential areas located north and south of Fairbanks Avenue on the west side of US 17-92. An additional 7.7% of the annual runoff inputs originate from Sub-basin 1 which is located on the north side of Lee Road, and includes professional office, commercial, and residential areas. The direct overland flow sub-basin contributes approximately 7.1% of the annual inputs. Approximately 5% of the annual runoff inputs originate from Sub-basin 24 which is located on the southwest side of the lake and includes a combination of commercial and residential land uses. Each of the remaining sub-basin areas contributes approximately 2.7% or less of the annual runoff inflows to Lake Killarney. The majority of annual runoff inputs to Lake Killarney originate from the five largest sub-basin areas as well as overland flow. Runoff inflows from the remaining sub-basin areas are relatively minimal on an annual basis.

Calculations are also provided on Table 4-4 for the generated and observed C values for each sub-basin area. The generated C values for sub-basin areas discharging to Lake Killarney range from 0.155-0.573, with an overall weighted annual C value of 0.314. The actual observed C values, reflecting actual discharges into Lake Killarney, also range from 0.155-0.573, with an overall weighted observed runoff C value of 0.302. On an annual basis, sub-basins which discharge directly to Lake Killarney generate approximately 735.75 ac-ft of runoff per year. Approximately 28.04 ac-ft of runoff is retained in stormwater management systems, with 707.97 ac-ft actually discharging to Lake Killarney.

TABLE 4-4

CALCULATED MEAN ANNUAL RUNOFF INPUTS FROM DIRECT SUB-BASIN AREAS TO LAKE KILLARNEY

SUB-BASIN	SUB-BASIN AREA (acres)	GENERATED RUNOFF VOLUME (ac-ft)	GENERATED C VALUE	VOLUME REMOVED (ac-ft)		OBSERVED RUNOFF VOLUME (ac-ft)	OBSERVED C VALUE	PERCENT OF TOTAL (%)
				Dry Ponds	Wet Ponds			
01	31.69	54.82	0.415	0.00	0.00	54.82	0.415	7.7
02	11.76	9.37	0.191	0.00	0.00	9.37	0.191	1.3
03	8.18	6.22	0.183	0.00	0.00	6.22	0.183	0.9
04	7.77	5.91	0.182	0.00	0.00	5.91	0.182	0.8
05	7.63	5.80	0.182	0.00	0.00	5.80	0.182	0.8
06	2.84	2.16	0.182	0.00	0.00	2.16	0.182	0.3
07	1.37	2.88	0.505	0.00	0.00	2.88	0.505	0.4
08	2.34	4.91	0.504	0.00	0.00	4.91	0.504	0.7
09	2.73	5.67	0.499	0.00	0.00	5.67	0.499	0.8
10	1.99	1.51	0.182	0.00	0.00	1.51	0.182	0.2
11	0.89	1.26	0.339	0.00	0.00	1.26	0.339	0.2
12	10.63	7.70	0.174	0.00	0.00	7.70	0.174	1.1
13	2.29	1.48	0.155	0.00	0.00	1.48	0.155	0.2
14	3.46	2.44	0.169	0.00	0.00	2.44	0.169	0.3
15	3.48	8.32	0.573	0.00	0.00	8.32	0.573	1.2
16	2.97	2.68	0.216	0.00	0.00	2.68	0.216	0.4
17	3.77	3.41	0.217	0.00	0.00	3.41	0.217	0.5
18	4.57	3.82	0.200	0.00	0.00	3.82	0.200	0.5
19	4.25	3.33	0.188	0.00	0.00	3.33	0.188	0.5
20	4.25	3.19	0.180	0.00	0.00	3.19	0.180	0.4
21	12.14	9.48	0.187	0.00	0.00	9.48	0.187	1.3
22	14.64	11.28	0.185	0.00	0.00	11.28	0.185	1.6
23	12.18	9.23	0.182	0.00	0.00	9.23	0.182	1.3
24	37.75	35.70	0.227	0.00	0.00	35.70	0.227	5.0
25	24.33	19.00	0.187	0.00	0.00	19.00	0.187	2.7
26	13.47	11.26	0.201	0.00	0.00	11.26	0.201	1.6
27	19.28	17.25	0.215	0.00	0.00	17.25	0.215	2.4
28	4.90	4.98	0.244	0.00	0.00	4.98	0.244	0.7
29	4.71	10.94	0.557	2.19	0.11	8.75	0.445	1.2
30	2.52	1.96	0.186	0.04	0.00	1.92	0.183	0.3
31	110.11	209.52	0.456	10.81	0.02	198.71	0.433	28.1
32	1.97	3.47	0.423	0.00	0.00	3.47	0.423	0.5
33	3.52	3.23	0.220	0.00	0.00	3.23	0.220	0.5
34	36.94	74.83	0.486	3.03	0.02	71.80	0.466	10.1
35	30.14	66.85	0.532	11.71	0.09	55.13	0.439	7.8
36	1.89	1.40	0.177	0.00	0.00	1.40	0.177	0.2
37	2.03	2.59	0.306	0.00	0.00	2.59	0.306	0.4
38	2.41	2.10	0.209	0.00	0.00	2.10	0.209	0.3
39	6.15	9.69	0.378	0.00	0.00	9.69	0.378	1.4
40	3.08	3.31	0.258	0.00	0.00	3.31	0.258	0.5
41	1.57	3.28	0.502	0.00	0.00	3.28	0.502	0.5
42	1.86	3.93	0.507	0.00	0.00	3.93	0.507	0.6
43	2.02	4.28	0.508	0.00	0.00	4.28	0.508	0.6
44	3.65	7.71	0.506	0.00	0.00	7.71	0.506	1.1
45	5.47	10.81	0.474	0.00	0.00	10.81	0.474	1.5
46	1.44	3.05	0.507	0.00	0.00	3.05	0.507	0.4
47	5.38	7.73	0.345	0.00	0.00	7.73	0.345	1.1
Overland Flow	77.08	50.03	0.156	0.01	0.00	50.02	0.156	7.1
TOTAL:	**561.50**	**735.75**	**0.314**	**27.79**	**0.25**	**707.97**	**0.302**	**100.0**

A summary of generated and observed runoff volumes in the intermittent drainage basin areas is provided on Table 4-5. Estimates are provided for the generated and observed runoff volume in each of the intermittent drainage basins. Drainage basin areas identified as Drainwell 01, Drainwell H-37, and Lake Rose are considered to be land-locked basins with no discharge on an annual basis. As a result, the observed runoff volume for these basins is assumed to be zero, with a corresponding C value of 0.000. The remaining sub-basin areas reflect basins which can potentially discharge to Lake Killarney on an intermittent basis. Some of these drainage basins are interconnected, and a discussion of the runoff volume actually reaching Lake Killarney on an annual basis is discussed in a subsequent section.

TABLE 4-5

CALCULATED MEAN ANNUAL RUNOFF INPUTS FROM INTERMITTENT SUB-BASIN AREAS TO LAKE KILLARNEY

BASIN	SUB-BASIN	SUB-BASIN AREA (acres)	GENERATED RUNOFF VOLUME (ac-ft)	GENERATED C VALUE	VOLUME REMOVED (ac-ft)		OBSERVED RUNOFF VOLUME (ac-ft)	OBSERVED C VALUE
					Dry Ponds	Wet Ponds		
Drainwell	Drainwell 01	86.07	124.79	0.348	5.60	0.02	0.00	0.000
Drainwell H-37	Drainwell H-37	29.14	27.98	0.230	1.61	0.01	0.00	0.000
Lake Bell	Lake Bell	125.35	111.05	0.212	0.00	0.00	111.05	0.212
Lake Mendsen	LM-01	236.73	331.56	0.336	106.35	0.11	225.20	0.228
	LM-02	40.27	95.95	0.571	1.60	0.01	94.35	0.562
	LM-03	32.74	90.84	0.666	45.50	0.33	45.33	0.332
Lake Rose	Lake Rose	2.94	4.15	0.338	0.00	0.00	0.00	0.000
Lake Wilderness	Lake Wilderness	217.60	314.18	0.346	16.01	0.02	298.16	0.329
Lee Rd. Wetland	Lee Rd. Wetland	121.42	174.13	0.344	3.52	0.01	170.60	0.337
TOTAL:		**892.26**	**1274.61**	**0.343**	**180.21**	**0.50**	**944.7**	**0.254**

Land-Locked Basins

4.1.3 <u>Shallow Groundwater Seepage</u>

Field investigations were performed by ERD to evaluate the quantity and quality of shallow groundwater seepage entering Lake Killarney during the monitoring period from July 2010-August 2011. Groundwater seepage was quantified using a series of underwater seepage meters installed at locations throughout each lake. Seepage meters provide a mechanism for direct measurement of groundwater inflow into a lake by isolating a portion of the lake bottom so that groundwater seeping up through the bottom sediments into the lake can be collected and characterized. Use of the direct seepage meter measurement technique avoids errors, assumptions, and extensive input data required when indirect techniques are used, such as the Gross Water Budget or Subtraction Method, as well as computer modeling and flow net analyses.

The seepage meter technique has been recommended by the U.S. Environmental Protection Agency (EPA) and has been established as an accurate and reliable technique in field and tank test studies (Lee, 1977; Erickson, 1981; Cherkauer and McBride, 1988; Belanger and Montgomery, 1992). With installation of adequate numbers of seepage meters and proper placement, seepage meters are a very effective tool to estimate groundwater-surface water interactions. One distinct advantage of seepage meters is that seepage meters can provide estimates of both water quantity and quality entering a lake system, whereas estimated methods can only provide information on water quantity.

4.1.3.1 Seepage Meter Construction and Locations

A schematic of a typical seepage meter installation used in Lake Killarney is given in Figure 4-2. A photograph of seepage meters being prepared for deployment in Lake Killarney is given in Figure 4-3. Seepage meters were constructed from a 2-ft diameter aluminum container with a closed top and open bottom. Each seepage meter isolated a sediment area of approximately 3.14 ft^2. Seepage meters were inserted into the lake sediments to a depth of approximately 8-12 inches, isolating a portion of the lake bottom. Approximately 3-6 inches of water was trapped inside the seepage meter above the lake bottom.

A 0.75-inch PVC fitting was threaded into the top of each aluminum container. The 0.75-inch PVC fitting was attached to a female quick-disconnect PVC camlock fitting. A flexible polyethylene bag, with an approximate volume of 40 gallons, was attached to the seepage meters using a quick-disconnect PVC male camlock fitting with a terminal ball valve. Each of the collection bags was constructed of black polyethylene to prevent light penetration into the bag. Light could potentially stimulate photosynthetic activity within the sample prior to collection and result in an undesirable alteration of the chemical characteristics of the sample.

Prior to attachment to the seepage meter, all air was removed from inside the polyethylene collection bag, and the PVC ball valve was closed so that lake water would not enter the collection container prior to attachment to the seepage meter. A diver then connected the collection bag to the seepage meter using the PVC camlock fitting. After attaching the collection bag to the seepage meter, the PVC ball valve was then opened. As groundwater influx occurs into the open bottom of the seepage meter, it is collected inside the flexible polyethylene bag.

Each seepage meter was installed with a slight tilt toward the outlet point so that any gases which may be generated inside the seepage meter would exit into the collection container. A plastic-coated fishing weight was placed inside each of the collection bags to prevent the bags from floating up towards the water surface as a result of trapped gases. The location of each seepage meter was indicated by a floating marker in the lake which was attached to the seepage meter using a coated wire cable.

Thirty (30) seepage meters were installed in Lake Killarney on July 16, 2010. Locations for the seepage meters are indicated on Figure 4-4. Since seepage inflow is often most variable around the perimeter of a lake, the majority of the seepage meters were installed around the perimeter of the lakes at a uniform water depth of approximately 4-5 ft. Seepage meters were also installed in central portions of the lake.

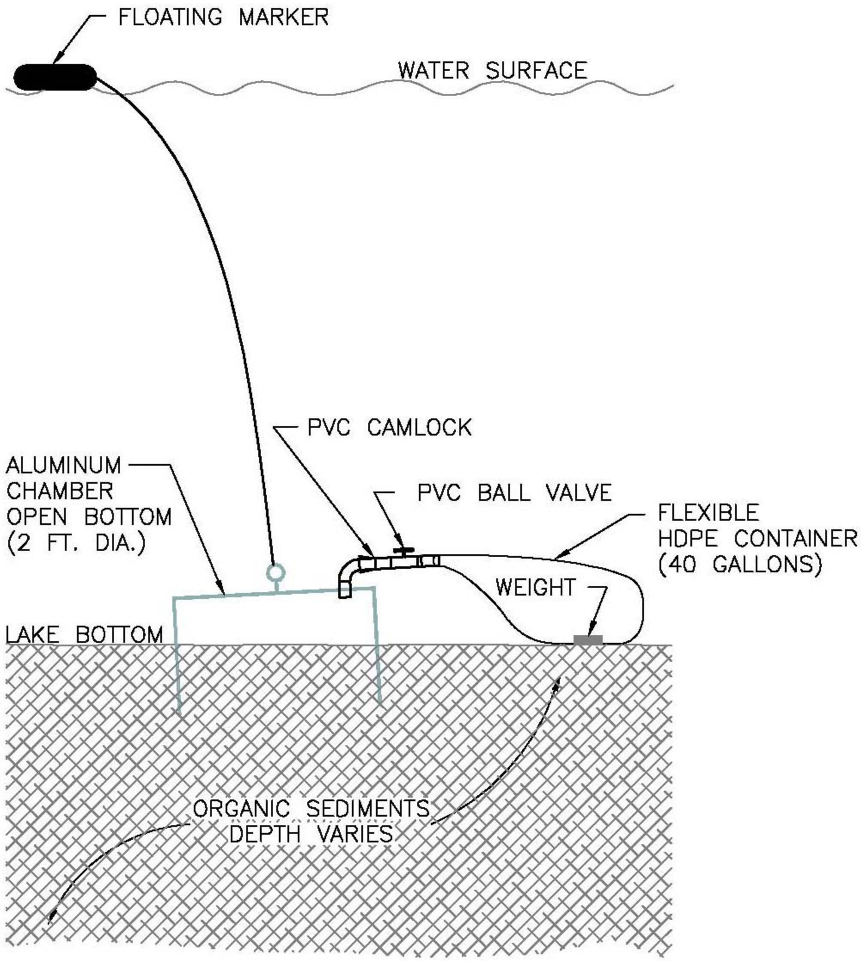


Figure 4-2. Typical Seepage Meter Installation.

Figure 4-3. Seepage Meters Being Prepared for Installation in Lake Killarney.

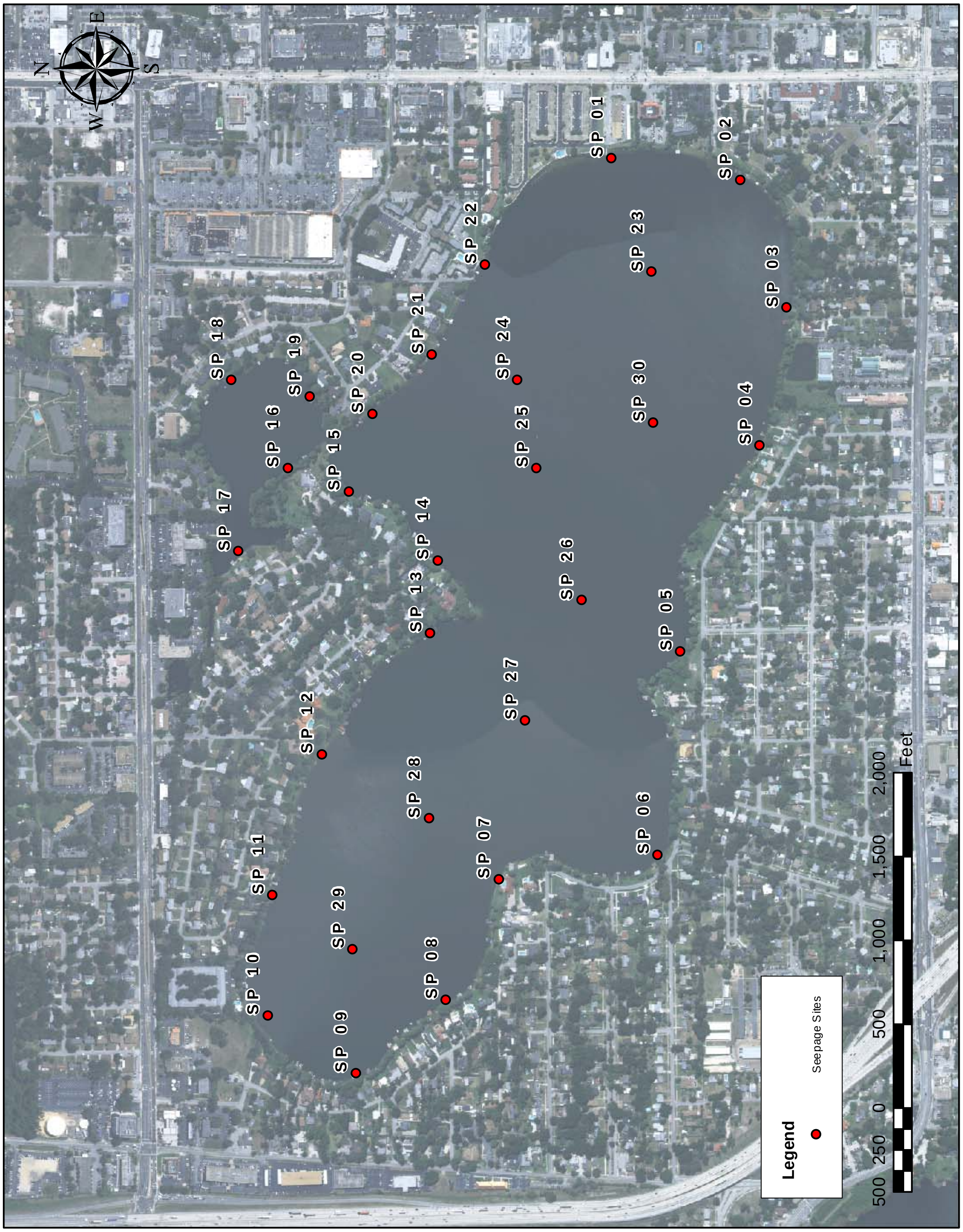


Figure 4-4. Locations of Seepage Meter Monitoring Sites in Lake Killarney.

Collection bags were installed on each of the seepage meters at the time of installation, and the monitoring program was initiated. Each of the seepage meters was monitored on approximately a monthly to bi-monthly basis, depending on rainfall, from July 2010-August 2011. During the initial monitoring event, the volume of seepage collected was recorded, and the sample was discarded since the water within the collection bag represented a combination of seepage and the initial lake water trapped at the time of installation. During all subsequent events, samples were retained for analysis of seepage characteristics. Eight separate seepage monitoring events were conducted for evaluation of seepage quantity, with seven events conducted to evaluate seepage quality at each of the monitoring sites. A total of 188 volumetric inflow samples was collected between the 30 sites over the 382-day monitoring program.

4.1.3.2 Seepage Meter Sampling Procedures

After the initial installation of collection bags, site visits were performed at monthly intervals to collect the seepage samples. During the collection process, a diver was used to close the PVC ball valve and remove the collection bag from the seepage meter using the quick-disconnect camlock fitting. The collection bag was placed onto the boat and the contents were emptied into a polyethylene container. The volume of seepage collected in the container was measured using either a 4-liter graduated cylinder or a 20-liter graduated polyethylene bucket, depending on the collected volume.

Following the initial purging, seepage meter samples were collected for return to the laboratory for chemical analysis. On many occasions, seepage meter samples were found to contain turbidity or particles originating from the sediments isolated within the seepage meter. Since these contaminants are not part of the seepage flow, all seepage meter samples collected for chemical analyses were field-filtered using a 0.45 micron disposable glass fiber filter typically used for filtration of groundwater samples. A new filter was used for each seepage sample. Seepage samples were filtered immediately following collection using a battery operated peristaltic pump at a flow rate of approximately 0.25 liter/minute. The filtered seepage sample was placed on ice for return to the ERD laboratory for further chemical analyses.

A summary of field measurements of seepage inflow over the monitoring period from July 2010-August 2011 is given in Appendix D.1. During collection of the seepage samples, information was recorded on the time of sample collection, the total volume of seepage collected at each site, and general observations regarding the condition of the seepage collection bags and replacement/repair details. The seepage flow rate at each location is calculated by dividing the total collected seepage volume (liters) by the area of the seepage meter (0.27 m^2) and the time (days) over which the seepage sample was collected.

As seen in Appendix D.1, a number of seepage meter sites contain missing data for one or more events as a result of missing or damaged collection bags and seepage meters. A large portion of the lost data occurred from seepage meters located in central open portions of the lake. Periodic damage to these seepage meters resulted in missing samples for some of the monitoring sites. Some of the seepage meters in the open water were repeatedly moved or vandalized and were repaired or replaced numerous times.

4.1.3.3 Seepage Inflow

A statistical summary of seepage inflow measurements is given in Table 4-6. In general, mean seepage values measured at the monitoring sites range from 0.03-5.51 liters/m^2-day. However, the majority of mean values range from approximately 0.25-1.0 liters/m^2-day. Mean seepage rates are calculated by dividing the total seepage volume collected during the field monitoring program by the total number of days over which the seepage was collected.

TABLE 4-6

SUMMARY OF SEEPAGE INFLOWS MEASURED IN LAKE KILLARNEY FROM JULY 2010-AUGUST 2011

SITE	NUMBER OF SAMPLES	RANGE OF VALUES (liters/m^2-day)		
		Minimum	Maximum	Mean
1	7	0.32	1.80	0.63
2	6	0.45	1.78	0.90
3	8	0.37	1.51	0.63
4	7	0.35	2.17	0.72
5	4	0.37	3.09	0.38
6	4	0.37	20.9	3.26
7	8	1.22	6.42	3.60
8	8	0.43	30.9	5.51
9	7	1.08	7.73	3.00
10	8	0.61	2.10	0.85
11	8	0.61	1.42	0.82
12	7	0.90	2.93	1.40
13	8	0.34	1.61	0.64
14	8	0.32	1.85	0.58
15	8	0.30	1.54	0.62
16	8	0.03	2.42	1.06
17	8	0.24	1.79	0.71
18	8	0.61	2.90	0.96
19	7	0.45	1.98	0.72
20	8	0.35	1.42	0.67
21	7	0.46	6.97	1.54
22	7	0.57	3.83	1.16
23	6	0.43	2.59	0.80
24	4	0.68	1.22	0.49
25	2	0.50	0.75	0.24
26	1	0.32	0.32	0.03
27	3	0.29	2.04	0.25
28	3	0.41	1.48	0.24
29	4	0.37	1.05	0.24
30	6	0.39	1.21	0.55

The mean seepage values summarized on Table 4-6 were combined with the geographic coordinates for each site to generate an isopleth contour map for mean seepage inflow into the lake using the Autodesk Land Desktop 2007 Module for AutoCAD. Isopleths of mean seepage inflow into Lake Killarney from July 2010-August 2011 are given in Figure 4-5. The range of seepage values indicated on this figure is from <1-5 liter/m^2-day. Much of the area within Lake Killarney appears to exhibit relatively low seepage inflow, with large portions of the lake indicating seepage of approximately 1 liter/m^2-day or less. Areas of elevated seepage inflow were observed along the southwestern portion of Lake Killarney, with seepage rates increasing to as high as 5 liter/m^2-day. The areas with elevated seepage inflow are located adjacent to sub-basin areas with permeable soils and septic tanks which enhances the potential for migration of groundwater and nutrients into the lake.

The seepage isopleths indicated on Figure 4-5 were graphically integrated to obtain estimates of mean daily seepage influx into the lake. A summary of the results of this analysis is given in Table 4-7. The mean seepage influx to Lake Killarney during the field monitoring program was 0.90 liters/m^2-day, which is equivalent to approximately 0.71 ac-ft/day or 259 ac-ft/yr.

TABLE 4-7

ESTIMATED SEEPAGE INFLOW TO LAKE KILLARNEY FROM JULY 2010 - AUGUST 2011

PARAMETER	UNITS	VALUE
Lake Area	acres	239.6
Mean Seepage Inflow	liters/m^2-day ac-ft/year	0.90 259
Seepage/Surface Area Ratio	ft/yr	1.08

The calculated seepage/surface area ratio is provided in the final row of Table 4-7. This value provides an estimate of seepage inflow in terms of a water depth over the entire lake surface and provides a method for comparing relative seepage inflow between lakes without consideration of lake area. During the field monitoring program, seepage inflow into Lake Killarney contributed a water volume equivalent to 1.08 ft over the entire surface area of the lake. This value is slightly lower than the mean seepage loading rates measured by ERD in other Central Florida lakes. The seepage inflow listed on Table 4-is utilized in subsequent sections for development of an overall hydrologic budget for the lake.

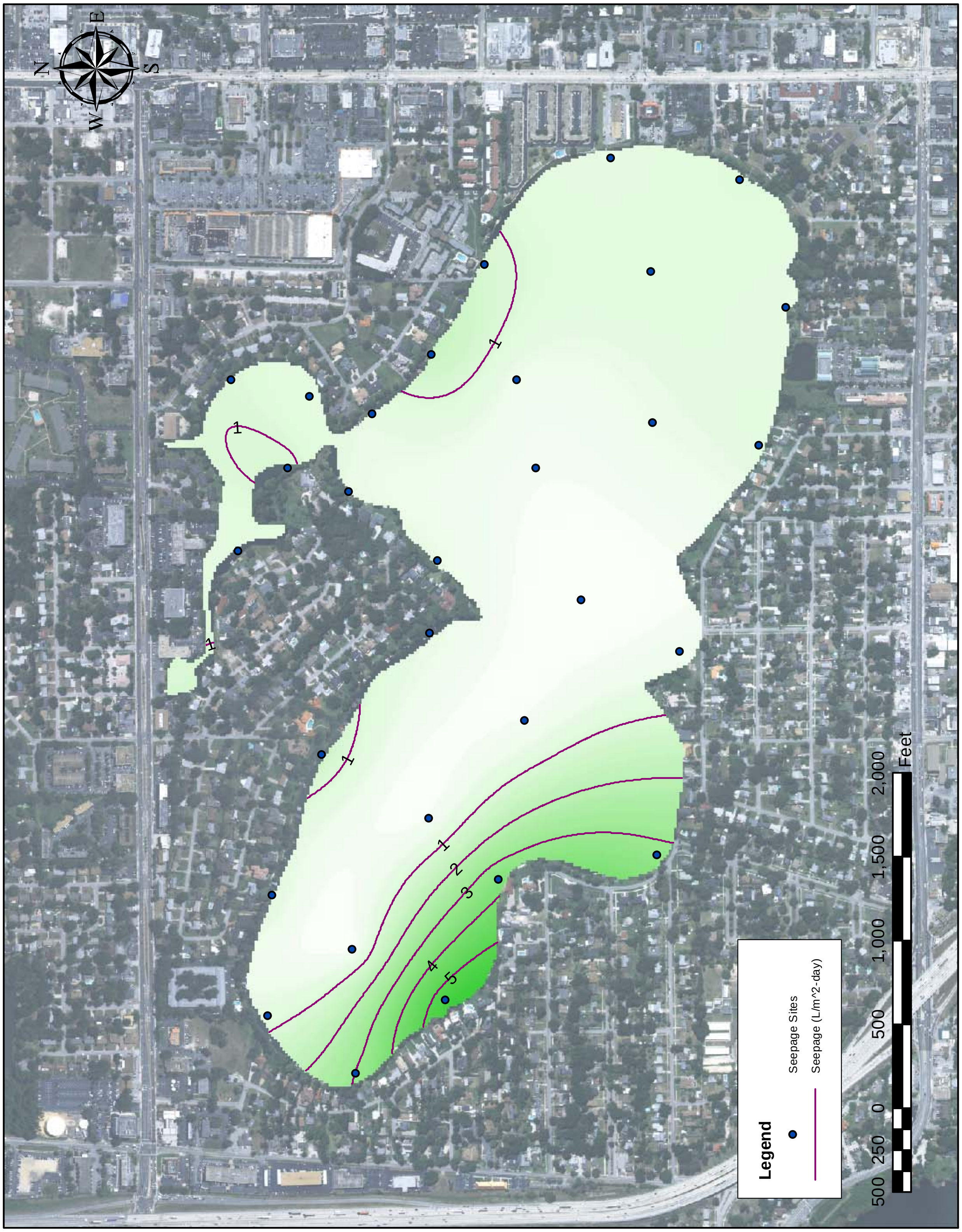


Figure 4-5. Isopleths of Mean Seepage Inflow into Lake Killarney from July 2010-August 2011.

4.1.4 Interconnected Waterbody Inflows

Estimates of the annual volumetric inflows to Lake Killarney from the interconnected waterbodies were also calculated since these discharges reflect inputs to the lake. Assuming that precipitation and evaporation are approximately equal in the interconnected drainage basins and that seepage inputs into the waterbodies are negligible, the estimated discharge from the interconnected waterbodies becomes simply the observed runoff volume minus the volume losses to deep recharge, (summarized later in Section 4.2.2 in Table 4-11).

A summary of calculated outfall discharges from interconnected waterbodies is given on Table 4-8. Calculations are provided for the interconnected sub-basin areas consisting of the Lee Road Wetland, Lake Wilderness, and Lake Bell, as well as Lake Mendsen. The observed runoff volumes for each of these sub-basin areas are provided on Table 4-8 based upon the information summarized in Table 4-5. Volume losses to deep recharge (Section 4.2.2) are subtracted from the observed runoff volume to provide an estimate of the excess volume generated in each sub-basin on an annual basis. Since the Lee Road Wetland, Lake Wilderness, and Lake Bell sub-basins are interconnected, the estimated annual discharge from Lake Bell to Lake Killarney is the sum of the excess volume generated within these three sub-basins. For Lake Mendsen, the estimated volume discharging to Lake Killarney is simply the excess volume for Lake Mendsen summarized in Table 4-8.

TABLE 4-8

CALCULATED OUTFALL DISCHARGES FROM INTERCONNECTED WATERBODIES

BASIN	OBSERVED RUNOFF VOLUME (ac-ft/yr)	VOLUME LOST TO RECHARGE (ac-ft/yr)	EXCESS VOLUME (ac-ft/yr)
Lee Road Wetland	170.6	29.9	140.7
Lake Wilderness	298.2	24.3	273.9
Lake Bell	111.1	39.4	71.7
Lake Mendsen	364.9	3.6	361.3

4.2 Hydrologic Losses

Hydrologic losses from Lake Killarney occur as a result of evaporation from the lake surface, discharge through the outfall structure, and discharges from deeper portions of the lake bottom to underground aquifers. Estimated losses from each of these sources are discussed in the following sections.

4.2.1 Evaporation Losses

Estimates of monthly evaporation from Lake Killarney were generated based upon mean monthly evaporation data collected at the Lake Alfred Experimental Station over the 30-year period from 1965-1994. The Lake Alfred Station is located approximately 30 miles southwest of Orlando and appears to be the closest long-term evaporation monitoring site to the Central Florida area. A summary of mean monthly evaporation for this site is given in Table 4-9. For purposes of this project, the mean evaporation measured at the Lake Alfred site is assumed to be similar to evaporation at Lake Killarney. The recorded data at the Lake Alfred site reflects pan evaporation, with lake evaporation assumed to be equal to 70% of the pan evaporation values.

TABLE 4-9

MEAN MONTHLY LAKE EVAPORATION AT THE LAKE ALFRED EXPERIMENTAL STATION SITE

MONTH	MEAN PAN EVAPORATION (inches)	LAKE EVAPORATION[1] (inches)	MONTH	MEAN PAN EVAPORATION (inches)	LAKE EVAPORATION[1] (inches)
January	3.47	2.43	July	7.57	5.30
February	4.21	2.95	August	7.16	5.01
March	6.26	4.38	September	6.28	4.40
April	7.60	5.32	October	5.51	3.86
May	8.47	5.93	November	3.98	2.79
June	7.65	5.36	December	3.22	2.25
			TOTAL:	**71.38**	**49.98**

1. Assumed to be 70% of pan evaporation

A summary of estimated monthly evaporation losses from Lake Killarney is given in Table 4-10. The values summarized in this table were obtained by multiplying the lake surface area times the estimated monthly lake evaporation values. Mean annual volumetric losses from lake evaporation remove approximately 998 ac-ft/yr from Lake Killarney.

TABLE 4-10

ESTIMATED MONTHLY HYDROLOGIC LOSSES FROM LAKE KILLARNEY AS A RESULT OF SURFACE EVAPORATION

MONTH	EVAPORATION	
	inches/month	ac-ft
January	2.43	48.5
February	2.95	58.9
March	4.38	87.5
April	5.32	106.2
May	5.93	118.4
June	5.36	107.0
July	5.30	105.8
August	5.01	100.0
September	4.40	87.9
October	3.86	77.1
November	2.79	55.7
December	2.25	44.9
TOTAL:	**49.98**	**998**

4.2.2 Deep Aquifer Recharge

In addition to losses through the two drainage wells, a portion of the annual hydrologic inputs to Lake Killarney and other waterbodies in the overall drainage basin area is lost as a result of downward migration of water in deeper permeable portions of the lakes into intermediate aquifer layers. This phenomenon occurs simultaneously with groundwater seepage which is a result of groundwater movement into the lake above the initial confining layer, while deep recharge occurs as a result of permeable connections in deeper portions of the lake to underlying aquifers.

Information on aquifer recharge rates for Lake Killarney and adjacent waterbodies was obtained from the SJRWMD GIS recharge map for the Middle St. Johns River Basin. A summary of the recharge map for areas in the vicinity of Lake Killarney is given on Figure 4-6. According to the SJRWMD GIS recharge map, deep recharge to the Floridan Aquifer in the vicinity of Lake Killarney is estimated to be approximately 8-12 inches/year. This implies that a volume equivalent to 8-12 inches over the lake surface would be lost as a result of recharge into deeper aquifers. The aquifer recharge rate for Lake Bell is approximately 12-20 inches/year, with deep recharge in Lake Wilderness ranging from 8-20 inches/year and Lake Mendsen ranging from 8-12 inches/year. A recharge rate of 12-20 inches/year is also assumed for the Lee Road Wetland system.

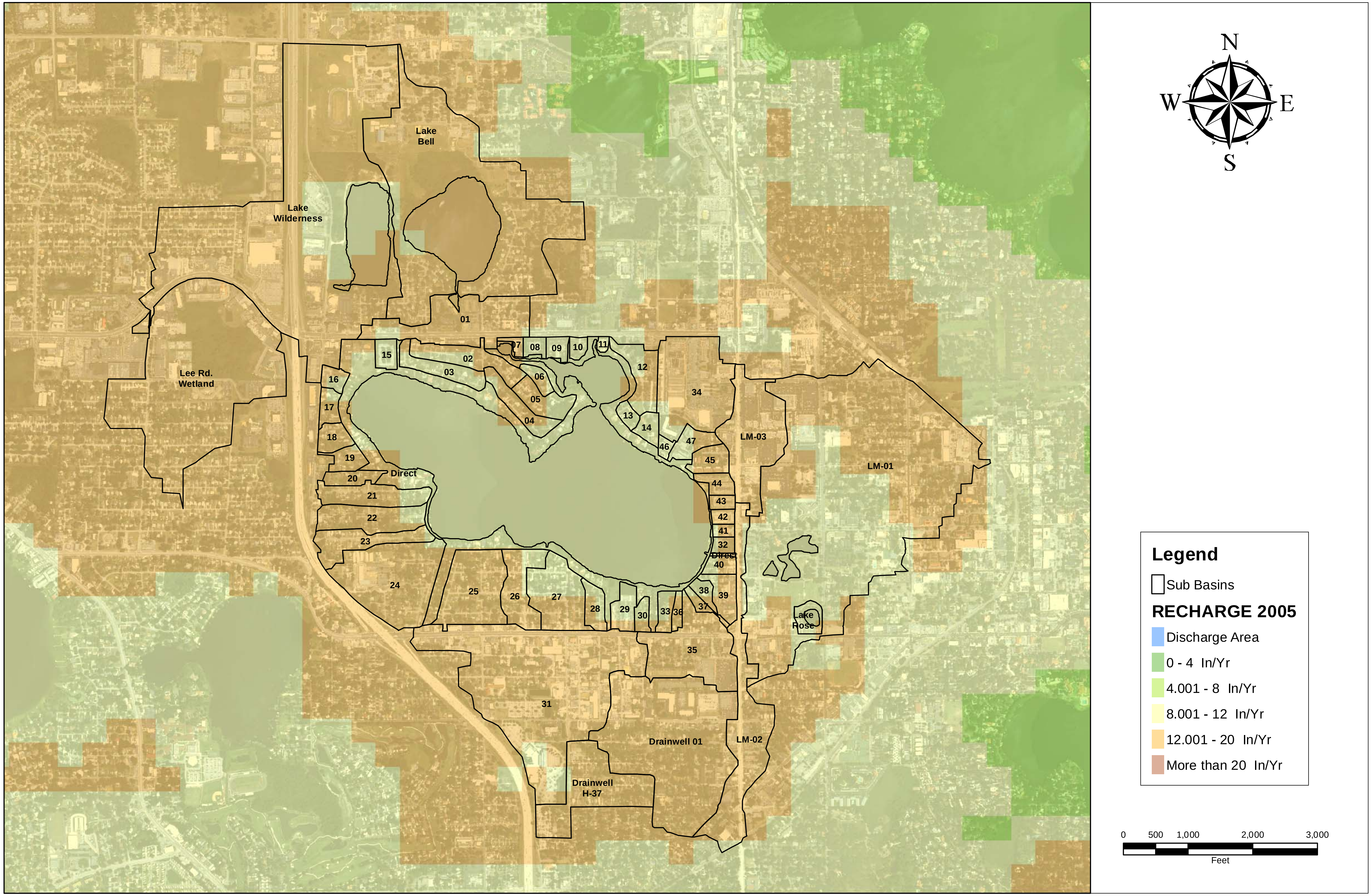


Figure 4-6. Estimated Annual Aquifer Recharge Rates in the Vicinity of Lake Killarney. (Source: SJRWMD)

Estimates of annual aquifer recharge for each of the five lakes were generated as the weighted average of the recharge rates illustrated on Figure 4-6 for each lake. A summary of estimated annual volumetric losses from deep recharge in each lake is given in Table 4-11. On an average annual basis, deep recharge removes approximately 400 ac-ft/yr from Lake Killarney, 3.6 ac-ft/yr from Lake Mendsen, 29.9 ac-ft/yr from the Lee Road Wetland, 24.3 ac-ft/yr from Lake Wilderness, and 39.4 ac-ft/yr from Lake Bell. The values summarized in Table 4-11 are subtracted from the estimated annual discharges from each lake to downstream waterbodies.

TABLE 4-11

ESTIMATED ANNUAL DEEP RECHARGE LOSSES FROM LAKE KILLARNEY AND ADJACENT WATERBODIES

LAKE	AREA (acres)	ESTIMATED DEEP RECHARGE LOSS	
		inches/year	ac-ft/yr
Lake Killarney	239.6	10	200
Lake Mendsen	4.3	10	3.6
Lee Road Wetland	22.4	16	29.9
Lake Wilderness	22.4	13	24.3
Lake Bell	36.4	13	39.4

4.2.3 Drainage Well / Outfall Discharges

Discharges from Lake Killarney are regulated by the combination of two drainage wells located on the southwest side of the lake and an outfall structure which is located in the north lobe of the lake. A discussion of the drainage wells and outfall structure is given in Section 2.6.

As indicated on Figure 2-29, water level elevations within Lake Killarney rarely reach a height sufficient to create discharges through the outfall structure. From 1960-1996, periods of discharge through the outfall structure occurred on only 8 separate occasions, with no measurable discharges through the outfall structure during a majority of the years included in this period.

During the most recent 15-year period from 1997-2011, which reflects current hydrologic conditions within the Lake Killarney watershed, lake water elevations did not exceed the outflow control elevation at any time, and no significant discharges occurred from Lake Killarney to Lake Gem. For purposes of this analysis, the mean annual discharge from Lake Killarney through the outfall structure is assumed to be approximately 0 ac-ft per year.

Excess water which does not discharge through the outfall structure is assumed to discharge into the two drainage well structures located on the lake. For purposes of this analysis, discharges from Lake Killarney through the drainage wells are calculated as the difference between quantified inputs and outputs for the lake on an annual basis according to the following relationship:

Drainage Well Discharge =

(Precipitation + Runoff Inputs + Seepage) - (Evaporation + Recharge + Outfall Discharge)

This information is calculated as part of the hydrologic budget summarized in Section 4.3.

4.3 Hydrologic Budget

A summary of identified hydrologic inputs to Lake Killarney on an average annual basis is given in Table 4-12. Estimates of hydrologic inputs are provided for direct precipitation, stormwater runoff, direct overland flow, groundwater seepage, and interconnected lake inflows. A graphical comparison of hydrologic inputs to Lake Killarney is given on Figure 4-7.

The largest annual hydrologic input to Lake Killarney is precipitation which contributes 36% of the total annual hydrologic inputs to the lake. Approximately 23% of the average annual hydrologic inputs originate as a result of stormwater runoff. Interconnected lake inflows from Lake Bell contribute approximately 17%, with 13% of the annual hydrologic inputs contributed by the inflow from Lake Mendsen. Groundwater seepage contributes approximately 9% of the annual hydrologic inputs, with 2% contributed by direct overland flow. On an average annual basis, approximately 2,813 ac-ft of water is discharged to Lake Killarney each year.

TABLE 4-12

CALCULATED HYDROLOGIC INPUTS TO LAKE KILLARNEY

SOURCE	ANNUAL INFLOW (ac-ft/yr)	PERCENT OF TOTAL (%)
Precipitation	999	36
Runoff	658	23
Direct Overland Flow	50.0	2
Lake Bell Inflow	486	17
Lake Mendsen Inflow	361	13
Groundwater Seepage	259	9
TOTAL:	**2,813**	**100**

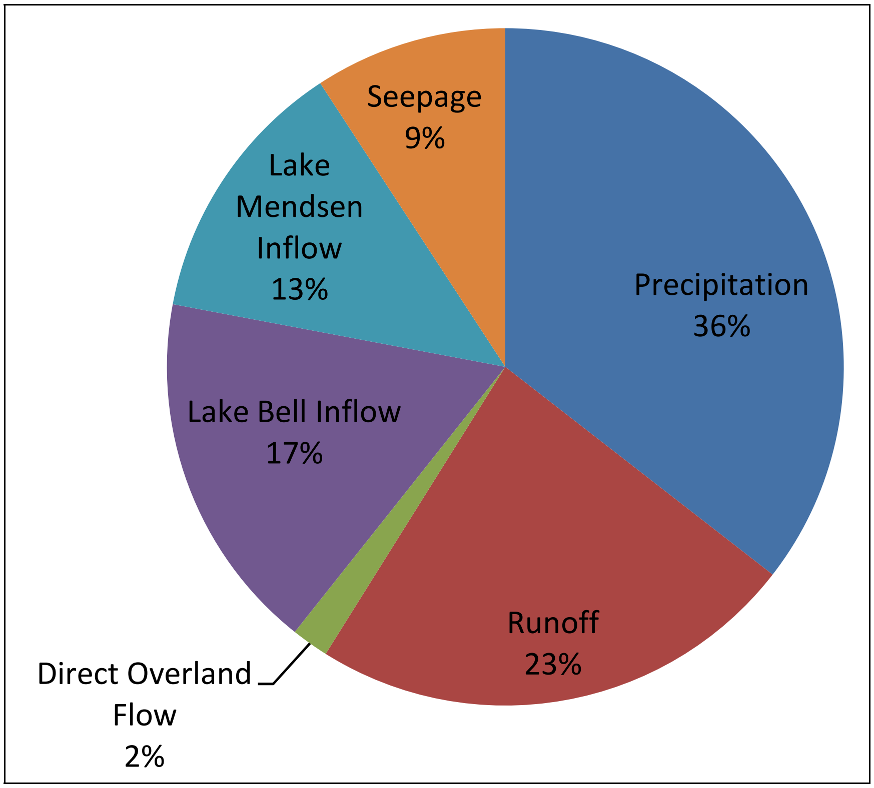


Figure 4-7. Summary of Mean Annual Hydrologic Inputs to Lake Killarney.

A summary of mean annual hydrologic losses from Lake Killarney is given in Table 4-13. Approximately 58% of the annual hydrologic inputs are discharged into the drainage wells, with 35% of the average annual hydrologic inputs lost to evaporation, and 7% lost as deep recharge to underground aquifers. A graphical comparison of mean annual hydrologic losses for Lake Killarney is given on Figure 4-8.

TABLE 4-13

CALCULATED HYDROLOGIC LOSSES FROM LAKE KILLARNEY

SOURCE	ANNUAL LOSSES (ac-ft/yr)	PERCENT OF TOTAL (%)
Evaporation	998	35
Deep Recharge	200	7
Outflow to Lake Gem	0	0
Drainage Wells	1,615	58
TOTAL:	**2,813**	**100**

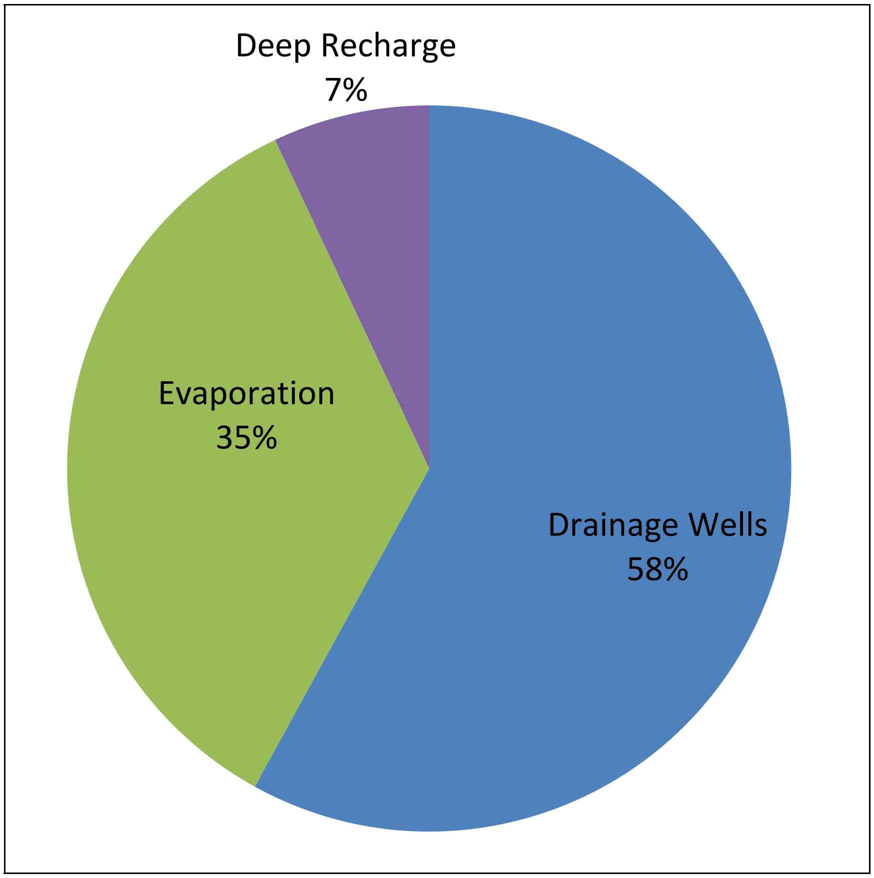


Figure 4-8. Summary of Mean Annual Hydrologic Losses from Lake Killarney.

4.4 Water Residence Time

The mean annual water residence time was calculated for Lake Killarney by dividing the estimated water volume for the lake (summarized in Table 2-2) by the calculated mean annual hydrologic inputs (summarized in Table 4-12). A summary of this information is given in Table 4-14. Based upon this analysis, the calculated residence time in Lake Killarney is approximately 460 days. The observed residence time in Lake Killarney is similar to residence times commonly observed in urban lakes.

TABLE 4-14

CALCULATED MEAN ANNUAL RESIDENCE TIMES IN LAKE KILLARNEY

LAKE VOLUME (ac-ft)	ANNUAL INFLOW (ac-ft/yr)	MEAN RESIDENCE TIME (days)
3,545	2,813	460

The whole-lake mean annual resident time of 460 days summarized in Table 4-14 may not accurately reflect actual water movement and residence times within Lake Killarney. Due to the narrow constriction which separates the northern lobe from the larger eastern and western lobes, Lake Killarney functions throughout much of the year as two separate interconnected lakes, with the eastern and western lobe representing one of these waterbodies and the northern lobe representing the other. The eastern and western lobes receive hydrologic inputs on an annual basis from each of the sources identified in previous sections. The northern lobe receives hydrologic inputs from sources which impact it directly and also receives excess water discharged from the east and west lobes. In effect, the northern lobe is impacted hydrologically by the entire annual inflow volume to Lake Killarney of 2,813 ac-ft/yr which either enters the northern lobe directly or discharges from the western and eastern lobes into the northern lobe.

Functional mean annual residence times were calculated separately for the combined eastern and western lobes and the northern lobe. Inflows into the northern lobe are assumed to be the total annual inflow volume of 2,813 ac-ft/yr. Direct inflows into the east and west lobes are calculated by subtracting direct inputs into the northern lobe from the total annual inflow volume. Direct runoff inputs into the northern lobe occur from Sub-basins 6-11, which contribute a combined annual inflow of 2.6 ac-ft/yr, as well as the inflow from Lake Bell which contributes approximately 486.3 ac-ft/yr. The combined sum of these inflows, approximately 489 ac-ft, is subtracted from the total annual inflow volume of 2,813 ac-ft/yr to estimate hydrologic inputs directly to the eastern and western lobes, approximately 2,324 ac-ft/yr.

A summary of functional mean annual residence times in Lake Killarney is given in Table 4-15. Based upon the bathymetric contour map summarized in Figure 2-2, the approximate water volume of the northern lobe is 90 ac-ft. The volume of the combined east and west lobes is calculated as the total lake volume of 3,545 ac-ft minus the 90 ac-ft contained in the northern lobe, resulting in an estimated volume of 3,455 ac-ft. As discussed previously, the northern lobe feels the hydrologic effects of the entire annual inflow of 2,813 ac-ft. The east and west lobes are hydrologically impacted by direct inputs into these lobes which are equivalent to the total annual inflow minus direct inputs into the northern lobe, resulting in an estimated annual inflow of 2,324 ac-ft. Based upon this analysis, the actual hydrologic residence time in the east and west lobes is approximately 543 days, with a mean annual residence time of only 12 days for the northern lobe. This difference in annual residence times is a contributing factor to the poor water quality observed in the northern lobe compared with other portions of Lake Killarney.

TABLE 4-15

FUNCTIONAL MEAN ANNUAL RESIDENCE TIMES IN LAKE KILLARNEY

AREA	VOLUME (ac-ft)	ANNUAL INFLOW (ac-ft)	MEAN RESIDENCE TIME (days)
East + West Lobes	3,455	2,324	543
North Lobe	90	2,813	12

SECTION 5

NUTRIENT INPUTS AND LOSSES

Lake Killarney receives nutrient inputs from a variety of sources which include bulk precipitation, stormwater runoff, interconnected lake inflow, shallow groundwater seepage, and internal recycling. A discussion of these inputs, along with calculated mass loadings, is given in the following sections. Information from each of these sources is used to generate annual average nutrient budgets for total nitrogen, total phosphorus and TSS for the lake. A conceptual schematic of evaluated nutrient sources and sinks in Lake Killarney is given in Figure 5-1.

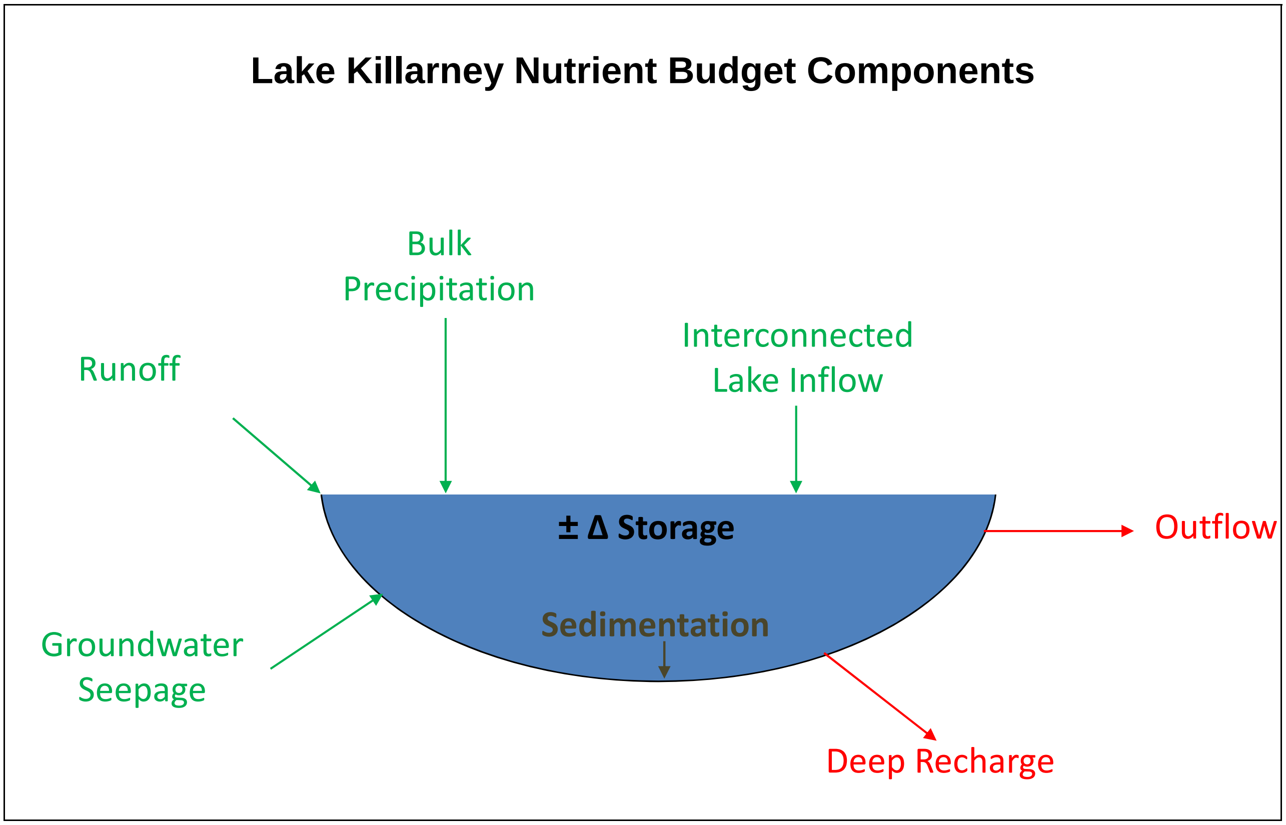


Figure 5-1. Conceptual Schematic of Evaluated Nutrient Inputs and Losses for Lake Killarney.

5.1 Characteristics of Nutrient Inputs

5.1.1 Bulk Precipitation

5.1.1.1 Field Monitoring

Field monitoring of the characteristics of bulk precipitation in the Lake Killarney drainage basin was conducted by ERD from September 2010-June 2011. A bulk precipitation collector was installed adjacent to Lake Mendsen and used to collect continuous samples of both wet and dry fallout. A photograph of the bulk precipitation collector installed adjacent to Lake Mendsen is given on Figure 5-2. Bulk precipitation samples were collected continuously as a composite of wet and dry fallout over periods ranging from approximately 2-4 weeks. The bulk precipitation samples were collected in the field and returned to the ERD Laboratory for analysis of general parameters and nutrients. A complete listing of the chemical characteristics of individual bulk precipitation samples collected at the Lake Mendsen monitoring site is given in Appendix E.1. A total of 12 separate composite bulk precipitation samples was collected during the field monitoring program.

Figure 5-2. Photograph of the Bulk Precipitation Collector at Lake Mendsen.

5.1.1.2 Chemical Characteristics

A tabular summary of the characteristics of bulk precipitation samples collected from the Lake Killarney drainage basin from September 2010-June 2011 is given on Table 5-1. Information is provided for the minimum value, maximum value, and geometric mean value for each of the measured general parameters and nutrients. In general, bulk precipitation samples were acidic in pH, with measured values ranging from 5.05-6.18. The collected bulk precipitation samples were generally low in alkalinity, with measured values ranging from 2.2-30.2 mg/l. Bulk precipitation samples were also characterized by low conductivity values which ranged from 12-133 μmho/cm.

TABLE 5-1

CHARACTERISTICS OF BULK PRECIPITATION IN THE LAKE KILLARNEY WATERSHED FROM SEPTEMBER 2010 - JUNE 2011

PARAMETER	UNITS	MINIMUM VALUE	MAXIMUM VALUE	GEOMETRIC MEAN
pH	s.u.	5.05	6.18	5.52
Alkalinity	mg/l	2.2	30.2	4.2
Conductivity	μmho/cm	12	133	37
Ammonia	μg/l	6	848	247
NO_x	μg/l	21	758	182
Diss. Org. N	μg/l	13	481	68
Particulate N	μg/l	15	248	75
Total N	μg/l	211	1,395	785
SRP	μg/l	2	184	18
Diss. Org. P	μg/l	3	41	13
Particulate P	μg/l	7	59	25
Total P	μg/l	14	284	68
Turbidity	NTU	0.5	6.5	2.1
Color	Pt-Co	2	15	7
TSS	mg/l	0.9	27.5	4.6

Highly variable concentrations of nitrogen species were observed in the collected bulk precipitation samples, with measured concentrations of ammonia ranging from 6-848 μg/l, and NO_x ranging from 21-758 μg/l. It appears that ammonia and NO_x reflect the dominant nitrogen species observed in bulk precipitation at the site. Overall total nitrogen concentrations in bulk precipitation range from 211-1395 μg/l with an overall mean of 785 μg/l.

Measured concentrations of phosphorus species in bulk precipitation exhibited a relatively high degree of variability in measured values. The dominant phosphorus species alternated between SRP and particulate phosphorus, depending upon the individual monitoring date. Overall, total phosphorus concentrations range from 14-284 μg/l, with an overall geometric mean value of 68 μg/l.

A relatively high degree of variability was also observed for measured concentrations of TSS, with measured values ranging from 0.9-27.5 mg/l. However, the overall geometric mean of 4.6 mg/l reflects a relatively low value. The geometric mean concentrations for total nitrogen, total phosphorus, and TSS summarized in Table 5-1 are assumed to reflect bulk precipitation characteristics which fall on Lake Killarney. The mean values for total nitrogen, total phosphorus, and TSS summarized in Table 5-1 are similar to values measured by ERD during other projects in the Central Florida area.

5.1.1.3 Mass Loadings

Estimates of annual mass loadings from bulk precipitation to Lake Killarney were calculated for total nitrogen, total phosphorus, and TSS based upon the assumed characteristics listed in Table 5-1 and the estimated annual average volumetric inputs from direct precipitation listed on Table 4-2. A summary of estimated mean annual loadings to Lake Killarney from bulk precipitation is given in Table 5-2. This information is used in a subsequent section to develop nutrient budgets for Lake Killarney.

TABLE 5-2

ESTIMATED MEAN ANNUAL LOADINGS TO LAKE KILLARNEY FROM BULK PRECIPITATION

PARAMETER	MASS LOADINGS (kg/yr)
Total N	967
Total P	83.8
TSS	5,667

5.1.2 Stormwater Runoff

5.1.2.1 Field Monitoring Program

A field monitoring program was conducted by ERD from August 2010-March 2011 to generate runoff characterization data for significant inflows into Lake Killarney. This monitoring was conducted to obtain site-specific runoff characteristics for discharges into the lake to increase the accuracy of the runoff loading calculations rather than using standard literature-based values. Runoff field monitoring was conducted at each of the 7 locations indicated on Figure 5-3. Each of the monitoring sites was located immediately upstream from the point of inflow into Lake Killarney to reflect the characteristics of runoff which reaches the lake. Drainage in the sub-basin areas is conveyed primarily by roadside ditches and swales, with the runoff ultimately discharging into the lake through shallow vegetated conveyance channels or underground stormsewers. A brief description of each of the monitoring sites is given in the following sections. In general, each of the sites is named for the adjacent street or location of the monitoring site.

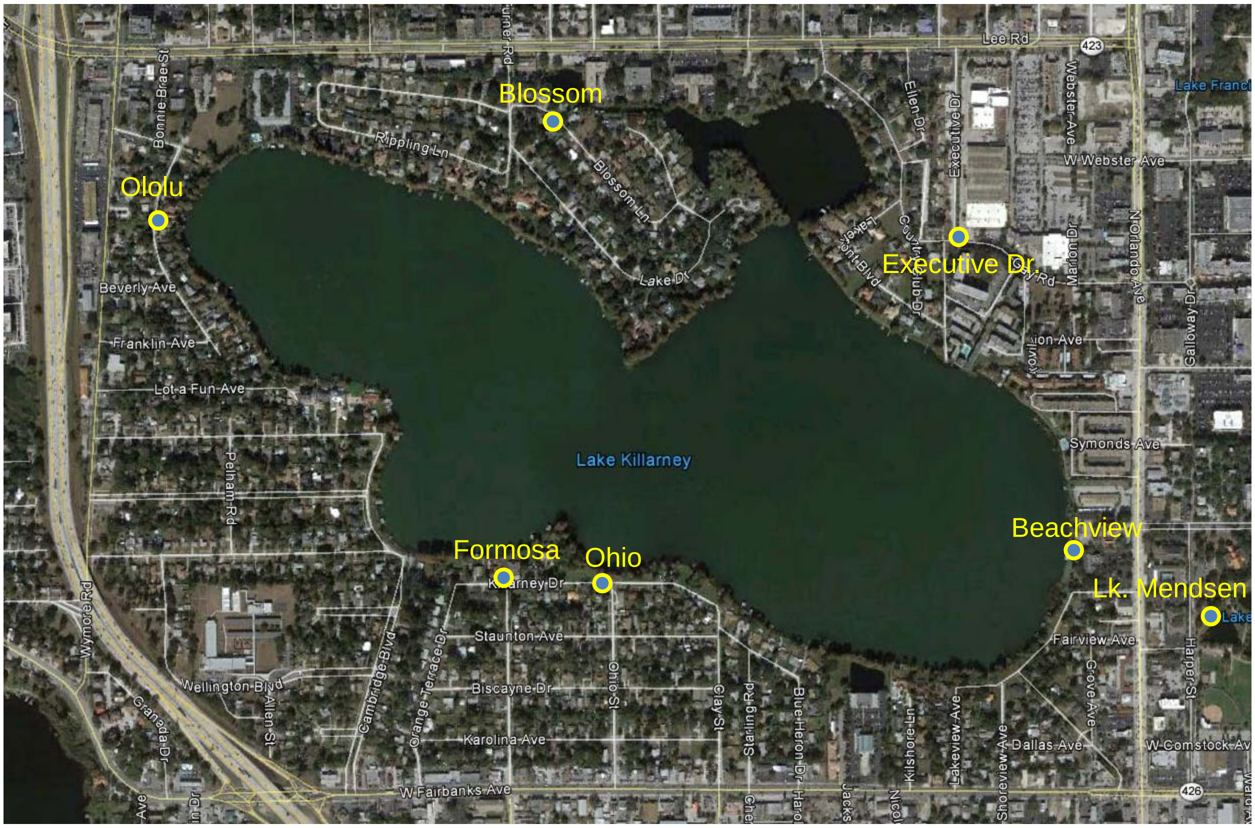


Figure 5-3. Locations of Inflow Monitoring Sites for Lake Killarney.

5.1.2.1.1 **Beachview Avenue Monitoring Site**

An overview of the Beachview Avenue monitoring site is given on Figure 5-4. The monitoring site is located on the eastern side of Lake Killarney at the intersection of Killarney Drive and Beachview Avenue. The monitoring site receives runoff from commercial areas along the west side of South Orlando Avenue, along with residential properties along Beachview Avenue, Killarney Drive, and intersecting streets.

Photographs of the Beachview Avenue monitoring site are given on Figure 5-5. Runoff is conveyed along a curb and gutter system and directed into a grate inlet and underground stormsewer system. The stormsewer discharges into a leaf and debris trap constructed from chain-link fencing and filter fabric outside of the pipe outfall. Field monitoring was conducted inside the grate inlet indicated on Figure 5-5a.

Figure 5-4. Overview of the Beachview Avenue Monitoring Site.

a. Inlet at end of Beachview Drive

b. Leaf and debris trap at pipe outfall

Figure 5-5. Photographs of the Beachview Avenue Monitoring Site.

5.1.2.1.2 <u>Blossom Lane Monitoring Site</u>

An overview of the Blossom Lane monitoring site is given on Figure 5-6. This site is located on the north-central portion of the Lake Killarney along Blossom Lane. Land use within the drainage basin is predominantly single-family residential. Runoff is conveyed through a curb and gutter system into a curb inlet structure.

A photograph of the Blossom Lane monitoring site is given on Figure 5-7. Runoff generated along Blossom Lane is collected in the inlet structure and conveyed through an underground stormsewer into the western end of the north lobe of Lake Killarney. Inflows from this site impact primarily the north lobe, with little impact on the main body of the lake.

5.1.2.1.3 <u>Executive Drive Monitoring Site</u>

An overview of the Executive Drive monitoring site is given on Figure 5-8. This site is located at the southwest corner of the shopping plaza near the intersection of Lee Road and Orlando Avenue. This site receives runoff from virtually all of the shopping center area which is collected in a series of underground stormsewers and conveyed through stormsewers to the point of discharge from the property at the monitoring site.

Photographs of the Executive Drive monitoring site are given on Figure 5-9. The grate structures indicated on Figure 5-9a are connected to an extensive underground stormsewer system which conveys drainage from the shopping center area and reflects the final point of access for the stormsewer system prior to discharge off-site. After leaving the site, the runoff is conveyed into the east lobe of Lake Killarney.

5.1.2.1.4 <u>Formosa Avenue Monitoring Site</u>

An overview of the Formosa Avenue monitoring site is given on Figure 5-10. This site is located near the intersection of Formosa Avenue and Killarney Drive on the south side of Lake Killarney and discharges into the west lobe of Lake Killarney. Land use contributing to this site consists primarily of single-family residential homes with a small amount of commercial areas along Fairbanks Avenue.

Photographs of the Formosa Avenue monitoring site are given on Figure 5-11. The drainage system along Formosa Avenue consists primarily of vegetated roadside swales which enter an underground stormsewer system near the intersection of Formosa Avenue and Killarney Drive. Runoff generated along Killarney Drive is conveyed in a curb and gutter system and combines with the runoff from Formosa Drive. The combined inflows then are conveyed through an underground stormsewer into Lake Killarney. Monitoring was conducted in the final stormsewer inlet prior to discharge to Lake Killarney.

Figure 5-6. Overview of the Blossom Lane Monitoring Site.

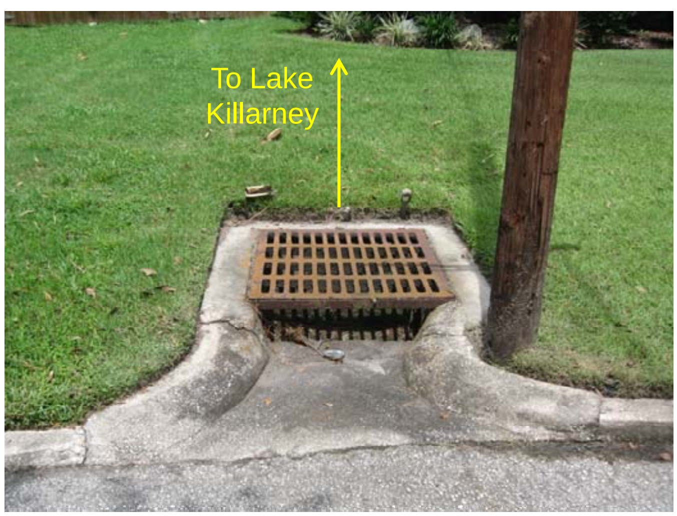


Figure 5-7. Photograph of the Blossom Lane Monitoring Site.

Figure 5-8. Overview of the Executive Drive Monitoring Site.

a. Final grate structures of stormsewer system

b. Off-site discharges occur to Lake Killarney

Figure 5-9. Photographs of the Executive Drive Monitoring Site.

Figure 5-10. Overview of the Formosa Avenue Monitoring Site.

a. Typical swale drainage system along Formosa Ave.

b. Inlet grate along Killarney Drive

Figure 5-11. Photographs of the Formosa Avenue Monitoring Site.

5.1.2.1.5 Ohio Street Monitoring Site

An overview of the Ohio Street monitoring site is given on Figure 5-12. This site is located one block east of the Formosa Avenue monitoring site near the intersection of Ohio Street and Killarney Drive. Runoff generated along both Ohio Street and Killarney Drive is conveyed through a curb and gutter system into a series of large curb inlets at the intersection of Ohio Street and Killarney Drive. The runoff flows combine at this location and are discharged into the east lobe of Lake Killarney.

Photographs of the Ohio Street monitoring street monitoring site are given on Figure 5-13. Runoff is conveyed into the inlet structures depicted on Figure 5-13 which combine into a single stormsewer and discharge directly to Lake Killarney. Runoff monitoring at this site was conducted in the final stormsewer structure prior to discharge to Lake Killarney, indicated on Figure 5-13c.

5.1.2.1.6 Ololu Drive Monitoring Site

An overview of the Ololu Drive monitoring site is given on Figure 5-14. This site is located on the western end of Lake Killarney east of Wymore Road. Land use within the drainage basin consists primarily of single-family residential homes. Runoff is collected at a single location along Ololu Drive and discharged through an underground stormsewer into Lake Killarney.

Photographs of the Ololu Drive monitoring site are given on Figure 5-15. Runoff generated along Ololu Drive is collected in a continuous grate inlet across the entire width of Ololu Drive. The runoff is then directed into an underground stormsewer and discharged into Lake Killarney. Monitoring at this site was conducted inside the grate structure indicated on Figure 5-15b which is the final access point for the stormsewer system prior to discharge to Lake Killarney.

5.1.2.1.7 Lake Mendsen Monitoring Site

An overview of the Lake Mendsen monitoring site is given on Figure 5-16. Lake Mendsen is located west of Orlando Avenue and south of Morse Blvd. Lake Mendsen receives runoff inflows from a relatively large watershed area located north and east of the lake. Land use within the Lake Mendsen drainage basin consists of a combination of commercial, professional office, and residential land uses.

Photographs of the Lake Mendsen monitoring site are given on Figure 5-17. Monitoring at Lake Mendsen was conducted in the stormsewer pipe which discharges from the outfall structure. This pipe was accessed by removing one of the metal grates on top of the outfall structure during each monitoring event. A photograph of Lake Mendsen under flooded conditions is given on Figure 5-17c.

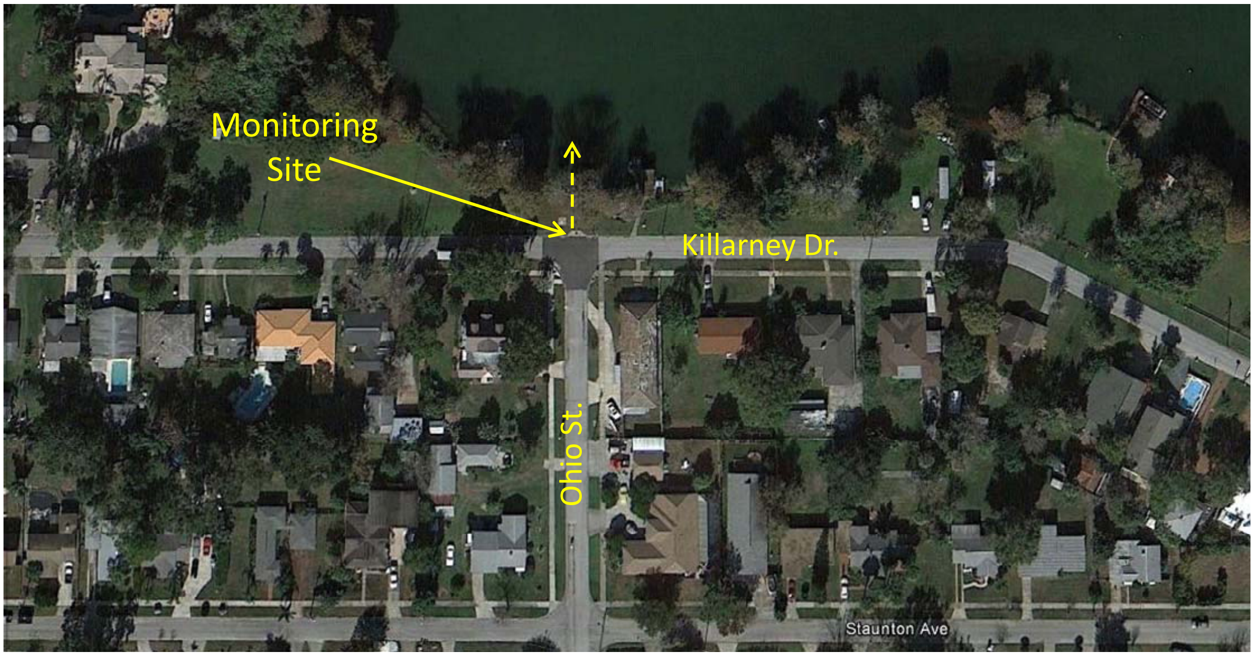


Figure 5-12. Overview of the Ohio Street Monitoring Site.

a. Curb inlet at end of Ohio Street

b. Curb inlet on Killarney Drive

c. Discharge to Lake Killarney

Figure 5-13.

Photographs of the
Ohio Street Monitoring Site.

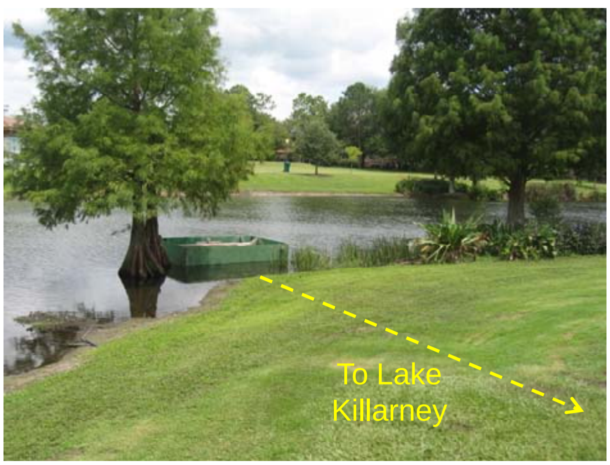
Figure 5-14. Overview of the Ololu Drive Monitoring Site.

a. Inlet grate across Ololu Street

b. Overflow grate with “Drains to Lake” decal

Figure 5-15. Photographs of the Ololu Drive Monitoring Site.

Figure 5-16. Overview of the Lake Mendsen Monitoring Site.



a. Lake Mendsen at outfall

b. Outfall structure to Lake Killarney

c. Lake Mendsen under flooded conditions

Figure 5-17.

Photographs of the Lake Mendsen Monitoring Site.

5.1.2.2 Characteristics of Monitored Inflow Samples

Field monitoring was conducted at each of the 7 inflow monitoring sites over the period from August 2010-March 2011 during significant rain events which occurred while ERD field personnel were in the general vicinity of Lake Killarney. A summary of the number of samples collected at each monitoring site during the field monitoring program is given on Figure 5-18. The number of samples collected at each of the inflow monitoring sites ranged from 2-10, with a total of 37 inflow samples collected during the field monitoring program.

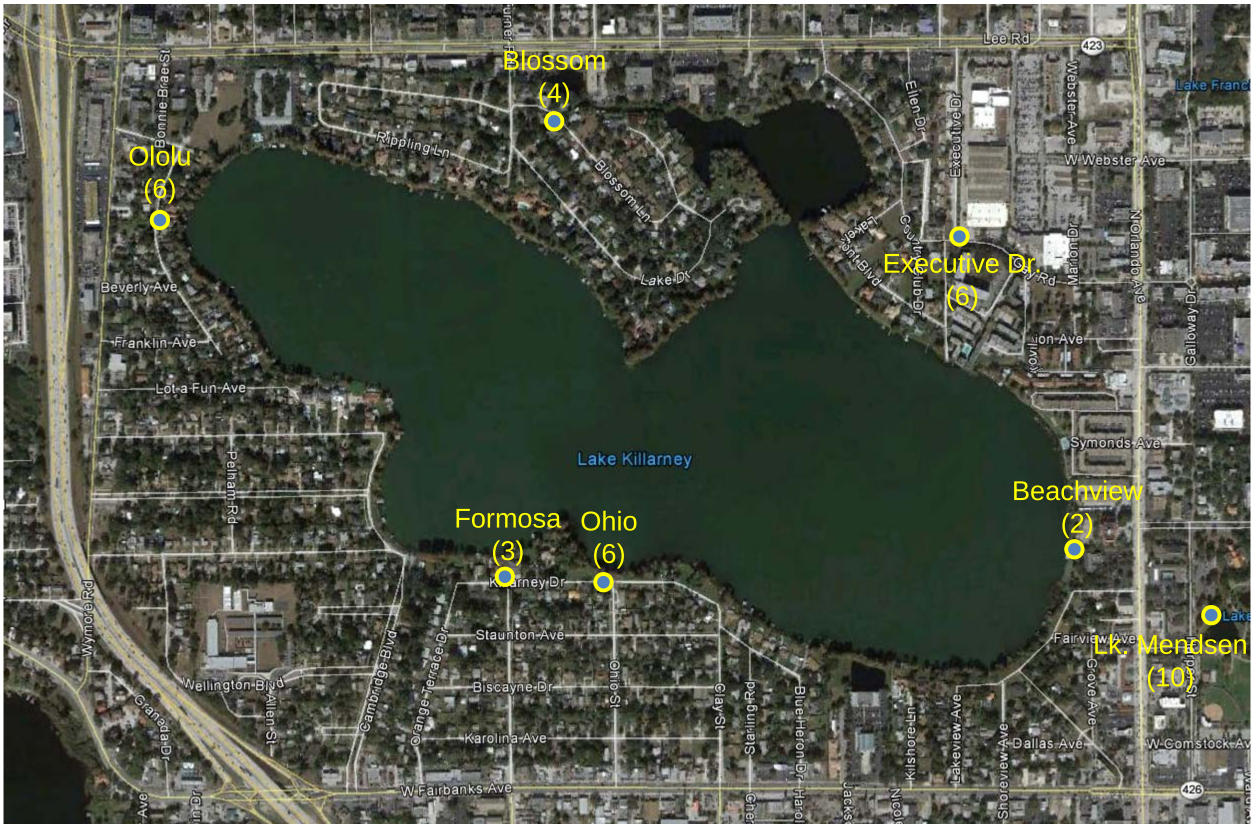


Figure 5-18. Number of Samples Collected at Each Site During the Field Monitoring Program.

Each of the collected samples was returned to the ERD Laboratory and analyzed for general parameters and nutrients. A complete listing of the results of laboratory analyses conducted on the inflow samples is given in Appendix E.2.

A tabular summary of mean chemical characteristics of inflow samples collected in the Lake Killarney drainage basin from August 2010-March 2011 is given on Table 5-3. The values summarized in this table reflect the log-normal or geometric mean of the data since the data exhibit a log-normal distribution.

TABLE 5-3

MEAN CHEMICAL CHARACTERISTICS OF INFLOW SAMPLES COLLECTED IN THE LAKE KILLARNEY DRAINAGE BASIN FROM AUGUST 2010-MARCH 2011

PARAMETER	UNITS	SITE						
		Beachview	Blossom	Executive	Formosa	Ohio	Ololu	Lake Mendsen
No. of Samples	--	2	4	6	3	6	6	10
pH	s.u.	6.14	6.47	6.60	6.45	6.86	6.96	6.89
Alkalinity	mg/l	24.1	31.7	28.4	29.5	50.2	41.9	64.6
Conductivity	μmho/cm	73	102	84	75	144	116	168
Ammonia	μg/l	436	195	145	40	111	109	216
NO_x	μg/l	15	238	185	235	269	180	96
Diss. Org. N	μg/l	51	203	243	417	293	167	336
Particulate N	μg/l	376	506	68	355	510	362	220
Total N	μg/l	973	1,384	709	1,076	1,273	1,142	951
SRP	μg/l	37	63	35	213	55	84	3
Diss. Org. P	μg/l	76	58	10	111	18	28	5
Particulate P	μg/l	111	168	6	62	58	110	36
Total P	μg/l	227	334	53	406	140	233	49
Turbidity	NTU	10.1	9.2	6.7	6.6	24.3	13.8	6.1
Color	Pt-Co	40	32	24	62	42	35	31
TSS	mg/l	11.6	52.0	7.4	6.5	29.5	39.0	7.4

Measured pH values in the Lake Killarney inflow samples were approximately neutral, with mean pH values ranging from 6.14-6.96. Inflow samples to Lake Killarney were moderately to poorly buffered with mean alkalinity values ranging from 21.4-64.6 mg/l. The highest mean alkalinity of 64.6 mg/l was measured in discharges from Lake Mendsen. Laboratory measured conductivity values were highly variable but generally low in value, with mean concentrations ranging from 73-168 μmho/cm. In general, these values are somewhat less than conductivity values commonly observed in urban runoff.

Measured nitrogen concentrations in the inflow samples were generally moderate in value. Relatively low concentrations of ammonia were measured at all of the inflow monitoring sites with the exception of the Beachview Avenue site which was characterized by a mean ammonia concentration of 436 µg/l. Mean ammonia concentrations at the remaining sites ranged from 40-216 µg/l. Measured concentrations of NO_x were highly variable at the monitoring sites, with mean values ranging from a low of 15 µg/l at the Beachview Avenue site to a high of 269 µg/l at the Ohio Street site. An individual NO_x concentration of 4673 µg/l was measured at the Ololu Drive site on September 28, 2010. Measured concentrations of dissolved organic nitrogen were also highly variable, with mean concentrations ranging from 51-417 µg/l. Low to moderate levels of particulate nitrogen were observed at the monitoring sites, with mean values ranging from 68-510 µg/l. Overall, total nitrogen concentrations ranged from 709 µg/l at the Executive Drive site to 1384 µg/l at the Blossom Lane site. An individual total nitrogen concentration of 5254 µg/l was measured at the Ololu Drive site on September 28, 2010. However, mean total nitrogen concentrations entering Lake Killarney were slightly lower than nitrogen concentrations commonly observed in urban runoff.

Highly variable concentrations of phosphorus species were observed during the field monitoring program between the various sites. Measured concentrations of soluble reactive phosphorus (SRP) ranged from low to elevated at the monitoring sites. The most elevated concentrations of SRP were observed at the Formosa Avenue site which was characterized by a mean SRP concentration of 213 µg/l. Mean SRP concentrations at the remaining sites ranged from 3-84 µg/l , with the lowest SRP concentration of 3 µg/l measured at the discharge from Lake Mendsen. Mean concentrations of dissolved organic phosphorus were also highly variable between the 7 monitoring sites, with values ranging from 5-111 µg/l. The most elevated dissolved organic phosphorus was observed at the Formosa Avenue site, with the lowest value observed at the Lake Mendsen outfall. Particulate phosphorus concentrations also exhibited a high degree of variability, with mean concentrations ranging from 6-168 µg/l, with the most elevated particulate phosphorus concentration measured at the Blossom Lane site. Overall, mean total phosphorus concentrations ranged from low to elevated at the various monitoring sites. The lowest mean total phosphorus concentration of 49 µg/l was measured at the outfall from Lake Mendsen. A relatively low total phosphorus concentration of 53 µg/l was also measured at the Executive Drive site. The most elevated total phosphorus concentration of 406 µg/l was measured at the Formosa Avenue site.

Measured concentrations of turbidity and TSS in the runoff samples are similar to or less than concentrations commonly observed in urban runoff. Particularly low levels of turbidity and TSS were measured at the Lake Mendsen outfall, Executive Drive site, and the Formosa Avenue site. Measured color concentrations in the inflow samples were moderate in value and relatively similar between the inflow sites.

A statistical summary of general parameters measured in inflow samples at Lake Killarney is given in Figure 5-19. A graphical summary of laboratory data is presented in the form of Tukey box plots, also often called “box and whisker plots”. The bottom of the box portion of each plot represents the lower quartile, with 25% of the data points lying below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data lying above this value. The **blue horizontal line** within the box represents the median value, with 50% of the data lying both above and below this value, while the **red horizontal line** represents the mean value. The vertical lines, also known as "whiskers", represent the 5 and 95 percentiles for the data sets. Individual values which lie outside of the 5-95 percentile range are indicated as **red dots**.

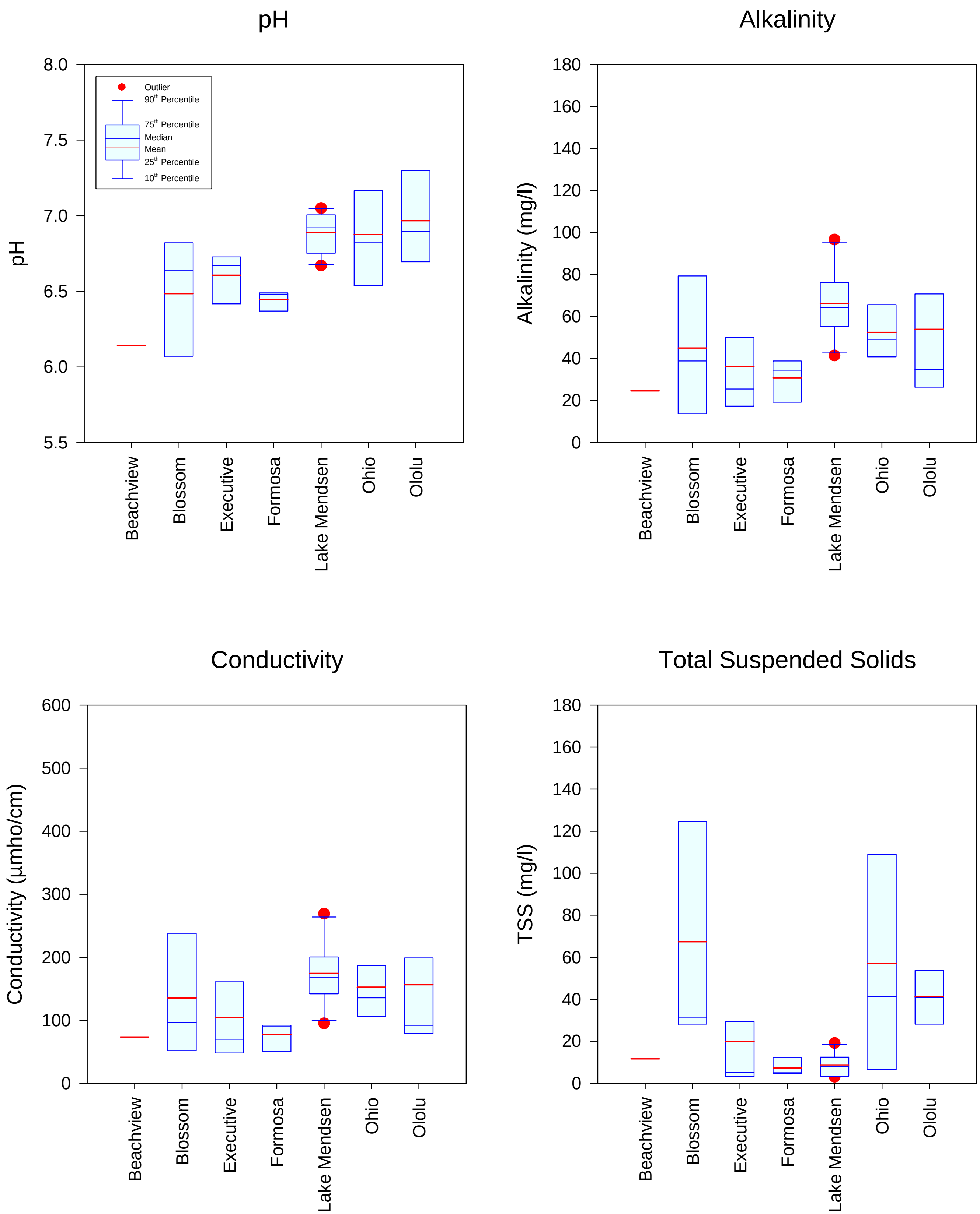


Figure 5-19. Statistical Summary of General Parameters Measured in Inflow Samples at Lake Killarney.

As seen in Figure 5-19, measured pH values were relatively similar at the Lake Mendsen, Ohio Street, and Ololu Drive sites, with slightly lower measured pH values at the remaining sites. However, the differences in measured pH values between the various sites are relatively small. Relatively similar alkalinity values were observed at the Lake Mendsen, Ohio Street, and Ololu Drive sites, with slightly lower values observed at the remaining sites. A similar pattern is also apparent for conductivity, with higher conductivity measurements observed at the Lake Mendsen, Ohio Street, and Ololu Drive sites, and lower values at the remaining sites. Somewhat elevated and highly variable concentrations of TSS were observed at the Blossom Lane and Ohio Street sites, and to a lesser degree at the Ololu Drive site. Substantially lower TSS measurements were observed at the remaining sites.

A statistical summary of measured concentrations of nitrogen species in inflow samples collected at each of the 7 monitoring sites is given on Figure 5-20. A relatively high degree of variability was observed in measured ammonia concentrations at 6 of the 7 monitoring sites, with substantially lower concentrations and a lower degree of variability observed at the Formosa Avenue site. Highly variable and somewhat elevated concentrations of NO_x were observed at the Ololu Drive site, with substantially lower concentrations and a lower degree of variability in NO_x concentrations at the remaining sites. Somewhat elevated and highly variable concentrations of particulate nitrogen were observed at the Blossom Lane and Ololu Drive sites, with lower concentrations and a lower degree of variability at each of the remaining sites. Overall, measured total nitrogen concentrations were relatively similar at each of the monitoring sites, with the exception of the Executive Drive site which was characterized by a somewhat lower concentrations.

A statistical summary of measured concentrations of phosphorus species in inflow samples at each of the 7 monitoring sites is given on Figure 5-21. Highly variable and somewhat elevated concentrations of SRP and dissolved organic phosphorus were observed at the Formosa Avenue site, with substantially lower concentrations and lower degrees of variability in measured concentrations observed at the remaining sites. The lowest measured concentrations for SRP and dissolved organic phosphorus occurred at the Lake Mendsen outfall site. Somewhat elevated and highly variable levels of particulate phosphorus were measured at the Blossom Lane site, with lower and generally less variable values measured at the remaining sites. The lowest particulate phosphorus concentrations were observed at the Executive Drive site. Overall, total phosphorus concentrations were highly variable between the 7 monitoring sites, with somewhat elevated concentrations measured at the Blossom Lane and Formosa Avenue sites, moderate concentrations observed at the Ololu Drive site, and relatively low total phosphorus concentrations observed at the remaining sites. The lowest total phosphorus concentrations were measured at the Lake Mendsen outfall site.

A statistical summary of measured concentrations for turbidity and color in inflow samples collected at each of the 7 monitoring sites is given on Figure 5-22. Highly variable and somewhat elevated levels of turbidity were observed at the Ohio Street site, with substantially lower concentrations and a lower degree of variability observed at the remaining sites. A moderately elevated color concentration was observed at the Formosa Avenue site, with somewhat lower values observed at the remaining sites.

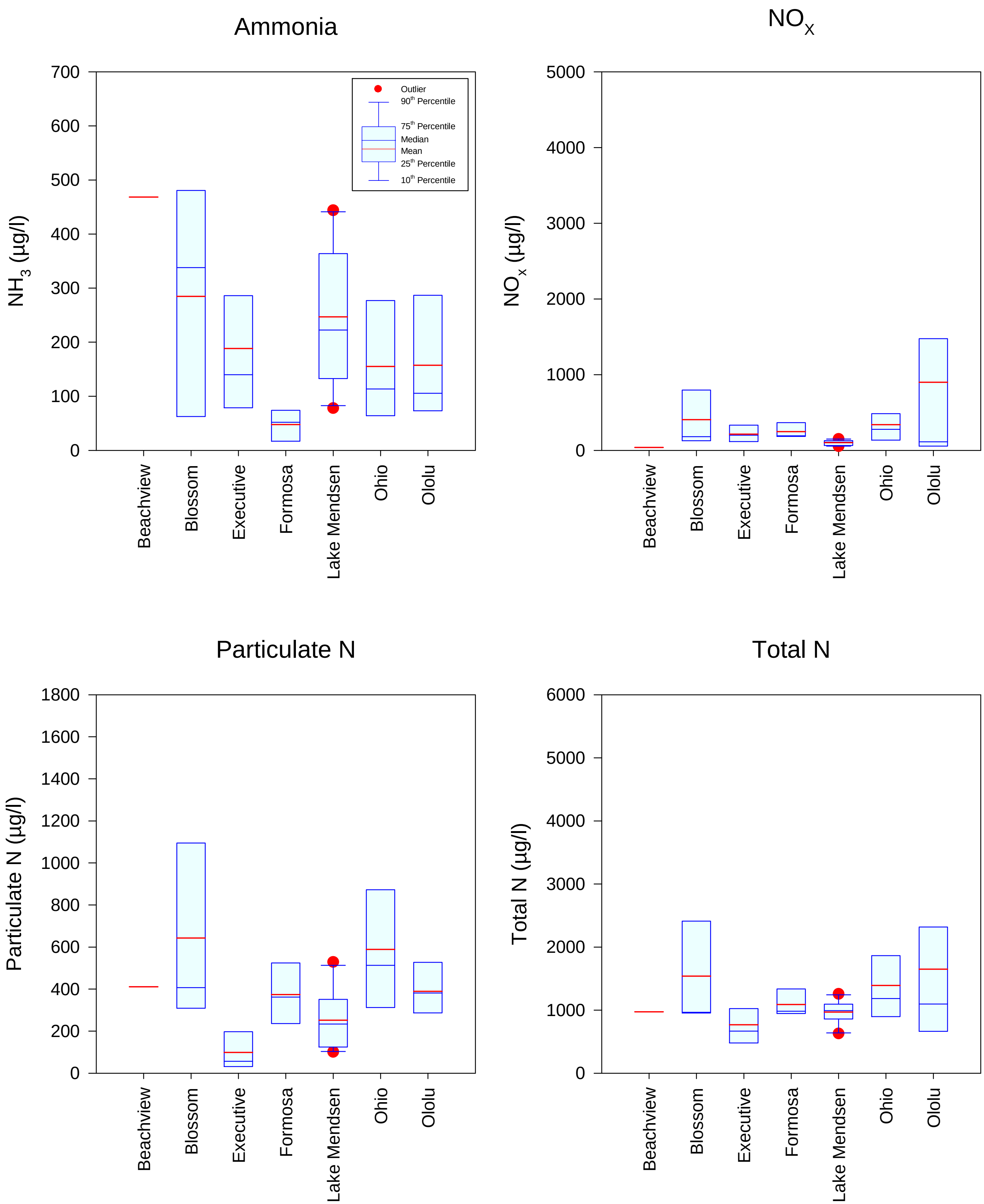


Figure 5-20. Statistical Summary of Nitrogen Species Measured in Inflow Samples at Lake Killarney.

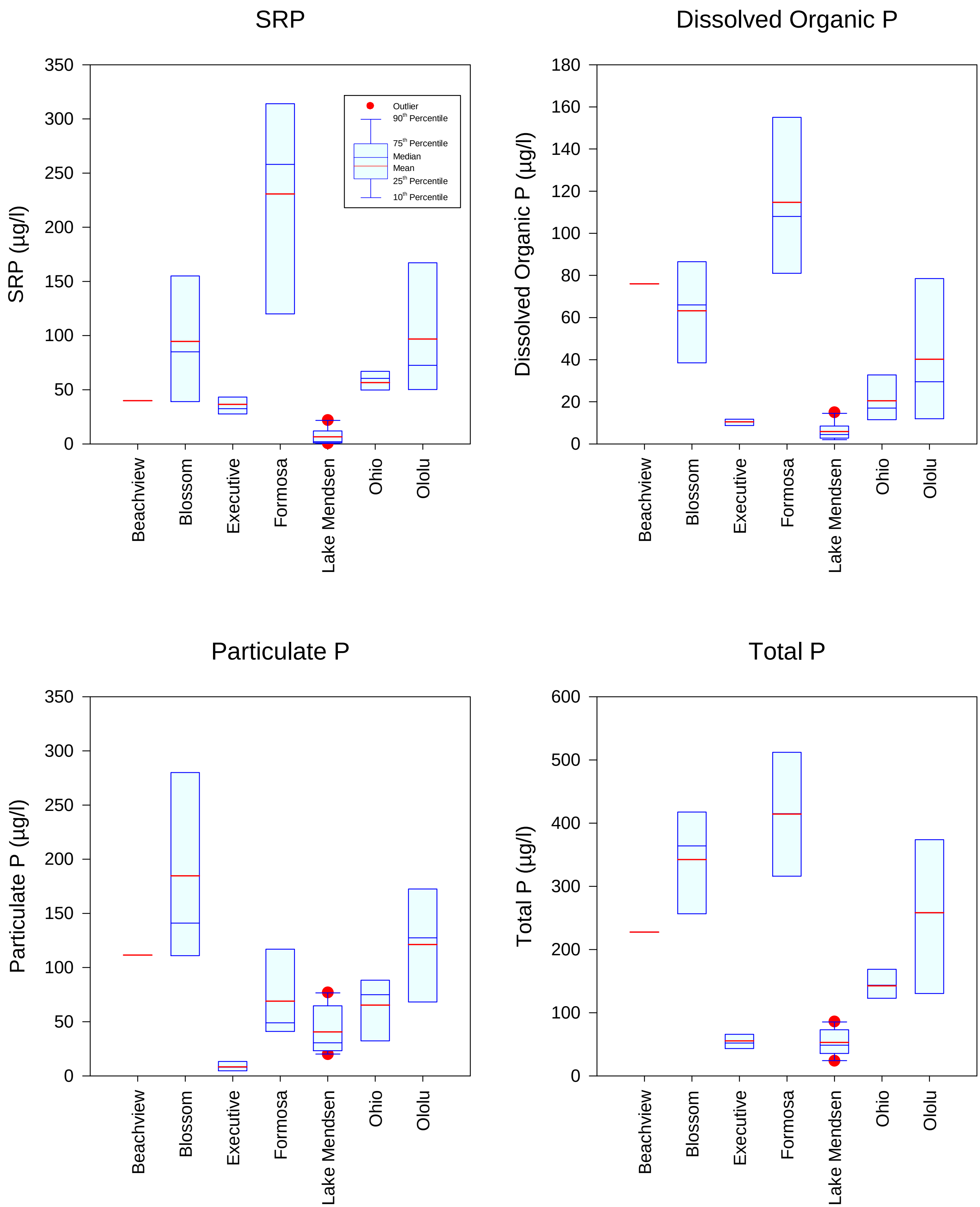


Figure 5-21. Statistical Summary of Phosphorus Species Measured in Inflow Samples at Lake Killarney.

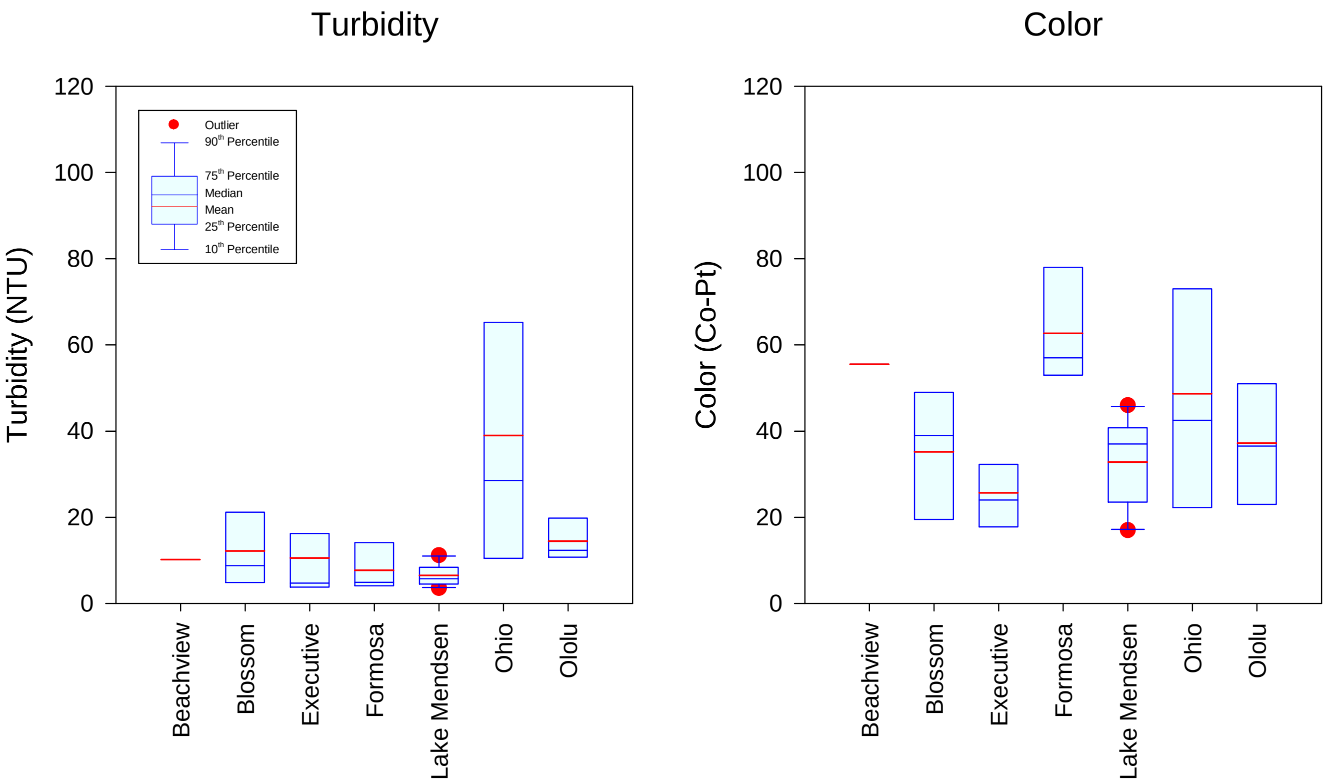


Figure 5-22. Statistical Summary of Turbidity and Color Measured in Inflow Samples at Lake Killarney.

5.1.2.3 <u>Selection of Runoff Characterization Data</u>

Runoff characterization data for total nitrogen, total phosphorus, and TSS is necessary to estimate annual loadings to Lake Killarney from stormwater inflows. Of the 48 sub-basin areas which discharge directly into Lake Killarney, only 6 of these sub-basins were monitored directly as part of the field monitoring program, along with 1 of the 2 interconnected lake inflow sites. However, many of the unmonitored sub-basins are adjacent to areas which were monitored and have similar watershed and land use characteristics. In most cases, runoff characteristics generated in these unmonitored sub-basin areas can be assumed to be similar to characteristics measured in the adjacent monitored sub-basins.

A summary of assumed runoff characteristics for sub-basin areas discharging directly to Lake Killarney, along with the intermittent drainage basin areas, is given in Table 5-4. Runoff characterization data are provided for each of the sub-basin areas discharging to Lake Killarney based upon either direct measurements or similarities between measured sub-basin areas. Direct measurements of runoff characteristics were conducted for Sub-basin 2 (Blossom Lane site), Sub-basin 17 (Ololu Drive site), Sub-basin 25 (Formosa Avenue site), Sub-basin 26 (Ohio Street site), Sub-basin 34 (Executive Drive site), and Sub-basin 40 (Beachview Avenue site).

TABLE 5-4

ASSUMED RUNOFF CHARACTERISTICS FOR LAKE KILLARNEY SUB-BASIN AREAS

SUB-BASIN	RUNOFF VOLUME (ac-ft)	RUNOFF CONCENTRATION (mg/l)			RUNOFF CONCENTRATION REFERENCE
		Total N	Total P	TSS	
01	54.82	1.07	0.179	47.5	Assumed emc - Low Intensity Commercial
02	9.37	1.384	0.334	52.0	Direct Measurement - Blossom Ln. Site
03	6.22	1.384	0.334	52.0	Assumed similar to Blossom Ln. Site
04	5.91	1.384	0.334	52.0	Assumed similar to Blossom Ln. Site
05	5.80	1.384	0.334	52.0	Assumed similar to Blossom Ln. Site
06	2.16	1.384	0.334	52.0	Assumed similar to Blossom Ln. Site
07	2.88	1.07	0.179	47.5	Assumed emc - Low Intensity Commercial
08	4.91	1.07	0.179	47.5	Assumed emc - Low Intensity Commercial
09	5.67	1.07	0.179	47.5	Assumed emc - Low Intensity Commercial
10	1.51	1.07	0.179	47.5	Assumed emc - Low Intensity Commercial
11	1.26	1.07	0.179	47.5	Assumed emc - Low Intensity Commercial
12	7.70	1.384	0.334	52.0	Assumed similar to Blossom Ln. Site
13	1.48	1.384	0.334	52.0	Assumed similar to Blossom Ln. Site
14	2.44	1.384	0.334	52.0	Assumed similar to Blossom Ln. Site
15	8.32	1.07	0.179	47.5	Assumed emc - Low Intensity Commercial
16	2.68	1.142	0.233	39.0	Assumed similar to Olohu Dr. Site
17	3.41	1.142	0.233	39.0	Direct Measurement - Olohu Dr.
18	3.82	1.142	0.233	39.0	Assumed similar to Olohu Dr. Site
19	3.33	1.142	0.233	39.0	Assumed similar to Olohu Dr. Site
20	3.19	1.142	0.233	39.0	Assumed similar to Olohu Dr. Site
21	9.48	1.076	0.406	6.5	Assumed similar to Formosa Ave. Site
22	11.28	1.076	0.406	6.5	Assumed similar to Formosa Ave. Site
23	9.23	1.076	0.406	6.5	Assumed similar to Formosa Ave. Site
24	35.70	1.076	0.406	6.5	Assumed similar to Formosa Ave. Site
25	19.00	1.076	0.406	6.5	Direct Measurement - Formosa Ave. Site
26	11.26	1.273	0.140	29.5	Direct Measurement - Ohio St.
27	17.25	1.273	0.140	29.5	Assumed similar to Ohio St. Site
28	4.98	1.273	0.140	29.5	Assumed similar to Ohio St. Site
29	8.75	0.973	0.227	11.6	Assumed similar to Beachview Ave.
30	1.92	1.273	0.140	29.5	Assumed similar to Ohio St. Site
31	198.71	0.973	0.227	11.6	Assumed similar to Beachview Ave.
32	3.47	0.973	0.227	11.6	Assumed similar to Beachview Ave.
33	3.23	1.273	0.140	29.5	Assumed similar to Ohio St. Site
34	71.80	0.709	0.053	7.4	Direct Measurement - Executive Dr.
35	55.13	0.973	0.227	11.6	Assumed similar to Beachview Ave.
36	1.40	1.273	0.140	29.5	Assumed similar to Ohio St. Site
37	2.59	0.973	0.227	11.6	Assumed similar to Beachview Ave.
38	2.10	0.973	0.227	11.6	Assumed similar to Beachview Ave.
39	9.69	0.973	0.227	11.6	Assumed similar to Beachview Ave.
40	3.31	0.973	0.227	11.6	Direct Measurement - Beachview Ave.
41	3.28	0.709	0.053	7.4	Assumed similar to Executive Dr. Site
42	3.93	0.709	0.053	7.4	Assumed similar to Executive Dr. Site
43	4.28	0.709	0.053	7.4	Assumed similar to Executive Dr. Site
44	7.71	0.709	0.053	7.4	Assumed similar to Executive Dr. Site
45	10.81	0.709	0.053	7.4	Assumed similar to Executive Dr. Site
46	3.05	0.709	0.053	7.4	Assumed similar to Executive Dr. Site
47	7.73	0.709	0.053	7.4	Assumed similar to Executive Dr. Site
Overland Flow	50.02	1.056	0.183	20.6	Average of the other monitored sites

Additional sub-basin areas in the vicinity of the directly measured sub-basin areas that exhibited similar land use characteristics are assumed to have runoff characteristics similar to those in the directly measured sub-basins. For example, Sub-basin areas in the vicinity of the Blossom Lane site with similar land use characteristics (including Sub-basins 3, 4, 5, 6, 12, 13, and 14) are all single-family residential watersheds located on the north side of Lake Killarney. Each of these areas is assumed to have runoff characteristics similar to those measured at the Blossom Lane site.

Sub-basin areas in the immediate vicinity of the Ololu Drive site (including Sub-basins 16, 18-20) all reflect single-family residential watersheds on the west side of Lake Killarney. Each of these sub-basins is assumed to have runoff characteristics similar to those measured at the Ololu Drive site. The Formosa Avenue site (Sub-basin 25) reflects primarily residential land use characteristics along with commercial properties located on the north side of Fairbanks Avenue. Similar watersheds include Sub-basins 21-24.

The Ohio Street site (Sub-basin 26) reflects a relatively large drainage basin area with primarily curb and gutter drainage systems. Similar sub-basin areas are assumed to be Sub-basins 27-28, 30, 33, and 36. The Beachview Avenue monitoring site (Sub-basin 40) reflects a combination of residential and commercial land use activities on the west side of Lake Killarney, and similar sub-basin areas are assumed to be Sub-basins 29, 31-33, and 35-39. Commercial land use areas located on the northeast side of Lake Killarney are all assumed to have runoff characteristics similar to the Executive Drive site (Sub-basin 34) which includes Sub-basins 41-47.

Multiple sub-basin areas exist along Lee Road which consist primarily of commercial and professional office spaces, with a small amount of residential land use. Runoff monitoring was not conducted during this project in a sub-basin area which characteristics similar to the areas along Lee Road. Therefore, runoff characteristics for these areas are assumed to be similar to the low-intensity commercial state-wide characteristics in the Florida emc database.

Runoff data were not collected from any of the overland flow drainage areas since these areas contribute runoff by shallow diffuse flow over a large area. Therefore, for purposes of this analysis, the runoff generated from the overland flow sub-basin associated with Lake Killarney is assumed to be equal to the mean runoff characteristics for each of the other sub-basin areas.

5.1.2.4 Mass Loadings

Estimates of annual mass loadings of total nitrogen, total phosphorus, and TSS discharging from direct sub-basin areas into Lake Killarney as a result of stormwater runoff are summarized in Table 5-5. The mass loadings summarized in this table were obtained by multiplying the assumed runoff characteristics for each sub-basin area summarized in Table 5-4 times the observed runoff volume for each sub-basin area summarized in Table 4-4 for the direct discharge sub-basins. The loading values summarized in Table 5-5 reflect the impacts of stormwater treatment systems discussed previously. Overall, the direct sub-basins to Lake Killarney, including the overland flow sub-basin, contribute approximately 877 kg/yr of total nitrogen, 187 kg/yr of total phosphorus, and 16,564 kg/yr of TSS to Lake Killarney.

TABLE 5-5

CALCULATED ANNUAL MASS LOADINGS FROM STORMWATER RUNOFF TO LAKE KILLARNEY

SUB-BASIN	SUB-BASIN AREA (ac)	MASS LOADINGS (kg/yr)			PERCENT OF TOTAL RUNOFF LOAD (%)			AREAL LOADINGS (kg/ac-yr)		
		Total N	Total P	TSS	Total N	Total P	TSS	Total N	Total P	TSS
01	31.69	72	12.1	3,212	8.2	6.5	19.4	2.28	0.38	101
02	11.76	16.0	3.9	600	1.8	2.1	3.6	1.36	0.33	51.1
03	8.18	10.6	2.6	399	1.2	1.4	2.4	1.30	0.31	48.8
04	7.77	10.1	2.4	379	1.2	1.3	2.3	1.30	0.31	48.7
05	7.63	9.9	2.4	372	1.1	1.3	2.2	1.30	0.31	48.7
06	2.84	3.7	0.9	138	0.4	0.5	0.8	1.30	0.31	48.7
07	1.37	3.8	0.6	169	0.4	0.3	1.0	2.77	0.46	123
08	2.34	6.5	1.1	288	0.7	0.6	1.7	2.77	0.46	123
09	2.73	7.5	1.3	332	0.9	0.7	2.0	2.74	0.46	122
10	1.99	2.0	0.3	89	0.2	0.2	0.5	1.00	0.17	44.4
11	0.89	1.7	0.3	74	0.2	0.1	0.4	1.86	0.31	82.9
12	10.63	13.1	3.2	493	1.5	1.7	3.0	1.24	0.30	46.4
13	2.29	2.5	0.6	95	0.3	0.3	0.6	1.10	0.27	41.3
14	3.46	4.2	1.0	156	0.5	0.5	0.9	1.20	0.29	45.1
15	3.48	10.9	1.8	487	1.2	1.0	2.9	3.14	0.53	140
16	2.97	3.8	0.8	129	0.4	0.4	0.8	1.27	0.26	43.4
17	3.77	4.8	1.0	164	0.5	0.5	1.0	1.27	0.26	43.6
18	4.57	5.4	1.1	184	0.6	0.6	1.1	1.18	0.24	40.2
19	4.25	4.7	1.0	160	0.5	0.5	1.0	1.10	0.23	37.7
20	4.25	4.5	0.9	153	0.5	0.5	0.9	1.06	0.22	36.1
21	12.14	12.6	4.7	77	1.4	2.5	0.5	1.04	0.39	6.3
22	14.64	15.0	5.6	91	1.7	3.0	0.5	1.02	0.39	6.2
23	12.18	12.3	4.6	75	1.4	2.5	0.4	1.01	0.38	6.1
24	37.75	47.4	17.9	288	5.4	9.6	1.7	1.25	0.47	7.6
25	24.33	25.2	9.5	153	2.9	5.1	0.9	1.04	0.39	6.3
26	13.47	17.7	1.9	409	2.0	1.0	2.5	1.31	0.14	30.4
27	19.28	27.1	3.0	626	3.1	1.6	3.8	1.40	0.15	32.5
28	4.90	7.8	0.9	181	0.9	0.5	1.1	1.59	0.18	36.9
29	4.71	10.5	2.4	125	1.2	1.3	0.8	2.23	0.52	26.5
30	2.52	3.0	0.3	70	0.3	0.2	0.4	1.20	0.13	27.7
31	110.11	238.4	55.6	2,841	27.2	29.8	17.2	2.17	0.51	25.8
32	1.97	4.2	1.0	50	0.5	0.5	0.3	2.12	0.49	25.2
33	3.52	5.1	0.6	117	0.6	0.3	0.7	1.44	0.16	33.3
34	36.94	62.8	4.7	653	7.2	2.5	3.9	1.70	0.13	17.7
35	30.14	66.2	15.4	788	7.5	8.3	4.8	2.20	0.51	26.2
36	1.89	2.2	0.2	51	0.3	0.1	0.3	1.16	0.13	26.9
37	2.03	3.1	0.7	37	0.4	0.4	0.2	1.53	0.36	18.3
38	2.41	2.5	0.6	30	0.3	0.3	0.2	1.05	0.24	12.5
39	6.15	11.6	2.7	139	1.3	1.5	0.8	1.89	0.44	22.5
40	3.08	4.0	0.9	47	0.5	0.5	0.3	1.29	0.30	15.4
41	1.57	2.9	0.2	30	0.3	0.1	0.2	1.83	0.14	19.0
42	1.86	3.4	0.3	36	0.4	0.1	0.2	1.85	0.14	19.2
43	2.02	3.7	0.3	39	0.4	0.1	0.2	1.85	0.14	19.2
44	3.65	6.7	0.5	70	0.8	0.3	0.4	1.85	0.14	19.2
45	5.47	9.5	0.7	98	1.1	0.4	0.6	1.73	0.13	18.0
46	1.44	2.7	0.2	28	0.3	0.1	0.2	1.85	0.14	19.2
47	5.38	6.8	0.5	70	0.8	0.3	0.4	1.26	0.09	13.1
Overland Flow	77.08	65.1	11.3	1,272	7.4	6.1	7.7	0.85	0.15	16.5
TOTAL:	**561.50**	**877**	**187**	**16,564**	**100.0**	**100.0**	**100.0**	**1.57**	**0.29**	**39.0**

Areal loading rates > 50% above mean value

Estimates of the percentage of the total runoff loading are also provided for each of the sub-basin areas. The most significant runoff generated loadings to Lake Killarney appear to originate from Sub-basin 31 which contributes approximately 27.2% of the annual nitrogen loadings, 29.8% of the annual phosphorus loadings, and 17.2% of the annual TSS loadings from runoff to Lake Killarney. The magnitude of loadings discharged from this sub-basin into Lake Killarney is substantially larger than the loadings originating from any other sub-basin area, but this appears to be related to the large size of the sub-basin area in comparison with the other much smaller delineated sub-basin areas. The next most significant loadings appear to originate from Sub-basin 1 which contributes 8.2% of the total nitrogen, 6.5% of the total phosphorus, and 19.4% of the TSS loadings to Lake Killarney. The next most significant loadings to Lake Killarney appear to originate from Sub-basin 35, located on the southeast side of the lake, followed by overland flow and Sub-basin 34 which consists of the commercial areas near the intersection of Lee Road and Orlando Avenue. A relatively large contribution also occurs from Sub-basin 24, located on the southwest side of Lake Killarney, particularly for total phosphorus. Runoff contributions from each of the remaining sub-basin areas appear to be relatively minimal in terms of the overall loadings to the lake.

Calculated areal loadings, in terms of kg/ac-yr, are provided in the final columns of Table 5-5 for each sub-basin area. This calculation provides a comparison of generated runoff loadings in each of the sub-basin areas after normalization for the size of the basin. This process allows an evaluation of runoff loadings which are independent of the size of the watershed and is often useful in identifying "hot spots" for loadings within the basin. On an average annual basis, total nitrogen loadings within the Lake Killarney watershed are approximately 1.57 kg/ac-yr, with 0.29 kg/ac-yr of total phosphorus, and 39.0 kg/ac-yr of TSS. Sub-basin areas with areal loadings exceeding 50% of the mean areal loadings are highlighted in yellow in Table 5-5. Areas of substantially elevated nitrogen loadings are apparent in Sub-basins 7, 8, 9, and 15. Each of these sub-basins reflect residential areas discharging into the lake. Higher than average areal loadings of total phosphorus appear to occur in Sub-basins 7, 8, 9, 15, 24, 29, 30, 31, and 39. The majority of these sub-basin areas are also residential although some primarily commercial basins are also included. Elevated areal loadings of TSS are apparent in Sub-basins 1, 7, 8, 9, 11, 15, and 29. Most of these areas also reflect residential areas, although Sub-basin 1 includes the office and commercial areas along Lee Road.

5.1.3 Groundwater Seepage

5.1.3.1 Chemical Characteristics

Nutrient influx from groundwater seepage was quantified using a total of 30 underwater seepage meters in Lake Killarney. A discussion of the hydrologic inputs resulting from groundwater seepage is given in Section 4.1.3. Each of the collected groundwater seepage samples was analyzed in the ERD Laboratory for pH, alkalinity, conductivity, total nitrogen, and total phosphorus. A complete listing of laboratory measurements conducted on seepage samples at each of the 30 seepage monitoring sites is given in Appendix D.2

A tabular summary of mean chemical characteristics of seepage samples collected in Lake Killarney from July 2010-August 2011 is given on Table 5-6. The mean values listed in Table 5-6 reflect log-normal mean or geometric mean values since the data exhibit a log-normal distribution.

TABLE 5-6

MEAN CHARACTERISTICS OF GROUNDWATER SEEPAGE SAMPLES COLLECTED IN LAKE KILLARNEY FROM JULY 2010 - AUGUST 2011

SITE	NO. OF SAMPLES	pH (s.u.)	ALKALINITY (mg/l)	CONDUCTIVITY (μmho/cm)	TOTAL N (μg/l)	TOTAL P (μg/l)
1	6	7.58	200	585	7,991	592
2	5	7.62	195	456	5,280	208
3	7	7.77	196	475	4,399	233
4	5	7.47	106	270	1,033	43
5	3	7.83	245	543	9,865	736
6	3	7.04	112	338	3,109	54
7	7	7.81	229	456	4,965	61
8	7	7.19	67.8	435	3,082	84
9	5	7.51	150	400	1,323	152
10	7	7.38	124	306	3,265	234
11	7	7.74	161	395	4,905	362
12	6	7.79	94.8	238	1,399	91
13	7	7.75	160	434	8,974	859
14	7	7.72	147	376	8,451	802
15	7	7.56	173	424	5,342	460
16	7	7.52	185	476	8,970	652
17	7	7.61	188	495	8,642	1,219
18	7	7.61	207	532	9,570	1,504
19	6	7.66	138	383	7,804	1,148
20	7	7.90	193	529	7,566	1,029
21	6	7.76	207	464	4,612	366
22	6	7.65	89.7	244	1,614	116
23	6	7.23	105	282	3,555	168
24	3	7.55	108	266	3,544	124
25	3	7.36	100	290	2,023	188
26	1	7.13	123	294	1,386	407
27	2	7.64	112	313	2,622	335
28	2	7.59	92.5	256	1,869	178
29	2	7.25	124	295	3,128	158
30	6	7.15	116	291	3,213	414

In general, seepage collected from Lake Killarney was found to be approximately neutral in value, with mean pH values at the individual seepage monitoring sites ranging from 7.04-7.83. Mean alkalinity values in the collected seepage samples were moderate to high in value at the majority of the monitoring sites. Elevated levels of alkalinity measured in groundwater seepage may be an indication of deeper groundwater upwelling from limestone aquifers. Mean conductivity values in groundwater seepage ranged from 238-585 μmho/cm and at most sites was greater than values measured in the lake. Elevated conductivity values measured in groundwater seepage may indicate the presence of potential pollutant sources from either shallow or deeper groundwater.

Mean concentrations of total nitrogen in groundwater seepage were highly variable between the various monitoring locations, with mean concentrations ranging from 1033-9865 μg/l. A high degree of variability in total nitrogen concentrations is common in seepage samples. In general, the measured total nitrogen concentrations appear to be moderate to high in value compared with concentrations by ERD in other urban lakes. Measured concentrations of total phosphorus in groundwater seepage were extremely low in value in the seepage samples collected in Lake Killarney. Mean phosphorus concentrations measured at the seepage sites ranged from low to elevated, with 17 of the 30 sites exhibiting mean concentrations in excess of 200 μg/l. Seepage phosphorus concentrations entering Lake Killarney appear to be greater in value than seepage inflows measured by ERD in other Central Florida lakes.

Isopleths of mean pH values in groundwater seepage entering Lake Killarney from July 2010-August 2011 are illustrated on Figure 5-23. The most elevated seepage pH values were typically observed in perimeter portions of Lake Killarney, with lower pH values generally in areas of accumulated organic muck.

Isopleths of mean alkalinity values in groundwater seepage entering Lake Killarney from July 2010-August 2011 are illustrated on Figure 5-24. In general, measured alkalinity levels throughout the lake are greater in value than measurements commonly observed in seepage entering urban lakes. The most elevated alkalinity values occur primarily in perimeter portions of the lake, particularly along the northern, eastern, and southern portions of the lake. The lowest alkalinity values appear to occur primarily in central portions of Lake Killarney, although an area of low alkalinity is apparent on the southwest shoreline of the lake.

Isopleths of mean conductivity values in groundwater seepage entering Lake Killarney from July 2010-August 2011 are illustrated on Figure 5-25. In general, the most elevated levels of alkalinity appear to occur in perimeter portions of the lake, with lower conductivity values in central portions of the lake. Elevated conductivity values were measured on the perimeter of the lake and southern-central portion of the lake, where conductivity values in excess of 550 μmho/cm were observed. Values in this range are somewhat greater than conductivity values commonly observed in seepage entering urban lakes and suggests a significant introduction of dissolved ions through these areas.

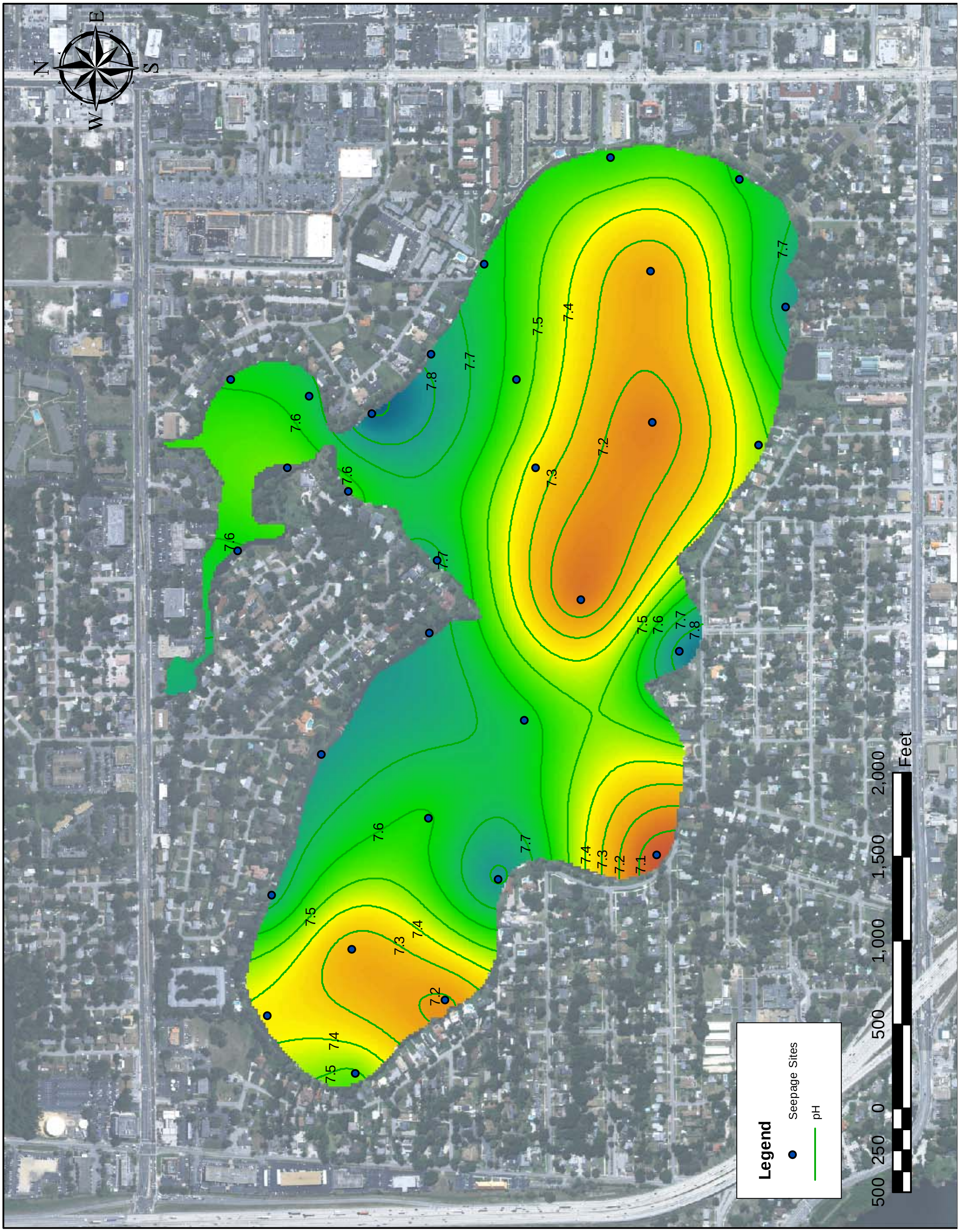


Figure 5-23. Isopleths of Mean pH Values in Groundwater Seepage Entering Lake Killarney from July 2010-August 2011.

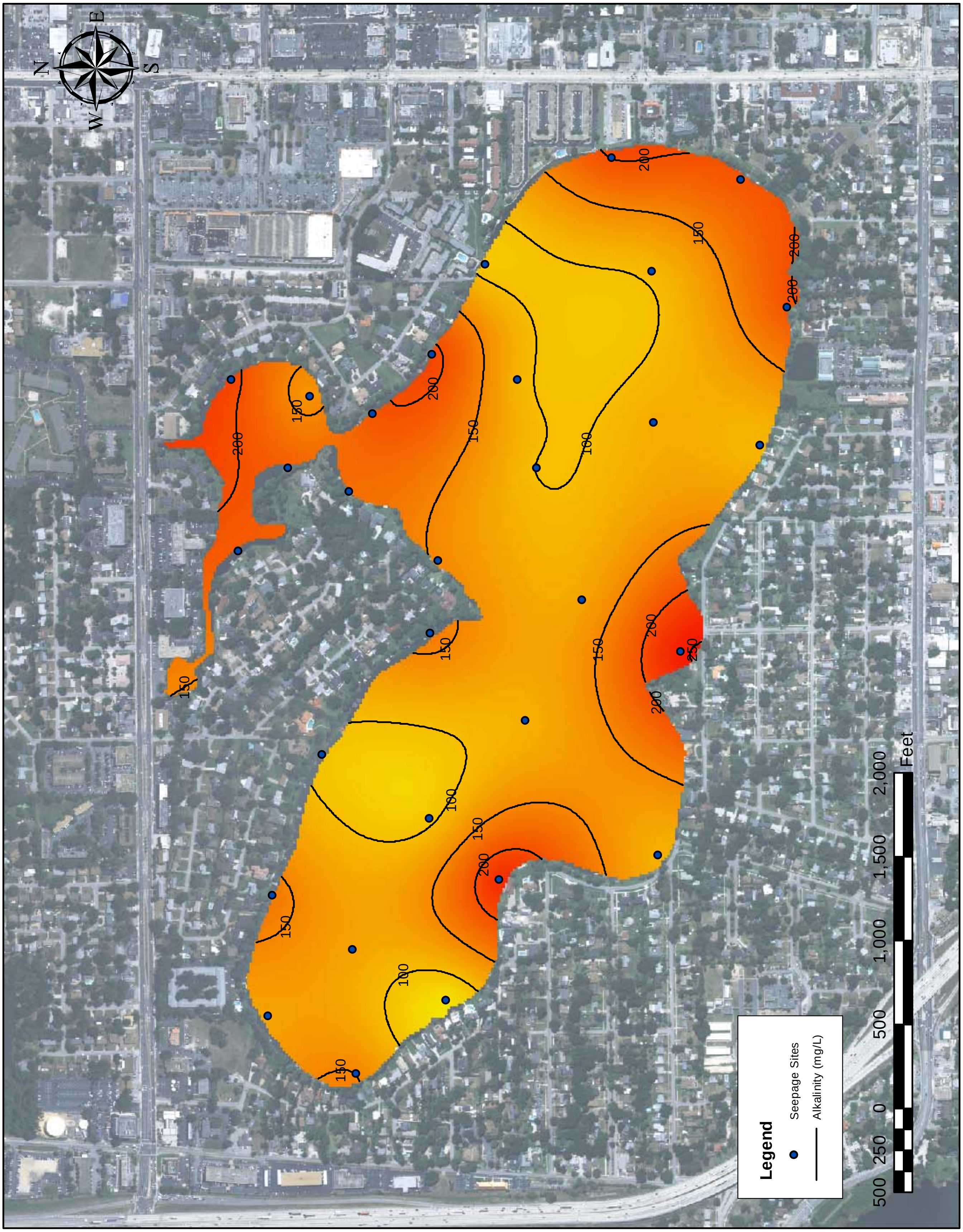


Figure 5-24. Isopleths of Mean Alkalinity Values in Groundwater Seepage Entering Lake Killarney from July 2010-August 2011.

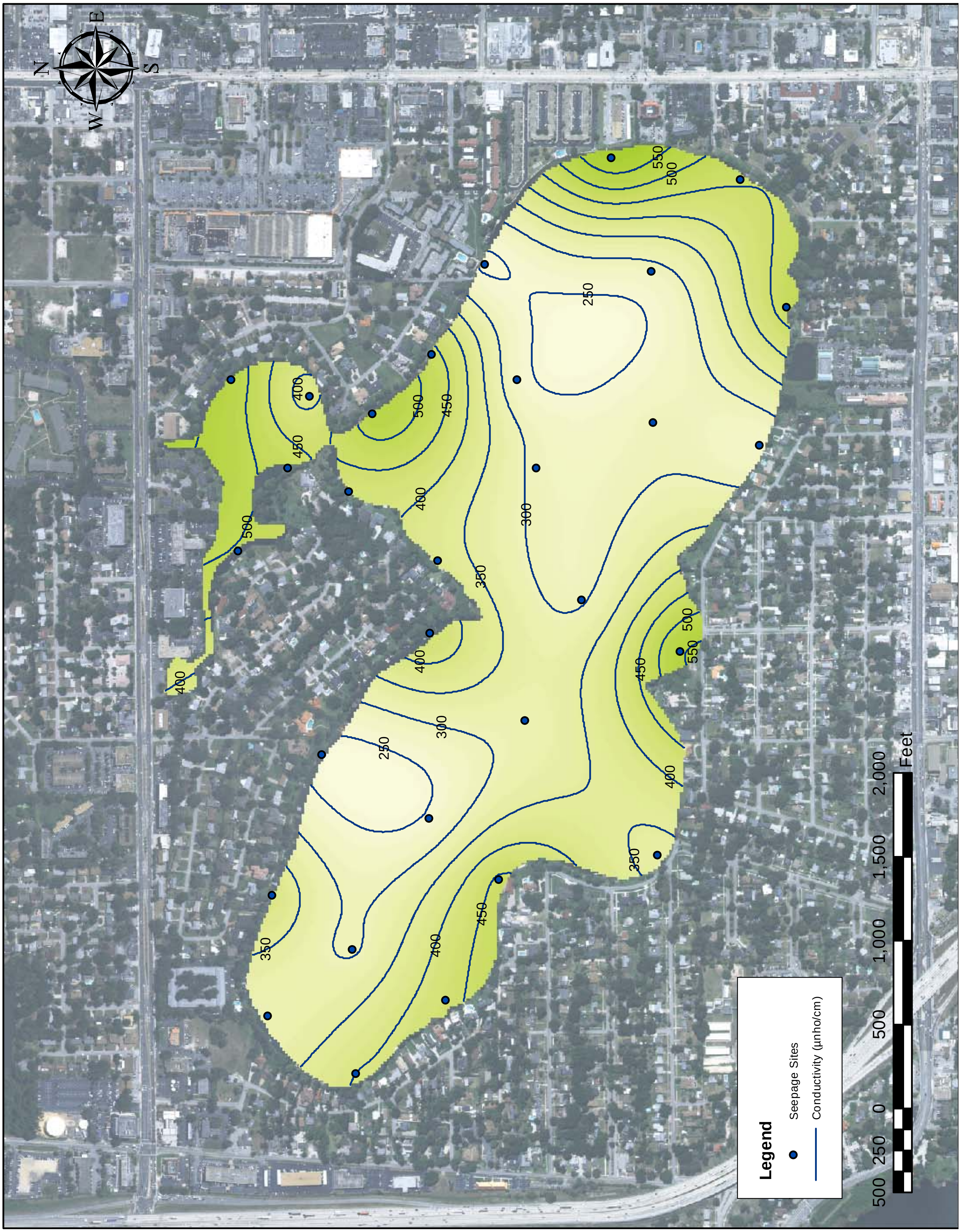


Figure 5-25. Isopleths of Mean Conductivity Values in Groundwater Seepage Entering Lake Killarney from July 2010-August 2011.

Isopleths of mean total nitrogen concentrations in groundwater seepage entering Lake Killarney from July 2010-August 2011 are illustrated on Figure 5-26. In general, the areas of elevated total nitrogen concentrations are similar to the areas of elevated conductivity values illustrated on Figure 5-25. The most elevated total nitrogen concentrations, with values exceeding 8,000-10,000 μg/l, were observed in the northern lobe and in the extreme eastern and central-southern portions of the lake. Mean seepage concentrations of total nitrogen in central and western portions of the lake were substantially lower in value and typical of concentrations commonly observed in urban lakes.

Isopleths of mean total phosphorus concentrations in groundwater seepage entering Lake Killarney from July 2010-August 2011 are illustrated on Figure 5-27. Similar to the trends observed for total nitrogen and conductivity, the most elevated levels of total phosphorus were observed in the northern lobe, eastern end of the lake, and northern- and southern-central portions of the lake, with seepage phosphorus concentrations in the remaining areas similar to concentrations commonly observed in urban lakes. Seepage inflow into the northern lobe contained extremely elevated phosphorus concentrations which frequently exceeded 1000 μg/l in the collected samples.

5.1.3.2 Mass Loadings

Mean seepage isopleths for nitrogen and phosphorus influx, in terms of μg/m^2-day, were generated by combining the concentration isopleths for total nitrogen and total phosphorus (illustrated on Figures 5-26 and 5-27) with the hydrologic isopleths for groundwater seepage (summarized on Figure 4-5). This procedure results in estimates of nutrient influx in terms of mass per square meter of lake surface per day. For purposes of this analysis, "influx" or "flux" is defined as the areal mass input or loading per unit of time.

Isopleths of mean seepage influx of total nitrogen into Lake Killarney from July 2010-August 2011 are illustrated on Figure 5-28. In general, nitrogen influx from groundwater seepage ranges from approximately 5,000-20,000 μg/m^2-day. The most elevated levels of nitrogen influx were observed in the southwestern shoreline of the lake as well as within the northern lobe. Mass influx of total nitrogen in other portions of the lake were typically equal to 5,000 μg/m^2-day or less.

Isopleths of mean seepage influx of total phosphorus into Lake Killarney from July 2010-August 2011 are illustrated on Figure 5-29. Extremely elevated levels of phosphorus influx occur in the northern lobe where phosphorus influx ranges from approximately 750-1,250 μg/m^2-day. Phosphorus influx from groundwater seepage in the remaining portions of Lake Killarney ranges from approximately 250-500 μg/m^2-day.

The isopleths summarized on Figures 5-28 and 5-29 were integrated to develop estimates of the total influx of nitrogen and phosphorus from groundwater seepage into Lake Killarney during the field monitoring program from July 2010-August 2011. A summary of estimated annual mass loadings of total nitrogen and total phosphorus to Lake Killarney from groundwater seepage is given in Table 5-7. On an average annual basis, groundwater seepage contributes approximately 1,253 kg/yr of total nitrogen and 81 kg/yr of total phosphorus to Lake Killarney.

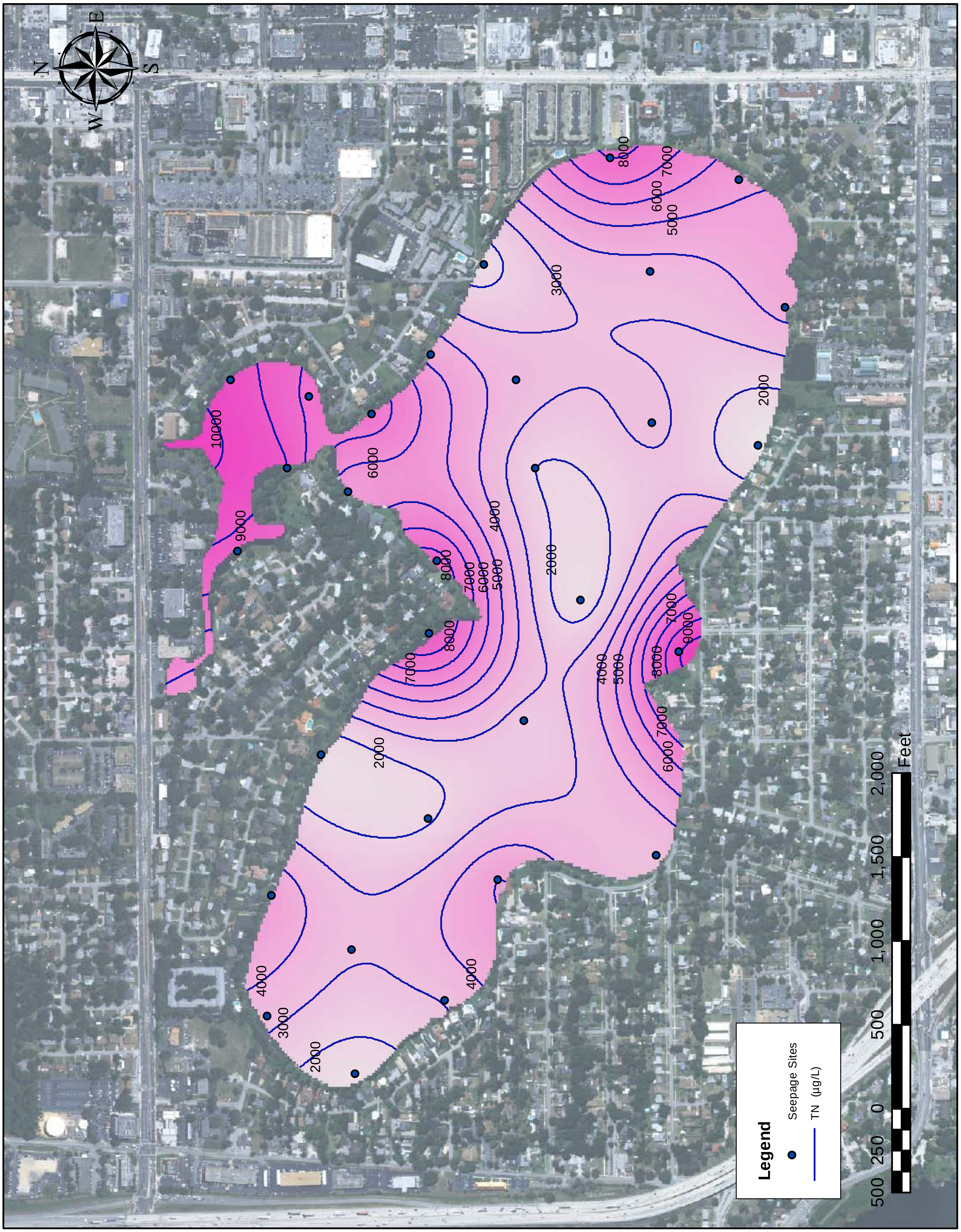


Figure 5-26. Isopleths of Mean Total Nitrogen Values in Groundwater Seepage Entering Lake Killarney from July 2010-August 2011.

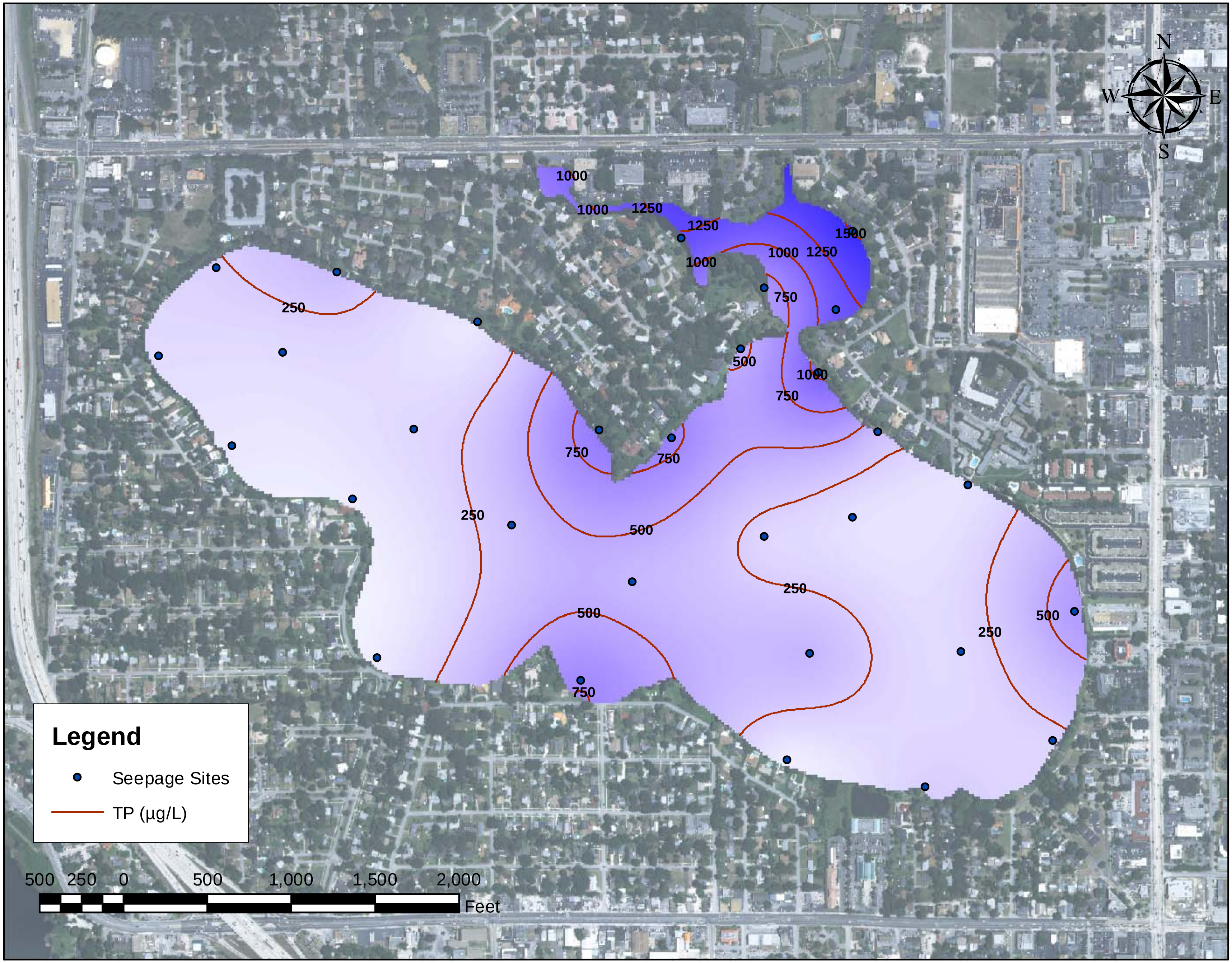


Figure 5-27. Isopleths of Mean Total Phosphorus Values in Groundwater Seepage Entering Lake Killarney from July 2010-August 2011.

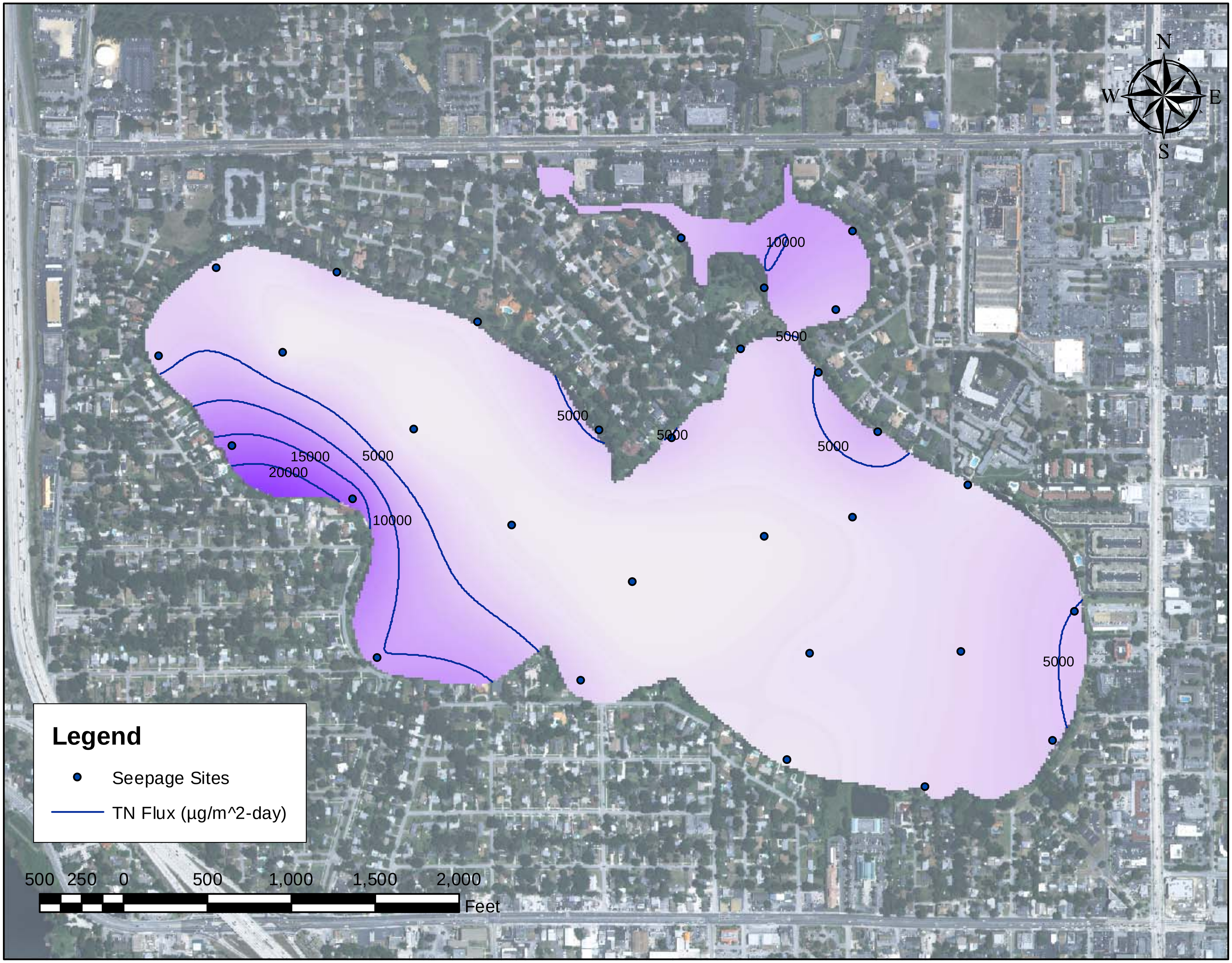


Figure 5-28. Isopleths of Mean Total Nitrogen Influx Values in Groundwater Seepage Entering Lake Killarney from July 2010-August 2011.

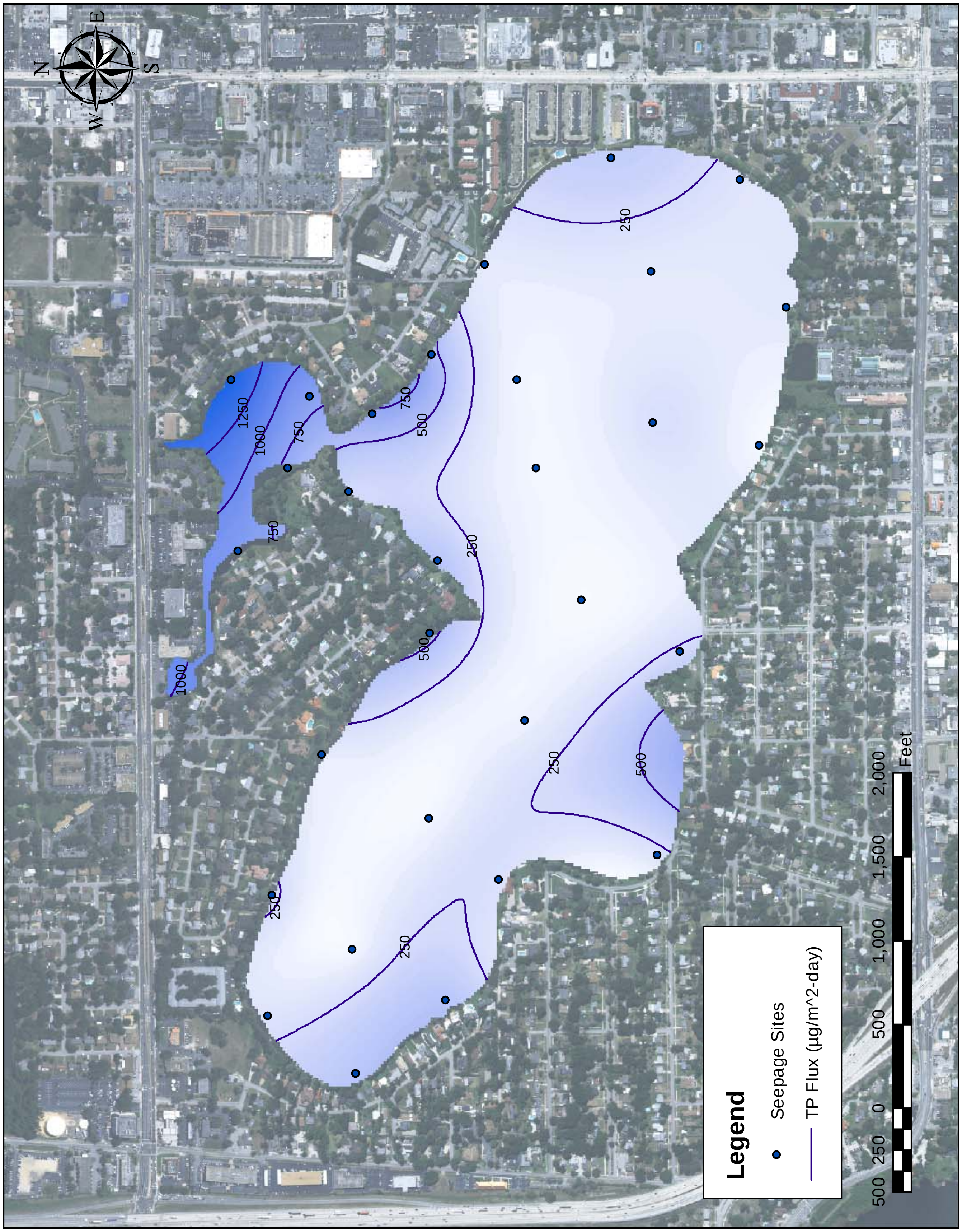


Figure 5-29. Isopleths of Mean Total Phosphorus Influx Values in Groundwater Seepage Entering Lake Killarney from July 2010-August 2011.

TABLE 5-7

ESTIMATED ANNUAL MASS LOADINGS TO LAKE KILLARNEY FROM GROUNDWATER SEEPAGE

TOTAL N			TOTAL P			AREAL LOADING (kg/ac-yr)	
μg/m²-day	**g/day**	**kg/yr**	**μg/m²-day**	**g/day**	**kg/yr**	**Total N**	**Total P**
3,538	3,433	1,253	288	221	81	5.23	0.338

Calculated areal loadings of groundwater seepage are provided in the final columns of Table 5-7 which reflect the mass influx divided by the lake surface area. These values provide a way of comparing seepage loadings between lakes without consideration of lake size. The mean total nitrogen areal loading to Lake Killarney is approximately 5.23 kg/ac-yr, with an areal phosphorus loading of 0.338 kg/ac-yr. The areal total nitrogen rate is similar to values commonly observed in Central Florida urban lakes, while the areal loading rate for total phosphorus appears to be somewhat more elevated.

5.1.4 <u>Internal Recycling</u>

Quantification of sediment phosphorus release as a result of internal recycling in lakes is difficult, and a variety of methods have been used by researchers to obtain this estimate. One method which has been used in reservoirs is called the Mass Balance Method. This method is best suited to a waterbody with well defined inputs and outputs. A mass balance is then conducted on the waterbody over a one- to two-week period. An increase of phosphorus mass within the lake, after accounting for inputs and losses, would suggest that a net internal loading has occurred. However, this method appears inappropriate for use in Lake Killarney since the lake is impacted by a wide variety of hydrologic and pollutant sources.

A method which has been used extensively in deep northern lakes is to measure changes in phosphorus content in the hypolimnion of a stratified lake over an extended period of anoxia. The increase in phosphorus mass within the stratified hypolimnion can then be directly correlated with sediment release rates. However, this method also appears inappropriate for use in Lake Killarney since the lake is relatively shallow, and although a well defined hypolimnion may develop, circulation events may be relatively common.

A third method of quantifying the internal loadings is through trophic state modeling. Using this approach, hydrologic and nutrient inputs are estimated from all quantifiable sources. A trophic state model is then developed to predict water column concentrations of total phosphorus. If the model underestimates phosphorus concentrations, then a missing phosphorus load may be present which can be attributed to internal recycling. However, this methodology can be highly inaccurate and is dependent upon the accuracy of the estimated loadings for other variables.

The final method used for quantification of internal loadings is to perform sediment nutrient release experiments. In this method, large diameter sediment cores are collected from various locations within the lake and incubated in the laboratory under a variety of conditions to simulate variability in the lake throughout the year. Changes in phosphorus concentrations are measured in the overlying sediments, and this information is extrapolated to an areal release rate within the lake. This is the only method of estimating internal loadings which provides a direct measurement of phosphorus release. This method has been used by ERD on multiple occasions in previous work efforts and was selected as the quantification method for Lake Killarney.

Field and laboratory investigations were performed by ERD to quantify the mass of phosphorus released as a result of internal recycling from the sediments to the overlying water column in Lake Killarney under both aerobic and anoxic conditions. Large diameter lake sediment core samples were collected at multiple locations in the lake and incubated under anoxic and aerobic conditions. Periodic measurements of orthophosphorus and other water quality parameters were used to estimate sediment phosphorus release under the evaluated conditions. This information is used to provide an estimate of the significance of mass loadings of phosphorus from lake sediments as part of the overall nutrient budget for the lake.

5.1.4.1 Field and Laboratory Procedures

Sediment core samples were collected at 4 locations in Lake Killarney using 4-inch diameter clear acrylic core tubes. Locations used for collection of the sediment core tubes are indicated on Figure 5-30. Water depths at each site are also provided for reference purposes. In general, the sample locations reflect the major lobe areas of the lake. Each of the acrylic tubes was driven into the sediments to the maximum possible depth using a large sledge hammer. A 4-inch x 4-inch wooden beam was placed on top of the acrylic core tube to evenly distribute the force of each sledge hammer blow and to prevent direct contact between the sledge hammer and the acrylic tube.

The acrylic tubes were penetrated into the sediments to depths ranging from approximately 2-6 ft, depending upon the physical characteristics of the sediments at each of the selected monitoring sites or until a firm bottom material was encountered. Each of the core tubes was retrieved intact, along with the overlying water column present at each of the collection sites. Upon retrieval, a rubber cap was attached to the bottom of each core tube to prevent loss of sediments. The collected water volume above the trapped sediments was carefully siphoned off until a water depth of 18 inches remained in each of the collected columns above the sediment-water interface. Each of the acrylic core tubes was then cut at a uniform height of 6 inches above the water level, leaving a 6-inch air space between the water level and the top of the column. A 4-inch PVC cap was then placed on the top of each collected core tube. Each of the collected core tubes was then returned to the ERD laboratory for incubation experimentation. All samples were transported to the ERD laboratory in a vertical position to avoid mixing of the sediment layers.

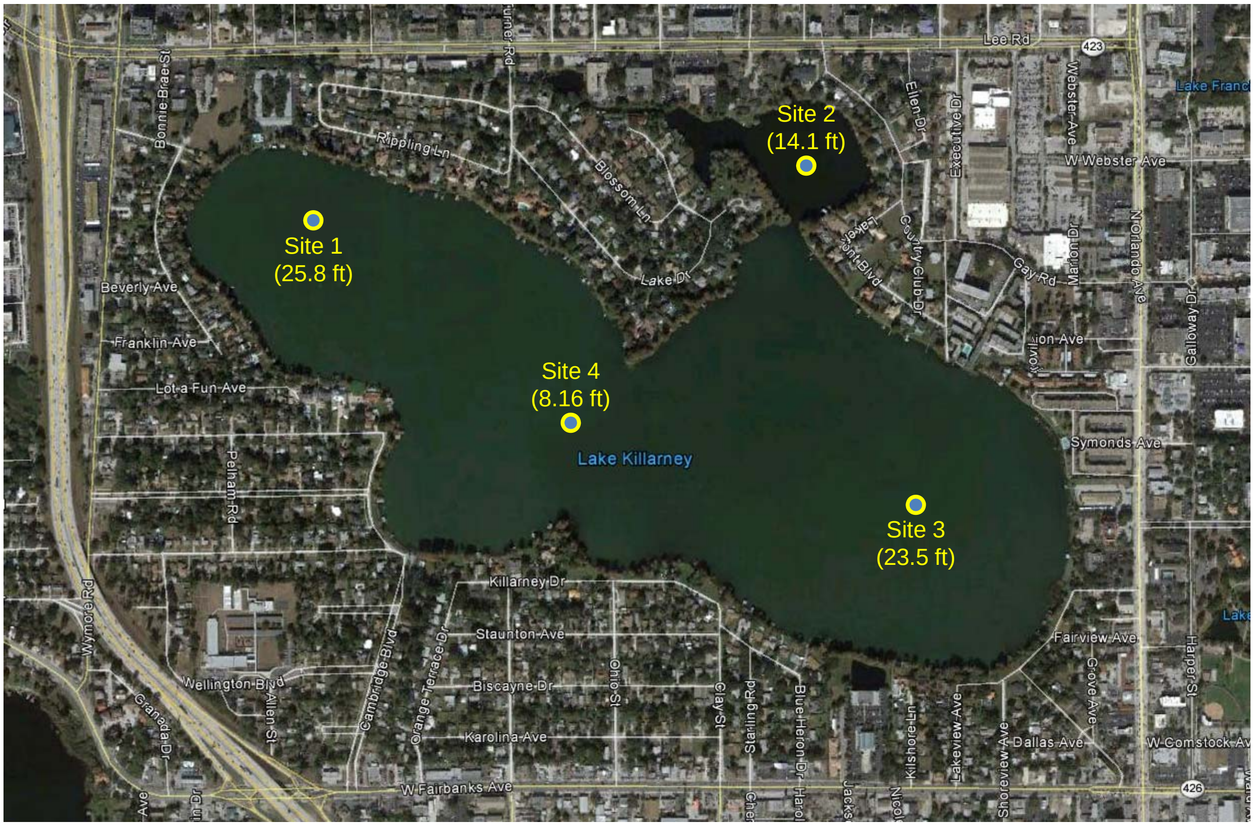


Figure 5-30. Locations for Collection of Large Core Samples in Lake Killarney.
(Water depths indicated in parentheses)

After return to the laboratory, each of the four collected core samples was attached to a laboratory work bench in a vertical position. Two separate 0.25-inch diameter holes were then drilled into the PVC cap attached to the top of each core sample. A 0.25-inch diameter semi-rigid polyethylene tube was inserted through one of the holes to a depth of approximately 2-3 inches above the sediment surface. An air stone diffuser was attached to the end of the tubing inside each core tube. This system was used to introduce selected gases into the core tubes to encourage aerobic or anoxic conditions.

A separate piece of polyethylene tubing was inserted into the second hole in the top of each core tube, approximately 1 inch below the level of the cap, but well above the water level contained in each tube. The other end of the tubing was connected to a water trap to minimize loss of water from each column as a result of evaporation. This tubing also provided a point of exit for gases which were bubbled into each core tube. A schematic of the sediment incubation apparatus is given in Figure 5-31.

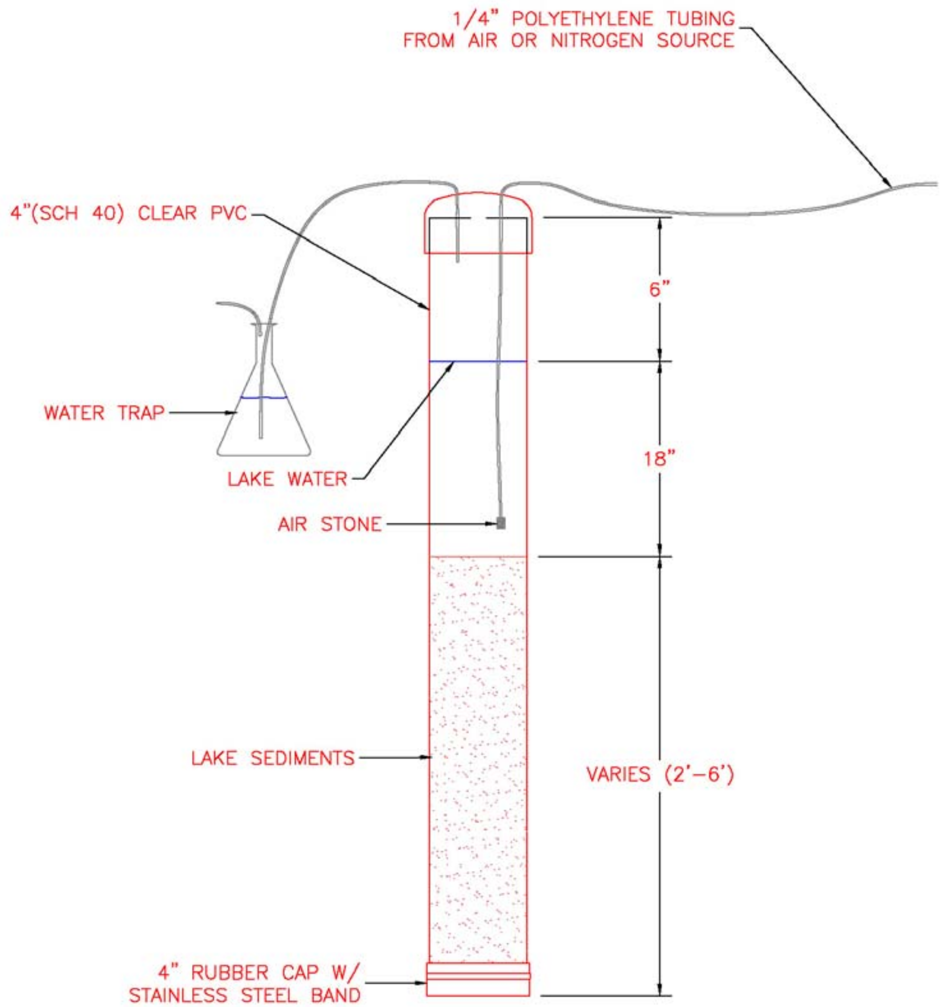


Figure 5-31. Schematic of Sediment Incubation Apparatus.

After initial set-up of the incubation apparatus, a compressed stream of nitrogen gas was introduced into each of the core tubes through the individual air stone diffusers. This process quickly created anoxic conditions within each of the core tubes. After anoxic conditions were established, as verified by an H_2S smell in the outflow from the water trap, the nitrogen gas addition was reduced to 1-2 hours per day, generally in association with a sampling event to ensure completely mixed conditions within the tube. This process was continued in each of the core tubes for a period of approximately 32 days. The gas addition was used to ensure that water within each of the core tubes was well mixed without disturbing the sediments, so that phosphorus released from the sediments could be quantified as a function of changes in phosphorus concentrations within the water column of each core tube. On approximately a 1-2 day interval, 20 ml of water was withdrawn from each of the columns using a 0.25-inch polyethylene tube and a plastic laboratory syringe. Each of the collected samples was immediately filtered using a 0.45 micron syringe type membrane filter and analyzed for orthophosphorus, total phosphorus, total nitrogen, and other significant laboratory parameters for research purposes.

At the conclusion of the experimentation under anoxic conditions, the compressed nitrogen source was replaced with a compressed air source. Compressed air was gently bubbled through each of the columns to increase dissolved oxygen and create aerobic conditions within each tube. In general, creation of aerobic conditions, as indicated by measurements of redox potential (> 200 mv) within each of the columns, occurred after approximately 5-7 days. At the onset of aerobic conditions, sample collection was conducted at a 1-2 day interval from each of the 4 columns for a period of 30 days using the method previously outlined for anoxic conditions.

Collection of the large diameter (4-inch) sediment core samples was conducted on May 20, 2011. Experimentation under anoxic conditions was conducted in each core tube for a period of 32 days. Aerobic experimentation was initiated at the end of the anoxic experiments and was continued for a period of 30 days.

5.1.4.2 Laboratory Results

A summary of the laboratory results of samples collected during the testing period is given in Appendix F.1. Graphical comparisons of phosphorus release from the isolation chamber experiments under aerobic and anoxic conditions are given in Appendix F.2. Changes in phosphorus concentrations over time are provided for each of the isolation chamber experiments under both aerobic and anoxic conditions. Concentrations of both SRP and total phosphorus increased steadily during the first 20-25 days of the isolation chamber experiments under both aerobic and anoxic conditions, followed by a general decline in concentrations after this time. Phosphorus release occurred under both aerobic and anoxic conditions, but the release of both SRP and total phosphorus was about 50% higher under anoxic conditions than aerobic conditions.

5.1.4.3 Mass Release

The results of the phosphorus release experiments discussed in the previous section were extrapolated to estimate sediment phosphorus release from Lake Killarney on an annual basis. The first step in this extrapolation process is to develop estimates of sediment release rates within each of the incubation chambers. The phosphorus release rate in the incubation experiments is defined as the slope of the rising limb of the SRP and total phosphorus release plots presented in Appendix F.2. In some chambers, an initial delay in phosphorus release occurred as anoxic or aerobic conditions were established within each chamber. In these cases, the release rate is calculated using the data obtained between the start of the upward release trend and the maximum phosphorus concentrations measured within a sample. In some experiments, phosphorus concentrations began to decrease after reaching the maximum concentration, presumably due to biological uptake within the chamber. These data are also excluded from estimation of the release rate. Regression relationships developed for estimation of sediment phosphorus release rates in the incubation experiments under aerobic and anoxic conditions are also included in Appendix F.2.

Estimates of the areal extent and frequency of aerobic and anoxic conditions within the sediments of Lake Killarney were obtained from the vertical field profiles conducted in the lake by ERD from August 2010-July 2011. These profiles (summarized in Figures 2-21 through 2-23) provide seasonal patterns of dissolved oxygen concentrations throughout each lobe of the lake. The percentage of events indicating anoxic conditions at the water-sediment interface were calculated for each of the field monitoring sites and used to estimate the seasonal distribution of aerobic and anoxic conditions throughout the lake.

A summary of calculated sediment phosphorus release rates during the isolation chamber experiments is given in Table 5-8. Phosphorus release rates are provided for each of the 4 isolation chamber core samples under both aerobic and anoxic conditions, with individual release rates provided for SRP, total phosphorus, and total nitrogen. The release rates reflect the slope of the SRP, total phosphorus, and total nitrogen release rate plots provided in Appendix F.2. The calculated release rates are converted into a mass release per day by multiplying by the surface area of the 4-inch diameter incubation chambers. This mass release is then converted into an areal mass release in terms of mg/m^2-day. Under aerobic conditions, the mean mass release rate for total phosphorus in the four core tubes ranged from 1.48-4.13 mg/m^2-day, with the highest release at Site 1 and lowest at Site 4. Under anoxic conditions, the mass release rates increased substantially, ranging from 3.76-4.83 mg/m^2-day, with the highest release at Site 2 and the lowest release at Site 4.

TABLE 5-8

CALCULATED SEDIMENT PHOSPHORUS RELEASE RATES DURING THE ISOLATION CHAMBER EXPERIMENTS

CONDITION	SITE	MASS PHOSPHORUS RELEASE (μg/day)			MASS RELEASE (mg/m^2-day)		
		SRP	Total P	Total N	SRP	Total P	Total N
Aerobic	1	13.4	33.0	139	1.68	4.13	17.4
	2	19.8	20.6	121	2.48	2.58	15.1
	3	5.34	13.1	98.6	0.67	1.64	12.3
	4	2.98	11.8	71.5	0.37	1.48	8.9
Mean	**--**	**10.4**	**19.6**	**108**	**1.30**	**2.45**	**13.4**
Anoxic	1	9.15	33.6	58.5	1.14	4.20	7.31
	2	29.3	38.6	453	3.66	4.83	56.6
	3	31.3	32.3	95.4	3.91	4.04	11.9
	4	9.71	30.1	103	1.21	3.76	12.9
Mean	**--**	**19.9**	**33.7**	**178**	**2.48**	**4.21**	**22.2**

A summary of calculated annual mass sediment phosphorus release in each of the large diameter core samples is given in Table 5-9. The release is calculated using the mass release rates summarized on Table 5-8 for each of the 4 isolation chamber sites which is weighted by the fraction of aerobic and anoxic conditions assumed to occur in the vicinity of the collection site for each large diameter core tube, based upon the vertical field profiles collected by ERD from August 2010-July 2011, summarized in Section 2. For example, the core sample collected at Site 1 is located in the western lobe of the lake which exhibited anoxic conditions at the water-sediment interface during 8 of the 12 monthly monitoring events conducted by ERD from August 2010-July 2011, reflecting approximately 67% of the annual period, with aerobic conditions observed during 4 of the 12 events (33%). A similar pattern was observed in the north lobe which is reflected by the core sample identified as Site 2. Therefore, for Site 2, anoxic conditions are also assumed during approximately 67% of the year with aerobic conditions during 33%.

TABLE 5-9

CALCULATED ANNUAL SEDIMENT RELEASE OF TOTAL PHOSPHORUS AND TOTAL NITROGEN IN LAKE KILLARNEY

SITE	AREA	FREQUENCY OF CONDITION (%)		WEIGHTED RELEASE (mg/m^2-day)			ASSUMED AREA (acres)	MASS RELEASE (kg/yr)		
		Aerobic	Anoxic	SRP	Total P	Total N		SRP	Total P	Total N
1	West Lobe	33	67	1.3	4.2	10.6	37.5	73.1	231	589
2	North Lobe	33	67	3.3	4.1	42.9	13.9	67.4	84.1	885
3	East Lobe	0	100	3.9	4.0	11.9	37.5	217	224	66
4	Center	100	0	0.4	1.5	8.9	150.7	82.9	328	1,990
Log-Normal Mean:				**1.58**	**3.17**	**14.9**	**239.6**	**440**	**868**	**4,125**

Core sample Site 3 is located in the eastern lobe of Lake Killarney which exhibited anoxic conditions near the water-sediment interface during each of the 12 monthly monitoring events. Therefore, the frequency of anoxic conditions at Site 3 is assumed to be 100%, with 0% assumed for aerobic conditions. Site 4 is located in central portions of Lake Killarney where water depths range from approximately 8-10 ft. Vertical profiles were not collected at this site as part of the monitoring conducted by ERD. However, based upon the vertical field profiles collected in other portions of Lake Killarney, aerobic conditions were maintained throughout the year to depths which exceed the water depths within the central portions of the lake. Therefore, aerobic conditions are assumed to exist 100% of the time in this portion of the lake, with no anoxic conditions assumed.

The measured aerobic and anoxic release rates are weighted by the estimated frequency of occurrence of aerobic and anoxic conditions to get estimates of mean annual release of SRP, total phosphorus, and total nitrogen within each core tube. Overall, the log-normal mean SRP release rate in the large diameter core samples is approximately 1.58 mg/m^2-day, with a weighted total phosphorus release of 3.17 mg/m^2-day and a weighted total nitrogen release of 14.9 mg/m^2-day.

As indicated on Figure 5-30, large diameter sediment core samples collected at Sites 1 and 3 reflect center portions of the western and eastern lobes, respectively. As seen on Figure 2-3, the core samples were collected in areas with deep accumulations of organic muck and are assumed to reflect release rates from areas with deep muck deposits within Lake Killarney. Based upon the muck depth contours summarized on Figure 2-3, areas in the eastern and western lobes of Lake Killarney with muck accumulations of 1 ft or greater cover an area of approximately 75 acres. Core sample Site 2 is located in the north lobe of the lake and is assumed to reflect sediment release rates throughout the northern lobe which covers approximately 13.9 acres of Lake Killarney. The center monitoring site (Site 4) is assumed to reflect release rates for areas in Lake Killarney with muck accumulations of 1 ft or less. The release rates measured at Site 4 are assumed to reflect the remaining acreage which is left after subtracting the 75 acres represented by the east and west lobe core sites and the 13.9 acres included in the northern lobe, approximately 150.7 acres of Lake Killarney.

The weighted sediment release rates summarized in the middle column of Table 5-9 are assumed to reflect release rates within each of the lake areas described previously. The weighted release rates for the west and east lobes are assumed to reflect a total of approximately 75 acres of Lake Killarney. For purposes of this analysis the area is split evenly between the west and north lobe, resulting in an estimated area of 37.5 acres which exhibit release rates measured in the west lobe core sample (Site 1) and 37.5 acres which exhibit release rates measured in the east lobe core sample (Site 3). Release rates measured in the north lobe (Site 2) are assumed to reflect release rates in 13.9 acres of Lake Killarney. The sediment release rates measured in the center portion of the lake area (Site 4) are assumed to reflect release rates in all remaining areas of Lake Killarney which is equivalent to approximately 150.7 acres. These assumed areas are multiplied by the weighted areal release rates summarized in the middle columns of Table 5-9 to obtain estimates of the total release within each of the identified areas on an annual basis. A summary of the results of this analysis is given in the final columns of Table 5-9.

Final estimates of annual mass release of nitrogen and phosphorus from the sediments in Lake Killarney are given at the bottom of Table 5-9. Based upon the core sample experiments, the sediments of Lake Killarney release approximately 440 kg/yr of SRP, 868 kg/yr of total phosphorus, and 4,125 kg/yr of total nitrogen. However, the measured SRP release rates probably under-estimate the sediment release which occurs within the lake since other forms of phosphorus are released from sediments in addition to SRP, and a portion of the released SRP is likely utilized by biological activity within the isolation chambers. In contrast, the measured annual total phosphorus release probably overestimates phosphorus release from Lake Killarney since the total phosphorus measured in the core chamber experiments also includes biological growth which occurred within the isolation chambers as a result of uptake of SRP. In reality, the actual sediment phosphorus release in Lake Killarney probably lies somewhere between the listed annual loadings for SRP and total phosphorus. Therefore, for purposes of estimating nutrient loadings to Lake Killarney, the annual sediment phosphorus release is assumed to be the mean of the mass release of SRP (440 kg/yr) and total phosphorus (868 kg/yr) which is equivalent to approximately 654 kg/yr.

5.1.5 <u>Inputs from Interconnected Lakes</u>

In addition to the mass loading inputs discussed previously, Lake Killarney also receives loadings as a result of the identified inflows from Lake Bell and Lake Mendsen. Estimates of mass loadings discharging to Lake Killarney from these sources were calculated by multiplying the estimated annual volumetric inflows (summarized in Table 4-12) times assumed water quality characteristics for each inflow. The water quality characteristics of inflows from Lake Mendsen were measured directly as part of this project and were previously summarized in Table 5-3.

The chemical characteristics of inflows from Lake Bell were not measured as part of this project. As a result, estimates of the mean chemical characteristics of discharges from Lake Bell were obtained from water quality monitoring conducted in Lake Bell from 2000-2011. Information on historical water quality monitoring in Lake Bell was obtained from the Orange County Water Atlas and measured concentrations of total nitrogen and total phosphorus were averaged over the period from 2000-2011 to reflect relatively recent water quality characteristics. A summary of the results of this process is given in Table 5-10. Over the period from 2000-2011, Lake Bell has been characterized by a mean total nitrogen concentration of 660 μg/l, with a total phosphorus of 27 μg/l. These concentrations are assumed to be representative of the characteristics of inflows into the north lobe of Lake Killarney from Lake Bell.

TABLE 5-10

MEAN CHEMICAL CHARACTERISTICS OF LAKE BELL FROM 2000-2011 (Source: Orange County Water Atlas)

PARAMETER	UNITS	MEAN VALUE (2000-2011)
Total N	μg/l	660
Total P	μg/l	27

A summary of estimated annual mass loadings of total nitrogen and total phosphorus from Lake Bell and Lake Mendsen to Lake Killarney is given in Table 5-11. On an average annual basis, Lake Bell contributes approximately 396 kg/yr of total nitrogen and 16.2 kg/yr of total phosphorus to Lake Killarney. Lake Mendsen contributes approximately 423 kg/yr of total nitrogen and 21.8 kg/yr of total phosphorus to Lake Killarney. This information is used in a subsequent section to develop overall nutrient budgets for Lake Killarney.

TABLE 5-11

ESTIMATED ANNUAL MASS LOADINGS OF TOTAL NITROGEN AND TOTAL PHOSPHORUS FROM LAKE BELL AND LAKE MENDSEN TO LAKE KILLARNEY

SOURCE	ANNUAL INFLOW (ac-ft/yr)	ASSUMED INFLOW CONCENTRATION (μg/l)		MASS LOADING (kg/yr)	
		Total N	Total P	Total N	Total P
Lake Bell	486	660	27	396	16.2
Lake Mendsen	361	951	49	423	21.8

5.2 <u>Nutrient Losses</u>

Nutrient losses from Lake Killarney occur primarily as a result of discharges to the drainage wells and through the lake outfall structure. Pollutant mass which is not discharged to the drainage wells and the outfall structure is assumed to accumulate into the sediments of the lake. Estimates of the magnitude of losses through the lake outfall structure are given in the following sections.

5.2.1 Drainage Wells/Outfall Structure Discharges

5.2.1.1 Chemical Characteristics of Drainage Wells/Outfall Discharges

Chemical characteristics of discharges from Lake Killarney through the drainage wells and outfall structure are assumed to be similar to historical water quality characteristics in Lake Killarney. A summary of historical water quality characteristics of Lake Killarney from 2000-2010 is given in Table 5-12 based on the information provided in Table 2-9. The period from 2000-2010 is used to reflect relatively current water quality characteristics within the lake. Characteristics of discharges to the drainage wells and the Lake Killarney outfall are assumed to be equivalent to the values summarized in Table 5-12.

TABLE 5-12

MEAN WATER COLUMN CHARACTERISTICS OF LAKE KILLARNEY FROM 2000-2010

TOTAL N (μg/l)	TOTAL P (μg/l)	TSI (mg/l)
729	18	2.3

5.2.1.2 Mass Loadings

Calculated mass losses to the drainage wells and the outfall structure for Lake Killarney are summarized in Table 5-13. These values were obtained by multiplying the mean water column characteristics (summarized in Table 5-12) times the mean annual volumetric discharges to the drainage wells and the outfall structure (summarized in Table 4-13). Mass losses to the drainage wells remove approximately 1452 kg of total nitrogen, 35.9 kg of total phosphorus, and 4581 kg of TSS from Lake Killarney each year. No significant mass discharges are assumed to occur through the outfall structure.

TABLE 5-13

CALCULATED MEAN ANNUAL MASS LOSSES FROM LAKE KILLARNEY TO THE DRAINAGE WELLS AND THE OUTFALL STRUCTURE

SOURCE	DISCHARGE VOLUME (ac-ft)	MASS LOSS (kg/yr)		
		Total N	Total P	TSS
Drainage Wells	1,615	1,452	35.9	4,581
Outflow to Lake Gem	0	0	0	0
Total:	**1,615**	**1,452**	**35.9**	**4,581**

5.3 Mean Annual Mass Budgets

Estimated mean annual mass budgets were developed for total nitrogen, total phosphorus, and TSS entering Lake Killarney based upon the analyses presented in the previous sections. A summary of estimated mass inputs and losses to Lake Killarney is given in the following sections.

5.3.1 Mass Inputs

A summary of estimated mean annual mass loadings of total nitrogen, total phosphorus, and TSS to Lake Killarney is given in Table 5-14 based upon the assumptions and analyses presented in previous sections. The dominant source of nitrogen loadings to Lake Killarney appears to be internal recycling which contributes approximately 51% of the annual nitrogen loadings to the lake. Inflows from groundwater seepage contribute approximately 16% of the annual total nitrogen loadings, with 12% contributed by bulk precipitation and 10% by stormwater runoff. Nitrogen loadings from overland flow, and inflows from Lake Mendsen and Lake Bell are relatively minimal on an annual basis.

TABLE 5-14

ESTIMATED MEAN ANNUAL MASS LOADINGS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND TSS TO LAKE KILLARNEY

SOURCE	TOTAL NITROGEN		TOTAL PHOSPHORUS		TSS	
	kg/yr	% of Total	kg/yr	% of Total	kg/yr	% of Total
Precipitation	967	12	84	8	5,667	20
Runoff	812	10	175	17	15,292	54
Overland Flow	65.1	1	11.3	1	1,272	4
Groundwater Seepage	1,253	16	81	8	0	0
Lake Mendsen	423	5	22	2	3,295	12
Lake Bell	396	5	16	1	2,997	10
Recycling	4,125	51	654	63	0	0
Total:	**8,041**	**100**	**1,043**	**100**	**28,522**	**100**

Internal recycling appears to be the largest phosphorus input to Lake Killarney on an annual basis, contributing 63% of the estimated annual loadings. Approximately 17% is contributed by stormwater runoff, with 8% each by bulk precipitation and groundwater seepage. Phosphorus loadings from overland flow and inflows from Lake Mendsen and Lake Bell are relatively minimal.

The dominant source of TSS loadings to Lake Killarney originates from stormwater runoff which contributes 54% of the annual loadings. Approximately 20% of the annual TSS loadings are contributed by bulk precipitation, with 12% from Lake Mendsen and 11% from Lake Bell. This analysis assumes that no significant inputs of TSS are generated as a result of groundwater seepage or internal recycling.

5.3.2 Mass Losses

A summary of estimated mass losses of total nitrogen, total phosphorus, and TSS from Lake Killarney is given on Table 5-15. The vast majority of inputs of nitrogen, phosphorus, and TSS accumulate primarily within the sediments of the lake, with 82% of the annual nitrogen loadings, 97% of the annual phosphorus loadings, and 84% of the annual TSS loadings retained within the sediments. The remaining loadings of nitrogen, phosphorus, and TSS which are not retained within the sediments are assumed to discharge to the drainage wells. A graphical comparison of estimated annual mass inputs and losses for total nitrogen, total phosphorus, and TSS in Lake Killarney is given on Figures 5-32, 5-33, and 5-34, respectively.

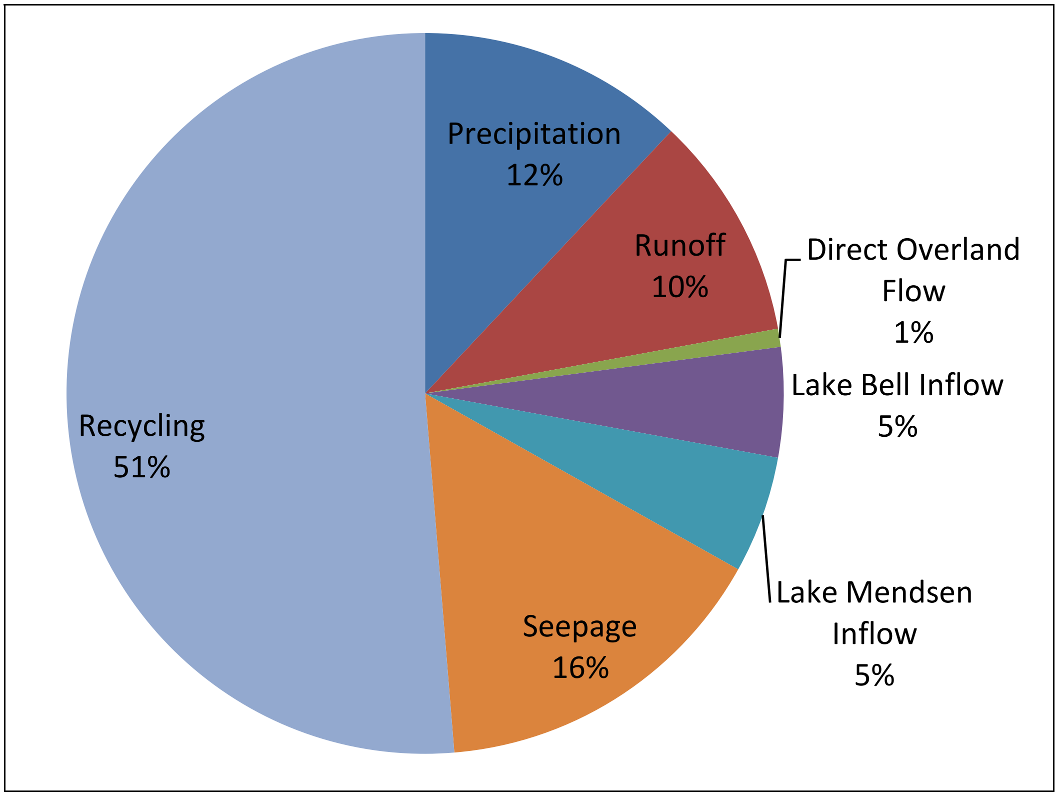
TABLE 5-15

ESTIMATED MEAN ANNUAL MASS LOSSES OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND TSS FROM LAKE KILLARNEY

SOURCE	TOTAL NITROGEN		TOTAL PHOSPHORUS		TSS	
	kg/yr	% of Total	kg/yr	% of Total	kg/yr	% of Total
Drainage Wells	1,452	18	35.8	4	4,581	16
Sediments	6,589	82	1,007	96	23,941	84
Outfall to Lake Gem	0	0	0	0	0	0
Total:	**8,041**	**100**	**1,043**	**100**	**28,522**	**100**

5.3.3 Areal Nutrient Loadings Rates

A comparison of estimated annual total and areal loadings of nitrogen and phosphorus to Lake Killarney, based upon the nutrient budgets summarized in Table 5-14, is given in Table 5-16. Based upon the identified phosphorus inputs, the areal phosphorus loading to Lake Killarney is approximately 1.08 g/m^2-yr. A summary of permissible nutrient loading levels for lakes up to 15 m deep, developed by Vollenweider (1968), is provided at the bottom of Table 5-16. According to Vollenweider, lakes with areal phosphorus loadings less than 0.1 g/m^2-yr typically maintain oligotrophic characteristics, while lakes with more than 0.2 g/m^2-yr will exhibit a trend of accelerated algal growth and potential for seasonal algal blooms. Based upon these criteria, the current phosphorus loading to Lake Killarney substantially exceeds the permissible loading level recommended by Vollenweider.



INPUTS

LOSSES

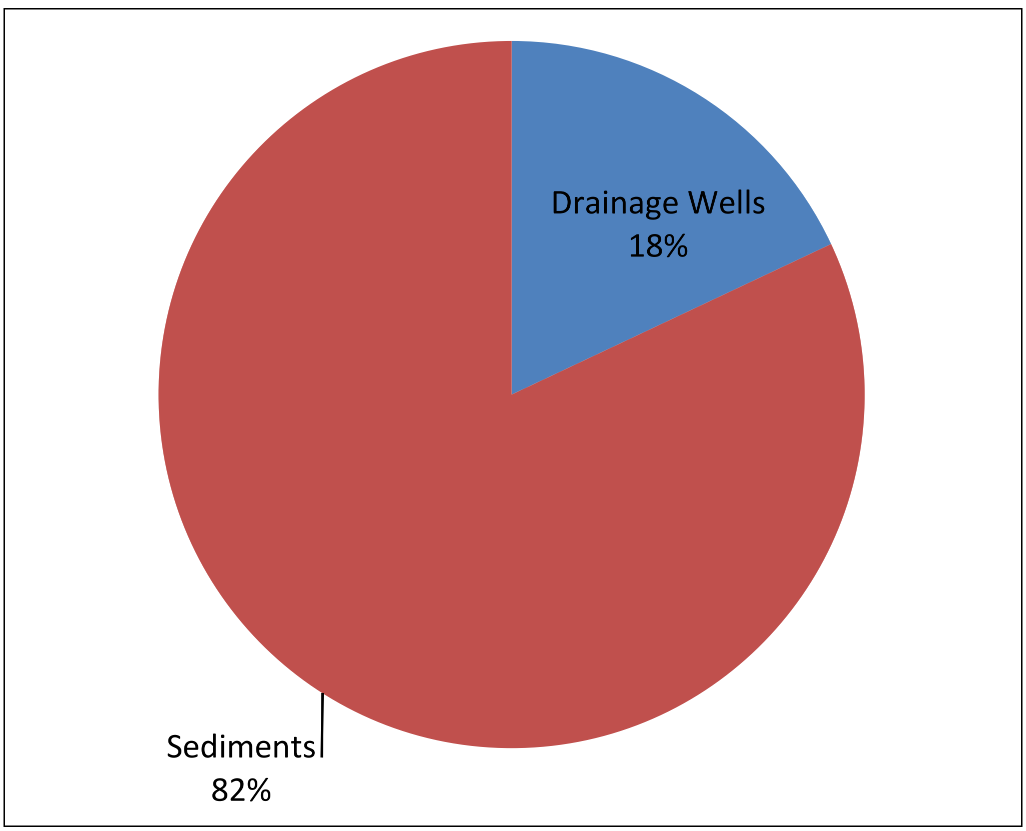
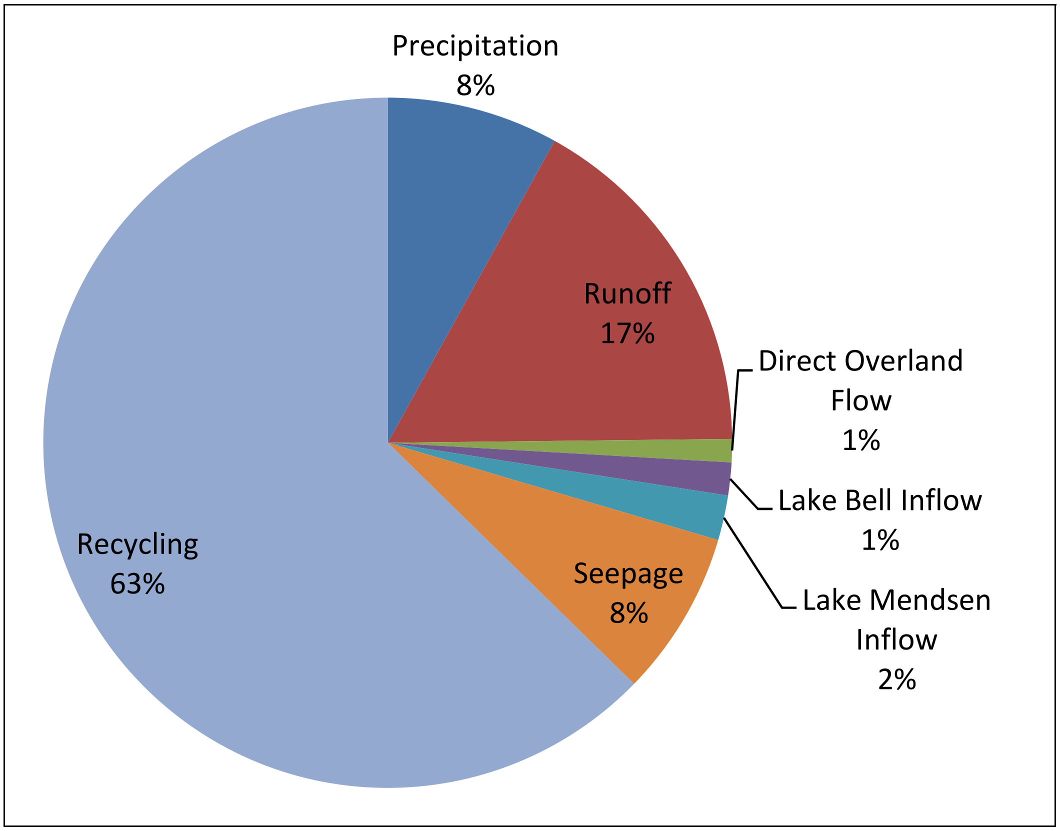


Figure 5-32. Estimated Annual Inputs and Losses of Total Nitrogen for Lake Killarney.



INPUTS

LOSSES

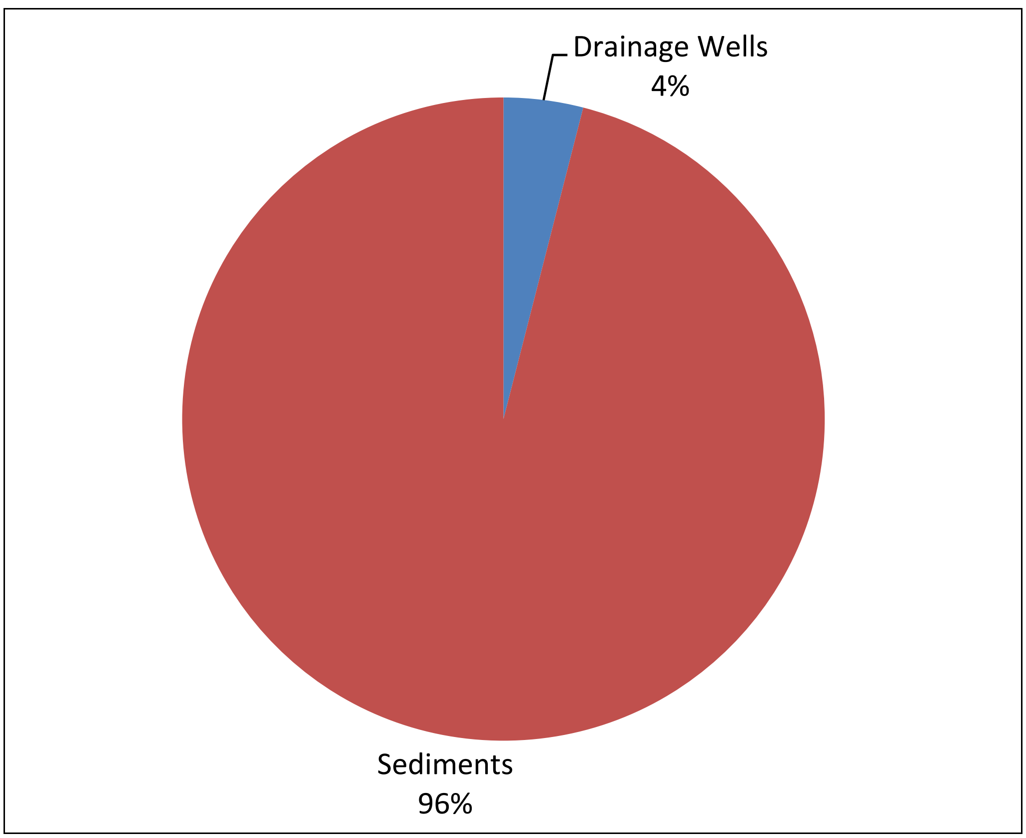
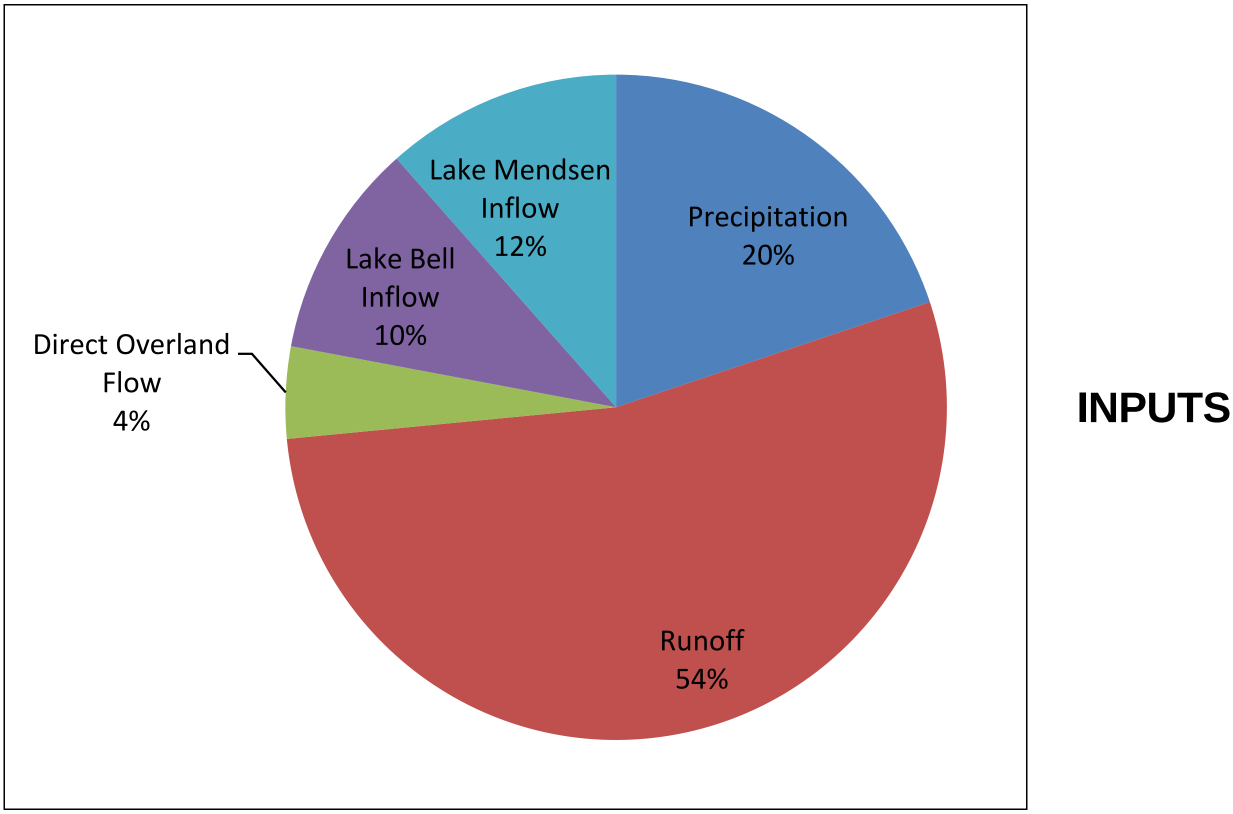


Figure 5-33. Estimated Annual Inputs and Losses of Total Phosphorus for Lake Killarney.



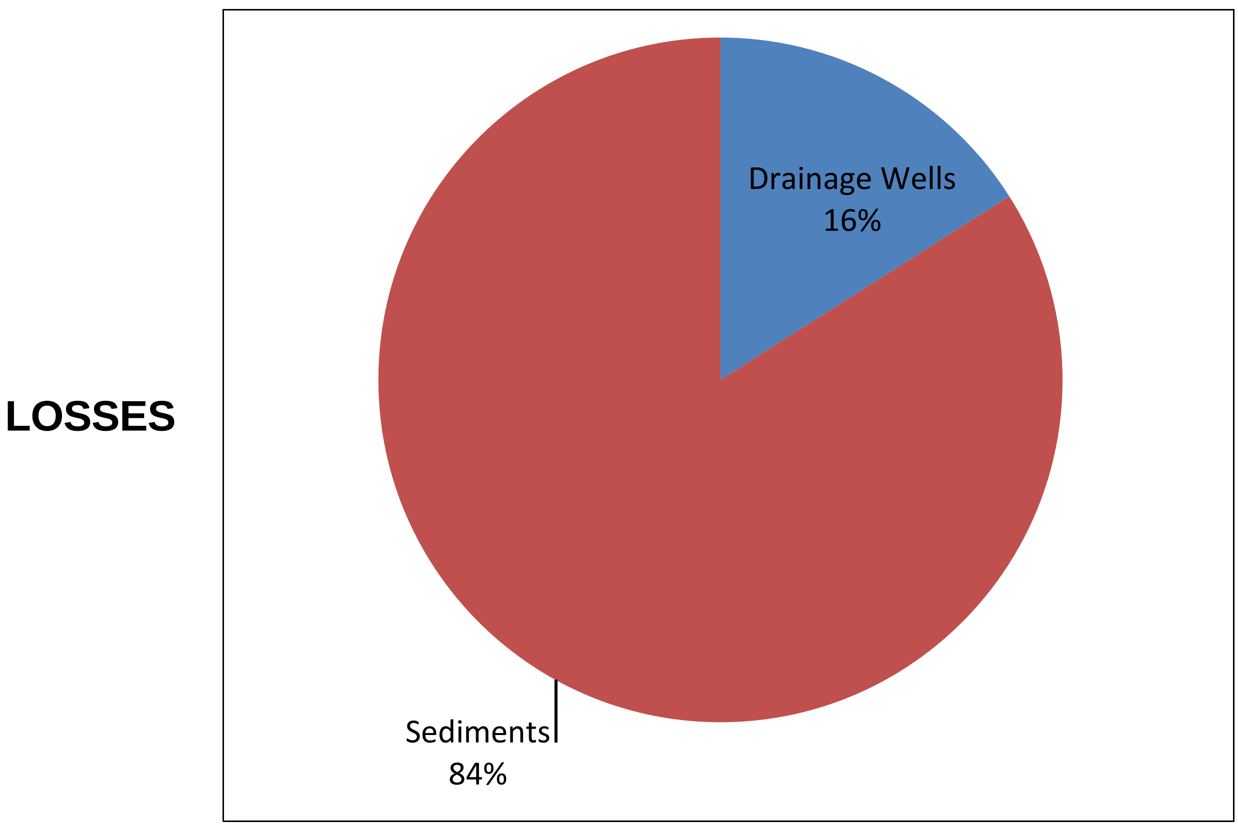


Figure 5-34. Estimated Annual Inputs and Losses of TSS for Lake Killarney.

TABLE 5-16

COMPARISON OF ESTIMATED ANNUAL TOTAL AND AREAL LOADINGS OF NITROGEN AND PHOSPHORUS TO LAKE KILLARNEY

AREA (acres)	PHOSPHORUS LOADING		NITROGEN LOADING	
	kg/yr	g/m^2-yr	kg/yr	g/m^2-yr
239.6	1,403	1.08	8,041	8.3

Permissible Loading Levels (Vollenweider, 1968) for Lakes up to 15 m Deep:

1. Phosphorus: a. Permissible: <0.1 g/m^2-yr
   b. Dangerous: >0.2 g/m^2-yr

2. Nitrogen: a. Permissible: <1.5 g/m^2-yr
   b. Dangerous: >3.0 g/m^2-yr

Areal loading rates for total nitrogen in Lake Killarney are also summarized in Table 5-16. Based upon this analysis, Lake Killarney has an estimated annual nitrogen loading of 8.3 g/m^2-yr. This value substantially exceeds the dangerous level of 3.0 g/m^2-yr for nitrogen established by Vollenweider.

SECTION 6

NUTRIENT SOURCE PARTITIONING

In view of the large number of septic tanks in the vicinity of Lake Killarney, additional investigations were conducted to evaluate the relative impacts of the existing septic tanks on nutrient loadings to Lake Killarney from groundwater seepage which is the primary pathway for septic tank loadings to reach the lake. A portion of the collected groundwater seepage samples was forwarded to the Colorado Plateau Stable Isotope Laboratory (CPSIL), based at Northern Arizona University (NAU), for analysis of stable isotopes of nitrogen and oxygen which can be used to identify the origins of nitrogen and oxygen contained in nitrates. The presence of an isotopic signature for nitrate in groundwater seepage would indicate that sewage leachate from septic tanks is reaching Lake Killarney through groundwater seepage. Unfortunately, phosphorus does not have stable isotopes which can be used to identify the source of phosphorus loadings. However, a strong signature for the presence of sewage in nitrate would provide presumptive evidence that phosphorus originating from sewage may also be reaching Lake Killarney through groundwater seepage. A discussion of the theory of isotope analyses and a discussion of data collected in Lake Killarney is given in the following sections.

6.1 Theory of Stable Isotope Use and Measurement

6.1.1 Introduction

Isotopes are atoms of an element that differ in mass, due to differing numbers of neutrons in the atoms' nucleus. Some isotopes are unstable and are referred to as radioisotopes. Other isotopes have no known decay constants and are referred to as stable isotopes. Isotopes of the same element have the same numbers of protons and electrons, and so have similar chemical properties and similar chemical reactions. But, because of the difference in bond strength due to differing numbers of neutrons, different stable isotopes react at slightly different rates. In general, molecules containing heavier isotopes react more slowly. Differences in reaction rates give rise to "fractionation", such that isotopes are distributed unevenly in natural systems. Biological systems often exhibit strong fractionation effects, such that molecules containing the light isotope of an element react more quickly with a biological enzyme than do molecules containing the heavier isotope. Thus, molecules from different sources in the environment often exhibit isotopic "fingerprints" which can be useful in source partitioning studies.

There are two stable isotopes of nitrogen, ^{14}N and ^{15}N, where the superscripts describe the atomic mass of the isotope. ^{14}N contains seven protons and neutrons, whereas ^{15}N contains seven protons but eight neutrons. ^{14}N is the more abundant isotope of nitrogen since most nitrogen reservoirs in nature (e.g., the atmosphere) contain approximately 99.6% ^{14}N and only 0.4% ^{15}N. Fractionation processes cause very slight variations in this composition, differences that can be detected using isotope-ratio mass spectroscopy, routinely distinguishing samples that differ by as little as 0.0001 atom percent ^{15}N.

6.1.2 Theory of Measurement

Stable isotopes of carbon, nitrogen, sulfur, oxygen, and hydrogen, which are the most commonly used isotopes in ecological and environmental research, are measured by gas isotope-ratio mass spectroscopy. The sample is converted into a gas, such as N_2O, CO_2, N_2, SO_2, or H_2, and the gas molecules are ionized in the Ion Source (Figure 6-1) which strips an electron from each of them, causing each molecule to be positively charged. The charged molecules then enter a flight tube. The flight tube is bent, and a magnet is positioned over it such that the charged molecules separate according to their mass, with molecules containing the heavier isotope bending less than those containing the lighter isotope.

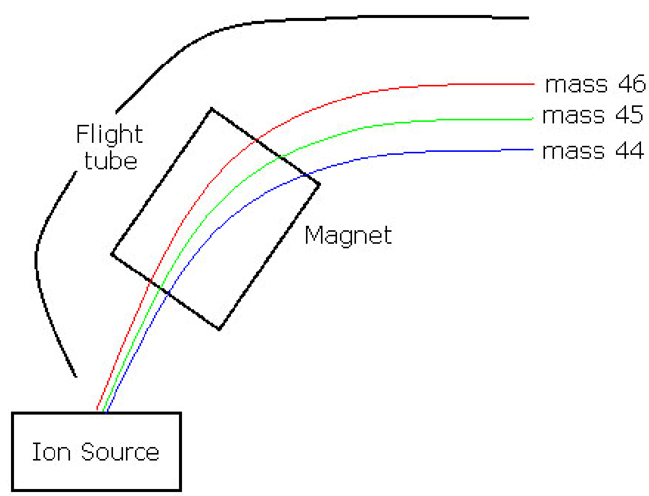


Figure 6-1. Separation of Isotopes by Gas Isotope-Ratio Mass Spectrometry.

Faraday collectors are present at the end of the flight tube to measure the intensity of each beam of ions of a given mass after they have been separated by the magnet. For N_2O, three faraday collectors are set to collect ion beams of masses 44, 45, and 46. Several masses are collected simultaneously, so that the ratios of these masses can be determined very precisely.

In the flight tube, the magnet causes the ions to be deflected, with a radius of deflection that is proportional to the mass-to-charge ratio of the ion. Heavier ions are deflected less than lighter ions. For example, N_2O, mass 46 has the largest radius of deflection, mass 44 has the smallest, and mass 45 is intermediate. Charge also affects the radius of deflection but, for the most part, this is held constant because the ion source strips only one electron from most molecules.

Stable isotope abundances are expressed as the ratio of the two most abundant isotopes in the sample compared to the same ratio in an international standard, using the "delta" (δ) notation. Because the differences in ratios between the sample and standard are very small, they are expressed as parts per thousand or "per mil" (‰) deviation from the standard:

$$\delta X\ sample = \{({}^{H}X / {}^{L}X\ sample) / ({}^{H}X / {}^{L}X\ standard) - 1\}\ x\ 100$$

Where "^{H}X and ^{L}X" are the heavy and light stable isotopes of element X, "sample" refers to the environmental sample being analyzed, and "standard" refers to the international standard for element X. This equation defines the delta value of the standard as 0‰. For carbon, the international standard is Pee Dee Belemnite, a carbonate formation, with a generally accepted absolute ratio of $^{13}C/^{12}C$ equal to 0.0112372. Materials with ratios of $^{13}C/^{12}C$ greater than 0.0112372 have positive delta values, and those with ratios less than 0.0112372 have negative delta values.

Stable isotope techniques rely on natural differences in the ways that "heavy" and "light" isotopes are processed in the environment through chemical, biological, and physical transformations. These are referred to as "natural abundance isotope techniques". Stable nitrogen isotopes of dissolved nutrients also provide specific information about the origin of nutrients. Pastureland, residential communities, and golf courses all produce nitrogen with unique isotopic signatures (Kendall, 1998). Land that is covered with a significant amount of cattle often produce nitrate with very heavy $\delta^{15}N$ values. This isotopic signature is due to the large amount of $^{14}NH_3$ released during ammonia volatilization of animal wastes which leaves the remaining material enriched in the heavier nitrogen isotope, ^{15}N.

Nitrogen derived from treated sewage undergoes similar biogeochemical processing through denitrification, which is the heterotrophic breakdown of organic matter. Denitrification produces N_2 with a high concentration of ^{14}N, leaving the remaining bulk waste material concentrated in ^{15}N. Consequently, nitrate that originates from pastureland and sewage have similar $\delta^{15}N$ values (12- 20‰). Contrastingly, nitrate derived from residential soils often has an intermediate nitrogen isotopic range (3-8‰). Possible contributions to the residential signal may include nitrogen derived from septic tanks, fertilizer application, or soil redistribution and relocation. Residential land development may also transport the ^{15}N-enriched organic matter that normally occurs in deeper soil layers to the surface.

The isotopic signature of nitrogen derived from golf courses is also unique. The fertilizer applied to golf courses is often derived from atmospheric nitrogen. This causes golf course runoff to contain nitrate with ^{15}N values similar to those of atmospheric N_2 (0-3‰). Golf course areas which irrigate with reclaimed water derived from sewage often exhibit a sewage signal (i.e., 12-20‰, as above). However, $\delta^{15}N$ can be used as a tracer only if large verifiable differences in $\delta^{15}N$ exist between the potential nitrogen sources.

One complication of source partitioning using stable isotopes of N and O in nitrate is that microbial transformations of nitrate can alter its isotopic signature, potentially obscuring the identity of the original source (Kellman et al, 1998). Nitrification and denitrification are the major fractionating processes altering the isotopic composition of nitrate. Both processes preferentially utilize the lighter substrate, such that nitrification produces NO_3^- isotopically depleted compared to the NH_4^+ substrate, whereas denitrification preferentially utilizes isotopically depleted NO_3^-, leaving behind NO_3^- relatively enriched in $\delta^{15}N$ and $\delta^{18}O$. Predictable relationships among NO_3^- concentration, $\delta^{15}N$- NO_3^-, and $\delta^{18}O$- NO_3^- provide one means of detecting whether denitrification is influencing the isotopic composition of NO_3^-. For example, co-varying enrichment of $\delta^{15}N$ and $\delta^{18}O$ in nitrate provides evidence for denitrification, if the ratio of enrichments are between 1.3:1 and 2.1:1 (Aravena and Robertson, 1998; Fukada, et al., 2003). In a system where nitrate inputs are negligible, a negative relationship between $[NO_3^-]$ and $\delta^{15}N$-NO_3^- with a slope consistent with microbial fractionation during denitrification can also be used as a diagnostic for the importance of denitrification as a loss pathway, or in source identification, for the need to consider internal changes to $\delta^{15}N$ values observed in-situ to the expected $\delta^{15}N$ signature of the NO_3^- source. Analysis of $\delta^{15}N$-NH_4^+, and nitrification and denitrification rates at a given site can also constrain the influence of these processes on the observed isotopic signatures.

6.2 Methods of Analysis

All stable isotope analyses were conducted by the Colorado Plateau Stable Isotope Laboratory (CPSIL), based at Northern Arizona University (NAU). This laboratory was designed to serve students, researchers, and faculty at NAU who require stable isotope analyses for their research, although analyses are also conducted for researchers outside the university. All isotope analyses were overseen by Dr. Bruce Hungate, Professor and Director of CPSIL. Details concerning sample collection, preservation, and shipping were provided to ERD by CPSIL.

Seepage samples were collected in the field by ERD, and a portion of the sample was filtered through a 0.1-micron membrane filter and frozen to prevent further microbial activity. The frozen samples were packaged and shipped to the CPSIL for further preparation and analysis. Samples were measured for NO_3^- concentrations using automated colorimetry on a Lachat QuikChem 8000 to determine appropriate volumes for isotope analyses. The denitrifier method was used to measure the $\delta^{15}N$ and $\delta^{18}O$ composition of nitrate in each water sample (Sigman, et al., 2001; Casciotti et al., 2002; Révész and Casciotti, 2007). In this method, isotopes of both elements are measured simultaneously after the nitrate is converted to nitrous oxide (N_2O). Mass ratios of 45:44 and 46:44 distinguish $\delta^{15}N$ and $\delta^{18}O$ signatures, respectively.

Pseudomonas aurefaciens lacks N_2O reductase, the enzyme that converts N_2O to N_2 during denitrification, so the reaction stops at N_2O, unlike normal denitrification which converts most of the NO_3^- to N_2. *Pseudomonas aurefaciens* cultures were grown in tryptic soy broth, centrifuged to concentrate bacterial cells, and concentrated suspensions of cells were added to sealed vials with headspace. The headspace vials were purged with helium gas to promote the anaerobic conditions suitable for denitrification, and the environmental samples containing NO_3^- were added to the vials and the volume of sample adjusted to obtain sufficient N_2O for analysis. Several drops of anti-foaming agent were added to each vial to reduce bubble formation during the reaction. The vials were allowed to incubate for 8 hours, during which time NO_3^- is converted completely to N_2O. After the 8-hour period, 0.1 ml of 10N NaOH was added to each vial to stop the reaction and to absorb CO_2 which can interfere with N_2O analysis. The samples were then placed on an autosampler tray interfaced with the mass spectrometer, and interspersed with standards with known $\delta^{15}N$ and $\delta^{18}O$ composition.

6.3 Source Identification

Stable isotope analyses were conducted to assist in evaluating sources for nutrient loadings entering Lake Killarney from groundwater seepage. A discussion of the results of the source identification study is given in the following sections.

6.3.1 Isotope Analyses

Analyses were conducted for stable isotopes of nitrogen and oxygen on 142 groundwater seepage samples collected from Lake Killarney during the field monitoring program. A summary of the isotope analysis results is given in Appendix G, along with plots of temporal variability in concentrations of the stable isotope ions.

The isotope methodology involves analysis of NO_x as well as stable isotopes of NO_x. A discussion of NO_x concentrations in seepage inflow has been previously provided in Section 5 based upon analyses conducted by ERD. Therefore, the results of the NO_x analyses conducted by the CPSIL are omitted from this discussion except where necessary to assist in data evaluation.

6.3.1.1 Evidence for *in situ* Denitrification

Two lines of evidence could support *in situ* denitrification as a major pathway of NO_x removal, and thus as a confounding signal for interpreting isotopes in source partitioning. One sign of denitrification is a negative slope for the relationship between $[NO_3^-]$ and $\delta^{15}N\text{-}NO_x$, reflecting preferential removal of $^{14}N\text{-}NO_x$ through denitrification. A second sign of *in situ* denitrification is co-varying enrichment of $\delta^{15}N$ and $\delta^{18}O$ in nitrate, if the ratios of enrichments are between 1.3 and 2.1 to 1 (Aravena and Robertson 1998; Fukada, et al. 2003). A tabular summary of relationships for $[NO_3]$ vs. $\delta^{15}N$ and $\delta^{15}N$ vs. $\delta^{18}O$ in groundwater seepage samples collected from Lake Killarney is given in Table 6-1. The values provide a summary of linear regression relationships for each of the two pairs of variables. Information is provided in the table for the number of data points included in each regression analysis, the slope of the linear regression line, the r^2 value for the regression, and a p value which reflects the statistical significance of the relationship between the two variables. For this analysis, all p values ≤ 0.10 are assumed to have a statistically significant relationship between the two variables, with the remaining sites exhibiting non-significant relationships. As indicated above, *in situ* denitrification is indicated by a statistically significant negative slope for the relationship between NO_3 and $\delta^{15}N$. Only three of the 30 groundwater seepage monitoring sites indicated on Table 6-1 meet the criteria of a statistically significant negative slope. Therefore, although evidence of *in situ* denitrification is present, it is limited to only a few of the monitoring sites, and this process appears to have little impact on the overall conclusions for this evaluation.

TABLE 6-1

RELATIONSHIPS FOR $[NO_3]$ vs. $\delta^{15}N$ AND $\delta^{15}N$ vs. $\delta^{18}O$ IN GROUNDWATER SEEPAGE SAMPLES COLLECTED FROM LAKE KILLARNEY

SITE	$[NO_3]$ vs. $\delta^{15}N$				$\delta^{15}N$ vs. $\delta^{18}O$			
	n	Slope	r^2	p value	n	Slope	r^2	p value
SP 01	5	0.24	0.13	0.56	5	1.40	0.62	0.12
SP 02	5	0.26	0.10	0.60	5	-5.82	0.78	0.05
SP 03	6	0.29	0.11	0.52	6	1.57	0.32	0.24
SP 04	5	0.15	0.32	0.32	5	-0.03	0.00	0.96
SP 05	2	0.00	1.00		2	6.08	1.00	
SP 06	3	-0.01	0.04	0.87	3	1.03	0.55	0.47
SP 07	6	0.57	0.58	0.08	6	-0.44	0.54	0.10
SP 08	6	0.18	0.34	0.23	6	0.97	0.79	0.02
SP 09	5	0.00	0.00	0.95	5	1.35	0.94	0.01
SP 10	6	-0.12	0.62	0.06	6	-1.79	0.68	0.04
SP 11	6	-0.16	0.02	0.81	6	-0.39	0.04	0.71
SP 12	5	-0.34	0.82	0.03	5	-2.19	0.45	0.22
SP 13	6	0.78	0.15	0.46	6	0.82	0.47	0.13
SP 14	6	0.04	0.00	0.97	6	0.55	0.17	0.41
SP 15	6	-0.12	0.02	0.81	6	0.71	0.37	0.20
SP 16	6	-0.66	0.48	0.13	6	-0.36	0.03	0.76
SP 17	6	0.19	0.02	0.80	6	1.12	0.90	0.00
SP 18	6	-0.20	0.04	0.69	6	1.63	0.40	0.18
SP 19	5	-0.57	0.01	0.86	5	0.26	0.14	0.53
SP 20	6	0.08	0.01	0.87	6	-2.37	0.56	0.09
SP 21	5	-0.43	0.32	0.32	5	1.61	0.02	0.80
SP 22	5	-0.24	0.65	0.10	5	-0.25	0.04	0.74
SP 23	4	0.09	0.31	0.45	4	2.76	0.52	0.28
SP 24	3	0.13	0.96	0.12	3	-0.44	0.53	0.48
SP 25	3	0.04	0.59	0.44	3	1.89	0.87	0.24
SP 26	0				0			
SP 27	2	2.07	1.00		2	1.91	1.00	
SP 28	2	-0.37	1.00		2	3.97	1.00	
SP 29	3	0.00	0.00	0.99	3	0.75	0.54	0.47
SP 30	5	0.04	0.32	0.32	6	2.15	0.27	0.29

As indicated above, a second side of *in situ* denitrification is enrichment of ^{15}N and ^{18}O in nitrate to enrichment ratios ranging between 1.3 and 2.1. As indicated on Table 6-1, statistically significant relationships between the two variables were observed at 7 of the 30 monitoring sites, but only one of these significant relationships resulted in a positive slope which ranged between 1.3 and 2.1. Therefore, it appears that *in situ* denitrification may be present, but the overall significance with respect to source partitioning appears to be minimal.

6.3.1.2 Source Partitioning

Samples with $\delta^{15}N-NO_x$ values greater than +3 and $\delta^{18}O-NO_x$ values ranging from approximately -10 to +12 are within the 90% confidence interval for nitrogen concentrations associated with manure or sewage. A tabular summary of samples which fall within the 90% confidence interval for the presence of manure or sewage in groundwater seepage entering Lake Killarney are indicated on Table 6-2 by an "x". Virtually all of the seepage monitoring sites indicated nitrogen sources originating from manure or sewage during at least one of the six seepage monitoring events. Information on the average number of samples with "hits" indicating the presence of manure or sewage are also provided for each seepage site and each of the six monitoring dates. Monitoring sites where seepage samples were not collected during a given monitoring event are highlighted in yellow in Table 6-2, and the calculated percentages of collected samples with manure or sewage signatures do not include these missing samples. The percentage of monitoring sites exhibiting a signature for manure or sewage for the individual monitoring dates range from approximately 48-75%, with an overall average of approximately 59%. These data indicate that approximately 60% of the collected groundwater seepage samples at Lake Killarney contained nitrate which originated from manure or sewage.

Isopleths of mean $\delta^{15}N$ values in seepage samples collected from Lake Killarney during the monitoring program are illustrated on Figure 6-2. As indicated previously, samples with $\delta^{15}NO_x$ values greater than +3 are within the 90% confidence interval for nitrogen originating from manure or sewage. Isopleth lines indicating values greater than 3 are located along much of the southern shoreline of the lake, along with western and northern portions of the west lobe. All of these areas, including the northern lobe and western lobe, are serviced by individual septic tank systems. Isopleth contour lines of approximately zero (0) are located along the eastern end of the east lobe where a central sewer system is provided by the City of Winter Park. In general, it appears that $\delta^{15}N$ values in seepage are present in virtually all perimeter areas of Lake Killarney where septic tanks are located. Substantially lower $\delta^{15}N$ values are present in areas where central sewer systems are located.

6.4 Summary

The isotopic analyses indicate that nitrogen originating from manure or sewage is present in groundwater seepage entering Lake Killarney in shoreline areas where septic tanks are used for sewage disposal. Mean $\delta^{15}N$ values in central portions of Lake Killarney are substantially lower in value than perimeter shoreline areas, suggesting that the impacts of the adjacent septic tanks are limited primarily to shoreline seepage, and appear to have little impact on seepage in other parts of the lake.

TABLE 6-2

SAMPLES WHICH FALL IN THE 90% CONFIDENCE INTERVAL FOR THE PRESENCE OF MANURE OR SEWAGE

SITE	MONITORING DATE						AVERAGE[1] (%)
	9/22/10	11/29/10	2/21/11	5/5/11	6/10/11	8/2/11	
SP 01			x	x	x		60
SP 02			x				20
SP 03	x	x	x	x		x	83
SP 04		x	x	x	x		80
SP 05		x			x		100
SP 06		x			x		67
SP 07							0
SP 08	x		x	x	x		67
SP 09				x	x	x	60
SP 10				x	x		33
SP 11	x	x	x	x	x		83
SP 12			x	x	x	x	80
SP 13	x	x	x	x	x	x	100
SP 14	x			x	x	x	67
SP 15	x			x	x	x	67
SP 16	x	x			x		50
SP 17	x		x		x	x	67
SP 18	x	x			x	x	67
SP 19	x	x			x		60
SP 20	x			x		x	33
SP 21			x	x	x		60
SP 22			x		x		40
SP 23		x					20
SP 24							0
SP 25		x					33
SP 26							0
SP 27	x	x					100
SP 28		x					50
SP 29	x	x	x				100
SP 30		x	x			x	50
Average[1] (%)	**48**	**54**	**57**	**59**	**75**	**59**	**59**

1. Percentage of collected samples with manure or sewage signature

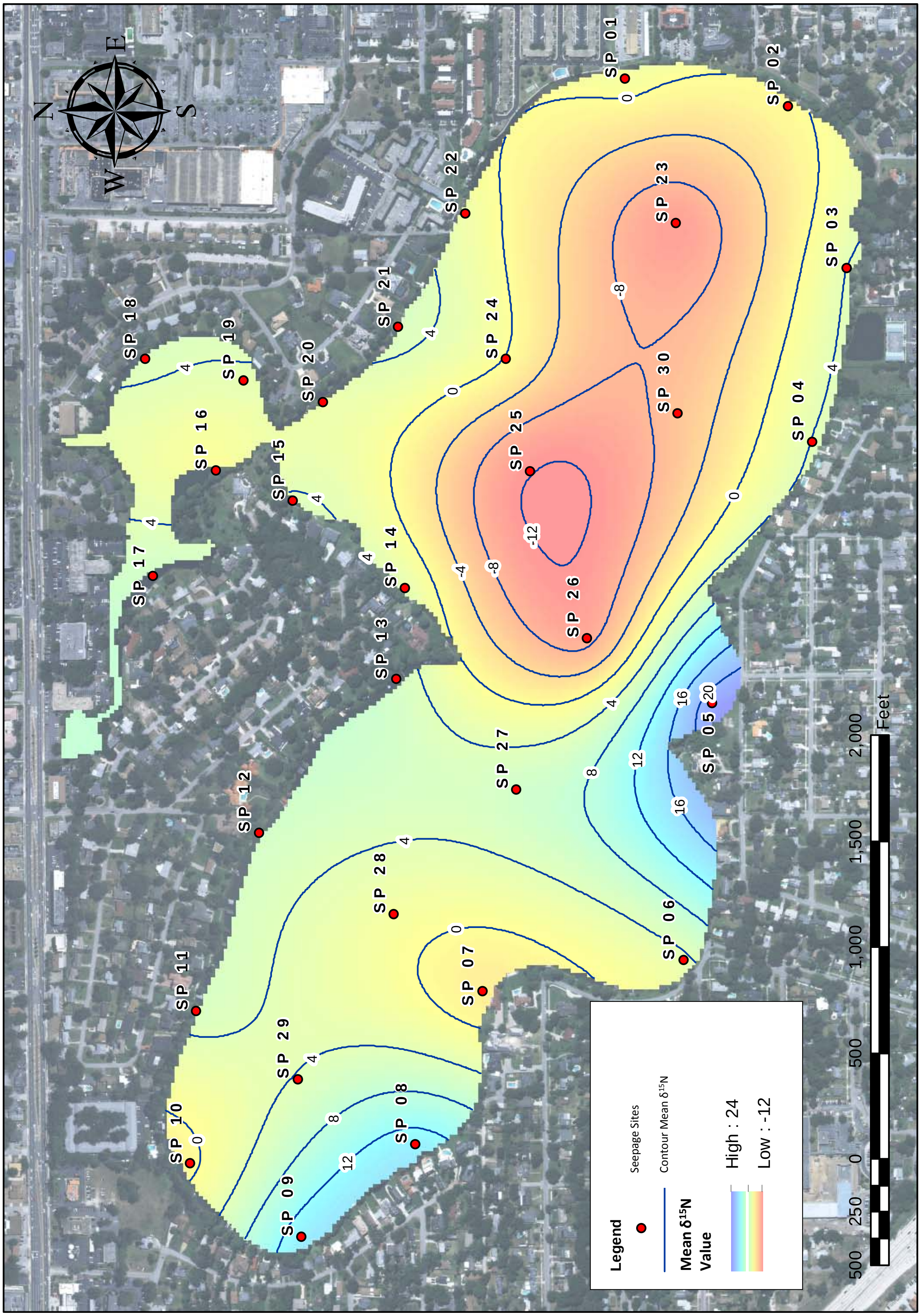


Figure 6-2. Isopleths of Mean $\delta^{15}N$ Values in Seepage Samples Collected from Lake Killarney.

However, the overall impact of septic tanks on loadings of nitrogen and phosphorus entering Lake Killarney must be evaluated in relationship to the significance of seepage loadings as a portion of the total nutrient loadings to the lake. As indicated on Table 5-14, groundwater seepage contributes approximately 16% of the annual loadings of total nitrogen and 8% of the annual loadings of total phosphorus. Since Lake Killarney is primarily a phosphorus-limited lake, the phosphorus loadings from groundwater seepage are more significant from a water quality improvement perspective than inputs of total nitrogen. Phosphorus loadings in groundwater seepage can be addressed simultaneously with phosphorus release from internal recycling as part of an alum treatment to the lake. Therefore, although nutrient loadings from septic tanks appear to be impacting Lake Killarney, the magnitude of nutrient loadings, particularly for total phosphorus, are low in comparison with other inputs such as internal recycling and stormwater runoff, and as indicated previously, inputs of phosphorus from septic tanks can be addressed as part of a relatively inexpensive alum sediment inactivation project.

SECTION 7

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APPENDICES

APPENDIX A

HISTORICAL WATER QUALITY DATA FOR LAKE KILLARNEY

Historical Water Quality Data for Lake Killarney

Data Source	Sample Date	pH (s.u.)	Alkalinity (mg/L)	Conductivity (µmho/cm)	Ammonia (µg/L)	NOx (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Chlorophyll-a (mg/m^3)	Secchi Depth (ft)	Color_pcu (Pt-Co)	Turbidity (NTU)	TSI
OCEPD	2/22/67	7.70	45.0		10	30			10	30					
	3/18/68	7.80	57.0		30	72	610	712	60	80					
	5/20/68	7.60	49.0		5	130	500	635	20	20					
	10/22/68	7.55	50.0		80	120	880	1,080	40	40					
	7/23/69	7.60	44.0	195	5	205	300	510	70						
	4/1/70	7.90	66.0	190	320	120	1,480	1,920	5	400		8.0			
	5/27/70	7.77	49.5	373	660	55	460	1,175	20						
	3/2/71	8.20	81.0	199	5	176	850	1,031	30	200		10.0			
	6/21/71	7.40	63.0	177	5	133	830	968	10	260					
	1/17/72			216	450	8	1,000	1,458	10	580		7.0			
	7/31/72	7.50	65.0	186	5	33	330	368	20	60		14.0			
	7/24/73	6.30	67.0	250	100	51	840	991	30	30		12.0		4.0	
	9/24/73	7.30	57.1	195	100	40	740	880	10	30		4.5		4.0	
	6/18/74	7.80	58.0	195	5	41	760	806	5	26		5.0		2.0	
	8/5/74	6.40	46.0	180	10	1	610	621	5	35		6.5		2.0	
	5/19/75	8.20	64.0	190	5	31	970	1,006	5	27		3.0		3.0	
	2/2/77	7.60	73.0	250	50	120	690	860	22	38				1.9	
	3/7/77	8.10	76.0	220	50	110	710	870	10	12		5.9		1.5	
	6/1/77	8.60	57.0	180	50	110	690	850	10	26		7.2		1.7	
	9/13/77	8.35	52.5	270	50	110	650	810	10	15		6.9		2.7	
	12/12/77	7.50	63.0		50	20	600	670	10	15		9.8		1.2	
	2/13/78	7.63	74.0	240	50	20	530	600	10	18		7.5		1.4	
	5/15/78	7.30	63.0	187	50	20	770	840	10	20		5.2		4.5	
	8/14/78	7.37	62.3	173	53	20	693	767	13	30		6.6			
	12/12/78	8.20	76.7		113	10	787	910	10	20		5.9			
	2/13/79	8.10	76.0	230	50	20	635	705	15	40		6.9			
	5/7/79	8.00	57.5	178	75	10	665	750	15	40		13.8			
	8/13/79	7.70	53.5	150	80	10	655	745	20	30		6.6		1.1	
	11/12/79	7.75	69.0	195	65	10	1,265	1,340	15	25		6.6		1.2	
	5/12/80	8.05	66.5	198	50	10	750	810	25	30		9.8		2.5	
	6/16/80	7.60	56.0	185	50	100	780	930	45	20		11.2		1.1	
	8/11/80	8.00	50.5	168	50	10	615	675	10	30		6.6		2.0	
	3/23/81	7.95	97.0	270	5				45	60		3.9		3.2	
	6/16/81	8.15	103.0	305	110	10	1,035	1,155	10	45		3.6		2.9	
	9/22/81	7.55	101.5	305	235	15	1,175	1,425		54		3.3		2.8	
	12/21/81			270	215	75	1,660	1,950	21	62		5.9		2.8	
	3/2/82	7.45	106.5	300	100	40	605	745	19	47		5.6		4.0	
	6/1/82	8.50	96.0	250	50	40	610	700	36	42		3.9		2.8	
	8/31/82	7.10	80.0	280	110	40	700	850	15	40		4.3		2.3	
	11/23/82	6.50	24.0	250	200	200	800	1,200	8	50		4.6		4.2	
	3/29/83	6.40	87.0	265	110	80	610	800	13	39		4.6		3.0	
	5/9/83	7.40	93.0		50	40	1,180	1,270	10	36		4.6		3.2	
	9/19/83	8.10	83.0	200	70	40	470	580	34	11		2.6		1.8	
	12/6/83	7.80	84.0	230	50	40	760	850	20	35		3.3		1.9	
	1/14/84	7.90	74.0	260	50	40	940	1,030	11	46		3.9		3.0	
	1/24/84	7.90	73.0	265	60	40	990	1,090	13	59				3.3	
	4/25/84	7.30	79.2	270	50	40	230	320	14	74		3.3		2.1	
	7/24/84	7.80	66.0	220	160	40	680	880	16	46		4.6		1.5	
	10/24/84	7.70	68.0	200	60	40	300	400	33	71		3.3		2.2	
	1/30/85	7.90	71.9	215	50	40	520	610	23	36		3.3		2.0	
	5/7/85	7.90	77.2	205	50	40	870	960	12	36		3.9		2.3	

Historical Water Quality Data for Lake Killarney

Data Source	Sample Date	pH (s.u.)	Alkalinity (mg/L)	Conductivity (µmho/cm)	Ammonia (µg/L)	NOx (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Chlorophyll-a (mg/m^3)	Secchi Depth (ft)	Color_pcu (Pt-Co)	Turbidity (NTU)	TSI
OCEPD	9/24/85	8.40	59.0	180	140	40	850	1,030	25	36		2.3		2.5	
	11/19/85	7.80	58.8	190	210	40	900	1,150	8	35		2.3		2.3	
	2/4/86	7.40	64.0	200	110	160	610	880	9	65		3.9		2.1	
	4/2/86	6.50	78.4	193	135	40	525	700	8	44		1.4		2.3	
	7/1/86	7.60	56.0	205	500	40	560	1,100	36	50		0.9		3.0	
	10/7/86	7.40	38.9	178	50	40	660	750	7	40		0.1		2.5	
	2/3/87	7.80	59.0	210	140	40	50	230	17	40		3.6		3.0	
	2/3/87	7.80	59.0	220	80	40	760	880	17	53		3.6		3.0	
	3/31/87	7.70	55.0	193	40	70	670	780				3.0		2.7	
	6/30/87	8.10	60.0	225	5	30			20	20		4.9		1.2	
	10/5/87	7.90	65.0	195	40	43	796	879	27	39		3.0		2.4	
	1/25/89	8.60	69.0	225	55	20				13		4.9		1.6	
	3/28/89	7.00	60.0	781	25	20	713	758	5	18		4.9		1.9	
	4/25/89	8.60	69.0	225	55	20	793	868	3	33		4.9		1.6	
	7/31/89	7.50	57.0	295	32	32	1,134	1,198	4	11		3.9		2.2	
	10/23/89	7.50	72.0	192	22	20	1,093	1,135	8	13		3.3		3.3	
	3/27/90	7.50	91.5	239	66	20	676	762	8	18		2.6	12.5	2.9	
	6/25/90	8.10	75.0	270	170	39	803	1,012	17	18		4.6	18	2.0	
	9/25/90	7.60	67.0	213	91	19	644	754	22	27		4.6		2.5	
	12/11/90	7.10	71.0	218	10	30	540	580	12	16		4.6			
	3/26/91	8.10	79.3		20	20	450	490	2	9		7.2	20	2.0	
	9/25/91	7.50	59.0	188	30	15	730	775	23	26		3.6	30	2.2	
	12/18/91	7.40	62.0	196	40	15	760	815	7	10		4.3	30	3.9	
	6/17/92	8.40	69.0	206	20	15	410	445	5	10		5.2	15	2.0	
	9/21/92			201	20	25	610	655	5	11		3.3	40	2.8	
	12/2/92			196	160	25	460	645	9	18		3.9	20	3.5	
	3/12/93	7.70	68.0	187	10	15	600	625	5	32		5.2		2.7	
	3/17/93	7.70	68.0	187	10	15	600	625		29		5.2	30	2.7	
	6/14/93	8.50	65.0	192	20	15	540	575	6	11		4.6		2.3	
	9/22/93	8.10	60.0	204	10	15	740	765	7	14		3.9		1.5	
	12/20/93	7.90	76.0	221	50	15	740	805	9	20		4.3		5.2	
	1/18/94	7.90	73.0	219	60	15	600	675	5	24	25.8	3.9		5.4	56
	4/19/94	8.00	75.0	236	40	15	730	785	5	11	7.2	6.6		3.7	47
	7/25/94	7.80	65.0	178	30	25	790	845	3	23	22.1	3.6		4.7	58
	12/20/94		60.0	179	100	66	800	966	5	16		6.6		3.4	
	1/17/95	7.61	60.0	182	80	13	220	313	22	35	23.2	4.9		3.5	48
	4/18/95	8.28	63.2	219	5						9.4	4.9		1.9	
	7/18/95	7.06	50.0	197	100	25	600	725	5	40	21.0	4.9		3.3	56
	10/31/95	7.42		155	5	12	737	754	21	28		3.3		3.0	
	1/23/96	7.28	48.0	143	10	22	700	732	8	11	9.5	8.2	15	2.7	45
	4/2/96	7.42	54.0	171	10	15	600	625		12	12.5	8.2	25	2.7	47
	7/23/96	8.24	44.0	155	10	15	800	825		9	15.6	5.7	15	2.8	48
	10/10/96	6.94	48.9	164	30	15	800	845		27	37.4	3.3	10	3.4	61
	1/8/97	8.63	31.6	163	20	15	700	735		11	20.0	4.1	15	3.0	
	4/29/97	7.88	64.0	185	10	15	900	925		11	32.6	4.1	10	3.1	
	7/9/97	8.61	56.0	179	10	45	800	855		10	33.7	4.1	15	2.8	
	10/29/97	8.08	61.0	183	10	15	1,100	1,125		17	39.3	4.1	20	5.1	
	2/10/98	8.10	59.0	176	20	15	600	635		13	0.5	4.9	20	2.5	
	5/12/98	8.55	59.8	188	10	15	700	725		14	11.6	4.9	15	3.3	
	8/10/98	8.70	60.9	175	10	15	900	925		11	22.0	2.0	15	4.2	
	10/20/98	8.14	67.0	190	10	15	900	925		15	15.0	1.6	15	4.4	

Historical Water Quality Data for Lake Killarney

Data Source	Sample Date	pH (s.u.)	Alkalinity (mg/L)	Conductivity (µmho/cm)	Ammonia (µg/L)	NOx (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Chlorophyll-a (mg/m^3)	Secchi Depth (ft)	Color_pcu (Pt-Co)	Turbidity (NTU)	TSI
OCEPD	2/23/99	8.13	70.0	180	5	15	813	833		15	8.2	2.6	10	2.7	
	6/14/99	8.56	73.0	205	10	15	740	765		10	12.1	3.9	10	2.2	
	9/2/99	8.51	69.0	208	10	15	830	855		14	20.4	3.3	5	3.0	
	11/30/99	7.18	68.0	208	15	15	900	930		18	24.4	3.0	5	4.0	
	2/5/01	7.25	84.2	232	12	15	1,100	1,127		11	20.1	4.9	15	3.2	
	5/31/01	8.92	84.8	235	10	15	530	555		10	7.3	4.9	5	3.1	
	7/25/01	7.81	79.4	213	16	15	900	931		11	18.6	4.9	5	3.1	
	11/27/01	6.72	82.4	203	20	15	620	655		15	21.4	3.3	15	3.6	
	6/10/02	7.85	75.5	198	10	15	470	495		12	14.3	5.2	10	2.3	48
	9/4/02	7.03	59.5	165	22	15	430	467		11	10.6	5.9	5	2.5	45
	12/5/02	6.02	56.7	160	15	15	200	230		18	29.3	2.6	10	2.8	43
	6/10/03	7.67	45.0	166	20	8	570	598		11	5.8	6.6	5	1.4	39
	9/21/04				5						22.0	18.0			
	1/25/05	7.71	68.0	194	20	356	660	1,036	98	20	18.1	5.2	18	2.4	
	6/13/05	8.49	68.0		20	398	770	1,188	3	19	22.1		15	4.6	54
	7/13/05				5						35.0				
	8/30/05	8.40	64.0		20	348	690	1,058	2	15	22.9		14.75	3.3	52
	9/15/05				5						20.0				
	10/14/05				5						25.0				
	3/7/06	7.90	39.0	209	20	8	355	383	4	11	8.7	4.9		2.5	48
	6/27/06	8.70	68.0	215	20	8	720	748	4	11	17.7	3.6		3.9	51
	9/25/06	8.40	76.0	207	5	5	690	700	4	12	18.0	2.0		4.6	51
	12/18/06	8.70			5						20.4				
	3/1/07	7.90	80.0	223	20	8	650	678	4	5	9.2	4.6	6.3	2.4	35
	5/24/07	7.80	86.0	241	20	4	770	794	4	15	9.4	5.2	8.6	1.8	49
	8/23/07	8.60	84.0	247	20	4	1,430	1,454	2	22	33.1	1.6	7.5	9.8	65
	10/11/07	7.40	101		5	16	1,400	1,421		24	40.3				
	12/10/07	8.20	109		20	4	1,105	1,129	2	23	34.6			12.0	61
	3/12/08	7.80	114	275	20	6	645	671	3	9	19.9	4.3	6	4.2	
	4/28/08	8.29	113	281	20	8	600	628	3	10	8.8	3.4	1.8	3.1	43
	9/23/08	8.30	80.0	219	30	6	1,085	1,121	3	15	30.9	2.6	6.6	4.8	59
	11/4/08	7.40	84.0	223	30	10	1,060	1,100	3	20	36.3	2.7	10.7	5.4	60
	3/19/09	8.30	90.0	245	30	4	670	704	2	9	3.7	9.2	7.9	1.3	38
	6/22/09	8.80	76.0	210	30	4	1,240	1,274	2	14	33.1	3.0	6.6	7.6	58
	8/27/09	8.40	73.0	206	20	4	1,150	1,174	2	12	35.8	2.0	10.1	7.2	56
	11/16/09	8.40	82.0	219	20	4	1,220	1,244	2	20	57.8	2.6	7.2	9.6	67
	2/9/10	7.70	89.0	233	5	66	990	1,061	2	20	20.2	3.6	9	4.9	55
	5/3/10	8.90	79.0	219		4	740	744	2	7	6.4	5.2	6.9	4.0	36
	8/16/10	8.20	76.0	217		4	550	554	2	8	7.5	9.5	8.5	2.2	40
	11/29/10	8.30	44.5	231		4	485	489	3	6	17.9	2.6	3.1	3.1	54
	2/2/11	8.30	92.0	234		6	980	986	3	9	24.3	3.0	8.3	7.8	49
	5/12/11	8.70	84.0	214		10	580	590	3	9	5.2	6.6	7.6	1.6	40
	8/17/11	8.40		215							11.9	3.9	4		
Minimum Value:		**6.02**	**24.0**	**143**	**5**	**1**	**50**	**230**	**2**	**5**	**0.5**	**0.1**	**2**	**1.1**	**35**
Maximum Value:		**8.92**	**114**	**781**	**660**	**398**	**1660**	**1950**	**98**	**580**	**57.8**	**18.0**	**40**	**12.0**	**67**
Geometric Mean:		**7.82**	**66.8**	**212**	**29**	**23**	**743**	**844**	**9**	**22**	**16.5**	**4.3**	**11**	**2.8**	**50**
No. of Samples:		**136**	**134**	**128**	**139**	**137**	**134**	**134**	**110**	**135**	**61**	**128**	**54**	**122**	**35**

Historical Water Quality Data for Lake Killarney

Data Source	Sample Date	pH (s.u.)	Alkalinity (mg/L)	Conductivity (µmho/cm)	Ammonia (µg/L)	NOx (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Chlorophyll-a (mg/m^3)	Secchi Depth (ft)	Color_pcu (Pt-Co)	Turbidity (NTU)	TSI
Winter Park	2/10/98											4.9		2.6	
	3/10/98											4.6		2.6	
	4/7/98											4.6		2.0	
	5/11/98											3.9		2.4	
	6/15/98											4.3			
	8/11/98											3.3		4.5	
	9/1/98											3.6		3.8	
	10/6/98											3.0		5.5	
	11/3/98											1.6		6.0	
	12/9/98											3.3		4.0	
	1/12/99											3.6		4.1	
	2/8/99											3.6		4.1	
	3/8/99											3.6		3.8	
	4/12/99											3.3		6.6	
	5/10/99											2.6		7.8	
	6/14/99													3.4	
	7/12/99											4.6		3.3	
	8/9/99											3.3		2.8	
	9/27/99											3.6		5.9	
	10/19/99											3.6		3.8	
	11/15/99											3.3		6.0	
	12/14/99											3.3		3.6	
	1/10/00											4.3		5.6	
	2/21/00											5.2		3.0	
	3/27/00											5.6		1.6	
	4/17/00											4.9		2.1	
	5/15/00											3.3		2.8	
	7/10/00											3.3		1.6	
	8/7/00											3.3			
	9/20/00											3.6		4.7	
	10/16/00											3.3		4.7	
	11/13/00											3.3		6.3	
	12/1/00											2.6		5.8	
	2/5/01											5.2		11.2	
	3/12/01											3.9		5.4	
	4/10/01											5.6		4.0	
	5/14/01											3.3		3.6	
	6/11/01											3.6		6.5	
	7/16/01											3.6		4.4	
	8/13/01											3.6		3.4	
	9/11/01											3.9		3.4	
	10/8/01											3.3		4.6	
	11/13/01											3.0		4.5	
	12/17/01											3.9		4.3	
	1/21/02											4.9		2.8	
	2/11/02											4.9		3.4	
	3/11/02											5.9		2.6	
	4/23/02											5.2		2.2	
	5/13/02											3.9		3.8	
	6/10/02											3.9		2.9	
	7/15/02											3.9		2.7	

Historical Water Quality Data for Lake Killarney

Data Source	Sample Date	pH (s.u.)	Alkalinity (mg/L)	Conductivity (µmho/cm)	Ammonia (µg/L)	NOx (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Chlorophyll-a (mg/m^3)	Secchi Depth (ft)	Color_pcu (Pt-Co)	Turbidity (NTU)	TSI
Winter Park	8/12/02											3.6		3.0	
	9/17/02											4.9		3.4	
	10/14/02											3.9		3.1	
	11/11/02											3.6		3.8	
	12/16/02											3.0		5.2	
	1/14/03											5.2		3.1	
	2/11/03											8.5		1.8	
	3/17/03													10.5	
	4/14/03											4.9		4.7	
	5/12/03											6.2		1.7	
	6/9/03											7.5		2.0	
	7/14/03											5.6		2.4	
	8/11/03											5.2		3.4	
	9/15/03	8.00										3.6		3.3	
	10/20/03	7.54										3.9		4.2	
	11/10/03	7.71										3.9		4.5	
	12/8/03	7.85										3.9		5.1	
	1/12/04	7.97										3.3		5.9	
	2/9/04	7.49										3.3		5.1	
	3/8/04	8.43										3.6		5.0	
	4/19/04	8.42										4.9		3.7	
	5/17/04	8.55										6.6		3.1	
	6/14/04	8.67										5.2		3.8	
	7/12/04	8.56										4.6		5.0	
	8/9/04	9.05										4.3		3.9	
	9/20/04	7.90										3.9		5.6	
	10/18/04	7.90										3.9		5.0	
	11/8/04	7.27										3.3		5.2	
	12/27/04	8.51										4.9		2.6	
	1/24/05	9.06										4.9		3.9	
	2/14/05	8.60										4.9		3.6	
	3/21/05	8.65										5.6		4.4	
	4/18/05	8.85										5.6		3.3	
	5/16/05	9.18										6.2		2.7	
	6/16/05	9.57										3.0		4.5	
	7/18/05	9.50										3.3		5.8	
	8/15/05	8.77										4.3		6.8	
	9/19/05	8.78										6.6		7.1	
	10/10/05	9.09												7.0	
	11/15/05	8.75										3.3		8.1	
	12/13/05	7.90										3.3		5.6	
	1/23/06	9.08										5.6		3.0	
	2/20/06	9.17										5.2		7.0	
	3/20/06	9.67										5.9			
	4/24/06	8.60										6.2		1.2	
	5/15/06	7.57										5.6		1.9	
	6/19/06	8.70										3.3		4.5	
	7/17/06	8.88										4.9		3.9	
	8/17/06	8.90										4.9		4.5	
	9/18/06	8.59										3.6		5.1	
	10/23/06	8.80										3.3		8.3	

Historical Water Quality Data for Lake Killarney

Data Source	Sample Date	pH (s.u.)	Alkalinity (mg/L)	Conductivity (µmho/cm)	Ammonia (µg/L)	NOx (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Chlorophyll-a (mg/m^3)	Secchi Depth (ft)	Color_pcu (Pt-Co)	Turbidity (NTU)	TSI
Winter Park	11/13/06	8.70										3.3		8.8	
	12/11/06	8.10										3.6		10.3	
	1/18/07	8.10										4.3		6.7	
	2/15/07	8.40										4.6		7.4	
	3/15/07	8.50										9.8		2.0	
	4/12/07	7.66										9.5		3.6	
	5/30/07	8.13										6.6		2.6	
	6/21/07	9.17										6.6		6.0	
	7/26/07	7.28										6.6		11.3	
	8/16/07	8.50										3.0		7.7	
	9/20/07	8.58										3.3		10.4	
	10/11/07	7.80										3.6		6.7	
	11/12/07	8.45										3.3		9.6	
	12/11/07	7.95										6.6		9.6	
	1/22/08	6.70										7.2		4.5	
	2/14/08	5.10										5.9		4.1	
	5/15/08	8.40										3.6		3.1	
	6/16/08	8.90										3.0		8.6	
	7/15/08	8.44										6.6		4.8	
	8/26/08	9.04										2.6		6.8	
	10/1/08	8.30										4.3		5.4	
	11/25/08	7.74										3.0		5.2	
	12/30/08	7.93										6.6		6.7	
	1/12/09	4.97										6.6		2.6	
	2/16/09	8.30									11.6	6.6		1.8	
	3/24/09	8.20				120		690			1.0	7.2		1.2	
	4/27/09	8.50									3.2	11.2		1.3	
	5/27/09									20	19.4	4.6		4.1	49
	6/22/09	9.60									31.7	3.0		9.3	
	7/21/09	8.83									29.3	6.6		6.9	
	8/10/09	9.20									26.1	3.0		9.2	
	9/15/09									37	30.1	2.6		2.0	51
	10/26/09	6.90								21	39.9	2.6		10.8	58
	11/17/09	9.00								43	25.8	3.0		7.9	55
	12/7/09	8.28								40	27.7	2.3		8.3	57
	1/11/10	8.21				178		848		47	19.0	7.2		5.8	56
	2/15/10	7.90				249		579		69	20.2	6.9		6.5	53
	3/15/10	8.06				153		673		42	5.6	3.3		7.8	45
	4/27/10	8.99								32	12.4	5.2		5.1	50
	5/17/10	7.40								25	7.3	6.9		2.6	43
	6/21/10	9.00				22		213		23	8.2	4.9		3.2	36
	7/26/10	9.00				20		224		20	7.6	5.6		2.1	38
	8/11/10	8.50				20		414		23	18.6	5.9		3.3	49
	9/13/10	9.10				20		120		29	17.1			4.6	35
	10/11/10	9.00				20		576		20	31.7	3.0		9.0	53
	11/8/10	8.50				20		952		34	18.0	3.6		7.5	54
	12/20/10	8.10				20		342		20	15.7	3.3		10.4	46
	1/10/11	7.70				20		820		33	13.7	3.6		7.6	51
	2/21/11	7.80				20		1,507		20	23.4	3.6		6.8	54

Historical Water Quality Data for Lake Killarney

Data Source	Sample Date	pH (s.u.)	Alkalinity (mg/L)	Conductivity (µmho/cm)	Ammonia (µg/L)	NOx (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Chlorophyll-a (mg/m^3)	Secchi Depth (ft)	Color_pcu (Pt-Co)	Turbidity (NTU)	TSI
Winter Park	3/21/11	7.98				20		421		20	16.7	2.6		5.7	47
	4/11/11	8.49				20		547		20	10.1	9.8		2.6	45
	5/17/11	8.10				20		421		20	8.0	4.9		3.9	42
	6/13/11	8.40				20		789		20	5.4	6.2		2.1	43
	7/11/11	8.40				56		661		20	5.6	5.9		1.8	44
	8/8/11	7.70				28		805		20	10.6	5.2		2.9	48
	9/12/11	8.00				20		820		23	16.3	3.9		4.3	53
	10/17/11	8.00				20		120		20	26.1	4.3		4.8	38
	11/1/11	7.80				76		176		14	25.3	2.6		6.4	44
	12/12/11	8.10				100		200		131	21.2	3.3		6.4	42
	1/9/12	8.00				45		1,003		45	18.8	5.6		4.1	56
	2/14/12	7.28				40		524		15	8.2	5.9		5.3	43
Minimum Value:		**4.97**	**-**	**-**	**-**	**20**	**-**	**120**	**-**	**14**	**1.0**	**1.6**	**-**	**1.2**	**35**
Maximum Value:		**9.67**	**-**	**-**	**-**	**249**	**-**	**1,507**	**-**	**131**	**39.9**	**11.2**	**-**	**11.3**	**58**
Geometric Mean:		**8.27**	**-**	**-**	**-**	**36**	**-**	**477**	**-**	**27**	**14.0**	**4.3**	**-**	**4.3**	**47**
No. of Samples:		**97**	**0**	**0**	**0**	**25**	**0**	**25**	**0**	**31**	**37**	**159**	**0**	**160**	**31**

Historical Water Quality Data for Lake Killarney

Data Source	Sample Date	pH (s.u.)	Alkalinity (mg/L)	Conductivity (µmho/cm)	Ammonia (µg/L)	NOx (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Chlorophyll-a (mg/m^3)	Secchi Depth (ft)	Color_pcu (Pt-Co)	Turbidity (NTU)	TSI
LakeWatch	8/20/87	8.70	63.5	190						20	17.0		15		52
	10/8/87	8.07	66.0	196						20	34.2		15		57
	3/9/88	8.35	67.0	194						20	14.0		27.5		48
	10/17/92									30	37.7	3.2			60
	3/28/93									28	9.3	6.3			46
	5/18/93									20	5.3	6.5			42
	6/13/93									18	4.3	6.3			37
	8/21/93									25	27.0	3.5			57
	10/24/93									31	52.7	3.7			61
	11/15/93									31	32.0	3.5			57
	12/13/93									38	37.5	3.5			59
	1/10/94									33	12.0	2.5			49
	2/15/94									32	21.3	2.8			53
	3/16/94									27	11.3	3.5			47
	4/12/94									19	18.0	4.7			51
	5/29/94									16	17.0	4.0			46
	6/17/94									27	15.0	3.7			51
	8/6/94									30	38.0	4.2			57
	9/12/94									28	14.0	4.0			53
	10/5/94									27	32.0	4.5			55
	12/8/94									39	43.7	4.8			60
	1/18/95									29	29.5	4.7			55
	2/14/95									26	16.7	4.3			49
	3/3/95									25	19.0	3.7			49
	4/27/95									24		4.5			
	5/20/95									22		5.0			
Minimum Value:		**8.07**	**63.5**	**190**	**-**	**-**	**-**	**-**	**-**	**16**	**4.3**	**2.5**	**15**	**-**	**37**
Maximum Value:		**8.70**	**67.0**	**196**	**-**	**-**	**-**	**-**	**-**	**39**	**52.7**	**6.5**	**28**	**-**	**61**
Geometric Mean:		**8.37**	**65.5**	**193**	**-**	**-**	**-**	**-**	**-**	**26**	**19.6**	**4.1**	**18**	**-**	**52**
No. of Samples:		**3**	**3**	**3**	**0**	**0**	**0**	**0**	**0**	**26**	**24**	**23**	**3**	**0**	**24**

APPENDIX B

RESULTS OF FIELD MONITORING IN LAKE KILLARNEY BY ERD FROM AUGUST 2010-JULY 2011

B.1 Vertical Field Profiles

B.2 Water Quality Characteristics of Surface Water Samples

B.1 Vertical Field Profiles

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	8/31/2010	7:05	0.25	29.35	7.75	240	153	6.9	91	551	1.21
		7:05	0.50	29.34	7.72	240	154	6.9	90	532	
		7:06	1.00	29.31	7.73	240	154	7.0	92	516	
		7:07	1.50	29.36	7.72	240	154	6.8	89	502	
		7:08	2.00	29.36	7.72	241	154	6.9	91	490	
		7:08	2.50	29.37	7.73	240	154	6.8	89	480	
		7:09	3.00	29.37	7.74	240	154	7.1	93	469	
		7:10	3.50	29.37	7.75	240	154	7.0	91	459	
		7:11	4.00	29.36	7.77	240	154	6.9	90	452	
		7:12	4.50	29.36	7.78	240	154	7.1	93	445	
		7:12	5.00	29.34	7.78	241	154	7.2	95	440	
		7:13	5.50	29.34	7.79	239	153	7.2	94	434	
		7:14	6.00	29.34	7.79	238	152	7.2	94	428	
		7:15	6.50	28.84	7.13	259	166	4.2	55	448	
		7:16	7.00	27.51	6.79	313	200	2.9	37	411	
		7:17	7.50	26.80	6.68	352	225	2.5	32	308	
		7:18	7.56	26.57	6.68	377	241	2.2	28	249	
North	8/31/2010	7:38	0.25	28.91	7.87	275	176	6.5	84	210	1.41
		7:39	0.50	28.89	7.87	276	177	6.1	80	205	
		7:40	1.00	28.92	7.85	276	177	6.1	80	204	
		7:40	1.50	28.92	7.83	276	177	6.1	79	204	
		7:41	2.00	28.91	7.86	276	177	6.2	80	203	
		7:42	2.50	28.92	7.84	277	177	5.8	76	204	
		7:43	3.00	28.90	7.70	277	178	5.4	70	209	
		7:44	3.50	28.82	7.70	278	178	5.3	69	208	
		7:45	3.74	28.74	7.33	287	184	1.4	18	165	
East	8/31/2010	8:04	0.25	29.12	7.68	241	154	6.6	86	216	1.29
		8:04	0.50	29.12	7.66	241	154	6.5	85	215	
		8:05	1.00	29.12	7.65	241	154	6.2	81	215	
		8:06	1.50	29.11	7.62	241	154	6.3	82	216	
		8:07	2.00	29.11	7.64	242	155	6.3	82	214	
		8:07	2.50	29.11	7.63	241	155	6.2	81	214	
		8:08	3.00	29.11	7.64	242	155	6.1	80	214	
		8:09	3.50	29.10	7.64	242	155	6.0	78	213	
		8:09	4.00	29.11	7.65	241	154	6.1	79	213	
		8:10	4.50	29.10	7.66	242	155	6.0	78	212	
		8:11	5.00	29.09	7.66	241	154	6.2	81	212	
		8:12	5.50	29.08	7.67	241	154	6.0	78	212	
		8:13	6.00	29.06	7.67	242	155	6.0	79	212	
		8:14	6.50	29.02	7.65	241	154	5.7	75	212	
		8:17	6.68	28.87	6.55	308	197	0.9	12	180	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	9/22/2010	11:19	0.25	29.23	8.03	241	154	7.7	101	236	0.89
		11:19	0.50	29.23	8.03	242	155	7.5	98	237	
		11:20	1.00	29.21	8.02	242	155	7.5	98	238	
		11:21	1.50	29.20	8.00	242	155	7.4	97	239	
		11:21	2.00	29.15	7.99	242	155	7.4	97	240	
		11:22	2.50	29.12	7.99	242	155	7.4	96	240	
		11:22	3.00	29.10	7.99	242	155	7.3	95	241	
		11:23	3.50	29.03	7.96	241	154	7.1	93	242	
		11:23	4.00	28.96	7.89	244	156	6.9	90	244	
		11:24	4.50	28.94	7.88	242	155	7.0	90	246	
		11:24	5.00	28.92	7.87	242	155	6.9	89	246	
		11:25	5.50	28.90	7.87	243	155	5.7	74	247	
		11:26	6.00	28.88	7.86	243	155	6.7	86	248	
		11:27	6.50	28.81	7.69	244	156	6.3	82	252	
		11:28	7.00	27.83	6.91	305	195	1.6	21	-2	
		11:28	7.41	26.97	6.69	348	223	1.2	15	-218	
North	9/22/2010	11:44	0.25	29.15	7.80	274	175	7.6	99	147	1.15
		11:45	0.50	29.14	7.79	274	175	7.5	98	150	
		11:45	1.00	29.04	7.75	275	176	7.3	95	155	
		11:46	1.50	28.79	7.62	280	179	6.6	85	160	
		11:47	2.00	28.60	7.42	280	179	5.6	72	166	
		11:47	2.50	28.52	7.37	281	180	5.1	65	169	
		11:48	3.00	28.49	7.42	281	180	5.3	68	169	
		11:51	3.48	28.18	7.37	289	185	5.0	65	153	
East	9/22/2010	12:05	0.25	28.88	8.03	241	154	7.5	98	170	0.86
		12:05	0.50	28.87	8.03	241	154	7.5	97	170	
		12:06	1.00	28.81	8.00	242	155	7.4	96	173	
		12:06	1.50	28.80	7.99	243	156	7.3	94	175	
		12:07	2.00	28.75	7.97	244	156	7.2	94	177	
		12:07	2.50	28.72	7.96	243	156	7.2	93	178	
		12:08	3.00	28.70	7.98	244	156	7.2	93	178	
		12:08	3.50	28.67	7.96	244	156	7.1	92	178	
		12:09	4.00	28.61	7.88	243	156	6.9	89	181	
		12:09	4.50	28.53	7.84	244	156	6.5	84	183	
		12:10	5.00	28.47	7.72	244	156	6.2	80	186	
		12:10	5.50	28.46	7.55	243	155	5.6	72	188	
		12:11	6.00	28.46	7.47	245	157	5.3	68	188	
		12:11	6.50	28.45	7.39	248	159	5.0	65	180	
		12:13	6.61	28.44	6.79	269	172	2.8	36	164	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	10/26/2010	11:51	0.25	26.14	8.08	225	144	8.2	102	132	1.16
		11:51	0.50	26.09	8.06	224	143	8.0	99	132	
		11:52	1.00	26.06	8.06	225	144	8.0	99	132	
		11:53	1.50	25.99	8.05	224	144	7.9	97	133	
		11:54	2.00	25.86	8.03	225	144	8.0	98	133	
		11:54	2.50	25.85	8.05	225	144	7.9	97	133	
		11:55	3.00	25.81	8.02	225	144	7.7	95	134	
		11:56	3.50	25.79	8.02	225	144	7.6	94	134	
		11:57	4.00	25.60	7.67	226	145	6.3	77	144	
		11:57	4.50	25.40	7.49	227	145	5.5	67	150	
		11:58	5.00	25.34	7.40	227	145	5.0	61	153	
		11:59	5.50	25.10	7.23	227	146	3.6	44	157	
		12:00	6.00	24.96	7.13	228	146	2.6	32	160	
		12:00	6.50	24.93	7.02	229	146	1.5	18	163	
		12:01	7.00	24.92	6.89	238	152	0.5	7	66	
		12:02	7.25	24.89	6.47	284	182	0.2	2	-162	
North	10/26/2010	12:17	0.25	26.66	8.13	260	167	8.5	106	87	0.94
		12:18	0.50	26.41	8.10	261	167	8.4	105	90	
		12:18	1.00	25.93	7.98	261	167	7.8	96	95	
		12:19	1.50	25.62	7.76	263	169	6.8	83	103	
		12:20	2.00	25.52	7.79	262	168	6.9	84	103	
		12:21	2.50	25.45	7.74	263	168	6.2	76	106	
		12:22	3.00	25.14	7.27	265	170	3.4	42	117	
		12:23	3.36	25.07	6.67	276	176	0.5	6	-65	
East	10/26/2010	12:39	0.25	26.05	8.06	225	144	7.8	96	88	1.29
		12:40	0.50	26.02	8.07	225	144	7.6	94	90	
		12:41	1.00	25.84	8.11	226	145	7.7	94	90	
		12:41	1.50	25.62	8.11	225	144	7.4	90	91	
		12:42	2.00	25.51	8.04	226	145	7.2	88	94	
		12:43	2.50	25.47	8.01	225	144	7.1	87	96	
		12:44	3.00	25.07	7.41	228	146	4.3	52	112	
		12:45	3.50	24.99	7.34	228	146	3.9	47	114	
		12:46	4.00	24.98	7.33	227	145	3.8	46	114	
		12:46	4.50	24.95	7.29	228	146	3.6	44	116	
		12:47	5.00	24.93	7.27	227	146	3.4	41	115	
		12:48	5.50	24.85	7.20	228	146	2.8	34	117	
		12:48	6.00	24.81	7.10	229	146	1.8	22	119	
		12:49	6.50	24.80	7.07	238	152	0.5	8	-50	
		12:49	6.81	24.82	6.80	263	168	0.3	3	-170	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	12/22/10	13:50	0.25	14.05	7.77	228	146	10.0	98	416	1.52
		13:50	0.50	13.94	7.82	229	147	9.7	94	418	
		13:51	1.00	13.90	7.86	229	147	9.4	91	418	
		13:52	1.50	13.75	7.90	229	147	9.4	91	419	
		13:53	2.00	13.62	7.95	229	147	9.5	91	418	
		13:53	2.50	13.45	7.97	228	146	9.5	91	419	
		13:54	3.00	13.43	7.97	228	146	9.3	89	420	
		13:55	3.50	13.37	7.94	228	146	9.2	88	422	
		13:55	4.00	13.26	7.88	228	146	8.9	85	425	
		13:56	4.50	13.19	7.86	228	146	8.9	85	427	
		13:57	5.00	13.16	7.81	228	146	8.7	83	430	
		13:58	5.50	13.13	7.75	228	146	8.5	81	432	
		13:59	6.00	13.11	7.72	228	146	8.3	79	434	
		13:59	6.50	13.10	7.70	228	146	8.3	79	435	
		14:01	7.00	13.73	7.16	227	145	5.6	54	334	
North	12/22/10	14:17	0.27	14.99	8.01	279	179	9.4	93	406	0.88
		14:18	0.52	14.83	8.05	279	178	9.5	94	407	
		14:19	1.01	14.25	8.21	272	174	9.9	97	406	
		14:20	1.50	13.58	8.15	276	176	9.8	94	410	
		14:21	2.00	13.37	8.19	274	175	9.7	93	411	
		14:22	2.54	13.24	8.11	277	177	9.4	90	414	
		14:23	3.01	13.13	7.62	277	178	7.0	67	429	
		14:26	3.44	13.25	7.22	273	175	3.5	33	393	
East	12/22/10	14:40	0.25	13.73	8.09	230	147	10.2	99	407	1.47
		14:41	0.50	13.70	8.12	231	148	10.1	97	408	
		14:41	1.00	13.69	8.15	231	148	9.9	96	409	
		14:42	1.50	13.68	8.17	231	148	9.9	96	410	
		14:43	2.00	13.66	8.17	230	148	9.8	94	411	
		14:44	2.50	13.60	8.16	231	148	9.9	95	413	
		14:44	3.00	13.63	8.17	231	148	9.9	95	414	
		14:45	3.50	13.61	8.17	231	148	9.9	95	415	
		14:46	4.00	13.63	8.16	230	148	9.8	94	417	
		14:46	4.50	13.54	8.14	232	148	9.8	94	419	
		14:47	5.00	13.38	8.06	231	148	9.6	92	422	
		14:48	5.50	13.02	7.93	231	148	9.3	88	425	
		14:48	6.00	12.81	7.75	232	148	8.4	80	430	
		14:50	6.50	13.14	7.12	244	156	1.5	15	374	
		14:51	6.66	13.18	7.08	246	157	0.8	8	376	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	1/27/2011	10:58	0.25	15.07	7.83	230	147	9.8	97	483	1.23
		10:59	0.50	15.08	7.83	229	147	9.6	96	482	
		11:00	1.00	15.05	7.82	230	147	9.6	96	482	
		11:00	1.50	15.03	7.83	229	147	9.3	93	480	
		11:01	2.00	15.01	7.77	230	147	9.4	93	482	
		11:02	2.50	15.00	7.77	230	147	9.3	93	482	
		11:02	3.00	14.99	7.74	231	148	9.1	90	483	
		11:03	3.50	14.98	7.72	230	148	9.0	90	484	
		11:04	4.00	14.98	7.74	230	147	9.0	90	483	
		11:05	4.50	14.97	7.73	230	147	8.8	88	483	
		11:05	5.00	14.95	7.74	231	148	9.0	89	483	
		11:07	5.50	14.90	7.74	231	148	9.1	90	483	
		11:08	6.00	14.87	7.73	231	148	9.0	89	483	
		11:09	6.50	14.67	7.49	232	148	7.7	76	490	
		11:10	7.00	14.19	7.16	235	151	3.9	38	498	
		11:11	7.49	14.19	7.08	241	154	2.4	24	477	
North	1/27/2011	11:23	0.26	15.94	7.84	257	164	9.1	92	449	0.66
		11:24	0.51	15.89	7.86	257	165	8.8	89	446	
		11:25	1.01	15.86	7.84	256	164	8.7	88	447	
		11:26	1.53	15.75	7.82	257	164	8.5	85	447	
		11:26	2.02	15.70	7.77	256	164	8.3	83	450	
		11:27	2.50	15.61	7.71	255	164	8.1	82	452	
		11:28	2.99	15.27	7.34	264	169	5.0	50	462	
		11:31	3.38	15.28	7.07	261	167	0.4	4	435	
East	1/27/2011	11:51	0.25	15.21	7.80	230	147	10.6	105	436	1.14
		11:52	0.50	15.19	7.81	230	147	10.0	100	436	
		11:53	1.00	15.15	7.81	229	147	9.5	95	436	
		11:54	1.50	15.10	7.78	230	147	9.3	93	438	
		11:54	2.00	15.08	7.77	230	147	9.0	89	438	
		11:55	2.50	15.07	7.77	229	147	8.9	89	439	
		11:56	3.00	15.06	7.77	230	147	8.8	87	439	
		11:57	3.50	15.06	7.77	229	147	8.7	86	439	
		11:58	4.00	15.05	7.77	230	147	8.7	87	440	
		11:58	4.50	15.04	7.75	230	147	8.6	86	441	
		11:59	5.00	14.95	7.68	230	147	8.6	85	443	
		12:00	5.50	14.94	7.68	231	148	8.5	84	444	
		12:01	6.00	14.92	7.67	230	148	8.4	83	445	
		12:02	6.50	14.90	7.67	230	147	8.4	83	445	
		12:04	7.01	14.86	7.66	231	148	8.3	82	446	
		12:05	7.50	15.08	6.96	239	153	3.0	30	440	
		12:06	7.73	15.16	6.84	268	171	0.9	9	446	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	2/21/2011	9:55	0.25	19.09	8.49	232	149	11.1	120	471	1.39
		9:55	0.50	19.09	8.50	232	149	10.9	118	469	
		9:56	1.00	19.03	8.48	232	149	11.1	120	470	
		9:57	1.50	19.01	8.50	232	149	11.0	119	469	
		9:58	2.00	18.99	8.47	233	149	10.3	111	469	
		9:58	2.50	17.74	8.00	233	149	9.6	101	483	
		9:59	3.00	16.77	7.65	234	150	8.4	87	495	
		10:00	3.50	16.21	7.43	233	149	7.2	74	503	
		10:01	4.00	15.79	7.17	233	149	5.5	55	513	
		10:02	4.50	15.68	7.23	234	150	5.8	58	514	
		10:03	5.00	15.64	7.10	234	150	4.6	46	518	
		10:03	5.50	15.62	7.06	234	150	4.1	41	520	
		10:04	6.00	15.58	7.09	233	149	4.5	46	521	
		10:05	6.50	15.59	7.03	234	150	3.8	39	523	
		10:06	7.00	15.60	7.01	235	151	3.3	33	492	
		10:07	7.22	15.64	6.96	241	154	1.7	17	447	
East	2/21/2011	10:25	0.25	19.51	7.71	270	173	8.1	88	457	1.22
		10:26	0.50	19.47	7.73	270	173	8.0	87	456	
		10:26	1.00	19.41	7.72	269	172	7.9	86	458	
		10:27	1.50	19.35	7.70	269	172	7.6	82	458	
		10:28	2.00	18.71	7.68	264	169	7.1	76	460	
		10:29	2.50	17.27	7.34	264	169	5.3	55	471	
		10:29	3.00	16.90	7.14	266	170	3.8	40	479	
		10:30	3.41	16.84	6.98	269	172	1.5	15	450	
North	2/21/2011	11:10	0.25	19.06	8.43	234	150	11.5	124	443	0.87
		11:10	0.50	19.11	8.46	234	150	11.4	123	440	
		11:10	1.00	19.00	8.48	234	150	11.2	120	438	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	3/21/2011	11:38	0.25	23.19	8.56	235	150	10.7	125	428	1.48
		11:39	0.50	23.17	8.59	236	151	10.4	122	426	
		11:39	1.00	22.92	8.57	236	151	10.2	118	427	
		11:40	1.50	22.72	8.53	236	151	9.7	113	429	
		11:41	2.00	22.60	8.49	236	151	9.7	113	430	
		11:42	2.50	22.53	8.53	236	151	9.5	110	430	
		11:44	3.00	21.39	8.57	235	150	11.0	125	431	
		11:45	3.50	20.32	8.40	236	151	10.0	111	439	
		11:46	4.00	18.97	7.56	238	152	6.6	71	461	
		11:46	4.50	18.65	7.31	238	152	4.8	52	471	
		11:47	5.00	18.31	7.12	238	152	2.8	29	477	
		11:48	5.50	17.98	6.96	235	150	0.9	10	483	
		11:49	6.00	17.69	6.93	236	151	0.5	5	477	
		11:49	6.50	17.26	6.95	248	158	0.4	4	389	
		11:49	7.00	17.07	6.91	256	164	0.3	3	311	
		11:50	7.11	17.10	6.86	258	165	0.2	3	273	
North	3/21/2011	12:07	0.25	23.69	8.80	269	172	12.2	145	368	1.02
		12:08	0.50	23.68	8.82	269	172	12.0	142	369	
		12:09	1.00	23.21	8.77	269	172	11.7	137	373	
		12:10	1.50	22.79	8.58	272	174	9.8	114	382	
		12:11	2.00	22.47	8.48	271	174	9.5	106	393	
		12:13	2.50	20.70	7.61	276	176	6.0	67	416	
		12:13	3.00	20.12	7.26	278	178	2.6	28	425	
		12:14	3.32	19.89	7.09	379	243	0.7	8	391	
East	3/21/2011	12:36	0.25	22.85	8.56	234	150	9.9	115	399	1.41
		12:37	0.50	22.79	8.58	235	150	9.9	115	399	
		12:38	1.00	22.52	8.60	234	150	10.0	116	399	
		12:39	1.50	22.30	8.61	234	150	9.9	114	400	
		12:39	2.00	22.19	8.57	234	150	9.7	111	403	
		12:40	2.50	21.69	8.52	234	150	9.8	111	406	
		12:42	3.00	21.50	8.56	235	151	10.3	117	407	
		12:43	3.50	20.91	8.52	236	151	10.2	114	410	
		12:44	4.00	19.78	8.44	234	150	9.9	108	415	
		12:45	4.50	18.98	7.62	238	152	6.7	73	437	
		12:46	5.00	18.59	7.32	239	153	4.4	47	446	
		12:47	5.50	18.24	7.11	239	153	2.2	24	452	
		12:47	6.00	18.02	6.98	236	151	0.7	8	454	
		12:48	6.50	17.90	6.98	245	157	0.4	4	431	
		12:48	7.00	17.78	6.97	249	159	0.3	3	369	
		12:49	7.49	17.80	6.84	270	173	0.2	2	268	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	4/26/2011	10:43	0.25	27.00	8.48	216	138	8.6	108	425	1.35
		10:44	0.50	26.99	8.51	216	138	8.5	107	423	
		10:45	1.00	26.94	8.54	216	138	8.1	102	424	
		10:46	1.50	26.90	8.56	216	138	8.0	100	422	
		10:46	2.00	26.85	8.56	215	138	8.2	103	423	
		10:47	2.50	26.78	8.57	215	138	7.6	95	422	
		10:48	3.00	26.74	8.56	216	138	7.7	97	422	
		10:49	3.50	26.67	8.55	216	138	8.2	103	423	
		10:50	4.00	26.55	8.48	217	139	7.6	94	426	
		10:51	4.50	25.07	7.80	221	141	6.9	83	445	
		10:51	5.00	22.71	7.21	217	139	3.7	43	462	
		10:52	5.50	21.18	6.90	213	137	0.6	7	472	
		10:52	6.00	19.98	6.89	245	157	0.3	4	474	
		10:53	6.50	19.31	6.94	275	176	0.3	3	471	
		10:54	7.00	19.21	6.91	293	188	0.3	3	447	
North	4/26/2011	11:16	0.25	27.28	7.94	248	159	6.5	82	421	0.92
		11:17	0.50	27.28	7.95	249	159	6.2	78	421	
		11:18	1.00	27.20	7.96	249	159	6.2	78	421	
		11:19	1.50	27.08	7.92	248	159	5.9	74	424	
		11:19	2.00	26.99	7.87	249	159	5.8	72	426	
		11:20	2.50	26.94	7.81	249	159	5.2	65	429	
		11:21	3.00	26.76	7.61	252	161	4.6	58	434	
		11:22	3.24	26.52	6.85	264	169	0.8	10	383	
East	4/26/2011	11:44	0.25	27.20	8.56	214	137	8.6	109	394	1.33
		11:45	0.50	27.13	8.58	214	137	8.5	107	394	
		11:45	1.00	26.92	8.60	214	137	8.3	104	395	
		11:46	1.50	26.60	8.60	214	137	8.6	107	396	
		11:47	2.00	26.60	8.60	213	137	8.1	102	397	
		11:48	2.50	26.54	8.58	213	136	7.9	99	401	
		11:49	3.00	26.44	8.42	214	137	7.3	91	404	
		11:49	3.50	26.34	8.31	214	137	7.3	91	410	
		11:50	4.00	25.91	8.26	217	139	7.6	93	429	
		11:51	4.50	24.63	7.70	220	141	6.5	78	427	
		11:52	5.00	23.43	7.20	218	139	2.8	33	442	
		11:53	5.50	22.13	6.97	224	143	0.6	7	450	
		11:53	6.00	21.15	7.00	262	167	0.3	4	445	
		11:54	6.50	20.76	7.03	276	177	0.2	3	433	
		11:54	7.00	20.46	7.08	287	184	0.2	2	371	
		11:55	7.54	20.35	6.97	308	197	0.2	3	318	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^{o}C)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	5/19/2011	10:24	0.25	26.57	8.27	201	129	8.1	101	440	1.15
		10:25	0.50	26.50	8.31	201	129	8.1	101	436	
		10:26	1.00	26.34	8.34	201	128	8.0	100	434	
		10:26	1.50	26.23	8.36	200	128	7.8	96	432	
		10:27	2.00	26.16	8.38	201	129	8.2	101	430	
		10:27	2.50	26.13	8.40	200	128	7.6	94	431	
		10:28	3.00	26.09	8.38	200	128	7.3	90	429	
		10:28	3.50	26.03	8.33	201	128	7.2	89	433	
		10:29	4.00	25.83	8.23	202	129	7.2	88	433	
		10:30	4.50	25.74	8.20	202	129	7.0	87	435	
		10:30	5.00	25.53	7.98	203	130	6.5	79	440	
		10:31	5.50	25.12	7.53	203	130	4.4	53	448	
		10:31	6.00	24.72	7.27	207	132	2.0	24	454	
		10:31	6.50	22.90	7.05	254	163	0.6	7	462	
		10:32	7.00	20.85	7.12	326	209	0.4	5	465	
		10:33	7.10	20.80	6.98	399	255	0.3	3	455	
North	5/19/2011	10:46	0.25	26.78	8.70	248	159	10.9	137	384	0.86
		10:47	0.50	26.91	8.71	247	158	10.9	136	383	
		10:48	1.00	26.63	8.69	250	160	10.6	132	384	
		10:49	1.50	26.37	8.64	249	159	9.8	122	388	
		10:49	2.00	26.28	8.55	249	160	8.8	109	390	
		10:50	2.50	26.21	8.44	252	161	8.0	98	396	
		10:51	3.00	26.10	8.08	254	163	5.8	71	407	
		10:52	3.26	25.89	7.54	314	201	1.7	21	412	
East	5/19/2011	11:10	0.25	26.46	8.27	203	130	7.9	98	395	1.19
		11:11	0.50	26.40	8.28	202	129	7.8	97	396	
		11:12	1.00	26.26	8.29	203	130	7.8	96	397	
		11:12	1.50	26.09	8.30	205	131	7.7	95	397	
		11:13	2.00	25.99	8.27	204	131	7.7	95	399	
		11:14	2.50	25.93	8.26	205	131	7.6	94	401	
		11:14	3.00	25.83	8.25	205	131	7.4	91	402	
		11:15	3.50	25.68	8.20	205	131	7.2	88	405	
		11:15	4.00	25.63	8.15	204	131	7.1	87	407	
		11:16	4.50	25.54	8.10	205	131	6.9	85	409	
		11:17	5.00	25.44	7.97	206	132	6.5	79	413	
		11:17	5.50	25.32	7.80	206	132	5.7	70	417	
		11:18	6.00	25.17	7.57	210	134	4.6	55	422	
		11:18	6.50	24.56	7.20	227	145	0.7	8	430	
		11:19	7.00	24.08	7.09	248	158	0.3	4	434	
		11:19	7.43	23.34	6.98	303	194	0.2	2	398	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	6/28/11	9:11	0.25	29.82	8.18	202	130	7.2	94	290	1.43
		9:12	0.50	29.81	8.20	203	130	6.9	91	285	
		9:12	1.00	29.83	8.21	203	130	6.9	91	283	
		9:13	1.50	29.85	8.21	203	130	6.9	91	281	
		9:14	2.00	29.85	8.21	204	130	6.8	89	281	
		9:15	2.50	29.85	8.21	203	130	6.9	91	280	
		9:15	3.00	29.84	8.22	204	130	6.8	89	279	
		9:16	3.50	29.85	8.21	203	130	6.9	91	278	
		9:17	4.00	29.86	8.22	204	131	7.0	92	277	
		9:18	4.50	29.85	8.16	204	131	6.6	87	279	
		9:18	5.00	29.80	8.00	205	131	6.0	79	283	
		9:19	5.50	29.57	7.61	209	134	4.4	58	295	
		9:20	6.00	29.36	7.34	212	135	2.4	32	304	
		9:20	6.50	28.70	7.12	218	139	0.4	5	312	
		9:21	7.00	27.62	7.03	248	159	0.3	3	313	
		9:21	7.50	26.23	6.96	284	182	0.2	3	291	
		9:22	7.80	25.83	6.77	363	233	0.2	2	244	
North	6/28/11	9:38	0.25	29.49	8.12	250	160	5.6	71	235	0.91
		9:39	0.50	29.48	8.11	250	160	5.3	69	234	
		9:39	1.00	29.48	8.09	252	161	5.2	68	234	
		9:40	1.50	29.49	8.08	253	162	5.2	68	234	
		9:41	2.00	29.48	8.07	253	162	5.0	66	234	
		9:41	2.50	29.46	8.06	254	163	5.0	66	234	
		9:42	3.00	29.37	7.98	256	164	4.6	60	237	
		9:43	3.17	28.94	7.21	268	171	0.6	7	248	
East	6/28/11	9:59	0.25	29.74	8.22	199	127	6.7	88	254	1.39
		10:00	0.50	29.73	8.23	198	127	6.6	87	251	
		10:01	1.00	29.72	8.23	200	128	6.5	85	249	
		10:02	1.50	29.70	8.22	200	128	6.4	84	249	
		10:02	2.00	29.69	8.20	200	128	6.3	83	248	
		10:03	2.50	29.69	8.20	201	128	6.3	82	247	
		10:04	3.00	29.69	8.20	201	129	6.2	82	247	
		10:05	3.50	29.68	8.17	202	129	6.1	81	247	
		10:06	4.00	29.66	8.15	201	129	6.2	82	247	
		10:07	4.50	29.65	8.13	202	129	6.2	81	247	
		10:08	5.00	29.47	7.50	203	130	3.4	45	265	
		10:09	5.50	29.34	7.27	204	131	1.8	23	273	
		10:09	6.00	28.83	7.07	210	134	0.2	3	278	
		10:10	6.50	27.87	7.00	238	152	0.2	2	256	
		10:10	7.00	27.14	7.03	256	164	0.2	2	133	
		10:11	7.27	26.90	6.78	297	190	0.2	2	-68	

Vertical Field Profiles Collected in Lake Killarney from August 2010 - July 2011

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
West	7/27/2011	9:04	0.25	30.65	8.02	203	130	7.1	95	450	1.36
		9:05	0.50	30.65	8.02	203	130	6.9	92	444	
		9:05	1.00	30.68	8.02	204	130	6.8	91	441	
		9:06	1.50	30.68	8.02	205	131	6.8	91	438	
		9:06	2.00	30.69	8.02	204	131	6.7	90	435	
		9:07	2.50	30.68	8.02	204	131	6.7	90	432	
		9:08	3.00	30.68	8.02	205	131	6.7	89	428	
		9:08	3.50	30.68	8.01	205	131	6.7	90	427	
		9:09	4.00	30.68	8.01	205	131	6.6	89	424	
		9:09	4.50	30.67	7.96	205	131	6.7	89	424	
		9:10	5.00	30.24	7.27	203	130	2.9	38	444	
		9:11	5.50	29.90	6.99	191	122	0.7	9	454	
		9:11	6.00	29.21	6.92	214	137	0.3	4	456	
		9:11	6.50	28.76	6.88	232	148	0.2	3	453	
		9:12	7.00	27.90	6.82	255	163	0.2	3	377	
		9:12	7.41	27.64	6.63	308	197	0.2	3	340	
North	7/27/2011	9:27	0.25	30.12	7.42	222	142	4.1	55	347	0.77
		9:27	0.50	30.14	7.40	222	142	4.1	54	346	
		9:28	1.00	30.14	7.40	223	142	4.0	53	345	
		9:29	1.50	30.14	7.40	223	143	3.9	51	344	
		9:29	2.00	30.14	7.41	222	142	3.9	52	343	
		9:30	2.50	30.12	7.42	222	142	4.1	54	342	
		9:31	3.00	30.10	7.41	222	142	3.9	51	342	
		9:31	3.50	29.73	7.18	220	141	2.4	32	343	
		9:32	3.62	29.70	6.77	249	160	0.5	7	313	
East	7/27/2011	9:50	0.25	30.39	8.12	202	129	6.8	90	307	1.25
		9:51	0.50	30.40	8.12	202	129	6.6	88	306	
		9:51	1.00	30.42	8.13	203	130	6.5	87	306	
		9:52	1.50	30.42	8.12	203	130	6.5	86	306	
		9:52	2.00	30.42	8.13	203	130	6.4	86	306	
		9:53	2.50	30.42	8.12	204	130	6.4	86	307	
		9:53	3.00	30.42	8.12	204	130	6.6	88	308	
		9:54	3.50	30.42	8.12	204	130	6.6	89	308	
		9:55	4.00	30.41	8.11	203	130	6.5	87	309	
		9:55	4.50	30.38	8.01	205	131	6.0	80	312	
		9:56	5.00	29.90	7.20	198	127	0.7	9	331	
		9:56	5.50	29.51	7.02	208	133	0.2	3	333	
		9:57	6.00	29.17	6.92	215	138	0.2	3	314	
		9:57	6.50	28.53	6.86	232	148	0.2	2	152	
		9:58	7.00	28.37	6.76	266	170	0.1	1	1	
		9:58	7.35	28.16	6.47	409	262	0.1	2	-23	

B.2 Water Quality Characteristics of Surface Water Samples

Characteristics of Surface Water Samples Collected from Lake Killarney from August 2010 - July 2011

Site	Depth	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Ammonia (µg/L)	NO_X (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	Color (Pt-Co)	Chly-a (mg/m^3)
East	Surface	8/31/10	7.51	81.6	223	17	1	184	577	779	2	3	4	9	3.2	15	9.6
East	Surface	9/22/10	7.64	87.4	227	17	1	243	209	470	1	2	10	13	5.6	11	15.3
East	Surface	10/26/10	7.81	85.2	225	42	1	426	441	910	1	2	10	13	7.8	10	59.6
East	Surface	11/30/10	8.20	85.6	214	120	1	113	175	409	1	3	21	25	8.0	10	29.1
East	Surface	12/22/10	8.00	94.8	229	14	1	207	178	400	2	4	27	33	6.5	12	8.9
East	Surface	1/27/11	7.58	94.0	231	49	6	245	305	605	1	2	20	23	6.8	11	21.9
East	Surface	2/21/11	8.02	91.0	220	19	3	192	447	661	2	4	24	30	6.5	10	18.0
East	Surface	3/21/11	7.52	90.6	238	27	1	147	451	626	1	2	31	33	4.3	10	19.0
East	Surface	4/26/11	8.22	83.4	227	64	1	132	394	591	1	3	16	20	2.6	12	3.4
East	Surface	5/19/11	7.95	75.4	218	15	1	235	363	614	2	8	21	31	1.9	13	13.8
East	Surface	6/28/11	7.42	80.4	209	22	1	197	298	518	1	9	17	27	2.2	12	15.9
East	Surface	7/27/11	7.56	81.4	199	78	1	113	364	556	1	5	10	16	2.5	11	13.0
	Minimum Value:		**7.42**	**75.4**	**199**	**14**	**1**	**113**	**175**	**400**	**1**	**2**	**4**	**9**	**1.9**	**10**	**3.4**
	Maximum Value:		**8.22**	**94.8**	**238**	**120**	**6**	**426**	**577**	**910**	**2**	**9**	**31**	**33**	**8.0**	**15**	**59.6**
	Median Value:		**7.73**	**85.4**	**224**	**25**	**1**	**195**	**364**	**598**	**1**	**3**	**19**	**24**	**5.0**	**11**	**15.6**
	Log Normal Mean:		**7.78**	**85.7**	**221**	**31**	**1**	**189**	**329**	**579**	**1**	**3**	**16**	**21**	**4.3**	**11**	**15.3**
East	Bottom	8/31/10	7.49	79.8	208	13	2	241	265	521	1	9	41	51	3.3	12	-
East	Bottom	9/22/10	7.44	80.0	230	41	1	254	343	639	1	4	37	42	9.0	9	-
East	Bottom	10/26/10	7.33	84.2	228	180	5	421	379	985	1	6	28	35	6.8	9	-
East	Bottom	11/30/10	8.33	90.4	199	137	1	326	242	706	1	5	31	37	7.0	12	-
East	Bottom	12/22/10	8.02	97.4	229	14	4	508	143	669	2	7	30	39	6.6	12	-
East	Bottom	1/27/11	7.53	89.6	231	65	9	341	330	745	1	5	25	31	8.5	11	-
East	Bottom	2/21/11	8.04	90.2	223	63	15	454	701	1233	3	3	37	43	6.7	11	-
East	Bottom	3/21/11	7.13	96.0	255	229	1	448	651	1329	1	8	13	22	6.4	10	-
East	Bottom	4/26/11	7.20	107	276	289	1	396	673	1359	1	4	51	56	10.7	13	-
East	Bottom	5/19/11	7.06	90.6	235	166	1	434	585	1186	4	3	32	39	7.5	13	-
East	Bottom	6/28/11	6.80	89.2	240	471	1	338	488	1298	2	2	60	64	8.2	12	-
East	Bottom	7/27/11	7.24	91.2	231	735	1	498	308	1542	2	3	25	30	10.3	11	-
	Minimum Value:		**6.80**	**79.8**	**199**	**13**	**1**	**241**	**143**	**521**	**1**	**2**	**13**	**22**	**3.3**	**9**	-
	Maximum Value:		**8.33**	**107**	**276**	**735**	**15**	**508**	**701**	**1542**	**4**	**9**	**60**	**64**	**10.7**	**13**	-
	Median Value:		**7.39**	**90.3**	**231**	**152**	**1**	**409**	**361**	**1085**	**1**	**5**	**32**	**39**	**7.3**	**12**	-
	Log Normal Mean:		**7.46**	**90.2**	**231**	**109**	**1**	**378**	**385**	**959**	**1**	**4**	**32**	**39**	**7.3**	**11**	-

Characteristics of Surface Water Samples Collected from Lake Killarney from August 2010 - July 2011

Site	Depth	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Ammonia (µg/L)	NO_X (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	Color (Pt-Co)	Chly-a (mg/m^3)
North	Surface	8/31/10	7.54	104	253	7	2	439	295	743	17	5	39	61	2.5	21	16.0
North	Surface	9/22/10	7.26	109	263	13	1	340	515	869	13	7	42	62	2.8	15	15.4
North	Surface	10/26/10	7.45	103	263	41	1	352	339	733	8	4	47	59	3.4	13	26.2
North	Surface	11/30/10	8.11	106	266	105	1	132	205	443	20	12	60	92	4.3	13	84.0
North	Surface	12/22/10	7.64	113	275	16	7	133	154	310	17	5	52	74	4.7	12	23.8
North	Surface	1/27/11	7.44	105	251	40	1	244	163	448	6	6	49	61	4.0	14	52.1
North	Surface	2/21/11	7.50	112	298	39	1	164	235	439	4	4	32	40	3.1	14	18.1
North	Surface	3/21/11	7.47	118	274	40	1	295	530	866	7	8	33	48	8.9	13	32.4
North	Surface	4/26/11	7.56	101	261	71	1	212	429	713	14	3	47	64	3.7	18	16.6
North	Surface	5/19/11	8.59	114	270	27	1	120	978	1126	2	6	48	56	4.5	21	15.8
North	Surface	6/28/11	7.21	112	259	5	1	174	490	670	19	8	55	82	2.6	20	38.2
North	Bottom	7/27/11	6.91	96.6	210	11	2	219	226	458	17	10	69	96	2.8	22	23.6
	Minimum Value:		**6.91**	**96.6**	**210**	**5**	**1**	**120**	**154**	**310**	**2**	**3**	**32**	**40**	**2.5**	**12**	**15.4**
	Maximum Value:		**8.59**	**118**	**298**	**105**	**7**	**439**	**978**	**1126**	**20**	**12**	**69**	**96**	**8.9**	**22**	**84.0**
	Median Value:		**7.49**	**108**	**263**	**33**	**1**	**216**	**317**	**691**	**14**	**6**	**48**	**62**	**3.6**	**15**	**23.7**
	Log Normal Mean:		**7.55**	**108**	**261**	**24**	**1**	**216**	**328**	**611**	**10**	**6**	**47**	**64**	**3.7**	**16**	**25.9**
North	Bottom	8/31/10	7.44	103	254	13	1	213	271	498	21	5	53	79	4.6	23	-
North	Bottom	9/22/10	7.49	106	266	13	4	114	113	244	22	10	36	68	2.8	15	-
North	Bottom	10/26/10	7.23	109	260	37	1	151	318	507	25	6	47	78	4.0	14	-
North	Bottom	11/30/10	7.59	119	255	70	1	100	126	297	25	2	54	81	3.9	13	-
North	Bottom	12/22/10	7.80	120	274	8	6	156	103	273	13	2	48	63	5.6	13	-
North	Bottom	1/27/11	7.41	112	253	33	1	158	434	626	4	4	41	49	4.6	13	-
North	Bottom	2/21/11	7.27	110	292	19	1	144	587	751	3	2	59	64	4.5	17	-
North	Bottom	3/21/11	7.34	113	238	302	1	239	503	1045	2	2	55	59	5.7	13	-
North	Bottom	4/26/11	7.50	113	262	84	9	237	636	966	26	6	47	79	3.8	18	-
North	Bottom	5/19/11	7.76	110	214	36	1	472	366	875	10	2	55	67	6.8	20	-
North	Bottom	6/28/11	7.44	109	263	10	1	286	268	565	16	2	54	72	2.9	20	-
North	Bottom	7/27/11	7.09	96.0	161	14	1	164	144	323	21	8	40	69	2.2	21	-
	Minimum Value:		**7.09**	**96.0**	**161**	**8**	**1**	**100**	**103**	**244**	**2**	**2**	**36**	**49**	**2.2**	**13**	-
	Maximum Value:		**7.80**	**120**	**292**	**302**	**9**	**472**	**636**	**1045**	**26**	**10**	**59**	**81**	**6.8**	**23**	-
	Median Value:		**7.44**	**110**	**258**	**26**	**1**	**161**	**295**	**536**	**19**	**3**	**51**	**69**	**4.3**	**16**	-
	Log Normal Mean:		**7.44**	**110**	**247**	**28**	**1**	**185**	**269**	**518**	**12**	**4**	**49**	**68**	**4.1**	**16**	-

Characteristics of Surface Water Samples Collected from Lake Killarney from August 2010 - July 2011

Site	Depth	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Ammonia (µg/L)	NO_X (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	Color (Pt-Co)	Chly-a (mg/m^3)
West	Surface	8/31/10	7.48	75.6	205	21	2	270	288	581	1	5	9	15	3.0	10	14.1
West	Surface	9/22/10	7.55	82.2	226	37	1	218	327	583	1	2	4	7	4.6	8	12.3
West	Surface	10/26/10	7.22	81.8	217	46	3	489	416	954	1	3	13	17	8.0	8	17.8
West	Surface	11/30/10	8.07	84.2	191	148	1	265	200	614	1	5	21	27	8.3	8	37.0
West	Surface	12/22/10	7.52	87.6	224	25	11	221	297	554	2	4	28	34	7.2	10	16.9
West	Surface	1/27/11	7.16	88.4	216	14	1	142	313	470	1	3	16	20	7.0	10	27.4
West	Surface	2/21/11	7.93	91.4	257	94	2	121	584	801	2	4	18	24	7.4	11	2.3
West	Surface	3/21/11	7.11	88.2	246	70	1	280	764	1115	1	3	15	19	5.9	9	5.5
West	Surface	4/26/11	8.13	84.6	221	68	1	294	759	1122	1	3	13	17	2.6	11	2.0
West	Surface	5/19/11	8.07	72.4	198	20	3	281	748	1052	1	7	9	16	1.6	10	6.3
West	Surface	6/28/11	7.41	70.2	201	22	1	223	148	394	1	5	8	14	1.6	10	7.6
West	Surface	7/27/11	7.27	73.8	238	18	4	179	266	467	2	3	6	11	1.8	10	8.7
	Minimum Value:		**7.11**	**70.2**	**191**	**14**	**1**	**121**	**148**	**394**	**1**	**2**	**4**	**7**	**1.6**	**8**	**2.0**
	Maximum Value:		**8.13**	**91.4**	**257**	**148**	**11**	**489**	**764**	**1122**	**2**	**7**	**28**	**34**	**8.3**	**11**	**37.0**
	Median Value:		**7.50**	**83.2**	**219**	**31**	**2**	**244**	**320**	**598**	**1**	**4**	**13**	**17**	**5.3**	**10**	**10.5**
	Log Normal Mean:		**7.57**	**81.4**	**219**	**37**	**1**	**234**	**373**	**681**	**1**	**4**	**12**	**17**	**4.1**	**10**	**9.5**
West	Bottom	8/31/10	7.48	83.2	219	42	1	201	465	709	1	5	11	17	3.0	11	-
West	Bottom	9/22/10	7.50	81.4	224	40	1	329	390	760	1	3	13	17	4.2	7	-
West	Bottom	10/26/10	6.94	81.4	224	232	2	209	449	892	1	4	20	25	5.7	8	-
West	Bottom	11/30/10	7.94	84.0	197	75	1	236	282	594	1	3	18	22	8.3	9	-
West	Bottom	12/22/10	7.57	88.0	226	32	7	278	186	503	2	3	32	37	8.5	11	-
West	Bottom	1/27/11	7.49	92.2	227	40	5	139	312	496	1	6	13	20	6.1	8	-
West	Bottom	2/21/11	7.06	88.6	254	92	9	113	349	563	2	2	26	30	4.6	12	-
West	Bottom	3/21/11	6.76	94.6	244	143	1	208	344	696	1	2	23	26	11.1	10	-
West	Bottom	4/26/11	6.85	81.2	251	248	1	119	721	1089	1	4	26	31	7.9	10	-
West	Bottom	5/19/11	6.97	98.6	250	353	1	139	1212	1705	1	3	48	52	9.5	13	-
West	Bottom	6/28/11	6.89	96.4	245	261	1	278	569	1109	4	4	28	36	7.9	11	-
West	Bottom	7/27/11	6.57	69.0	201	36	1	143	516	696	2	3	40	45	10.2	10	-
	Minimum Value:		**6.57**	**69.0**	**197**	**32**	**1**	**113**	**186**	**496**	**1**	**2**	**11**	**17**	**3.0**	**7**	-
	Maximum Value:		**7.94**	**98.6**	**254**	**353**	**9**	**329**	**1212**	**1705**	**4**	**6**	**48**	**52**	**11.1**	**13**	-
	Median Value:		**7.02**	**86.0**	**227**	**84**	**1**	**205**	**420**	**702**	**1**	**3**	**25**	**28**	**7.9**	**10**	-
	Log Normal Mean:		**7.16**	**86.2**	**229**	**93**	**1**	**188**	**431**	**765**	**1**	**3**	**23**	**28**	**6.8**	**10**	-

APPENDIX C

HYDROLOGIC MODEL USED TO ESTIMATE RUNOFF INPUTS TO LAKE KILLARNEY

Hydrologic Model of Runoff Inputs to Lake Killarney

Basin	Sub Basin	Treatment	Land Use	Hydrologic Soil Group	Area (ac.)	DCIA1 (%)	Non - DCIA CN Value2	Runoff C Value4	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Runoff Volume (ac-ft)
Drainwell	Drainwell 01	Dry Pond	Commercial	A	0.16	39.2	43.5	0.323	0.21	0.80	0.04
Drainwell	Drainwell 01	Wet Pond	Commercial	A	8.78	90.0	68.5	0.734	26.85	0.20	21.48
Drainwell	Drainwell 01	Wet Pond	Open	A	0.56	0.0	39.0	0.127	0.30	0.20	0.24
Drainwell	Drainwell 01	None	Commercial	A	25.38	67.6	71.8	0.568	60.10	0.00	60.10
Drainwell	Drainwell 01	None	Commercial	A/D	2.20	67.0	72.8	0.565	5.19	0.00	5.19
Drainwell	Drainwell 01	None	High Density Residential	A	1.37	40.0	58.7	0.341	1.94	0.00	1.94
Drainwell	Drainwell 01	None	High Density Residential	A/D	1.36	40.0	58.7	0.341	1.93	0.00	1.93
Drainwell	Drainwell 01	None	Institutional	A/D	0.09	60.0	68.5	0.507	0.20	0.00	0.20
Drainwell	Drainwell 01	None	Med Density Residential	A	16.64	17.4	54.2	0.158	10.93	0.00	10.93
Drainwell	Drainwell 01	None	Med Density Residential	A/D	29.40	14.6	51.7	0.136	16.70	0.00	16.70
Drainwell	Drainwell 01	None	Transportation	A	0.14	90.0	68.5	0.734	0.43	0.00	0.43
Drainwell H-37	Drainwell H-37	Wet Pond	Institutional	A	2.13	57.8	56.3	0.478	4.24	0.20	3.39
Drainwell H-37	Drainwell H-37	Wet Pond	Institutional	A/D	1.16	69.1	67.3	0.575	2.77	0.20	2.22
Drainwell H-37	Drainwell H-37	Wet Pond	Med Density Residential	A	0.51	60.0	53.8	0.494	1.06	0.20	0.85
Drainwell H-37	Drainwell H-37	None	Institutional	A	2.46	53.8	62.2	0.452	4.63	0.00	4.63
Drainwell H-37	Drainwell H-37	None	Institutional	A/D	1.65	51.0	63.1	0.431	2.96	0.00	2.96
Drainwell H-37	Drainwell H-37	None	Med Density Residential	A	11.00	14.6	51.4	0.136	6.24	0.00	6.24
Drainwell H-37	Drainwell H-37	None	Med Density Residential	A/D	10.23	15.6	52.7	0.143	6.08	0.00	6.08
Lake Bell	Lake Bell	Dry Pond	Institutional	A/D	0.00	30.0	55.9	0.259	0.00	0.80	0.00
Lake Bell	Lake Bell	Wetland	Wetlands	D	12.35	0.0	95.0	0.464	23.91	0.00	23.91
Lake Bell	Lake Bell	None	Commercial	A	0.24	50.2	62.7	0.425	0.42	0.00	0.42
Lake Bell	Lake Bell	None	Commercial	A/D	0.18	60.0	68.5	0.507	0.39	0.00	0.39
Lake Bell	Lake Bell	None	High Density Residential	A	9.74	43.1	58.8	0.365	14.83	0.00	14.83
Lake Bell	Lake Bell	None	High Density Residential	A/D	0.19	57.9	59.5	0.481	0.39	0.00	0.39
Lake Bell	Lake Bell	None	Institutional	A	1.74	24.0	45.6	0.203	1.47	0.00	1.47
Lake Bell	Lake Bell	None	Institutional	A/D	22.23	10.9	48.0	0.133	12.31	0.00	12.31
Lake Bell	Lake Bell	None	Med Density Residential	A	38.78	19.3	56.6	0.176	28.42	0.00	28.42
Lake Bell	Lake Bell	None	Med Density Residential	A/D	24.50	18.7	55.8	0.170	17.37	0.00	17.37
Lake Bell	Lake Bell	None	Recreational	A	3.59	0.0	39.0	0.127	1.90	0.00	1.90
Lake Bell	Lake Bell	None	Scrub	A	1.34	0.0	35.0	0.125	0.70	0.00	0.70
Lake Bell	Lake Bell	None	Scrub	A/D	6.49	0.0	77.0	0.199	5.40	0.00	5.40
Lake Bell	Lake Bell	None	Woods	A/D	3.98	0.0	79.8	0.214	3.55	0.00	3.55

Hydrologic Model of Runoff Inputs to Lake Killarney

Basin	Sub Basin	Treatment	Land Use	Hydrologic Soil Group	Area (ac.)	DCIA1 (%)	Non - DCIA CN Value2	Runoff C Value4	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Runoff Volume (ac-ft)
Lake Killarney	01	Wetland	Wetlands	D	0.03	0.0	95.0	0.464	0.05	0.00	0.05
Lake Killarney	01	None	Commercial	A	12.81	56.3	66.0	0.476	25.40	0.00	25.40
Lake Killarney	01	None	Commercial	A/D	0.31	60.0	68.5	0.507	0.66	0.00	0.66
Lake Killarney	01	None	High Density Residential	A	4.38	40.9	58.7	0.348	6.35	0.00	6.35
Lake Killarney	01	None	High Density Residential	A/D	0.10	40.0	58.7	0.341	0.15	0.00	0.15
Lake Killarney	01	None	Med Density Residential	A	9.06	20.0	57.4	0.183	6.90	0.00	6.90
Lake Killarney	01	None	Transportation	A	5.00	90.0	68.5	0.734	15.30	0.00	15.30
Lake Killarney	02	None	Commercial	A	0.31	60.0	68.5	0.507	0.65	0.00	0.65
Lake Killarney	02	None	Med Density Residential	A	11.32	20.0	57.4	0.183	8.62	0.00	8.62
Lake Killarney	02	None	Med Density Residential	A/D	0.14	20.0	57.4	0.183	0.10	0.00	0.10
Lake Killarney	03	None	Med Density Residential	A	8.18	20.0	57.4	0.183	6.22	0.00	6.22
Lake Killarney	04	None	Med Density Residential	A	7.77	20.0	57.4	0.182	5.91	0.00	5.91
Lake Killarney	05	None	Med Density Residential	A	7.39	20.0	57.4	0.182	5.62	0.00	5.62
Lake Killarney	05	None	Med Density Residential	A/D	0.24	19.6	57.6	0.180	0.18	0.00	0.18
Lake Killarney	06	None	Med Density Residential	A	1.07	20.0	57.4	0.183	0.82	0.00	0.82
Lake Killarney	06	None	Med Density Residential	A/D	1.77	19.9	57.5	0.182	1.34	0.00	1.34
Lake Killarney	07	None	Commercial	A	0.91	59.8	68.2	0.505	1.92	0.00	1.92
Lake Killarney	07	None	Commercial	A/D	0.45	59.8	68.2	0.505	0.95	0.00	0.95
Lake Killarney	08	None	Commercial	A	2.12	59.9	68.4	0.506	4.46	0.00	4.46
Lake Killarney	08	None	Commercial	A/D	0.22	58.4	66.7	0.493	0.45	0.00	0.45
Lake Killarney	09	None	Commercial	A	1.92	59.9	68.4	0.506	4.05	0.00	4.05
Lake Killarney	09	None	Commercial	A/D	0.77	59.3	67.7	0.500	1.60	0.00	1.60
Lake Killarney	09	None	High Density Residential	A	0.04	0.0	39.0	0.127	0.02	0.00	0.02
Lake Killarney	10	None	High Density Residential	A	1.03	19.9	57.5	0.182	0.78	0.00	0.78
Lake Killarney	10	None	High Density Residential	A/D	0.97	19.8	57.6	0.181	0.73	0.00	0.73
Lake Killarney	11	None	Commercial	A	0.89	39.9	58.6	0.340	1.26	0.00	1.26
Lake Killarney	11	None	Med Density Residential	A	0.00	0.0	62.6	0.152	0.00	0.00	0.00
Lake Killarney	12	None	Commercial	A	0.42	15.4	61.5	0.154	0.27	0.00	0.27
Lake Killarney	12	None	Med Density Residential	A	10.21	19.1	56.4	0.175	7.43	0.00	7.43
Lake Killarney	13	None	Med Density Residential	A	1.89	16.4	53.5	0.150	1.18	0.00	1.18
Lake Killarney	13	None	Med Density Residential	A/D	0.40	19.5	56.9	0.178	0.30	0.00	0.30
Lake Killarney	14	None	High Density Residential	A	0.07	60.0	68.5	0.507	0.15	0.00	0.15
Lake Killarney	14	None	Med Density Residential	A	3.20	17.7	54.9	0.161	2.15	0.00	2.15
Lake Killarney	14	None	Med Density Residential	A/D	0.19	18.8	56.2	0.171	0.13	0.00	0.13

Hydrologic Model of Runoff Inputs to Lake Killarney

Basin	Sub Basin	Treatment	Land Use	Hydrologic Soil Group	Area (ac.)	DCIA1 (%)	Non - DCIA CN Value2	Runoff C Value4	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Runoff Volume (ac-ft)
Lake Killarney	15	None	High Density Residential	A	3.47	69.9	58.6	0.574	8.31	0.00	8.31
Lake Killarney	15	None	Med Density Residential	A	0.01	0.0	62.6	0.152	0.01	0.00	0.01
Lake Killarney	16	None	Commercial	A	1.33	30.0	55.8	0.259	1.44	0.00	1.44
Lake Killarney	16	None	Med Density Residential	A	1.64	19.9	57.5	0.182	1.24	0.00	1.24
Lake Killarney	17	None	Commercial	A	1.72	30.0	55.9	0.259	1.86	0.00	1.86
Lake Killarney	17	None	Med Density Residential	A	2.05	19.9	57.5	0.182	1.55	0.00	1.55
Lake Killarney	18	None	Commercial	A	1.06	30.0	55.9	0.259	1.15	0.00	1.15
Lake Killarney	18	None	Med Density Residential	A	3.51	20.0	57.4	0.183	2.67	0.00	2.67
Lake Killarney	19	None	Commercial	A	0.32	30.0	55.9	0.259	0.34	0.00	0.34
Lake Killarney	19	None	Med Density Residential	A	3.94	20.0	57.5	0.182	2.99	0.00	2.99
Lake Killarney	20	None	Commercial	A	0.11	30.0	55.9	0.259	0.12	0.00	0.12
Lake Killarney	20	None	Med Density Residential	A	4.14	19.5	56.9	0.178	3.06	0.00	3.06
Lake Killarney	21	None	Commercial	A	0.74	30.0	55.9	0.259	0.80	0.00	0.80
Lake Killarney	21	None	Med Density Residential	A	11.40	20.0	57.4	0.183	8.68	0.00	8.68
Lake Killarney	22	None	Commercial	A	0.06	30.0	55.9	0.259	0.06	0.00	0.06
Lake Killarney	22	None	Commercial	A/D	0.36	30.0	55.9	0.259	0.39	0.00	0.39
Lake Killarney	22	None	Med Density Residential	A	13.85	20.0	57.4	0.183	10.54	0.00	10.54
Lake Killarney	22	None	Med Density Residential	A/D	0.37	20.0	57.4	0.183	0.28	0.00	0.28
Lake Killarney	23	None	Med Density Residential	A	11.85	19.9	57.4	0.182	8.99	0.00	8.99
Lake Killarney	23	None	Transportation	A	0.33	18.9	56.2	0.173	0.24	0.00	0.24
Lake Killarney	24	None	Commercial	A	0.57	60.0	68.4	0.507	1.20	0.00	1.20
Lake Killarney	24	None	Institutional	A	9.68	40.0	58.7	0.341	13.74	0.00	13.74
Lake Killarney	24	None	Med Density Residential	A	26.83	19.8	57.2	0.181	20.21	0.00	20.21
Lake Killarney	24	None	Transportation	A	0.67	21.4	56.3	0.192	0.54	0.00	0.54
Lake Killarney	25	None	Commercial	A	0.44	60.0	68.5	0.507	0.92	0.00	0.92
Lake Killarney	25	None	Med Density Residential	A	23.89	19.9	57.3	0.182	18.08	0.00	18.08
Lake Killarney	26	None	Commercial	A	0.74	60.0	68.5	0.507	1.57	0.00	1.57
Lake Killarney	26	None	Med Density Residential	A	11.29	20.0	57.4	0.183	8.60	0.00	8.60
Lake Killarney	26	None	Med Density Residential	A/D	1.45	20.0	57.4	0.183	1.10	0.00	1.10
Lake Killarney	27	None	Commercial	A	2.06	60.0	68.5	0.507	4.35	0.00	4.35
Lake Killarney	27	None	Med Density Residential	A	15.48	19.6	57.0	0.179	11.57	0.00	11.57
Lake Killarney	27	None	Med Density Residential	A/D	1.75	19.9	57.5	0.182	1.33	0.00	1.33
Lake Killarney	28	None	Commercial	A	0.93	60.0	68.5	0.507	1.96	0.00	1.96
Lake Killarney	28	None	Med Density Residential	A	3.04	19.9	57.5	0.182	2.31	0.00	2.31
Lake Killarney	28	None	Med Density Residential	A/D	0.94	20.0	57.4	0.183	0.71	0.00	0.71

Hydrologic Model of Runoff Inputs to Lake Killarney

Basin	Sub Basin	Treatment	Land Use	Hydrologic Soil Group	Area (ac.)	DCIA1 (%)	Non - DCIA CN Value2	Runoff C Value4	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Runoff Volume (ac-ft)
Lake Killarney	29	Wet Pond	Commercial	A	1.30	70.0	58.7	0.575	3.12	0.20	2.50
Lake Killarney	29	Wet Pond	Commercial	A/D	3.18	70.0	58.7	0.575	7.63	0.20	6.10
Lake Killarney	29	Wet Pond	Scrub	A/D	0.22	0.0	77.0	0.199	0.18	0.20	0.15
Lake Killarney	29	None	Commercial	A/D	0.00	0.0	39.0	0.127	0.00	0.00	0.00
Lake Killarney	29	None	Scrub	A/D	0.00	0.0	77.0	0.199	0.00	0.00	0.00
Lake Killarney	30	Wet Pond	Commercial	A/D	0.08	70.0	58.7	0.575	0.20	0.20	0.16
Lake Killarney	30	None	Med Density Residential	A/D	2.44	19.0	56.3	0.173	1.76	0.00	1.76
Lake Killarney	31	Wet Pond	Commercial	A	0.16	70.0	58.7	0.575	0.39	0.20	0.31
Lake Killarney	31	Wet Pond	Commercial	A/D	0.03	70.0	58.7	0.575	0.08	0.20	0.06
Lake Killarney	31	Wet Pond	Institutional	A	8.62	51.9	52.4	0.429	15.43	0.20	12.35
Lake Killarney	31	Wet Pond	Institutional	A/D	16.94	65.2	55.4	0.535	37.80	0.20	30.24
Lake Killarney	31	Wet Pond	Open	A/D	0.63	0.0	39.0	0.127	0.33	0.20	0.26
Lake Killarney	31	None	Commercial	A	43.55	62.1	70.2	0.525	95.32	0.00	95.32
Lake Killarney	31	None	Commercial	A/D	7.55	40.5	57.5	0.344	10.81	0.00	10.81
Lake Killarney	31	None	Institutional	A	2.62	54.7	68.4	0.466	5.10	0.00	5.10
Lake Killarney	31	None	Institutional	A/D	10.61	47.9	60.6	0.405	17.91	0.00	17.91
Lake Killarney	31	None	Med Density Residential	A	1.03	4.5	48.5	0.133	0.57	0.00	0.57
Lake Killarney	31	None	Med Density Residential	A/D	12.47	16.3	53.9	0.149	7.74	0.00	7.74
Lake Killarney	31	None	Transportation	A	5.75	90.0	68.5	0.734	17.60	0.00	17.60
Lake Killarney	31	None	Transportation	A/D	0.14	90.0	73.5	0.736	0.44	0.00	0.44
Lake Killarney	32	None	Commercial	A	1.97	50.0	62.6	0.423	3.47	0.00	3.47
Lake Killarney	33	None	Commercial	A/D	0.55	50.0	62.6	0.423	0.96	0.00	0.96
Lake Killarney	33	None	Med Density Residential	A/D	2.95	19.6	57.0	0.179	2.21	0.00	2.21
Lake Killarney	33	None	Transportation	A/D	0.02	90.0	73.5	0.736	0.06	0.00	0.06
Lake Killarney	34	Dry Pond	Commercial	A	1.79	60.0	68.5	0.507	3.79	0.80	0.76
Lake Killarney	34	None	Commercial	A	29.30	60.0	68.5	0.507	61.90	0.00	61.90
Lake Killarney	34	None	High Density Residential	A	3.58	58.9	67.3	0.497	7.41	0.00	7.41
Lake Killarney	34	None	Med Density Residential	A	2.27	20.0	57.4	0.183	1.73	0.00	1.73
Lake Killarney	35	Dry Pond	Commercial	A	5.23	81.6	69.9	0.671	14.64	0.80	2.93
Lake Killarney	35	None	Commercial	A	18.43	64.1	68.5	0.538	41.33	0.00	41.33
Lake Killarney	35	None	Commercial	A/D	0.38	50.0	62.6	0.423	0.67	0.00	0.67
Lake Killarney	35	None	Med Density Residential	A	2.68	18.9	56.2	0.173	1.93	0.00	1.93
Lake Killarney	35	None	Med Density Residential	A/D	0.95	20.0	57.4	0.183	0.72	0.00	0.72
Lake Killarney	35	None	Transportation	A	1.78	90.0	68.5	0.734	5.44	0.00	5.44
Lake Killarney	35	None	Transportation	A/D	0.69	90.0	73.5	0.736	2.12	0.00	2.12
Lake Killarney	36	None	Commercial	A/D	0.18	50.0	62.6	0.423	0.32	0.00	0.32
Lake Killarney	36	None	Med Density Residential	A/D	1.71	16.6	53.7	0.151	1.07	0.00	1.07

Hydrologic Model of Runoff Inputs to Lake Killarney

Basin	Sub Basin	Treatment	Land Use	Hydrologic Soil Group	Area (ac.)	DCIA1 (%)	Non - DCIA CN Value2	Runoff C Value4	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Runoff Volume (ac-ft)
Lake Killarney	37	None	Commercial	A	1.04	50.0	62.6	0.423	1.84	0.00	1.84
Lake Killarney	37	None	Med Density Residential	A	0.95	20.0	57.4	0.183	0.73	0.00	0.73
Lake Killarney	37	None	Med Density Residential	A/D	0.03	20.0	57.4	0.183	0.02	0.00	0.02
Lake Killarney	38	None	Commercial	A	0.98	36.3	67.4	0.325	1.33	0.00	1.33
Lake Killarney	38	None	Med Density Residential	A	1.43	6.5	43.8	0.130	0.77	0.00	0.77
Lake Killarney	39	None	Commercial	A	4.33	50.0	62.6	0.423	7.64	0.00	7.64
Lake Killarney	39	None	Med Density Residential	A	1.52	20.0	56.8	0.182	1.15	0.00	1.15
Lake Killarney	39	None	Transportation	A	0.29	90.0	68.5	0.734	0.89	0.00	0.89
Lake Killarney	40	None	Commercial	A	0.78	50.0	62.6	0.423	1.38	0.00	1.38
Lake Killarney	40	None	Med Density Residential	A	2.21	20.0	57.4	0.183	1.69	0.00	1.69
Lake Killarney	40	None	Transportation	A	0.08	90.0	68.5	0.734	0.25	0.00	0.25
Lake Killarney	41	None	Commercial	A	0.09	50.0	62.6	0.423	0.17	0.00	0.17
Lake Killarney	41	None	High Density Residential	A	1.48	60.0	68.5	0.507	3.12	0.00	3.12
Lake Killarney	42	None	High Density Residential	A	1.86	60.0	68.5	0.507	3.92	0.00	3.92
Lake Killarney	42	None	Transportation	A	0.00	90.0	68.5	0.734	0.01	0.00	0.01
Lake Killarney	43	None	High Density Residential	A	2.01	60.0	68.5	0.507	4.25	0.00	4.25
Lake Killarney	43	None	Transportation	A	0.01	90.0	68.5	0.734	0.03	0.00	0.03
Lake Killarney	44	None	Commercial	A	0.12	60.0	68.5	0.507	0.25	0.00	0.25
Lake Killarney	44	None	High Density Residential	A	3.53	60.0	68.5	0.506	7.46	0.00	7.46
Lake Killarney	44	None	Transportation	A	0.00	90.0	68.5	0.734	0.00	0.00	0.00
Lake Killarney	45	None	Commercial	A	1.29	60.0	68.5	0.507	2.73	0.00	2.73
Lake Killarney	45	None	High Density Residential	A	4.18	54.9	65.2	0.464	8.09	0.00	8.09
Lake Killarney	46	None	High Density Residential	A	1.44	60.0	68.5	0.507	3.05	0.00	3.05
Lake Killarney	47	None	Commercial	A	0.07	60.0	68.5	0.507	0.15	0.00	0.15
Lake Killarney	47	None	High Density Residential	A	5.31	40.6	55.4	0.342	7.58	0.00	7.58
Lake Killarney	Direct	Wet Pond	Commercial	A	0.01	23.9	96.8	0.588	0.03	0.20	0.02
Lake Killarney	Direct	Wet Pond	Commercial	A/D	0.01	70.0	58.7	0.575	0.01	0.20	0.01
Lake Killarney	Direct	Wet Pond	Med Density Residential	A	0.00	20.0	57.4	0.183	0.00	0.20	0.00
Lake Killarney	Direct	Wet Pond	Scrub	A/D	0.01	0.0	77.0	0.199	0.01	0.20	0.01
Lake Killarney	Direct	None	Commercial	A	6.36	34.5	50.2	0.289	7.68	0.00	7.68
Lake Killarney	Direct	None	Commercial	A/D	0.92	3.0	43.3	0.129	0.49	0.00	0.49
Lake Killarney	Direct	None	High Density Residential	A	3.38	1.1	45.4	0.131	1.84	0.00	1.84
Lake Killarney	Direct	None	High Density Residential	A/D	1.32	0.1	52.1	0.137	0.76	0.00	0.76
Lake Killarney	Direct	None	Med Density Residential	A	43.79	0.1	58.9	0.146	26.61	0.00	26.61
Lake Killarney	Direct	None	Med Density Residential	A/D	19.80	2.5	53.1	0.138	11.38	0.00	11.38
Lake Killarney	Direct	None	Scrub	A	0.02	0.0	35.0	0.125	0.01	0.00	0.01
Lake Killarney	Direct	None	Scrub	A/D	1.45	0.0	77.0	0.199	1.21	0.00	1.21
Lake Killarney	Direct	None	Transportation	A	0.00	90.0	68.5	0.734	0.00	0.00	0.00

Hydrologic Model of Runoff Inputs to Lake Killarney

Basin	Sub Basin	Treatment	Land Use	Hydrologic Soil Group	Area (ac.)	DCIA1 (%)	Non - DCIA CN Value2	Runoff C Value4	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Runoff Volume (ac-ft)
Lake Mendsen	LM-01	Dry Pond	Commercial	A	48.96	67.6	62.7	0.559	114.16	0.80	22.83
Lake Mendsen	LM-01	Dry Pond	Commercial	A/D	3.26	47.6	62.5	0.404	5.49	0.80	1.10
Lake Mendsen	LM-01	Dry Pond	Med Density Residential	A	7.77	32.6	51.5	0.276	8.94	0.80	1.79
Lake Mendsen	LM-01	Dry Pond	Med Density Residential	A/D	0.77	58.2	39.0	0.474	1.52	0.80	0.30
Lake Mendsen	LM-01	Dry Pond	Recreational	A	1.18	70.0	58.7	0.575	2.83	0.80	0.57
Lake Mendsen	LM-01	None	Commercial	A	59.87	55.5	61.7	0.465	116.00	0.00	116.00
Lake Mendsen	LM-01	None	Commercial	A/D	2.90	44.2	56.2	0.371	4.48	0.00	4.48
Lake Mendsen	LM-01	None	Institutional	A	0.45	60.0	68.5	0.507	0.95	0.00	0.95
Lake Mendsen	LM-01	None	Med Density Residential	A	74.06	16.5	50.4	0.146	45.23	0.00	45.23
Lake Mendsen	LM-01	None	Med Density Residential	A/D	9.04	13.8	48.4	0.133	5.02	0.00	5.02
Lake Mendsen	LM-01	None	Recreational	A	23.47	8.0	43.5	0.129	12.66	0.00	12.66
Lake Mendsen	LM-01	None	Transportation	A	5.01	84.0	56.2	0.684	14.28	0.00	14.28
Lake Mendsen	LM-02	Dry Pond	Commercial	A	0.94	53.4	64.3	0.451	1.76	0.80	0.35
Lake Mendsen	LM-02	Dry Pond	Med Density Residential	A	0.45	0.0	39.0	0.127	0.24	0.80	0.05
Lake Mendsen	LM-02	None	Commercial	A	22.05	69.6	66.4	0.578	53.11	0.00	53.11
Lake Mendsen	LM-02	None	High Density Residential	A	3.32	45.4	59.2	0.383	5.30	0.00	5.30
Lake Mendsen	LM-02	None	Med Density Residential	A	2.87	30.9	58.1	0.269	3.22	0.00	3.22
Lake Mendsen	LM-02	None	Transportation	A	10.64	89.5	65.9	0.729	32.32	0.00	32.32
Lake Mendsen	LM-03	Dry Pond	Commercial	A	18.61	89.9	68.5	0.733	56.88	0.80	11.38
Lake Mendsen	LM-03	None	Commercial	A	9.95	61.4	64.4	0.513	21.27	0.00	21.27
Lake Mendsen	LM-03	None	High Density Residential	A	0.12	60.0	68.5	0.507	0.25	0.00	0.25
Lake Mendsen	LM-03	None	Transportation	A	4.05	90.3	68.5	0.736	12.44	0.00	12.44
Lake Rose	Lake Rose	None	Commercial	A	1.63	60.0	68.5	0.507	3.44	0.00	3.44
Lake Rose	Lake Rose	None	Recreational	A	1.31	8.0	43.5	0.129	0.71	0.00	0.71

Hydrologic Model of Runoff Inputs to Lake Killarney

Basin	Sub Basin	Treatment	Land Use	Hydrologic Soil Group	Area (ac.)	DCIA1 (%)	Non - DCIA CN Value2	Runoff C Value4	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Runoff Volume (ac-ft)
Lake Wilderness	Lake Wilderness	Dry Pond	Commercial	A	1.15	51.5	42.7	0.421	2.02	0.80	0.40
Lake Wilderness	Lake Wilderness	Dry Pond	Institutional	A/D	4.14	30.0	55.9	0.259	4.48	0.80	0.90
Lake Wilderness	Lake Wilderness	Wet Pond	Commercial	A	19.09	72.8	58.7	0.597	47.49	0.20	37.99
Lake Wilderness	Lake Wilderness	Wet Pond	Commercial	A/D	1.51	80.0	68.5	0.658	4.14	0.20	3.31
Lake Wilderness	Lake Wilderness	Wet Pond	Open	A	1.43	0.0	39.0	0.127	0.75	0.20	0.60
Lake Wilderness	Lake Wilderness	Wet Pond	Open	A/D	0.09	0.0	80.0	0.216	0.08	0.20	0.06
Lake Wilderness	Lake Wilderness	Wet Pond	Water	W	0.47	100.0	98.0	0.809	1.60	0.20	1.28
Lake Wilderness	Lake Wilderness	Wetland	Wetlands	D	3.89	0.0	95.0	0.464	7.53	0.00	7.53
Lake Wilderness	Lake Wilderness	None	Commercial	A	37.70	63.7	55.5	0.524	82.30	0.00	82.30
Lake Wilderness	Lake Wilderness	None	Commercial	A/D	9.09	67.0	55.7	0.550	20.83	0.00	20.83
Lake Wilderness	Lake Wilderness	None	Industrial	A	1.23	50.0	73.5	0.441	2.26	0.00	2.26
Lake Wilderness	Lake Wilderness	None	Industrial	A/D	0.02	50.0	73.5	0.441	0.04	0.00	0.04
Lake Wilderness	Lake Wilderness	None	Institutional	A/D	42.63	5.3	43.6	0.129	23.00	0.00	23.00
Lake Wilderness	Lake Wilderness	None	Med Density Residential	A	6.82	20.9	57.0	0.189	5.37	0.00	5.37
Lake Wilderness	Lake Wilderness	None	Med Density Residential	A/D	23.61	24.5	55.0	0.215	21.13	0.00	21.13
Lake Wilderness	Lake Wilderness	None	Med Density Residential	B/D	2.15	25.0	70.9	0.248	2.23	0.00	2.23
Lake Wilderness	Lake Wilderness	None	Scrub	A	0.05	0.0	35.0	0.125	0.02	0.00	0.02
Lake Wilderness	Lake Wilderness	None	Scrub	A/D	4.19	0.0	77.0	0.199	3.48	0.00	3.48
Lake Wilderness	Lake Wilderness	None	Transportation	A	40.35	48.2	66.7	0.414	69.72	0.00	69.72
Lake Wilderness	Lake Wilderness	None	Transportation	A/D	1.61	0.0	73.4	0.183	1.23	0.00	1.23
Lake Wilderness	Lake Wilderness	None	Woods	A	0.06	0.0	39.1	0.127	0.03	0.00	0.03
Lake Wilderness	Lake Wilderness	None	Woods	A/D	15.49	0.0	79.4	0.212	13.72	0.00	13.72
Lake Wilderness	Lake Wilderness	None	Woods	D	0.82	0.0	79.9	0.215	0.73	0.00	0.73
Lee Rd. Wetland	Lee Rd. Wetland	Dry Pond	Institutional	A	1.53	13.9	43.8	0.130	0.83	0.80	0.17
Lee Rd. Wetland	Lee Rd. Wetland	Wet Pond	Commercial	A	2.23	86.0	50.6	0.698	6.48	0.20	5.19
Lee Rd. Wetland	Lee Rd. Wetland	Wet Pond	Commercial	A/D	4.10	55.6	51.3	0.458	7.83	0.20	6.27
Lee Rd. Wetland	Lee Rd. Wetland	Wetland	Wetlands	D	22.44	0.0	95.0	0.464	43.45	0.00	43.45
Lee Rd. Wetland	Lee Rd. Wetland	Wetland	Woods	A/D	1.93	0.0	79.0	0.210	1.69	0.00	1.69
Lee Rd. Wetland	Lee Rd. Wetland	Wetland	Woods	D	0.05	0.0	79.0	0.210	0.05	0.00	0.05
Lee Rd. Wetland	Lee Rd. Wetland	None	Commercial	A	29.77	66.3	52.9	0.543	67.36	0.00	67.36
Lee Rd. Wetland	Lee Rd. Wetland	None	Commercial	A/D	8.31	56.9	44.8	0.465	16.10	0.00	16.10
Lee Rd. Wetland	Lee Rd. Wetland	None	Institutional	A	0.74	10.0	39.0	0.127	0.39	0.00	0.39
Lee Rd. Wetland	Lee Rd. Wetland	None	Institutional	A/D	0.20	0.0	39.0	0.127	0.10	0.00	0.10
Lee Rd. Wetland	Lee Rd. Wetland	None	Med Density Residential	A	38.82	15.3	49.9	0.137	22.19	0.00	22.19
Lee Rd. Wetland	Lee Rd. Wetland	None	Med Density Residential	A/D	4.49	13.9	48.5	0.133	2.49	0.00	2.49
Lee Rd. Wetland	Lee Rd. Wetland	None	Recreational	A	5.66	9.7	74.1	0.185	4.37	0.00	4.37
Lee Rd. Wetland	Lee Rd. Wetland	None	Recreational	A/D	1.15	11.6	68.0	0.165	0.79	0.00	0.79

APPENDIX D

RESULTS OF GROUNDWATER SEEPAGE MONITORING IN LAKE KILLARNEY FROM JULY 2011-AUGUST 2012

D.1 Field Measurements of Seepage Inflow Rates

D.2 Chemical Characteristics of Collected Seepage Samples

D.1 Field Measurements of Seepage Inflow Rates

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney

Site: **1**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	10:00	-----	-----	-----	-----	-----	Bags Installed
8/9/10	9:49	11.25	7/16/10	10:00	24.0	1.74	Measured volume, no sample collected
8/24/10	8:17	7.25	8/9/10	9:49	14.9	1.80	Sample collected, bag in good condition
9/22/10	8:43	6.5	8/24/10	8:17	29.0	0.83	Sample collected, bag in good condition
11/29/10	10:22	6.5	9/22/10	8:43	68.1	0.35	Sample collected, bag in good condition
2/21/11	11:00	7.25	11/29/10	10:22	84.0	0.32	Sample collected, pinhole, bag replaced
5/5/11	10:02	10.25	2/21/11	11:00	73.0	0.52	Sample collected, bag in good condition
6/10/11	10:05	6.75	5/5/11	10:02	36.0	0.69	Sample collected, bag in good condition
8/2/11	8:50	-----	6/10/11	10:05	-----	-----	No sample collected, meter flipped
					Mean Value:	0.63	

Seepage Meter Field Measurements

Location: Lake Killarney

Site: **2**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	10:10	-----	-----	-----	-----	-----	Bags Installed
8/9/10	9:52	11.5	7/16/10	10:10	24.0	1.78	Measured volume, no sample collected
8/24/10	8:22	-----	8/9/10	9:52	-----	-----	No sample collected, bag damaged, bag replaced
9/22/10	8:58	6.5	8/24/10	8:22	29.0	0.83	Sample collected, bag in good condition
11/29/10	10:25	8.25	9/22/10	8:58	68.1	0.45	Sample collected, bag in good condition
2/21/11	11:05	18.75	11/29/10	10:25	84.0	0.83	Sample collected, pinhole, bag replaced
5/5/11	10:06	-----	2/21/11	11:05	-----	-----	No sample collected, bag damaged, bag replaced
6/10/11	10:10	12.5	5/5/11	10:06	36.0	1.29	Sample collected, bag in good condition
8/2/11	9:00	13.75	6/10/11	10:10	53.0	0.96	Sample collected, bag in good condition
					Mean Value:	0.90	

Seepage Meter Field Measurements

Location: Lake Killarney

Site: **3**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	10:20	-----	-----	-----	-----	-----	Bags Installed
8/9/10	9:55	9.75	7/16/10	10:20	24.0	1.51	Measured volume, no sample collected
8/24/10	8:40	1.5	8/9/10	9:55	14.9	0.37	Sample collected, bag in good condition
9/22/10	9:04	6.5	8/24/10	8:40	29.0	0.83	Sample collected, bag in good condition
11/29/10	10:28	7.5	9/22/10	9:04	68.1	0.41	Sample collected, bag in good condition
2/21/11	11:10	8.75	11/29/10	10:28	84.0	0.39	Sample collected, bag in good condition
5/5/11	10:10	16.75	2/21/11	11:10	73.0	0.85	Sample collected, bag in good condition
6/10/11	10:15	6.25	5/5/11	10:10	36.0	0.64	Sample collected, bag in good condition
8/2/11	9:15	7.5	6/10/11	10:15	53.0	0.52	Sample collected, bag in good condition
					Mean Value:	0.63	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **4**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	10:30	-----	-----	-----	-----	-----	Bags Installed
8/9/10	9:58	4.5	7/16/10	10:30	24.0	0.70	Measured volume, no sample collected
8/24/10	8:54	8.75	8/9/10	9:58	15.0	2.17	Sample collected, bag in good condition
9/22/10	9:36	7	8/24/10	8:54	29.0	0.89	Sample collected, bag in good condition
11/29/10	10:34	6.5	9/22/10	9:36	68.0	0.35	Sample collected, bag in good condition
2/21/11	11:15	18.5	11/29/10	10:34	84.0	0.82	Sample collected, bag in good condition
5/5/11	10:15	15.5	2/21/11	11:15	73.0	0.79	Sample collected, bag in good condition
6/10/11	10:18	13.5	5/5/11	10:15	36.0	1.39	Sample collected, bag in good condition
8/2/11	9:20	-----	6/10/11	10:18	53.0	-----	No sample collected, meter flipped
					Mean Value:	0.72	

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **5**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	10:40	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:01	15	7/16/10	10:40	24.0	2.32	Measured volume, no sample collected
8/24/10	9:04	12.5	8/9/10	10:01	15.0	3.09	Sample collected, bag in good condition
9/22/10	9:45	-----	8/24/10	9:04	29.0	-----	No sample collected, meter flipped, meter reinstalled
11/29/10	10:40	6.75	9/22/10	9:45	68.0	0.37	Sample collected, bag in good condition
2/21/11	11:20	-----	11/29/10	10:40	84.0	-----	No sample collected, meter flipped, meter reinstalled
5/5/11	10:42	-----	2/21/11	11:20	73.0	-----	No sample collected, meter flipped, meter reinstalled
6/10/11	10:34	5.25	5/5/11	10:42	36.0	0.54	Sample collected, bag in good condition
8/2/11	9:25	-----	6/10/11	10:34	53.0	-----	No sample collected, meter flipped
					Mean Value:	0.38	

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **6**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	10:50	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:05	135	7/16/10	10:50	24.0	20.86	Measured volume, no sample collected
8/24/10	9:11	-----	8/9/10	10:05	15.0	-----	No sample collected, bag missing, bag replaced
9/22/10	9:50	135	8/24/10	9:11	29.0	17.23	Sample collected, bag in good condition
11/29/10	10:48	6.75	9/22/10	9:50	68.0	0.37	Sample collected, pinhole, bag replaced
2/21/11	11:24	-----	11/29/10	10:48	84.0	-----	No sample collected, bag damaged, bag replaced
5/5/11	10:47	-----	2/21/11	11:24	73.0	-----	No sample collected, bag damaged, bag replaced
6/10/11	10:25	59.75	5/5/11	10:47	36.0	6.15	Sample collected, bag in good condition
8/2/11	9:30	-----	6/10/11	10:25	53.0	-----	No sample collected, bag damaged, bag replaced
					Mean Value:	3.26	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney Site: **7**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	11:00	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:09	18.5	7/16/10	11:00	24.0	2.86	Measured volume, no sample collected
8/24/10	9:17	10.5	8/9/10	10:09	15.0	2.60	Sample collected, bag in good condition
9/22/10	9:56	17.5	8/24/10	9:17	29.0	2.23	Sample collected, bag in good condition
11/29/10	10:55	22.5	9/22/10	9:56	68.0	1.22	Sample collected, pinhole, bag replaced
2/21/11	11:29	98.25	11/29/10	10:55	84.0	4.33	Sample collected, bag in good condition
5/5/11	10:51	94.5	2/21/11	11:29	73.0	4.80	Sample collected, bag in good condition
6/10/11	10:30	17.5	5/5/11	10:51	36.0	1.80	Sample collected, bag in good condition
8/2/11	9:35	91.75	6/10/11	10:30	53.0	6.42	Sample collected, bag in good condition
					Mean Value:	3.60	

Seepage Meter Field Measurements

Location: Lake Killarney Site: **8**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	11:10	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:11	135	7/16/10	11:10	24.0	20.87	Measured volume, no sample collected
8/24/10	9:22	125	8/9/10	10:11	15.0	30.93	Sample collected, bag in good condition
9/22/10	10:02	35.25	8/24/10	9:22	29.0	4.50	Sample collected, bag in good condition
11/29/10	11:00	130	9/22/10	10:02	68.0	7.08	Sample collected, bag in good condition
2/21/11	11:33	115.25	11/29/10	11:00	84.0	5.08	Sample collected, bag in good condition
5/5/11	10:55	8.5	2/21/11	11:33	73.0	0.43	Sample collected, bag in good condition
6/10/11	10:40	8.5	5/5/11	10:55	36.0	0.87	Sample collected, bag in good condition
8/2/11	9:40	10.25	6/10/11	10:40	53.0	0.72	Sample collected, bag in good condition
					Mean Value:	5.51	

Seepage Meter Field Measurements

Location: Lake Killarney Site: **9**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	11:20	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:23	23	7/16/10	11:20	24.0	3.56	Measured volume, no sample collected
8/24/10	9:37	15.25	8/9/10	10:23	15.0	3.77	Measured volume, no sample collected
9/22/10	10:07	25.25	8/24/10	9:37	29.0	3.22	Sample collected, pinhole, bag replaced
11/29/10	11:05	-----	9/22/10	10:07	68.0	-----	No sample collected, bag damaged, bag replaced
2/21/11	11:38	60.75	11/29/10	11:05	84.0	2.68	Sample collected, bag in good condition
5/5/11	11:00	21.25	2/21/11	11:38	73.0	1.08	Sample collected, bag in good condition
6/10/11	10:44	53.25	5/5/11	11:00	36.0	5.48	Sample collected, bag in good condition
8/2/11	9:55	110.5	6/10/11	10:44	53.0	7.73	Sample collected, bag in good condition
					Mean Value:	3.00	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **10**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	11:30	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:26	10	7/16/10	11:30	24.0	1.55	Measured volume, no sample collected
8/24/10	9:41	8.5	8/9/10	10:26	15.0	2.10	Sample collected, bag in good condition
9/22/10	10:12	8.25	8/24/10	9:41	29.0	1.05	Sample collected, bag in good condition
11/29/10	11:08	11.5	9/22/10	10:12	68.0	0.63	Sample collected, bag in good condition
2/21/11	11:43	18.75	11/29/10	11:08	84.0	0.83	Sample collected, bag in good condition
5/5/11	11:05	12.5	2/21/11	11:43	73.0	0.63	Sample collected, bag in good condition
6/10/11	10:47	9.75	5/5/11	11:05	36.0	1.00	Sample collected, bag in good condition
8/2/11	10:02	8.75	6/10/11	10:47	53.0	0.61	Sample collected, bag in good condition
					Mean Value:	0.85	

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **11**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	11:40	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:29	6.5	7/16/10	11:40	24.0	1.01	Measured volume, no sample collected
8/24/10	9:47	5.75	8/9/10	10:29	15.0	1.42	Sample collected, bag in good condition
9/22/10	10:30	6.5	8/24/10	9:47	29.0	0.83	Sample collected, pinhole, bag replaced
11/29/10	11:12	11.25	9/22/10	10:30	68.0	0.61	Sample collected, bag in good condition
2/21/11	11:47	19.5	11/29/10	11:12	84.0	0.86	Sample collected, bag in good condition
5/5/11	11:10	13.25	2/21/11	11:47	73.0	0.67	Sample collected, bag in good condition
6/10/11	10:51	7.5	5/5/11	11:10	36.0	0.77	Sample collected, bag in good condition
8/2/11	10:12	14.25	6/10/11	10:51	53.0	1.00	Sample collected, bag in good condition
					Mean Value:	0.82	

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **12**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	11:50	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:32	16.25	7/16/10	11:50	23.9	2.51	Measured volume, no sample collected
8/24/10	10:02	9.75	8/9/10	10:32	15.0	2.41	Sample collected, bag in good condition
9/22/10	10:35	-----	8/24/10	10:02	29.0	-----	No sample collected, bag damaged, bag replaced
11/29/10	11:38	19.5	9/22/10	10:35	68.0	1.06	Sample collected, bag in good condition
2/21/11	11:52	31.75	11/29/10	11:38	84.0	1.40	Sample collected, bag in good condition
5/5/11	11:31	17.75	2/21/11	11:52	73.0	0.90	Sample collected, bag in good condition
6/10/11	10:56	28.5	5/5/11	11:31	36.0	2.93	Sample collected, bag in good condition
8/2/11	10:19	20.5	6/10/11	10:56	53.0	1.43	Sample collected, bag in good condition
					Mean Value:	1.40	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney

Site: **13**

Date Installed: 7/16/10

Chamber Diameter: 0.58 m

Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	12:10	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:35	9.25	7/16/10	12:10	23.9	1.43	Measured volume, no sample collected
8/24/10	10:08	6.5	8/9/10	10:35	15.0	1.61	Sample collected, bag in good condition
9/22/10	10:40	5.75	8/24/10	10:08	29.0	0.73	Sample collected, bag in good condition
11/29/10	11:42	6.25	9/22/10	10:40	68.0	0.34	Sample collected, bag in good condition
2/21/11	12:00	17.5	11/29/10	11:42	84.0	0.77	Sample collected, bag in good condition
5/5/11	11:36	9.5	2/21/11	12:00	73.0	0.48	Sample collected, bag in good condition
6/10/11	11:01	5.5	5/5/11	11:36	36.0	0.57	Sample collected, bag in good condition
8/2/11	10:25	5.75	6/10/11	11:01	53.0	0.40	Sample collected, bag in good condition
					Mean Value:	0.64	

Seepage Meter Field Measurements

Location: Lake Killarney

Site: **14**

Date Installed: 7/16/10

Chamber Diameter: 0.58 m

Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	12:20	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:38	5.75	7/16/10	12:20	23.9	0.89	Measured volume, no sample collected
8/24/10	10:15	7.5	8/9/10	10:38	15.0	1.85	Sample collected, bag in good condition
9/22/10	11:00	5.5	8/24/10	10:15	29.0	0.70	Sample collected, bag in good condition
11/29/10	11:56	13.25	9/22/10	11:00	68.0	0.72	Sample collected, bag in good condition
2/21/11	12:05	7.25	11/29/10	11:56	84.0	0.32	Sample collected, bag in good condition
5/5/11	11:41	7.25	2/21/11	12:05	73.0	0.37	Sample collected, bag in good condition
6/10/11	11:05	5.25	5/5/11	11:41	36.0	0.54	Sample collected, bag in good condition
8/2/11	10:33	8.5	6/10/11	11:05	53.0	0.59	Sample collected, bag in good condition
					Mean Value:	0.58	

Seepage Meter Field Measurements

Location: Lake Killarney

Site: **15**

Date Installed: 7/16/10

Chamber Diameter: 0.58 m

Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	12:30	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:40	8.25	7/16/10	12:30	23.9	1.28	Measured volume, no sample collected
8/24/10	10:19	6.25	8/9/10	10:40	15.0	1.54	Sample collected, bag in good condition
9/22/10	11:04	5.5	8/24/10	10:19	29.0	0.70	Sample collected, bag in good condition
11/29/10	12:02	7.5	9/22/10	11:04	68.0	0.41	Sample collected, bag in good condition
2/21/11	12:10	6.75	11/29/10	12:02	84.0	0.30	Sample collected, bag in good condition
5/5/11	11:46	7.25	2/21/11	12:10	73.0	0.37	Sample collected, bag in good condition
6/10/11	11:10	13.25	5/5/11	11:46	36.0	1.36	Sample collected, bag in good condition
8/2/11	10:46	8.75	6/10/11	11:10	53.0	0.61	Sample collected, bag in good condition
					Mean Value:	0.62	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney Site: **16**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	12:40	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:45	4.25	7/16/10	12:40	23.9	0.66	Measured volume, no sample collected
8/24/10	10:24	5.25	8/9/10	10:45	15.0	1.30	Sample collected, bag in good condition
9/22/10	11:09	9.25	8/24/10	10:24	29.0	1.18	Sample collected, bag in good condition
11/29/10	12:08	6.75	9/22/10	11:09	68.0	0.37	Sample collected, bag in good condition
2/21/11	12:20	22.25	11/29/10	12:08	84.0	0.98	Sample collected, bag in good condition
5/5/11	11:54	47.75	2/21/11	12:20	73.0	2.42	Sample collected, bag in good condition
6/10/11	11:15	13.5	5/5/11	11:54	36.0	1.39	Sample collected, bag in good condition
8/2/11	10:55	0.4270833	6/10/11	11:15	53.0	0.03	Sample collected, bag in good condition
					Mean Value:	1.06	

Seepage Meter Field Measurements

Location: Lake Killarney Site: **17**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	12:50	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:48	8.5	7/16/10	12:50	23.9	1.32	Measured volume, no sample collected
8/24/10	10:29	7.25	8/9/10	10:48	15.0	1.79	Sample collected, bag in good condition
9/22/10	11:15	6.5	8/24/10	10:29	29.0	0.83	Sample collected, bag in good condition
11/29/10	12:13	12.5	9/22/10	11:15	68.0	0.68	Sample collected, bag in good condition
2/21/11	12:24	5.5	11/29/10	12:13	84.0	0.24	Sample collected, bag in good condition
5/5/11	11:59	13.5	2/21/11	12:24	73.0	0.69	Sample collected, bag in good condition
6/10/11	11:19	5.75	5/5/11	11:59	36.0	0.59	Sample collected, bag in good condition
8/2/11	11:02	13.25	6/10/11	11:19	53.0	0.93	Sample collected, bag in good condition
					Mean Value:	0.71	

Seepage Meter Field Measurements

Location: Lake Killarney Site: **18**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	13:00	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:50	14.25	7/16/10	13:00	23.9	2.21	Measured volume, no sample collected
8/24/10	10:34	11.75	8/9/10	10:50	15.0	2.90	Sample collected, bag in good condition
9/22/10	11:20	5.25	8/24/10	10:34	29.0	0.67	Sample collected, bag in good condition
11/29/10	12:18	13.5	9/22/10	11:20	68.0	0.73	Sample collected, bag in good condition
2/21/11	12:30	21.5	11/29/10	12:18	84.0	0.95	Sample collected, pinhole, bag replaced
5/5/11	12:04	17.75	2/21/11	12:30	73.0	0.90	Sample collected, bag in good condition
6/10/11	11:23	6.25	5/5/11	12:04	36.0	0.64	Sample collected, bag in good condition
8/2/11	11:09	8.75	6/10/11	11:23	53.0	0.61	Sample collected, bag in good condition
					Mean Value:	0.96	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney — Site: **19**

Date Installed: 7/16/10 — Chamber Diameter: 0.58 m — Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	13:10	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:54	9.75	7/16/10	13:10	23.9	1.51	Measured volume, no sample collected
8/24/10	10:38	7.25	8/9/10	10:54	15.0	1.79	Sample collected, bag in good condition
9/22/10	11:25	15.5	8/24/10	10:38	29.0	1.98	Sample collected, bag in good condition
11/29/10	12:24	8.25	9/22/10	11:25	68.0	0.45	Sample collected, bag in good condition
2/21/11	12:35	13.75	11/29/10	12:24	84.0	0.61	Sample collected, bag in good condition
5/5/11	12:09	12.5	2/21/11	12:35	73.0	0.63	Sample collected, bag in good condition
6/10/11	11:26	7.25	5/5/11	12:09	36.0	0.75	Sample collected, bag in good condition
8/2/11	11:17	-----	6/10/11	11:26	53.0	-----	No sample collected, bag damaged, bag replaced
					Mean Value:	0.72	

Seepage Meter Field Measurements

Location: Lake Killarney — Site: **20**

Date Installed: 7/16/10 — Chamber Diameter: 0.58 m — Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	13:15	-----	-----	-----	-----	-----	Bags Installed
8/9/10	10:57	6.5	7/16/10	13:15	23.9	1.01	Sample collected, bag in good condition
8/24/10	10:46	5.75	8/9/10	10:57	15.0	1.42	Sample collected, bag in good condition
9/22/10	11:30	7.25	8/24/10	10:46	29.0	0.92	Sample collected, bag in good condition
11/29/10	12:29	6.5	9/22/10	11:30	68.0	0.35	Sample collected, bag in good condition
2/21/11	12:40	9.75	11/29/10	12:29	84.0	0.43	Sample collected, bag in good condition
5/5/11	12:14	13.25	2/21/11	12:40	73.0	0.67	Sample collected, bag in good condition
6/10/11	11:34	10.75	5/5/11	12:14	36.0	1.11	Sample collected, bag in good condition
8/2/11	11:25	9.75	6/10/11	11:34	53.0	0.68	Sample collected, bag in good condition
					Mean Value:	0.67	

Seepage Meter Field Measurements

Location: Lake Killarney — Site: **21**

Date Installed: 7/16/10 — Chamber Diameter: 0.58 m — Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	13:20	-----	-----	-----	-----	-----	Bags Installed
8/9/10	11:00	45	7/16/10	13:20	23.9	6.97	Sample collected, bag in good condition
8/24/10	10:52	13.25	8/9/10	11:00	15.0	3.27	Sample collected, bag in good condition
9/22/10	11:44	4.25	8/24/10	10:52	29.0	0.54	Sample collected, bag in good condition
11/29/10	12:33	8.5	9/22/10	11:44	68.0	0.46	Sample collected, bag in good condition
2/21/11	12:45	68.5	11/29/10	12:33	84.0	3.02	Sample collected, bag in good condition
5/5/11	12:17	10.5	2/21/11	12:45	73.0	0.53	Sample collected, bag in good condition
6/10/11	11:39	8.75	5/5/11	12:17	36.0	0.90	Sample collected, bag in good condition
8/2/11	11:45	-----	6/10/11	11:39	53.0	-----	No sample collected, bag damaged, bag replaced
					Mean Value:	1.54	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney Site: **22**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	13:30	-----	-----	-----	-----	-----	Bags Installed
8/9/10	11:08	20	7/16/10	13:30	23.9	3.10	Sample collected, bag in good condition
8/24/10	10:58	15.5	8/9/10	11:08	15.0	3.83	Sample collected, bag in good condition
9/22/10	11:48	17.5	8/24/10	10:58	29.0	2.23	Sample collected, bag in good condition
11/29/10	12:39	13.5	9/22/10	11:48	68.0	0.73	Sample collected, bag in good condition
2/21/11	12:50	28.75	11/29/10	12:39	84.0	1.27	Sample collected, bag in good condition
5/5/11	12:23	11.25	2/21/11	12:50	73.0	0.57	Sample collected, bag in good condition
6/10/11	11:43	13.25	5/5/11	12:23	36.0	1.36	Sample collected, bag in good condition
8/2/11	12:05	-----	6/10/11	11:43	53.0	-----	No sample collected, meter flipped, meter reinstalled
					Mean Value:	1.16	

Seepage Meter Field Measurements

Location: Lake Killarney Site: **23**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/9/10	8:35	-----	-----	-----	-----	-----	Bags Installed
8/24/10	8:33	10.5	8/9/10	8:35	15.0	2.59	Measured volume, no sample collected
9/22/10	8:53	10.25	8/24/10	8:33	29.0	1.31	Sample collected, bag in good condition
11/29/10	12:48	19.5	9/22/10	8:53	68.2	1.06	Sample collected, bag in good condition
2/21/11	13:00	23.5	11/29/10	12:48	84.0	1.04	Sample collected, bag in good condition
5/5/11	10:25	8.5	2/21/11	13:00	72.9	0.43	Sample collected, bag in good condition
6/10/11	11:50	5.5	5/5/11	10:25	36.1	0.56	Sample collected, bag in good condition
8/2/11	12:12	-----	6/10/11	11:50	53.0	-----	No sample collected, can't find meter
					Mean Value:	0.80	

Seepage Meter Field Measurements

Location: Lake Killarney Site: **24**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
7/16/10	13:55	-----	-----	-----	-----	-----	Bags Installed
8/9/10	11:04	6.25	7/16/10	13:55	23.9	0.97	Measured volume, no sample collected
9/22/10	9:15	14.5	8/9/10	11:04	43.9	1.22	Sample collected, bag in good condition
11/29/10	12:53	12.5	9/22/10	9:15	68.2	0.68	Sample collected, bag in good condition
2/21/11	13:15	17.25	11/29/10	12:53	84.0	0.76	Sample collected, bag in good condition
5/5/11	12:27	-----	2/21/11	13:15	73.0	-----	No sample collected, meter flipped, meter reinstalled
6/10/11	11:55	-----	5/5/11	12:27	36.0	-----	No sample collected, can't find meter
8/2/11	12:18	-----	6/10/11	11:55	53.0	-----	No sample collected, can't find meter
					Mean Value:	0.49	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney Site: **25**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/9/10	8:50	-----	-----	-----	-----	-----	Bags Installed
8/24/10	11:15	-----	8/9/10	8:50	15.1	-----	No sample collected, bag missing, bag replaced
9/22/10	9:32	-----	8/24/10	11:15	28.9	-----	No sample collected, bag missing, bag replaced
11/29/10	12:58	13.75	9/22/10	9:32	68.1	0.75	Sample collected, bag in good condition
2/21/11	13:25	-----	11/29/10	12:58	84.0	-----	No sample collected, meter flipped, meter reinstalled
5/5/11	10:32	9.75	2/21/11	13:25	72.9	0.50	Sample collected, bag in good condition
6/10/11	12:00	-----	5/5/11	10:32	36.1	-----	No sample collected, can't find meter
8/2/11	12:23	-----	6/10/11	12:00	53.0	-----	No sample collected, can't find meter
					Mean Value:	0.24	

Seepage Meter Field Measurements

Location: Lake Killarney Site: **26**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/9/10	9:00	-----	-----	-----	-----	-----	Bags Installed
8/24/10	11:25	-----	8/9/10	9:00	15.1	-----	Did not check
9/22/10	9:25	2.5	8/24/10	11:25	28.9	0.32	Sample collected, bag in good condition
11/29/10	13:10	-----	9/22/10	9:25	68.2	-----	No sample collected, meter flipped, meter reinstalled
2/21/11	13:20	-----	11/29/10	13:10	84.0	-----	No sample collected, meter flipped, meter reinstalled
5/5/11	12:31	-----	2/21/11	13:20	73.0	-----	No sample collected, meter flipped, meter reinstalled
6/10/11	12:05	-----	5/5/11	12:31	36.0	-----	No sample collected, meter flipped, meter reinstalled
8/2/11	12:27	-----	6/10/11	12:05	53.0	-----	No sample collected, can't find meter
					Mean Value:	0.03	

Seepage Meter Field Measurements

Location: Lake Killarney Site: **27**

Date Installed: 7/16/10 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/9/10	9:10	-----	-----	-----	-----	-----	Bags Installed
8/24/10	9:00	8.25	8/9/10	9:10	15.0	2.04	Measured volume, no sample collected
9/22/10	11:40	10.75	8/24/10	9:00	29.1	1.37	Sample collected, bag in good condition
11/29/10	13:20	5.25	9/22/10	11:40	68.1	0.29	Sample collected, bag in good condition
2/21/11	13:25	-----	11/29/10	13:20	84.0	-----	No sample collected, meter flipped, meter reinstalled
5/5/11	12:40	-----	2/21/11	13:25	73.0	-----	No sample collected, meter flipped, meter reinstalled
6/10/11	12:25	-----	5/5/11	12:40	36.0	-----	No sample collected, can't find meter
8/2/11	12:50	-----	6/10/11	12:25	53.0	-----	No sample collected, can't find meter
					Mean Value:	0.25	

Seepage Meter Field Measurements Conducted in Lake Killarney

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **28**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/9/10	9:20	-----	-----	-----	-----	-----	Bags Installed
8/24/10	9:08	6	8/9/10	9:20	15.0	1.48	Measured volume, no sample collected
9/22/10	10:55	9.25	8/24/10	9:08	29.1	1.18	Sample collected, bag in good condition
11/29/10	11:50	7.5	9/22/10	10:55	68.0	0.41	Sample collected, bag in good condition
2/21/11	13:30	-----	11/29/10	11:50	84.1	-----	No sample collected, meter flipped, meter reinstalled
5/5/11	12:50	-----	2/21/11	13:30	73.0	-----	No sample collected, meter flipped, meter reinstalled
6/10/11	12:20	-----	5/5/11	12:50	36.0	-----	No sample collected, can't find meter
8/2/11	12:45	-----	6/10/11	12:20	53.0	-----	No sample collected, can't find meter
					Mean Value:	0.24	

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **29**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/9/10	9:30	-----	-----	-----	-----	-----	Bags Installed
8/24/10	9:50	4.25	8/9/10	9:30	15.0	1.05	Measured volume, no sample collected
9/22/10	10:50	3.25	8/24/10	9:50	29.0	0.41	Sample collected, bag in good condition
11/29/10	11:32	6.75	9/22/10	10:50	68.0	0.37	Sample collected, bag in good condition
2/21/11	13:35	8.75	11/29/10	11:32	84.1	0.39	Sample collected, bag in good condition
5/5/11	11:29	-----	2/21/11	13:35	72.9	-----	No sample collected, meter flipped, meter reinstalled
6/10/11	12:15	-----	5/5/11	11:29	36.0	-----	No sample collected, meter flipped, meter reinstalled
8/2/11	12:40	-----	6/10/11	12:15	53.0	-----	No sample collected, can't find meter
					Mean Value:	0.24	

Seepage Meter Field Measurements

Location: Lake Killarney   Site: **30**

Date Installed: 7/16/10   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/9/10	9:40	-----	-----	-----	-----	-----	Bags Installed
8/24/10	9:35	-----	8/9/10	9:40	15.0	-----	No sample collected, bag damaged, bag replaced
9/22/10	10:25	9.5	8/24/10	9:35	29.0	1.21	Sample collected, bag in good condition
11/29/10	11:24	7.25	9/22/10	10:25	68.0	0.39	Sample collected, bag in good condition
2/21/11	13:45	13.25	11/29/10	11:24	84.1	0.58	Sample collected, bag in good condition
5/5/11	11:30	10.75	2/21/11	13:45	72.9	0.55	Sample collected, bag in good condition
6/10/11	12:10	6.25	5/5/11	11:30	36.0	0.64	Sample collected, bag in good condition
8/2/11	12:33	6.5	6/10/11	12:10	53.0	0.45	Sample collected, bag in good condition
					Mean Value:	0.55	

D.2 Chemical Characteristics of Collected Seepage Samples

Characteristics of Groundwater Seepage Samples
Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 1	8/24/10	7.63	235	697	10,975	728
SP 1	9/22/10	7.71	276	773	7,294	880
SP 1	11/29/10	7.90	193	711	14,772	1,017
SP 1	2/21/11	7.49	264	567	10,830	537
SP 1	5/5/11	7.21	78	252	1,267	86
SP 1	6/10/11	7.42	87	263	1,377	83
Minimum Value:		**7.21**	**78**	**252**	**1,267**	**83**
Maximum Value:		**7.90**	**276**	**773**	**14,772**	**1,017**
Median Value:		**7.56**	**214**	**632**	**9,062**	**633**
Flow Weighted Mean:		**7.58**	**200**	**585**	**7,991**	**592**
SP 2	9/22/10	7.66	299	724	12,501	361
SP 2	11/29/10	7.56	135	342	5,098	153
SP 2	2/21/11	7.45	187	391	4,302	129
SP 2	6/10/11	7.94	206	473	4,236	303
SP 2	8/2/11	7.32	125	311	1,373	42
Minimum Value:		**7.32**	**125**	**311**	**1,373**	**42**
Maximum Value:		**7.94**	**299**	**724**	**12,501**	**361**
Median Value:		**7.56**	**187**	**391**	**4,302**	**153**
Flow Weighted Mean:		**7.62**	**195**	**456**	**5,280**	**208**
SP 3	8/24/10	7.39	84	240	1,122	140
SP 3	9/22/10	7.72	243	623	7,862	356
SP 3	11/29/10	7.87	201	578	9,597	358
SP 3	2/21/11	7.54	160	313	3,278	152
SP 3	5/5/11	7.71	176	453	2,428	172
SP 3	6/10/11	8.09	231	491	1,866	214
SP 3	8/2/11	7.92	216	466	4,320	188
Minimum Value:		**7.39**	**84**	**240**	**1,122**	**140**
Maximum Value:		**8.09**	**243**	**623**	**9,597**	**358**
Median Value:		**7.72**	**201**	**466**	**3,278**	**188**
Flow Weighted Mean:		**7.77**	**196**	**475**	**4,399**	**233**

Characteristics of Groundwater Seepage Samples Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 4	9/22/10	7.40	91	249	836	15
SP 4	11/29/10	7.65	123	289	1,768	101
SP 4	2/21/11	7.55	158	317	1,650	66
SP 4	5/5/11	7.32	89	263	846	63
SP 4	6/10/11	7.52	90	254	717	20
Minimum Value:		**7.32**	**89**	**249**	**717**	**15**
Maximum Value:		**7.65**	**158**	**317**	**1,768**	**101**
Median Value:		**7.52**	**91**	**263**	**846**	**63**
Flow Weighted Mean:		**7.47**	**106**	**270**	**1,033**	**43**
SP 5	8/24/10	7.90	294	634	12,508	947
SP 5	11/29/10	7.62	91	233	756	17
SP 5	6/10/11	7.58	68	229	918	13
Minimum Value:		**7.58**	**68**	**229**	**756**	**13**
Maximum Value:		**7.90**	**294**	**634**	**12,508**	**947**
Median Value:		**7.62**	**91**	**233**	**918**	**17**
Flow Weighted Mean:		**7.83**	**245**	**543**	**9,865**	**736**
SP 6	9/22/10	7.12	129	377	4,095	73
SP 6	11/29/10	6.96	83	236	833	6
SP 6	6/10/11	6.83	64	234	482	5
Minimum Value:		**6.83**	**64**	**234**	**482**	**5**
Maximum Value:		**7.12**	**129**	**377**	**4,095**	**73**
Median Value:		**6.96**	**83**	**236**	**833**	**6**
Flow Weighted Mean:		**7.04**	**112**	**338**	**3,109**	**54**
SP 7	8/24/10	7.94	301	405	12,792	44
SP 7	9/22/10	7.73	278	577	9,626	26
SP 7	11/29/10	7.43	173	407	5,178	23
SP 7	2/21/11	7.65	249	410	4,256	31
SP 7	5/5/11	7.78	195	469	2,501	71
SP 7	6/10/11	7.97	187	440	2,760	52
SP 7	8/2/11	7.95	218	468	3,071	102
Minimum Value:		**7.43**	**173**	**405**	**2,501**	**23**
Maximum Value:		**7.97**	**301**	**577**	**12,792**	**102**
Median Value:		**7.78**	**218**	**440**	**4,256**	**44**
Flow Weighted Mean:		**7.81**	**229**	**456**	**4,965**	**61**

Characteristics of Groundwater Seepage Samples
Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 8	8/24/10	7.51	79	479	2,824	127
SP 8	9/22/10	6.86	67	434	482	24
SP 8	11/29/10	6.51	49	410	4,694	10
SP 8	2/21/11	6.43	33	279	5,735	3
SP 8	5/5/11	7.06	54	276	549	14
SP 8	6/10/11	7.31	48	249	470	15
SP 8	8/2/11	7.45	72	252	513	11
Minimum Value:		**6.43**	**33**	**249**	**470**	**3**
Maximum Value:		**7.51**	**79**	**479**	**5,735**	**127**
Median Value:		**7.06**	**54**	**279**	**549**	**14**
Flow Weighted Mean:		**7.19**	**68**	**435**	**3,082**	**84**
SP 9	9/22/10	7.33	149	383	3,102	487
SP 9	2/21/11	7.39	141	337	1,947	10
SP 9	5/5/11	7.34	114	349	361	72
SP 9	6/10/11	7.51	150	416	688	95
SP 9	8/2/11	7.65	158	424	950	113
Minimum Value:		**7.33**	**114**	**337**	**361**	**10**
Maximum Value:		**7.65**	**158**	**424**	**3,102**	**487**
Median Value:		**7.39**	**149**	**383**	**950**	**95**
Flow Weighted Mean:		**7.51**	**150**	**400**	**1,323**	**152**
SP 10	8/24/10	7.45	152	360	4,961	232
SP 10	9/22/10	7.40	132	323	2,056	323
SP 10	11/29/10	7.07	150	369	7,965	761
SP 10	2/21/11	7.18	106	211	2,090	105
SP 10	5/5/11	7.42	82	259	819	86
SP 10	6/10/11	7.56	79	241	729	17
SP 10	8/2/11	7.33	125	307	2,989	228
Minimum Value:		**7.07**	**79**	**211**	**729**	**17**
Maximum Value:		**7.56**	**152**	**369**	**7,965**	**761**
Median Value:		**7.40**	**125**	**307**	**2,090**	**228**
Flow Weighted Mean:		**7.38**	**124**	**306**	**3,265**	**234**

Characteristics of Groundwater Seepage Samples Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 11	8/24/10	7.95	261	572	10,907	687
SP 11	9/22/10	7.81	185	492	7,564	651
SP 11	11/29/10	7.53	104	277	2,367	358
SP 11	2/21/11	7.65	154	297	2,379	188
SP 11	5/5/11	7.37	96	280	1,213	85
SP 11	6/10/11	7.71	98	272	1,162	83
SP 11	8/2/11	7.84	131	394	3,251	214
Minimum Value:		**7.37**	**96**	**272**	**1,162**	**83**
Maximum Value:		**7.95**	**261**	**572**	**10,907**	**687**
Median Value:		**7.71**	**131**	**297**	**2,379**	**214**
Flow Weighted Mean:		**7.74**	**161**	**395**	**4,905**	**362**
SP 12	8/24/10	7.78	257	578	11,218	977
SP 12	11/29/10	7.90	181	451	7,083	418
SP 12	2/21/11	7.61	125	250	1,764	114
SP 12	5/5/11	7.30	86	267	582	99
SP 12	6/10/11	7.99	115	315	898	51
SP 12	8/2/11	7.82	125	296	726	59
Minimum Value:		**7.30**	**86**	**250**	**582**	**51**
Maximum Value:		**7.99**	**257**	**578**	**11,218**	**977**
Median Value:		**7.80**	**125**	**306**	**1,331**	**107**
Flow Weighted Mean:		**7.79**	**95**	**238**	**1,399**	**91**
SP 13	8/24/10	7.82	203	580	16,480	1,816
SP 13	9/22/10	7.51	93	271	1,857	200
SP 13	11/29/10	7.58	101	273	2,507	373
SP 13	2/21/11	7.67	169	352	7,924	399
SP 13	5/5/11	8.10	197	566	9,390	788
SP 13	6/10/11	7.75	108	315	2,633	210
SP 13	8/2/11	7.81	169	455	7,882	530
Minimum Value:		**7.51**	**93**	**271**	**1,857**	**200**
Maximum Value:		**8.10**	**203**	**580**	**16,480**	**1,816**
Median Value:		**7.75**	**169**	**352**	**7,882**	**399**
Flow Weighted Mean:		**7.75**	**160**	**434**	**8,974**	**859**

Characteristics of Groundwater Seepage Samples Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 14	8/24/10	7.87	188	435	14,354	1,352
SP 14	9/22/10	7.70	179	532	11,470	1,347
SP 14	11/29/10	7.68	131	337	6,300	506
SP 14	2/21/11	7.43	117	250	3,324	212
SP 14	5/5/11	7.62	81	258	2,880	239
SP 14	6/10/11	7.63	87	261	982	74
SP 14	8/2/11	7.62	114	299	2,081	134
Minimum Value:		**7.43**	**81**	**250**	**982**	**74**
Maximum Value:		**7.87**	**188**	**532**	**14,354**	**1,352**
Median Value:		**7.63**	**117**	**299**	**3,324**	**239**
Flow Weighted Mean:		**7.72**	**147**	**376**	**8,451**	**802**
SP 15	8/24/10	7.65	251	567	10,064	926
SP 15	9/22/10	7.76	216	581	7,782	984
SP 15	11/29/10	7.75	314	675	10,969	433
SP 15	2/21/11	7.46	123	251	2,150	63
SP 15	5/5/11	7.37	76	248	581	98
SP 15	6/10/11	7.40	85	253	1,084	30
SP 15	8/2/11	7.53	109	285	773	71
Minimum Value:		**7.37**	**76**	**248**	**581**	**30**
Maximum Value:		**7.76**	**314**	**675**	**10,969**	**984**
Median Value:		**7.53**	**123**	**285**	**2,150**	**98**
Flow Weighted Mean:		**7.56**	**173**	**424**	**5,342**	**460**
SP 16	8/24/10	7.80	232	487	14,611	1,460
SP 16	9/22/10	7.46	111	304	792	1,860
SP 16	11/29/10	7.46	142	353	5,828	575
SP 16	2/21/11	7.65	272	629	13,866	238
SP 16	5/5/11	7.54	216	627	12,888	156
SP 16	6/10/11	7.19	101	274	1,253	55
SP 16	8/2/11	7.60	117	341	6,187	413
Minimum Value:		**7.19**	**101**	**274**	**792**	**55**
Maximum Value:		**7.80**	**272**	**629**	**14,611**	**1,860**
Median Value:		**7.54**	**142**	**353**	**6,187**	**413**
Flow Weighted Mean:		**7.52**	**185**	**476**	**8,970**	**652**

Characteristics of Groundwater Seepage Samples Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 17	8/24/10	7.75	222	593	14,373	1,956
SP 17	9/22/10	7.68	202	567	9,429	1,664
SP 17	11/29/10	7.35	137	303	1,591	797
SP 17	2/21/11	7.33	205	489	11,095	1,473
SP 17	5/5/11	7.87	274	747	14,535	1,439
SP 17	6/10/11	7.33	122	316	596	74
SP 17	8/2/11	7.53	123	310	2,170	210
Minimum Value:		**7.33**	**122**	**303**	**596**	**74**
Maximum Value:		**7.87**	**274**	**747**	**14,535**	**1,956**
Median Value:		**7.53**	**202**	**489**	**9,429**	**1,439**
Flow Weighted Mean:		**7.61**	**188**	**495**	**8,642**	**1,219**
SP 18	8/24/10	7.71	213	587	13,465	1,948
SP 18	9/22/10	7.69	194	504	4,407	1,375
SP 18	11/29/10	7.63	120	292	1,218	1,313
SP 18	2/21/11	7.47	220	437	10,706	1,350
SP 18	5/5/11	8.03	295	771	13,246	1,640
SP 18	6/10/11	7.71	293	649	8,570	1,212
SP 18	8/2/11	6.52	63	257	640	108
Minimum Value:		**6.52**	**63**	**257**	**640**	**108**
Maximum Value:		**8.03**	**295**	**771**	**13,465**	**1,948**
Median Value:		**7.69**	**213**	**504**	**8,570**	**1,350**
Flow Weighted Mean:		**7.61**	**207**	**532**	**9,570**	**1,504**
SP 19	8/24/10	7.83	145	477	13,599	1,465
SP 19	9/22/10	7.53	118	305	1,594	1,256
SP 19	11/29/10	7.51	158	413	8,440	890
SP 19	2/21/11	7.46	180	410	11,927	1,033
SP 19	5/5/11	7.77	112	242	4,205	547
SP 19	6/10/11	7.76	146	443	9,675	858
Minimum Value:		**7.46**	**112**	**242**	**1,594**	**547**
Maximum Value:		**7.83**	**180**	**477**	**13,599**	**1,465**
Median Value:		**7.65**	**146**	**412**	**9,058**	**962**
Flow Weighted Mean:		**7.66**	**138**	**383**	**7,804**	**1,148**

Characteristics of Groundwater Seepage Samples
Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 20	8/24/10	8.10	269	704	11,034	1,919
SP 20	9/22/10	7.80	210	589	9,459	1,374
SP 20	11/29/10	7.68	215	565	10,485	1,269
SP 20	2/21/11	7.73	180	502	9,682	957
SP 20	5/5/11	7.87	126	355	2,956	350
SP 20	6/10/11	7.86	127	333	2,310	292
SP 20	8/2/11	7.92	180	570	8,002	492
Minimum Value:		**7.68**	**126**	**333**	**2,310**	**292**
Maximum Value:		**8.10**	**269**	**704**	**11,034**	**1,919**
Median Value:		**7.86**	**180**	**565**	**9,459**	**957**
Flow Weighted Mean:		**7.90**	**193**	**529**	**7,566**	**1,029**
SP 21	8/24/10	7.68	195	476	4,535	312
SP 21	9/22/10	7.97	321	737	8,552	843
SP 21	11/29/10	7.94	276	688	9,504	922
SP 21	2/21/11	7.70	215	410	4,570	355
SP 21	5/5/11	8.02	181	436	1,968	258
SP 21	6/10/11	7.92	131	342	1,716	90
Minimum Value:		**7.68**	**131**	**342**	**1,716**	**90**
Maximum Value:		**8.02**	**321**	**737**	**9,504**	**922**
Median Value:		**7.93**	**205**	**456**	**4,553**	**334**
Flow Weighted Mean:		**7.76**	**207**	**464**	**4,612**	**366**
SP 22	8/24/10	7.69	84	241	1,631	26
SP 22	9/22/10	7.80	101	274	2,123	298
SP 22	11/29/10	7.60	105	251	1,860	151
SP 22	2/21/11	7.35	103	220	1,611	139
SP 22	5/5/11	7.70	80	244	1,210	154
SP 22	6/10/11	7.56	71	220	775	13
Minimum Value:		**7.35**	**71**	**220**	**775**	**13**
Maximum Value:		**7.80**	**105**	**274**	**2,123**	**298**
Median Value:		**7.65**	**93**	**243**	**1,621**	**145**
Flow Weighted Mean:		**7.65**	**90**	**244**	**1,614**	**116**

Characteristics of Groundwater Seepage Samples Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 23	8/24/10	7.26	94	233	1,496	46
SP 23	9/22/10	7.40	110	365	2,253	117
SP 23	11/29/10	7.31	92	239	3,238	178
SP 23	2/21/11	6.81	98	258	9,484	387
SP 23	5/5/11	7.32	159	392	5,429	320
SP 23	6/10/11	7.21	144	360	4,304	312
Minimum Value:		**6.81**	**92**	**233**	**1,496**	**46**
Maximum Value:		**7.40**	**159**	**392**	**9,484**	**387**
Median Value:		**7.29**	**104**	**309**	**3,771**	**245**
Flow Weighted Mean:		**7.23**	**105**	**282**	**3,555**	**168**
SP 24	9/22/10	7.74	124	312	5,750	203
SP 24	11/29/10	7.52	87	237	1,336	60
SP 24	2/21/11	7.28	102	218	1,970	53
Minimum Value:		**7.28**	**87**	**218**	**1,336**	**53**
Maximum Value:		**7.74**	**124**	**312**	**5,750**	**203**
Median Value:		**7.52**	**102**	**237**	**1,970**	**60**
Flow Weighted Mean:		**7.55**	**108**	**266**	**3,544**	**124**
SP 25	11/29/10	7.31	82	248	2,085	98
SP 25	5/5/11	7.31	108	295	1,396	109
SP 25	8/2/11	7.53	123	363	2,708	463
Minimum Value:		**7.31**	**82**	**248**	**1,396**	**98**
Maximum Value:		**7.53**	**123**	**363**	**2,708**	**463**
Median Value:		**7.31**	**108**	**295**	**2,085**	**109**
Flow Weighted Mean:		**7.36**	**100**	**290**	**2,023**	**188**
SP 26	9/22/10	7.13	123	294	1,386	407
Minimum Value:		**7.13**	**123**	**294**	**1,386**	**407**
Maximum Value:		**7.13**	**123**	**294**	**1,386**	**407**
Median Value:		**7.13**	**123**	**294**	**1,386**	**407**
Flow Weighted Mean:		**7.13**	**123**	**294**	**1,386**	**407**

Characteristics of Groundwater Seepage Samples
Collected from Lake Killarney

Site	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Total N (µg/L)	Total P (µg/L)
SP 27	9/22/10	7.63	108	303	2,062	311
SP 27	11/29/10	7.70	132	363	5,305	452
Minimum Value:		**7.63**	**108**	**303**	**2,062**	**311**
Maximum Value:		**7.70**	**132**	**363**	**5,305**	**452**
Median Value:		**7.67**	**120**	**333**	**3,684**	**382**
Flow Weighted Mean:		**7.64**	**112**	**313**	**2,622**	**335**
SP 28	9/22/10	7.57	94	259	2,086	228
SP 28	11/29/10	7.65	88	246	1,242	32
Minimum Value:		**7.57**	**88**	**246**	**1,242**	**32**
Maximum Value:		**7.65**	**94**	**259**	**2,086**	**228**
Median Value:		**7.61**	**91**	**253**	**1,664**	**130**
Flow Weighted Mean:		**7.59**	**93**	**256**	**1,869**	**178**
SP 29	9/22/10	7.36	151	370	4,324	221
SP 29	2/21/11	7.13	94	211	1,780	86
Minimum Value:		**7.13**	**94**	**211**	**1,780**	**86**
Maximum Value:		**7.36**	**151**	**370**	**4,324**	**221**
Median Value:		**7.25**	**123**	**291**	**3,052**	**154**
Flow Weighted Mean:		**7.25**	**124**	**295**	**3,128**	**158**
SP 30	9/22/10	7.05	97	244	1,017	421
SP 30	11/29/10	7.02	94	261	2,676	367
SP 30	2/21/11	6.95	89	216	4,189	288
SP 30	5/5/11	7.43	140	357	2,613	530
SP 30	6/10/11	7.23	149	363	5,542	305
SP 30	8/2/11	7.31	144	359	5,712	616
Minimum Value:		**6.95**	**89**	**216**	**1,017**	**288**
Maximum Value:		**7.43**	**149**	**363**	**5,712**	**616**
Median Value:		**7.14**	**118**	**309**	**3,433**	**394**
Flow Weighted Mean:		**7.15**	**116**	**291**	**3,213**	**414**

APPENDIX E

RESULTS OF INFLOW MONITORING CONDUCTED IN THE LAKE KILLARNEY WATERSHED

E.1 Bulk Precipitation

E.2 Runoff Monitoring

E.1 Bulk Precipitation

Characteristics of Bulk Precipitation Samples Collected at Lake Killarney from September 2010 - June 2011

Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Ammonia (µg/L)	NO_X (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/L)
9/28/10	5.66	4.8	133	510	214	481	190	1,395	140	28	14	182	1.7	9	3.2
11/2/10 - 11/4/10	5.61	3.8	28	233	431	93	15	772	22	19	21	62	0.8	10	3.0
11/5/10 - 12/6/10	6.18	8.8	71	848	429	31	55	1363	184	41	59	284	6.5	15	13.8
12/6/10 - 12/20/10	6.10	5.8	96	469	758	13	145	1385	26	8	48	82	3.6	15	27.5
12/20/10 - 1/6/11	5.29	4.6	40	584	639	46	24	1293	11	4	16	31	2.9	4	4.6
1/6/11 - 1/10/11	5.82	30.2	41	220	444	69	125	858	10	8	29	47	3.4	5	12.3
1/10/11 - 1/19/11	5.33	2.2	22	393	106	45	21	565	4	3	7	14	0.5	5	0.9
1/19/11 - 1/26/11	5.05	2.2	49	205	131	111	78	525	2	12	36	50	1.8	2	1.6
3/10/11	5.40	2.8	40	575	21	62	152	810	16	21	52	89	2.6	9	2.4
3/31/11	5.24	2.2	20	413	130	42	248	833	70	26	13	109	1.8	6	4.9
3/31/11 - 4/11/11	5.28	2.2	14	75	22	46	68	211	12	21	42	75	2.6	7	3.1
6/21/11 - 6/27/11	5.38	3.2	12	6	190	269	112	577	5	15	27	47	2.8	4	7.4
Minimum Value:	**5.05**	**2.2**	**12**	**6**	**21**	**13**	**15**	**211**	**2**	**3**	**7**	**14**	**0.5**	**2**	**0.9**
Maximum Value:	**6.18**	**30.2**	**133**	**848**	**758**	**481**	**248**	**1395**	**184**	**41**	**59**	**284**	**6.5**	**15**	**27.5**
Median Value:	**5.39**	**3.5**	**40**	**403**	**202**	**54**	**95**	**822**	**14**	**17**	**28**	**69**	**2.6**	**7**	**3.9**
Geometric Mean:	**5.52**	**4.2**	**37**	**247**	**182**	**68**	**75**	**785**	**18**	**13**	**25**	**68**	**2.1**	**7**	**4.6**

E.2 Runoff Monitoring

Characteristics of Inflow Samples to Lake Killarney Collected from August 2010 - March 2011

Sample Location	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Ammonia (µg/L)	NO_X (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/L)
Beachview	3/10/11	5.93	29.4	85	640	3	80	245	968	24	75	123	222	8.9	94	12.0
Beachview	3/31/11	6.35	19.8	62	297	73	33	576	979	56	77	100	233	11.5	17	11.2
Minimum Value:		**5.93**	**19.8**	**62**	**297**	**3**	**33**	**245**	**968**	**24**	**75**	**100**	**222**	**8.9**	**17**	**11.2**
Maximum Value:		**6.35**	**29.4**	**85**	**640**	**73**	**80**	**576**	**979**	**56**	**77**	**123**	**233**	**11.5**	**94**	**12.0**
Median Value:		**6.14**	**24.6**	**74**	**469**	**38**	**57**	**411**	**974**	**40**	**76**	**112**	**228**	**10.2**	**56**	**11.6**
Log Normal Mean:		**6.14**	**24.1**	**73**	**436**	**15**	**51**	**376**	**973**	**37**	**76**	**111**	**227**	**10.1**	**40**	**11.6**
Blossom	8/24/10	6.69	38.8	97	350	181	171	264	966	130	73	250	453	12.4	45	142
Blossom	9/28/10	6.95	112	343	338	1,369	236	354	2,297	71	66	120	257	2.9	53	29.0
Blossom	1/10/11	5.89	19.2	65	66	223	251	407	947	180	100	102	382	8.8	18	31.5
Blossom	1/17/11	6.25	8.2	38	59	178	200	521	958	85	30	141	256	6.8	39	27.3
Blossom	3/10/11	6.64	46.6	133	611	77	170	1,668	2,526	7	47	310	364	30.0	21	107
Minimum Value:		**5.89**	**8.2**	**38**	**59**	**77**	**170**	**264**	**947**	**7**	**30**	**102**	**256**	**2.9**	**18**	**27.3**
Maximum Value:		**6.95**	**112**	**343**	**611**	**1,369**	**251**	**1,668**	**2,526**	**180**	**100**	**310**	**453**	**30.0**	**53**	**142**
Median Value:		**6.64**	**38.8**	**97**	**338**	**181**	**200**	**407**	**966**	**85**	**66**	**141**	**364**	**8.8**	**39**	**31.5**
Log Normal Mean:		**6.47**	**31.7**	**102**	**195**	**238**	**203**	**506**	**1,384**	**63**	**58**	**168**	**334**	**9.2**	**32**	**52.0**
DOT Pond	8/23/10	6.95	62.2	166	126	151	542	294	1,113	2	2	20	24	8.0	19	10.5
DOT Pond	8/24/10	7.05	66.4	156	234	130	444	101	909	2	2	21	25	9.0	17	13.4
DOT Pond	9/28/10	6.76	55.6	142	78	66	725	124	993	7	5	30	42	8.2	25	12.1
DOT Pond	11/4/10	7.00	96.6	269	305	57	280	346	988	1	6	73	79	11.2	43	19.1
DOT Pond	1/6/11	6.73	74.4	195	347	105	134	125	711	10	4	25	39	4.5	37	3.1
DOT Pond	3/10/11	6.95	81.4	216	135	55	279	161	630	2	15	31	48	3.6	46	3.2
DOT Pond	3/31/11	6.67	53.8	142	211	127	408	211	957	1	8	77	86	4.6	40	6.7
DOT Pond	6/27/11	6.85	41.4	95	173	84	302	529	1,088	1	4	62	67	5.3	26	6.8
DOT Pond	1/10/11	7.02	71.6	194	444	110	337	367	1,258	18	10	43	71	4.5	37	3.4
DOT Pond	1/17/11	6.89	58.8	169	415	129	243	257	1,044	22	3	24	49	6.1	38	9.3
Minimum Value:		**6.67**	**41.4**	**95**	**78**	**55**	**134**	**101**	**630**	**1**	**2**	**20**	**24**	**3.6**	**17**	**3.1**
Maximum Value:		**7.05**	**96.6**	**269**	**444**	**151**	**725**	**529**	**1,258**	**22**	**15**	**77**	**86**	**11.2**	**46**	**19.1**
Median Value:		**6.92**	**64.3**	**168**	**223**	**108**	**320**	**234**	**991**	**2**	**5**	**31**	**49**	**5.7**	**37**	**8.1**
Log Normal Mean:		**6.89**	**64.6**	**168**	**216**	**96**	**336**	**220**	**951**	**3**	**5**	**36**	**49**	**6.1**	**31**	**7.4**
Executive	8/24/10	6.71	33.4	84	220	211	264	49	744	33	11	1	45	9.0	29	7.3
Executive	9/28/10	6.67	100	269	485	366	529	35	1,415	24	8	6	38	2.9	42	2.6
Executive	1/10/11	6.78	31.6	125	60	322	271	242	895	32	9	14	55	37.9	28	95.8
Executive	1/17/11	6.67	14.0	50	92	188	182	20	482	29	14	6	49	4.4	17	5.3
Executive	3/10/11	6.38	19.4	56	85	133	189	65	472	36	10	13	59	5.0	18	3.4
Executive	3/31/11	6.43	18.4	43	188	64	158	182	592	65	11	10	86	4.1	20	4.9
Minimum Value:		**6.38**	**14.0**	**43**	**60**	**64**	**158**	**20**	**472**	**24**	**8**	**1**	**38**	**2.9**	**17**	**2.6**
Maximum Value:		**6.78**	**100.0**	**269**	**485**	**366**	**529**	**242**	**1,415**	**65**	**14**	**14**	**86**	**37.9**	**42**	**95.8**
Median Value:		**6.67**	**25.5**	**70**	**140**	**200**	**227**	**57**	**668**	**33**	**11**	**8**	**52**	**4.7**	**24**	**5.1**
Log Normal Mean:		**6.60**	**28.4**	**84**	**145**	**185**	**243**	**68**	**709**	**35**	**10**	**6**	**53**	**6.7**	**24**	**7.4**

Characteristics of Inflow Samples to Lake Killarney Collected from August 2010 - March 2011

Sample Location	Date Collected	pH (s.u.)	Alk (mg/L)	Cond (µmho/cm)	Ammonia (µg/L)	NO_x (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/L)
Formosa	1/10/11	6.48	34.4	90	17	366	428	524	1,335	314	81	117	512	14.1	78	12.2
Formosa	1/17/11	6.49	19.2	50	52	192	468	236	948	258	108	49	415	4.1	53	5.0
Formosa	3/31/11	6.37	38.8	92	74	185	363	362	984	120	155	41	316	4.9	57	4.6
Minimum Value:		**6.37**	**19.2**	**50**	**17**	**185**	**363**	**236**	**948**	**120**	**81**	**41**	**316**	**4.1**	**53**	**4.6**
Maximum Value:		**6.49**	**38.8**	**92**	**74**	**366**	**468**	**524**	**1,335**	**314**	**155**	**117**	**512**	**14.1**	**78**	**12.2**
Median Value:		**6.48**	**34.4**	**90**	**52**	**192**	**428**	**362**	**984**	**258**	**108**	**49**	**415**	**4.9**	**57**	**5.0**
Log Normal Mean:		**6.45**	**29.5**	**75**	**40**	**235**	**417**	**355**	**1,076**	**213**	**111**	**62**	**406**	**6.6**	**62**	**6.5**
Ohio	8/24/10	7.01	60.6	157	95	118	150	450	813	62	35	35	132	12.7	44	7.4
Ohio	9/28/10	6.41	80.6	276	352	868	249	1,174	2,643	59	12	24	95	3.7	100	3.9
Ohio	1/10/11	7.02	45.8	147	22	333	311	772	1,438	67	10	71	148	110.0	41	154
Ohio	1/17/11	7.60	31.2	104	78	139	363	344	924	67	21	79	167	50.3	23	94.0
Ohio	3/10/11	6.63	52.4	107	132	222	358	217	929	57	32	85	174	24.1	64	29.3
Ohio	3/31/11	6.58	44.0	124	252	357	420	575	1,604	28	13	98	139	33.0	20	53.3
Minimum Value:		**6.41**	**31.2**	**104**	**22**	**118**	**150**	**217**	**813**	**28**	**10**	**24**	**95**	**3.7**	**20**	**3.9**
Maximum Value:		**7.60**	**80.6**	**276**	**352**	**868**	**420**	**1,174**	**2,643**	**67**	**35**	**98**	**174**	**110.0**	**100**	**154.0**
Median Value:		**6.82**	**49.1**	**136**	**114**	**278**	**335**	**513**	**1,184**	**61**	**17**	**75**	**144**	**28.6**	**43**	**41.3**
Log Normal Mean:		**6.86**	**50.2**	**144**	**111**	**269**	**293**	**510**	**1,273**	**55**	**18**	**58**	**140**	**24.3**	**42**	**29.5**
Ololu	8/24/10	6.97	36.6	81	17	26	132	165	340	165	86	107	358	10.2	50	29.8
Ololu	9/28/10	7.53	161	504	92	4,673	72	417	5,254	174	76	171	421	13.3	23	49.0
Ololu	1/10/11	6.82	25.8	90	112	411	299	515	1,337	80	35	177	292	19.1	42	62.6
Ololu	3/10/11	6.50	40.6	97	364	66	140	564	1,134	52	24	148	224	10.9	54	32.7
Ololu	3/31/11	6.76	32.8	94	261	65	119	327	772	65	6	51	122	11.4	31	23.3
Olulu	1/17/11	7.22	26.6	71	99	158	456	346	1,059	45	14	74	133	21.8	23	50.7
Minimum Value:		**6.50**	**25.8**	**71**	**17**	**26**	**72**	**165**	**340**	**45**	**6**	**51**	**122**	**10.2**	**23**	**23.3**
Maximum Value:		**7.53**	**161.0**	**504**	**364**	**4,673**	**456**	**564**	**5,254**	**174**	**86**	**177**	**421**	**21.8**	**54**	**62.6**
Median Value:		**6.90**	**34.7**	**92**	**106**	**112**	**136**	**382**	**1,097**	**73**	**30**	**128**	**258**	**12.4**	**37**	**40.9**
Log Normal Mean:		**6.96**	**41.9**	**116**	**109**	**180**	**167**	**362**	**1,142**	**84**	**28**	**110**	**233**	**13.8**	**35**	**39.0**

APPENDIX F

RESULTS OF SEDIMENT NUTRIENT RELEASE EXPERIMENTS CONDUCTED ON LAKE KILLARNEY CORE SAMPLES

F.1 Chemical Characteristics of Sediment Release Samples

F.2 Calculations of Sediment Nutrient Release

F.1 Chemical Characteristics of Sediment Release Samples

Reslts of Sediment Incubation Experiments Conducted on Lake Killarney Sediment Samples

Site	Redox Condition	Date Collected	No. of Days	NH3 (µg/L)	NOX (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Volume (L)	Total N (µg)	SRP (µg)	Total P (µg)
Site 1	Anoxic	5/23/11	0	210	143	1,911	5	260	3.63	6,938	18	944
Site 1		5/24/11	1	327	136	1,271	7	109	3.62	4,602	25	395
Site 1		5/25/11	2	411	399	1,221	4	131	3.61	4,410	14	473
Site 1		5/26/11	3	448	116	1,203	9	139	3.60	4,333	32	501
Site 1		5/27/11	4	505	114	1,216	11	152	3.59	4,369	40	546
Site 1		5/31/11	8	290	364	1,194	18	184	3.55	4,244	64	654
Site 1		6/1/11	9	318	378	1,287	32	192	3.55	4,563	113	681
Site 1		6/3/11	11	0	400	1,451	34	209	3.53	5,117	120	737
Site 1		6/6/11	14	0	546	1,303	35	251	3.50	4,558	122	878
Site 1		6/7/11	15	0	631	1,540	38	237	3.49	5,372	133	827
Site 1		6/10/11	18	0	633	1,416	33	187	3.46	4,900	114	647
Site 1		6/13/11	21	9	791	1,142	25	181	3.43	3,919	86	621
Site 1		6/15/11	23	11	750	1,236	20	192	3.41	4,218	68	655
Site 1		6/17/11	25	9	762	1,127	25	179	3.39	3,825	85	608
Site 1		6/20/11	28	15	688	1,193	15	154	3.37	4,015	50	518
Site 1		6/22/11	30	16	301	1,224	16	152	3.35	4,096	54	509
Site 1		6/24/11	32	0	241	1,074	12	157	3.33	3,574	40	522
Site 1	Aerobic	6/28/11	0	0	73	432	1	187	3.63	1,568	4	679
Site 1		6/29/11	1	0	80	400	3	181	3.62	1,448	11	655
Site 1		6/30/11	2	252	94	398	0	183	3.61	1,437	0	661
Site 1		7/1/11	3	0	104	368	1	172	3.60	1,325	4	619
Site 1		7/5/11	7	0	167	629	5	194	3.56	2,239	18	691
Site 1		7/6/11	8	0	201	994	8	152	3.55	3,528	28	540
Site 1		7/8/11	10	0	284	644	9	203	3.53	2,273	32	717
Site 1		7/11/11	13	0	411	606	18	205	3.50	2,121	63	717
Site 1		7/13/11	15	0	446	653	24	209	3.48	2,272	83	727
Site 1		7/15/11	17	0	564	1,138	57	308	3.46	3,936	197	1,065
Site 1		7/18/11	20	0	564	1,071	57	321	3.43	3,672	195	1,101
Site 1		7/22/11	24	33	653	1,456	76	333	3.39	4,933	258	1,128
Site 1		7/25/11	27	25	881	1,440	79	398	3.36	4,836	265	1,337
Site 1		7/28/11	30	0	1,065	1,757	103	424	3.33	5,847	343	1,411

Reslts of Sediment Incubation Experiments Conducted on Lake Killarney Sediment Samples

Site	Redox Condition	Date Collected	No. of Days	NH3 (µg/L)	NOX (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Volume (L)	Total N (µg)	SRP (µg)	Total P (µg)
Site 2		5/23/11	0	148	10	1,024	6	177	3.63	3,718	22	643
Site 2		5/24/11	1	137	8	808	6	163	3.62	2,926	22	590
Site 2		5/25/11	2	221	8	1,095	14	118	3.61	3,955	51	426
Site 2		5/26/11	3	300	5	1,056	20	147	3.60	3,804	72	530
Site 2		5/27/11	4	360	4	911	21	152	3.59	3,273	75	546
Site 2		5/31/11	8	681	16	1,668	42	173	3.55	5,929	149	615
Site 2		6/1/11	9	978	5	1,732	66	176	3.55	6,141	234	624
Site 2		6/3/11	11	1,363	26	1,762	67	205	3.53	6,214	236	723
Site 2	Anoxic	6/6/11	14	1,875	136	2,457	72	205	3.50	8,595	252	717
Site 2		6/7/11	15	2,440	5	2,985	105	215	3.49	10,413	366	750
Site 2		6/10/11	18	2,781	5	3,431	162	326	3.46	11,872	561	1,128
Site 2		6/13/11	21	3,084	6	3,458	203	362	3.43	11,867	697	1,242
Site 2		6/15/11	23	3,399	3	3,702	201	403	3.41	12,635	686	1,375
Site 2		6/17/11	25	3,136	5	4,366	228	366	3.39	14,818	774	1,242
Site 2		6/20/11	28	3,925	8	4,649	246	408	3.37	15,647	828	1,373
Site 2		6/22/11	30	4,322	66	4,652	224	345	3.35	15,569	750	1,155
Site 2		6/24/11	32	4,939	33	5,002	267	400	3.33	16,646	889	1,331
Site 2		6/28/11	0	632	44	676	11	179	3.63	2,454	40	650
Site 2		6/29/11	1	640	119	759	30	122	3.62	2,748	109	442
Site 2		6/30/11	2	440	394	834	35	172	3.61	3,011	126	621
Site 2		7/1/11	3	292	908	1,200	48	166	3.60	4,320	173	598
Site 2		7/5/11	7	138	1,243	1,381	67	188	3.56	4,916	239	669
Site 2		7/6/11	8	129	1,110	1,239	65	276	3.55	4,398	231	980
Site 2		7/8/11	10	158	1,196	1,354	81	266	3.53	4,779	286	939
Site 2	Aerobic	7/11/11	13	57	1,246	1,303	100	243	3.50	4,560	350	850
Site 2		7/13/11	15	41	1,228	1,269	116	277	3.48	4,415	404	964
Site 2		7/15/11	17	37	1,309	1,346	144	246	3.46	4,656	498	851
Site 2		7/18/11	20	26	1,457	1,483	149	259	3.43	5,085	511	888
Site 2		7/22/11	24	10	1,826	1,836	152	271	3.39	6,221	515	918
Site 2		7/25/11	27	28	1,905	1,933	140	264	3.36	6,491	470	887
Site 2		7/28/11	30	13	2,031	2,044	145	226	3.33	6,802	483	752

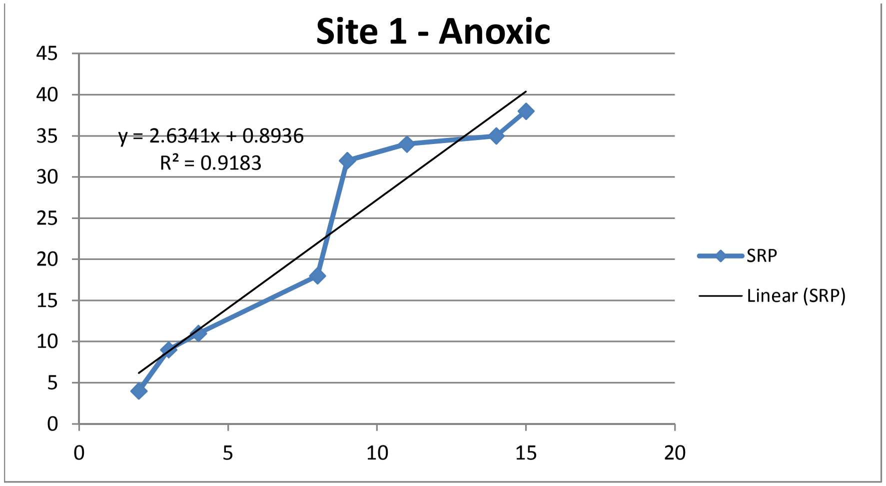
Reslts of Sediment Incubation Experiments Conducted on Lake Killarney Sediment Samples

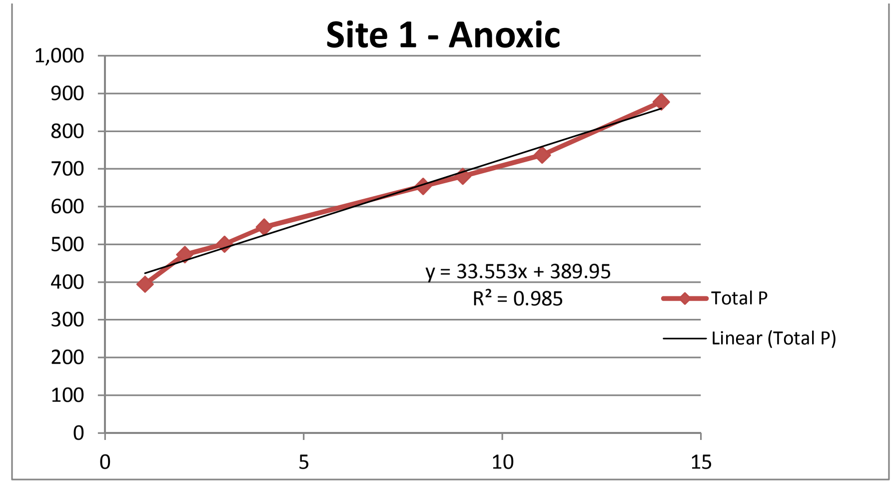
Site	Redox Condition	Date Collected	No. of Days	NH3 (µg/L)	NOX (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Volume (L)	Total N (µg)	SRP (µg)	Total P (µg)
Site 3	Anoxic	5/23/11	0	141	6	1,166	7	164	3.63	4,233	25	595
Site 3		5/24/11	1	209	7	1,193	18	210	3.62	4,322	65	761
Site 3		5/25/11	2	244	7	1,140	30	182	3.61	4,121	108	658
Site 3		5/26/11	3	365	2	1,102	47	234	3.61	3,975	170	844
Site 3		5/27/11	4	436	1	1,186	64	256	3.60	4,268	230	921
Site 3		5/31/11	8	584	0	1,193	94	277	3.57	4,256	335	988
Site 3		6/1/11	9	686	3	1,279	113	319	3.56	4,553	402	1,135
Site 3		6/3/11	11	750	7	1,472	115	328	3.54	5,216	408	1,162
Site 3		6/6/11	14	802	25	1,434	125	331	3.52	5,048	440	1,165
Site 3		6/7/11	15	977	22	1,883	146	349	3.51	6,614	513	1,226
Site 3		6/10/11	18	1,106	31	1,707	220	346	3.49	5,955	767	1,207
Site 3		6/13/11	21	902	244	1,500	227	353	3.46	5,197	787	1,223
Site 3		6/15/11	23	485	396	1,630	244	379	3.45	5,622	842	1,307
Site 3		6/17/11	25	551	517	1,870	258	386	3.43	6,421	886	1,325
Site 3		6/20/11	28	452	587	1,475	250	384	3.41	5,029	852	1,309
Site 3		6/22/11	30	503	309	1,443	228	360	3.39	4,898	774	1,222
Site 3		6/24/11	32	162	1,107	1,093	255	359	3.38	3,692	861	1,213
Site 3	Aerobic	6/28/11	0	0	117	479	3	247	3.63	1,739	11	897
Site 3		6/29/11	1	0	125	276	2	132	3.62	1,000	7	478
Site 3		6/30/11	2	108	162	291	5	143	3.61	1,052	18	517
Site 3		7/1/11	3	0	187	315	5	135	3.61	1,136	18	487
Site 3		7/5/11	7	0	301	457	11	158	3.57	1,632	39	564
Site 3		7/6/11	8	0	309	581	13	127	3.56	2,070	46	453
Site 3		7/8/11	10	0	346	554	18	129	3.55	1,965	64	457
Site 3		7/11/11	13	0	386	441	17	125	3.52	1,553	60	440
Site 3		7/13/11	15	0	444	567	12	136	3.50	1,987	42	477
Site 3		7/15/11	17	0	568	723	14	106	3.49	2,521	49	370
Site 3		7/18/11	20	0	563	726	14	130	3.46	2,514	48	450
Site 3		7/22/11	24	0	255	991	17	126	3.43	3,398	58	432
Site 3		7/25/11	27	6	948	1,128	20	94	3.40	3,839	68	320
Site 3		7/28/11	30	0	605	958	16	82	3.38	3,236	54	277

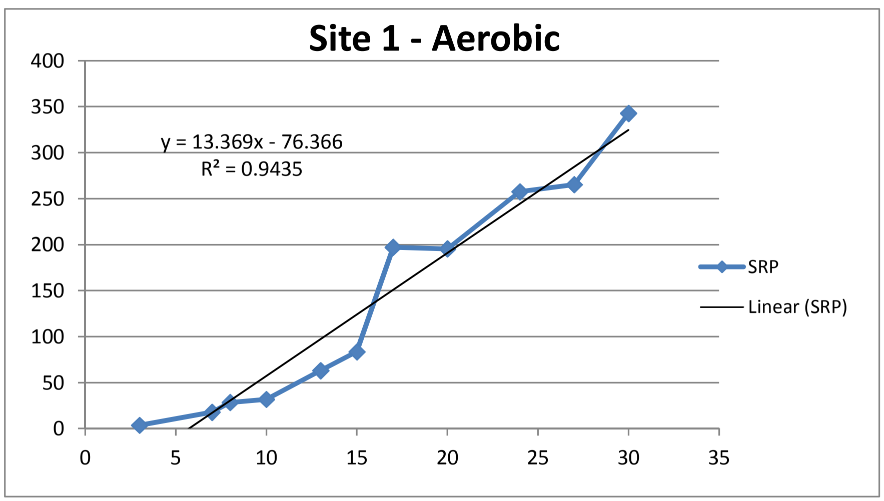
Reslts of Sediment Incubation Experiments Conducted on Lake Killarney Sediment Samples

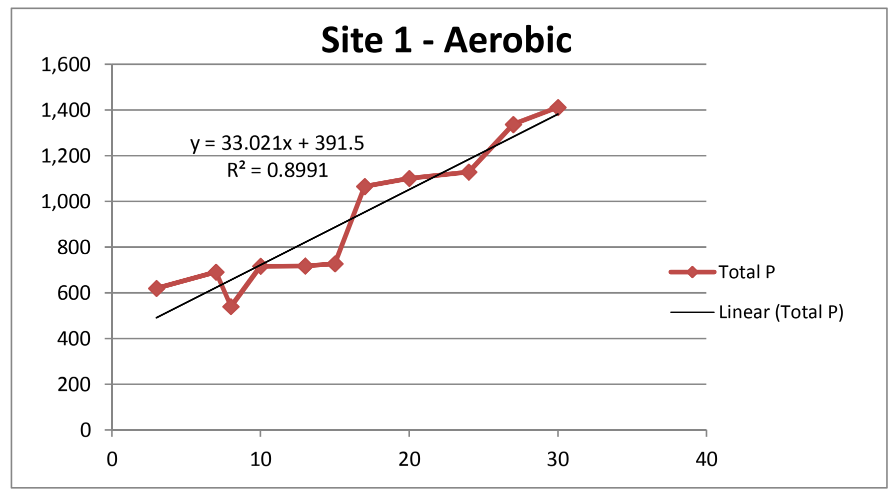
Site	Redox Condition	Date Collected	No. of Days	NH3 (µg/L)	NOX (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)	Volume (L)	Total N (µg)	SRP (µg)	Total P (µg)
Site 4	Anoxic	5/23/11	0	106	9	856	4	136	3.63	3,108	15	494
Site 4		5/24/11	1	136	7	882	5	152	3.62	3,195	18	551
Site 4		5/25/11	2	147	3	1,046	6	173	3.61	3,781	22	625
Site 4		5/26/11	3	243	3	1,059	11	196	3.61	3,820	40	707
Site 4		5/27/11	4	291	5	1,045	14	195	3.60	3,761	50	702
Site 4		5/31/11	8	451	1	1,133	19	208	3.57	4,042	68	742
Site 4		6/1/11	9	560	5	1,225	35	210	3.56	4,360	125	747
Site 4		6/3/11	11	699	4	1,400	39	205	3.54	4,961	138	726
Site 4		6/6/11	14	768	19	1,700	49	206	3.52	5,984	172	725
Site 4		6/7/11	15	832	16	1,529	52	207	3.51	5,370	183	727
Site 4		6/10/11	18	912	46	1,622	53	200	3.49	5,659	185	698
Site 4		6/13/11	21	153	419	1,589	59	194	3.46	5,506	204	672
Site 4		6/15/11	23	10	827	1,547	62	190	3.45	5,336	214	655
Site 4		6/17/11	25	16	912	1,605	76	196	3.43	5,511	261	673
Site 4		6/20/11	28	4	810	1,422	60	182	3.41	4,849	205	621
Site 4		6/22/11	30	0	992	1,393	61	190	3.39	4,728	207	645
Site 4		6/24/11	32	0	1,038	1,357	66	182	3.38	4,584	223	615
Site 4	Aerobic	6/28/11	0	0	51	212	1	201	3.63	770	4	730
Site 4		6/29/11	1	0	72	276	4	128	3.62	1,000	14	464
Site 4		6/30/11	2	11	99	231	5	148	3.61	835	18	535
Site 4		7/1/11	3	0	126	218	5	134	3.61	786	18	483
Site 4		7/5/11	7	0	249	419	11	144	3.57	1,496	39	514
Site 4		7/6/11	8	0	259	485	14	203	3.56	1,728	50	723
Site 4		7/8/11	10	0	297	447	19	144	3.55	1,585	67	511
Site 4		7/11/11	13	0	335	411	22	130	3.52	1,447	77	458
Site 4		7/13/11	15	0	361	416	15	122	3.50	1,458	53	428
Site 4		7/15/11	17	0	419	561	19	115	3.49	1,957	66	401
Site 4		7/18/11	20	0	415	538	19	123	3.46	1,863	66	426
Site 4		7/22/11	24	0	559	746	23	83	3.43	2,558	79	285
Site 4		7/25/11	27	19	711	804	28	99	3.40	2,736	95	337
Site 4		7/28/11	30	0	825	944	24	95	3.38	3,189	81	321

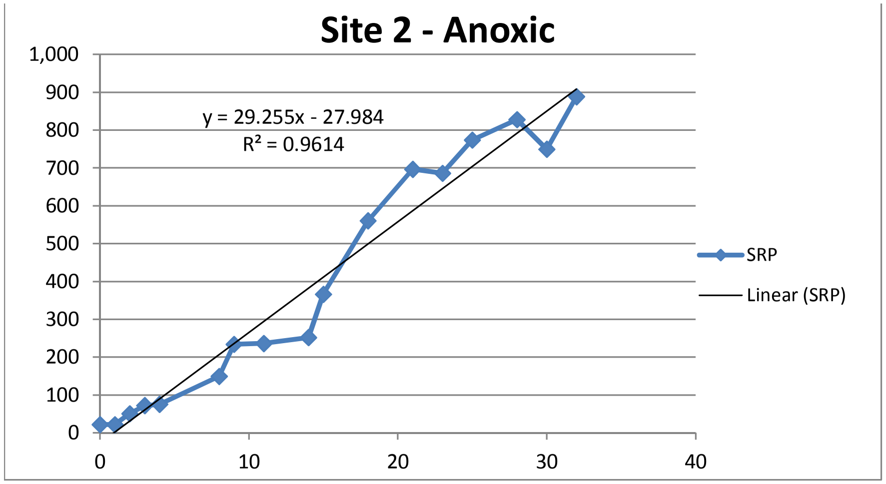
F.2 Calculations of Sediment Nutrient Release

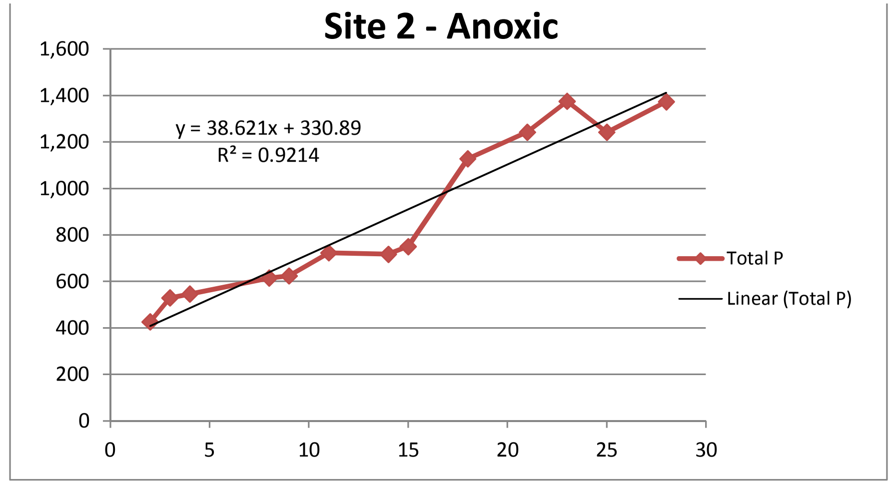

Site 1 - Anoxic
y = 2.6341x + 0.8936
R² = 0.9183
SRP
Linear (SRP)

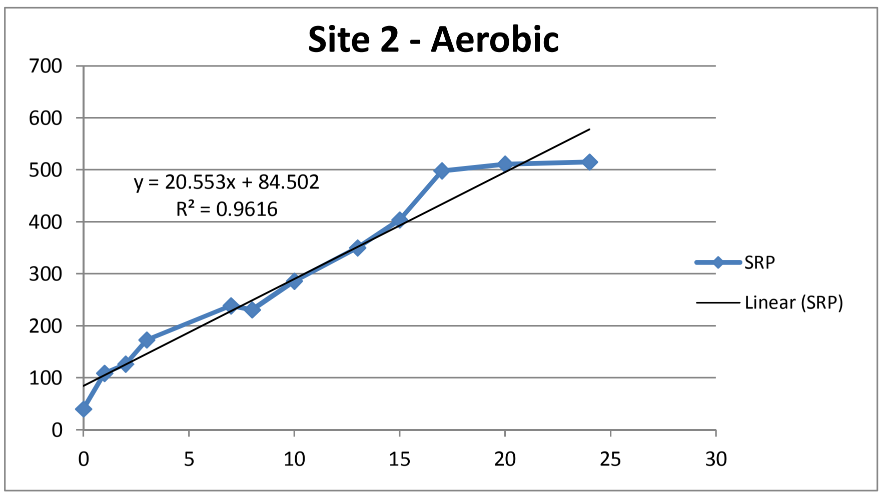

Site 1 - Anoxic
y = 33.553x + 389.95
R² = 0.985
Total P
Linear (Total P)

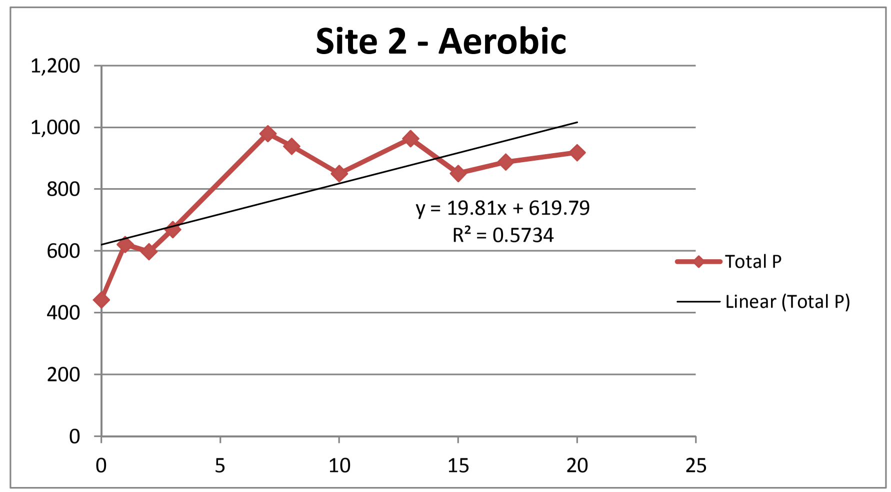

Site 1 - Aerobic
y = 13.369x - 76.366
R² = 0.9435
SRP
Linear (SRP)

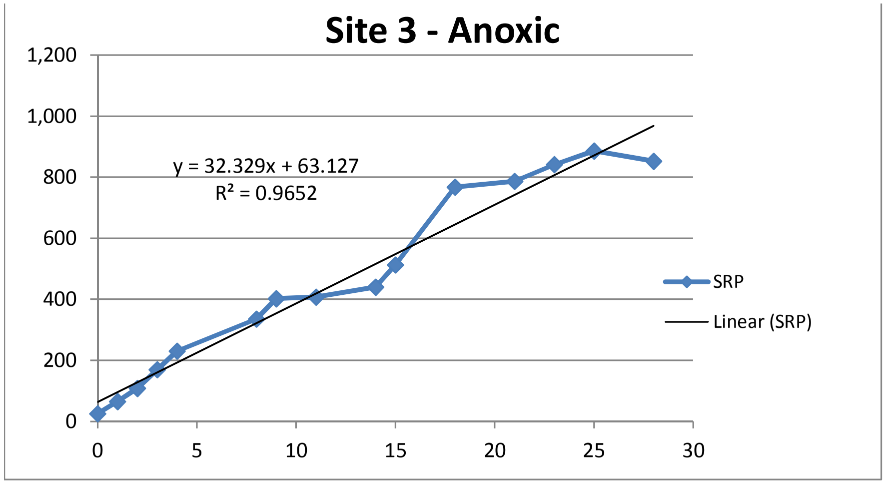

Site 1 - Aerobic
y = 33.021x + 391.5
R² = 0.8991
Total P
Linear (Total P)

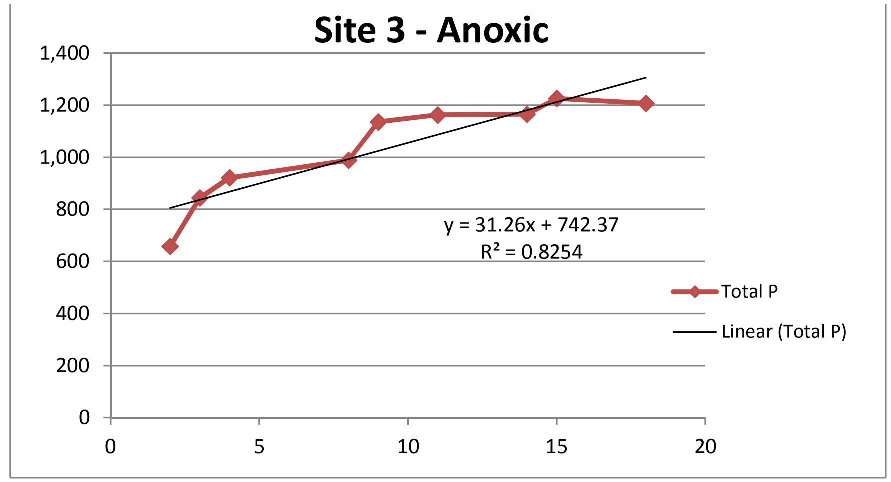

Site 2 - Anoxic
y = 29.255x - 27.984
R² = 0.9614
SRP
Linear (SRP)

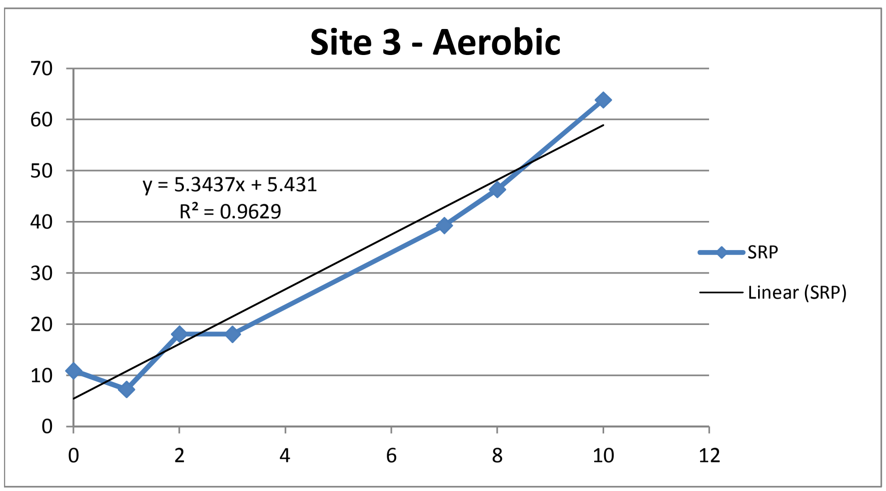

Site 2 - Anoxic
y = 38.621x + 330.89
R² = 0.9214
Total P
Linear (Total P)

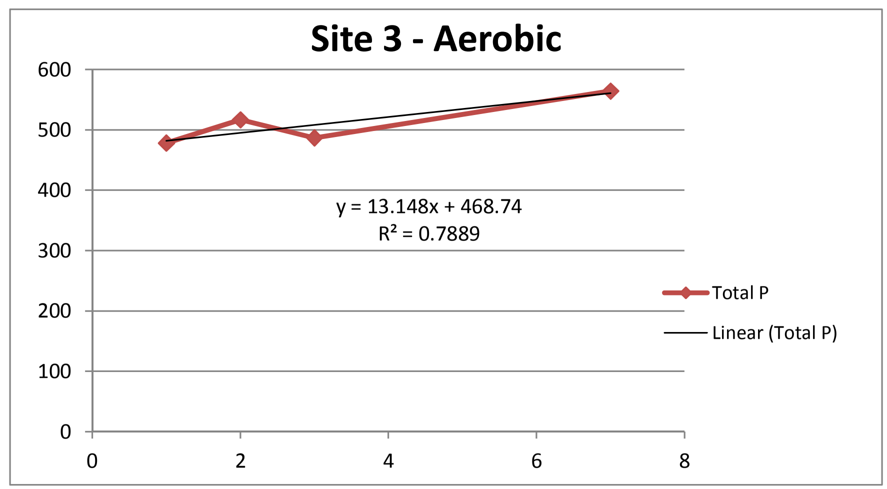

Site 2 - Aerobic
y = 20.553x + 84.502
R² = 0.9616
SRP
Linear (SRP)

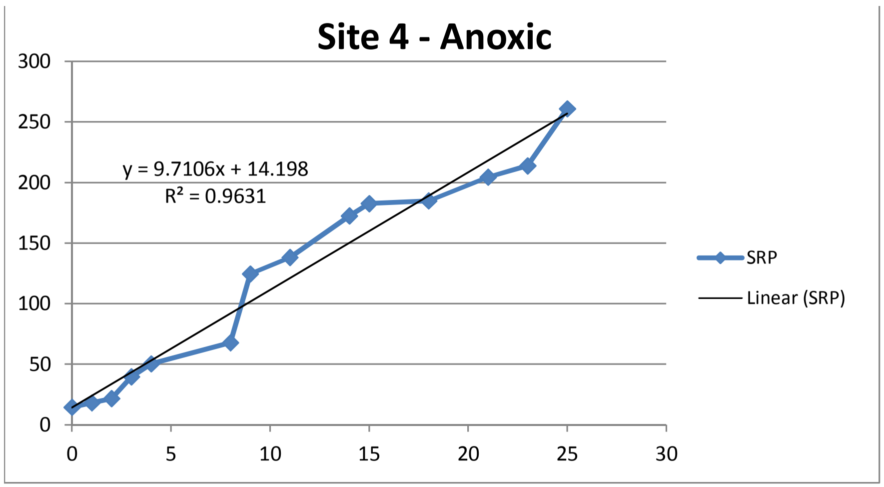

Site 2 - Aerobic
y = 19.81x + 619.79
R² = 0.5734
Total P
Linear (Total P)

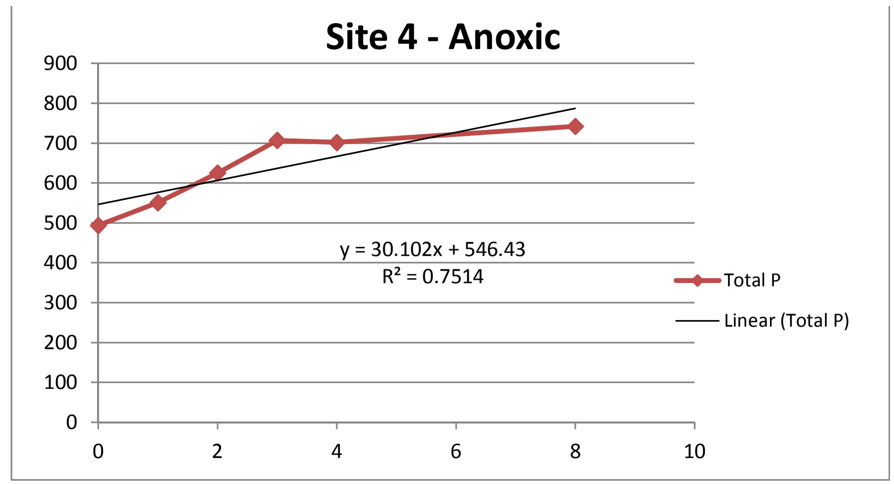

Site 3 - Anoxic
y = 32.329x + 63.127
R² = 0.9652
SRP
Linear (SRP)

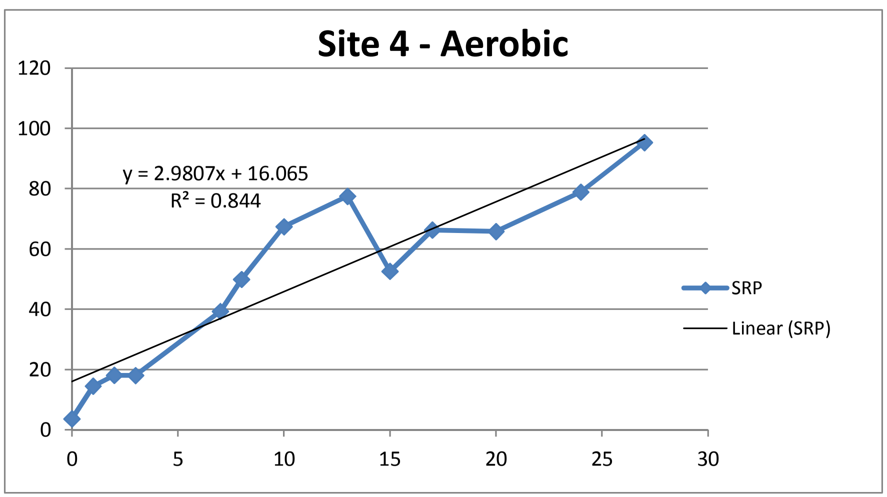

Site 3 - Anoxic
y = 31.26x + 742.37
R² = 0.8254
Total P
Linear (Total P)

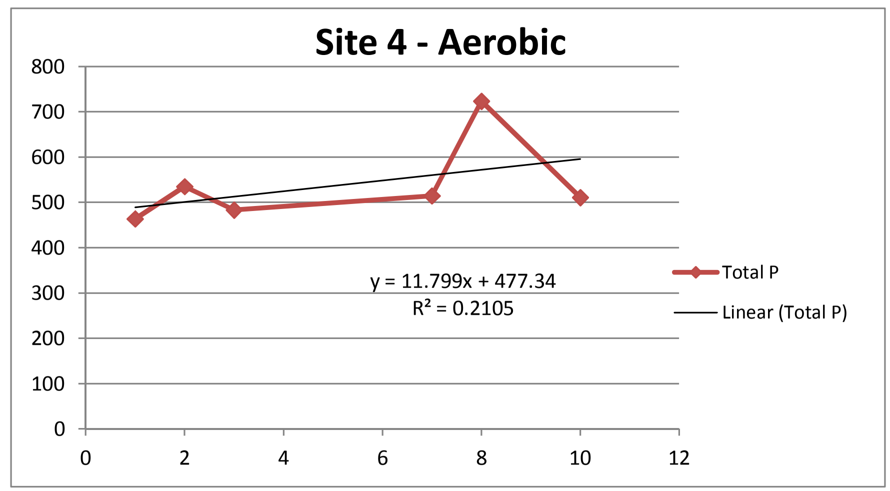

Site 3 - Aerobic
y = 5.3437x + 5.431
R² = 0.9629
SRP
Linear (SRP)

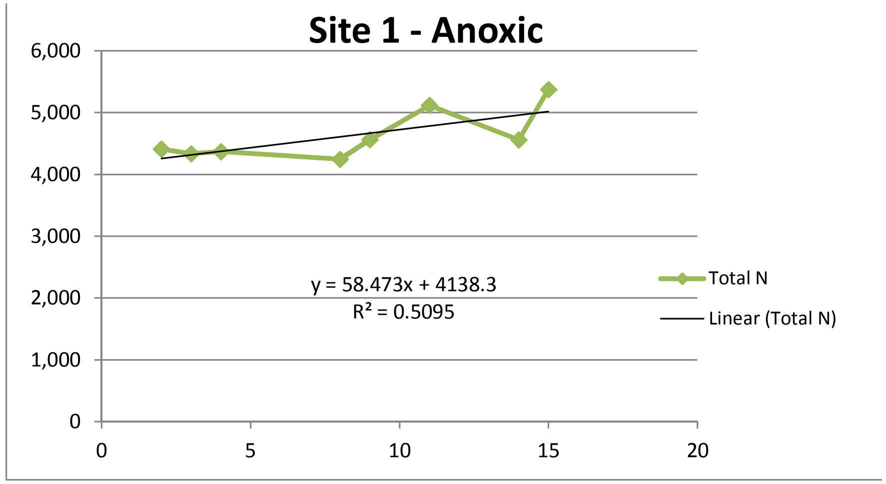

Site 3 - Aerobic
y = 13.148x + 468.74
R² = 0.7889
Total P
Linear (Total P)


Site 4 - Anoxic
y = 9.7106x + 14.198
R² = 0.9631
SRP
Linear (SRP)
300
250
200
150
100
50
0
0
5
10
15
20
25
30

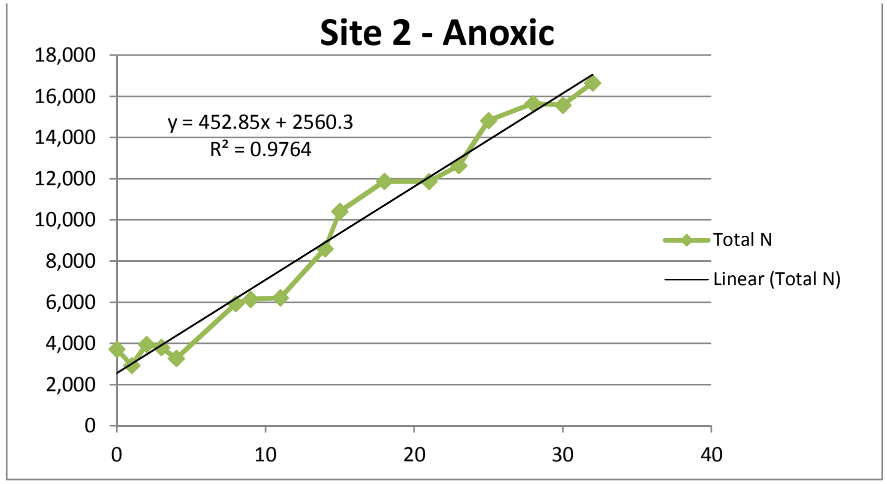

Site 4 - Anoxic
y = 30.102x + 546.43
R² = 0.7514
Total P
Linear (Total P)
900
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10


Site 4 - Aerobic
y = 2.9807x + 16.065
R² = 0.844
SRP
Linear (SRP)
120
100
80
60
40
20
0
0
5
10
15
20
25
30

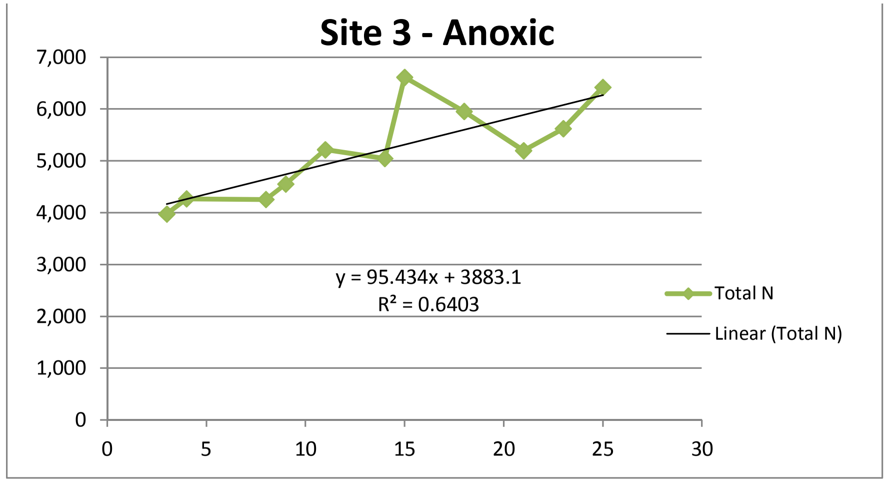

Site 4 - Aerobic
y = 11.799x + 477.34
R² = 0.2105
Total P
Linear (Total P)
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12


Site 1 - Anoxic
6,000
5,000
4,000
3,000
2,000
1,000
0
0
5
10
15
20
y = 58.473x + 4138.3
R² = 0.5095
Total N
Linear (Total N)

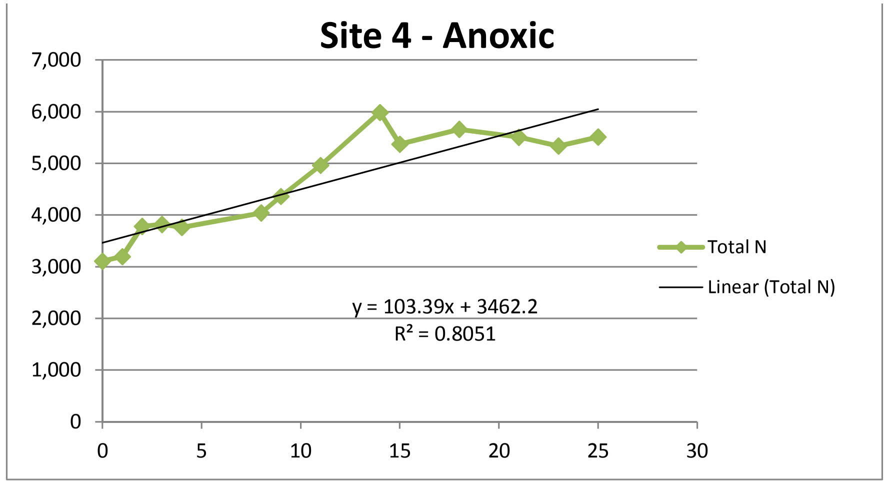

Site 1 - Aerobic
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
5
10
15
20
25
30
35
y = 138.93x + 1203.2
R² = 0.8525
Total N
Linear (Total N)

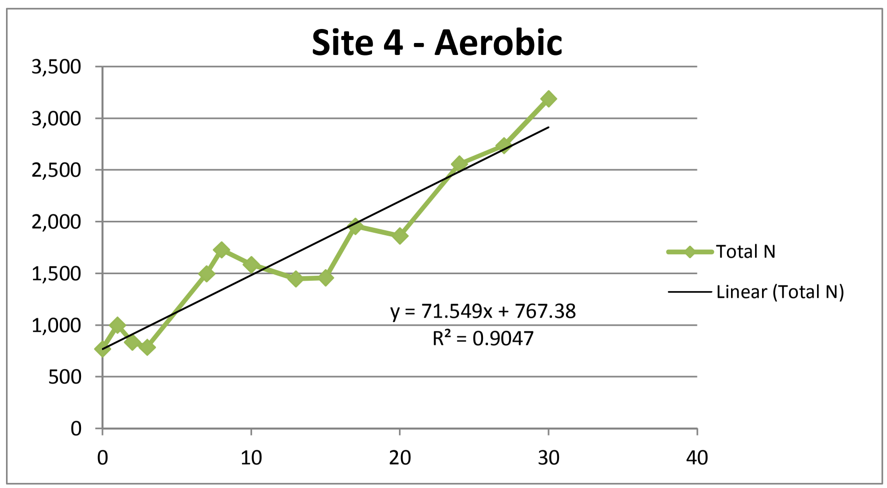

Site 2 - Anoxic
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
y = 452.85x + 2560.3
R² = 0.9764
Total N
Linear (Total N)


Site 2 - Aerobic
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
10
20
30
40
y = 120.68x + 3106.9
R² = 0.8407
Total N
Linear (Total N)


Site 3 - Anoxic
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
5
10
15
20
25
30
y = 95.434x + 3883.1
R² = 0.6403
Total N
Linear (Total N)


Site 3 - Aerobic
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
5
10
15
20
25
30
y = 98.645x + 847.1
R² = 0.8979
Total N
Linear (Total N)


Site 4 - Anoxic
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
5
10
15
20
25
30
Total N
Linear (Total N)
y = 103.39x + 3462.2
R² = 0.8051


Site 4 - Aerobic
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
10
20
30
40
Total N
Linear (Total N)
y = 71.549x + 767.38
R² = 0.9047

APPENDIX G

ISOTOPE ANALYSIS RESULTS

Results of Stable Isotope Analyses Conducted on Groundwater Seepage Samples Collected from Lake Killarney

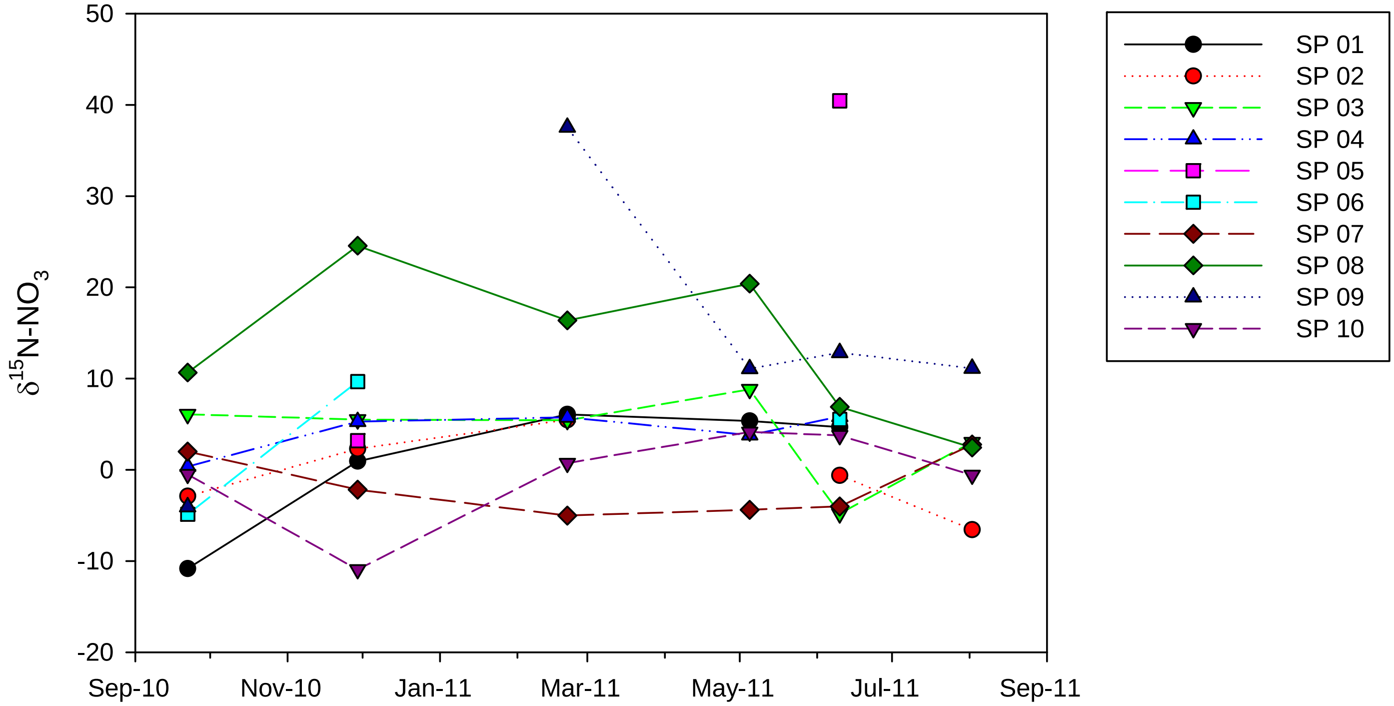
Site	Date Collected	NO3 Conc. (mg N/L)	Volume (ml)	Peak Area (V/s)	Peak Ampl (mV)	$d^{15}N_{Air}$ (‰)	$d^{18}O_{VSMOW}$ (‰)
SP 1	9/22/10	0.94	0.85	40.32	7,099	-10.82	-7.20
SP 2	9/22/10	10.01	0.08	39.33	7,016	-2.91	-0.49
SP 3	9/22/10	9.94	0.08	41.02	7,226	6.06	0.94
SP 4	9/22/10	0.23	3.42	48.62	8,325	0.34	-1.88
SP 6	9/22/10	0.34	2.32	47.37	8,301	-4.89	-1.68
SP 7	9/22/10	7.40	0.11	30.69	5,668	1.99	-16.07
SP 8	9/22/10	0.51	1.56	47.80	8,351	10.66	-4.64
SP 9	9/22/10	2.03	0.39	36.31	6,483	-4.07	-8.62
SP 10	9/22/10	0.12	6.00	42.03	7,422	-0.51	5.29
SP 11	9/22/10	8.31	0.10	40.05	7,246	4.16	-0.44
SP 13	9/22/10	2.37	0.34	42.47	7,482	3.80	-0.57
SP 14	9/22/10	14.57	0.05	48.48	8,219	4.84	-2.65
SP 15	9/22/10	9.79	0.08	39.22	7,177	6.43	2.69
SP 16	9/22/10	0.72	1.11	44.03	7,840	3.06	4.04
SP 17	9/22/10	12.41	0.06	37.66	7,014	7.81	4.67
SP 18	9/22/10	5.73	0.14	40.57	7,075	10.07	5.27
SP 19	9/22/10	2.01	0.40	45.27	8,107	4.88	1.67
SP 20	9/22/10	12.61	0.06	36.29	6,393	5.01	0.10
SP 21	9/22/10	10.76	0.07	41.09	7,223	2.88	-1.13
SP 22	9/22/10	1.73	0.46	35.99	6,961	-1.28	-0.14
SP 23	9/22/10	<0.02	6.00	0.67	134	-6.28	-1.58
SP 24	9/22/10	0.19	4.19	45.84	8,158	-2.64	5.30
SP 26	9/22/10	<0.02	6.00	2.74	517	-8.97	-0.28
SP 27	9/22/10	1.63	0.49	37.06	6,794	5.45	1.65
SP 28	9/22/10	2.31	0.35	44.31	7,716	-0.57	-0.88
SP 29	9/22/10	0.11	6.00	45.83	7,981	3.27	0.19
SP 30	9/22/10	<0.02	6.00	0.65	112	-13.89	-1.71
SP 1	11/29/10	6.49	0.12	36.17	7,070	0.93	-7.57
SP 2	11/29/10	3.53	0.23	41.39	8,247	2.29	-0.82
SP 3	11/29/10	10.10	0.08	35.57	6,868	5.50	-1.64
SP 4	11/29/10	1.20	0.66	39.91	7,745	5.27	-1.57
SP 5	11/29/10	0.38	2.12	38.66	7,706	3.19	-1.01
SP 6	11/29/10	0.03	6.00	10.28	2,024	9.65	7.77
SP 7	11/29/10	3.00	0.27	35.74	6,811	-2.20	-1.97
SP 8	11/29/10	4.57	0.18	37.99	7,728	24.55	14.14
SP 10	11/29/10	2.33	0.34	37.42	7,456	-10.95	7.15
SP 11	11/29/10	1.72	0.46	38.01	7,415	5.15	-2.66
SP 12	11/29/10	4.15	0.19	36.13	6,929	-1.52	-1.13
SP 13	11/29/10	1.83	0.44	38.74	7,521	3.91	-0.59
SP 14	11/29/10	4.65	0.17	35.92	6,820	0.08	0.25
SP 15	11/29/10	8.39	0.10	36.42	6,840	0.33	7.17
SP 16	11/29/10	5.01	0.16	36.44	6,814	3.71	-0.26
SP 17	11/29/10	0.02	6.00	8.15	1,581	-0.30	-3.33
SP 18	11/29/10	0.79	1.01	36.90	7,431	5.90	2.79
SP 19	11/29/10	7.43	0.11	36.09	6,817	4.18	0.97
SP 20	11/29/10	9.30	0.09	29.85	5,876	-1.68	1.23
SP 21	11/29/10	5.43	0.15	37.80	7,197	-2.87	-1.36
SP 22	11/29/10	0.87	0.92	38.44	7,651	2.55	-4.21
SP 23	11/29/10	2.38	0.34	35.26	6,817	4.27	4.42
SP 24	11/29/10	0.63	1.27	42.15	8,027	0.14	-2.16
SP 25	11/29/10	1.75	0.46	42.64	8,424	4.74	3.76
SP 27	11/29/10	4.35	0.18	37.13	7,232	6.77	2.34
SP 28	11/29/10	0.85	0.94	41.29	7,645	3.34	0.10
SP 29	11/29/10	0.44	1.81	39.65	7,415	6.00	3.25
SP 30	11/29/10	0.89	0.90	41.37	8,012	5.54	3.63

Results of Stable Isotope Analyses Conducted on Groundwater Seepage Samples Collected from Lake Killarney

Site	Date Collected	NO3 Conc. (mg N/L)	Volume (ml)	Peak Area (V/s)	Peak Ampl (mV)	$d^{15}N_{Air}$ (‰)	$d^{18}O_{VSMOW}$ (‰)
SP 1	2/21/11	11.45	0.07	35.38	6,689	6.08	0.49
SP 2	2/21/11	7.21	0.11	33.98	6,409	5.47	-1.99
SP 3	2/21/11	2.49	0.32	36.23	7,010	5.40	-1.04
SP 4	2/21/11	1.41	0.57	34.88	6,734	5.72	-3.86
SP 7	2/21/11	0.30	2.67	37.35	6,852	-5.03	-1.26
SP 8	2/21/11	6.10	0.13	33.96	6,277	16.38	9.62
SP 9	2/21/11	1.72	0.47	34.83	6,512	37.53	19.03
SP 10	2/21/11	1.56	0.51	36.27	6,665	0.70	0.45
SP 11	2/21/11	2.63	0.30	33.42	6,247	5.90	-3.15
SP 12	2/21/11	1.39	0.58	33.86	6,660	8.63	-4.00
SP 13	2/21/11	7.09	0.11	33.26	6,586	4.67	-2.78
SP 14	2/21/11	1.83	0.44	33.23	6,517	-0.96	-2.79
SP 15	2/21/11	1.12	0.71	36.85	7,137	-0.35	0.48
SP 16	2/21/11	8.02	0.10	30.10	5,749	-7.07	0.55
SP 17	2/21/11	8.55	0.09	33.26	6,193	15.61	9.99
SP 18	2/21/11	7.96	0.10	33.54	6,313	-3.37	-0.12
SP 19	2/21/11	13.47	0.06	43.44	8,525	2.89	-1.61
SP 20	2/21/11	3.17	0.25	31.17	6,021	-3.09	0.56
SP 21	2/21/11	3.43	0.23	34.67	6,534	8.79	-0.79
SP 22	2/21/11	0.83	0.97	39.29	7,402	3.44	-1.89
SP 23	2/21/11	6.71	0.12	33.02	6,654	-0.53	1.42
SP 24	2/21/11	0.75	1.06	39.58	7,828	1.94	0.46
SP 29	2/21/11	0.77	1.03	38.28	7,661	3.22	2.27
SP 30	2/21/11	2.75	0.29	37.81	7,380	6.58	4.02
SP 1	5/5/11	0.49	1.63	37.56	7,368	5.34	-0.52
SP 3	5/5/11	1.57	0.51	53.43	9,845	8.82	0.23
SP 4	5/5/11	0.11	6.00	26.22	5,140	3.78	1.91
SP 7	5/5/11	0.83	0.96	40.75	7,593	-4.39	-1.97
SP 8	5/5/11	0.34	2.35	36.19	6,782	20.39	9.77
SP 9	5/5/11	0.22	3.58	51.29	9,465	11.08	-1.95
SP 10	5/5/11	0.52	1.54	50.21	9,349	4.12	1.48
SP 11	5/5/11	0.50	1.60	49.96	9,474	5.87	-0.62
SP 12	5/5/11	0.33	2.43	38.28	7,454	6.62	-3.76
SP 13	5/5/11	10.57	0.08	38.86	7,468	6.43	-0.45
SP 14	5/5/11	0.68	1.18	37.90	7,222	5.60	-0.80
SP 15	5/5/11	0.33	2.41	35.46	6,829	3.51	0.76
SP 16	5/5/11	11.20	0.07	43.09	8,148	-2.31	1.89
SP 17	5/5/11	18.05	0.04	38.91	7,428	2.28	0.78
SP 18	5/5/11	12.46	0.06	30.69	5,792	0.76	4.76
SP 19	5/5/11	0.34	2.39	38.28	7,402	2.14	1.38
SP 20	5/5/11	2.65	0.30	37.96	7,273	9.41	-1.55
SP 21	5/5/11	1.51	0.53	39.31	7,395	8.68	-1.90
SP 22	5/5/11	0.15	5.19	36.13	6,895	2.18	-0.86
SP 23	5/5/11	0.01	6.00	2.72	524	-39.43	-5.66
SP 25	5/5/11	0.01	6.00	1.01	215	-31.87	-14.11
SP 30	5/5/11	0.02	6.00	4.64	924	-32.57	-1.35

Results of Stable Isotope Analyses Conducted on Groundwater Seepage Samples Collected from Lake Killarney

Site	Date Collected	NO3 Conc. (mg N/L)	Volume (ml)	Peak Area (V/s)	Peak Ampl (mV)	$d^{15}N_{Air}$ (‰)	$d^{18}O_{VSMOW}$ (‰)
SP 1	6/10/11	1.07	0.75	40.53	7,598	4.66	-0.72
SP 2	6/10/11	2.05	0.39	37.13	6,956	-0.63	-0.45
SP 3	6/10/11	1.22	0.66	46.20	8,485	-4.82	-2.25
SP 4	6/10/11	0.36	2.24	39.96	7,403	5.81	0.37
SP 5	6/10/11	0.30	2.63	24.30	4,840	40.43	5.11
SP 6	6/10/11	0.75	1.07	38.86	7,437	5.51	-1.39
SP 7	6/10/11	2.08	0.38	36.36	6,843	-4.02	-2.97
SP 8	6/10/11	0.40	1.99	37.54	7,277	6.89	-0.85
SP 9	6/10/11	0.61	1.30	39.00	7,064	12.84	-2.76
SP 10	6/10/11	0.43	1.88	32.90	6,207	3.76	2.07
SP 11	6/10/11	0.98	0.82	36.89	6,801	7.60	-1.03
SP 12	6/10/11	0.66	1.21	39.89	7,380	8.53	-2.46
SP 13	6/10/11	2.53	0.32	36.72	6,694	7.65	0.90
SP 14	6/10/11	0.94	0.85	38.83	7,092	5.35	-0.79
SP 15	6/10/11	0.55	1.44	39.52	7,655	3.57	1.16
SP 16	6/10/11	0.20	4.00	36.94	7,019	4.00	-1.31
SP 17	6/10/11	0.17	4.83	33.82	6,272	5.45	-0.28
SP 18	6/10/11	9.92	0.08	38.74	7,317	10.09	3.82
SP 19	6/10/11	10.38	0.08	37.48	6,965	3.16	-1.44
SP 20	6/10/11	1.48	0.54	37.13	6,988	1.24	-0.26
SP 21	6/10/11	1.44	0.55	34.07	6,239	7.79	-0.67
SP 22	6/10/11	0.24	3.28	35.86	7,062	4.23	0.03
SP 23	6/10/11	0.01	6.00	1.29	268	-7.02	-5.91
SP 30	6/10/11	0.01	6.00	0.69	145	-10.43	-6.25
SP 2	8/2/11	0.85	0.94	40.34	7,951	-6.57	-0.21
SP 3	8/2/11	4.20	0.19	35.98	6,920	3.01	-3.75
SP 7	8/2/11	2.92	0.27	38.53	7,199	2.77	-5.64
SP 8	8/2/11	0.15	5.51	36.30	6,916	2.43	-1.86
SP 9	8/2/11	0.78	1.02	39.14	7,587	11.10	-3.94
SP 10	8/2/11	1.06	0.76	38.85	7,315	-0.59	3.90
SP 11	8/2/11	0.93	0.86	37.90	7,268	0.95	-1.02
SP 12	8/2/11	0.69	1.16	38.84	7,379	6.75	-1.57
SP 13	8/2/11	7.28	0.11	33.36	6,429	7.41	1.42
SP 14	8/2/11	1.51	0.53	38.12	7,210	6.35	3.76
SP 15	8/2/11	0.73	1.10	34.66	6,544	12.66	10.27
SP 16	8/2/11	6.37	0.13	39.31	7,467	2.56	-1.08
SP 17	8/2/11	1.58	0.51	37.45	7,031	6.68	0.92
SP 18	8/2/11	0.17	4.61	37.66	7,087	4.63	1.38
SP 20	8/2/11	8.57	0.09	33.80	6,516	5.75	-2.91
SP 25	8/2/11	0.00	6.00	1.18	236	-8.39	-8.43
SP 30	8/2/11	0.36	2.20	37.28	6,941	6.62	-0.91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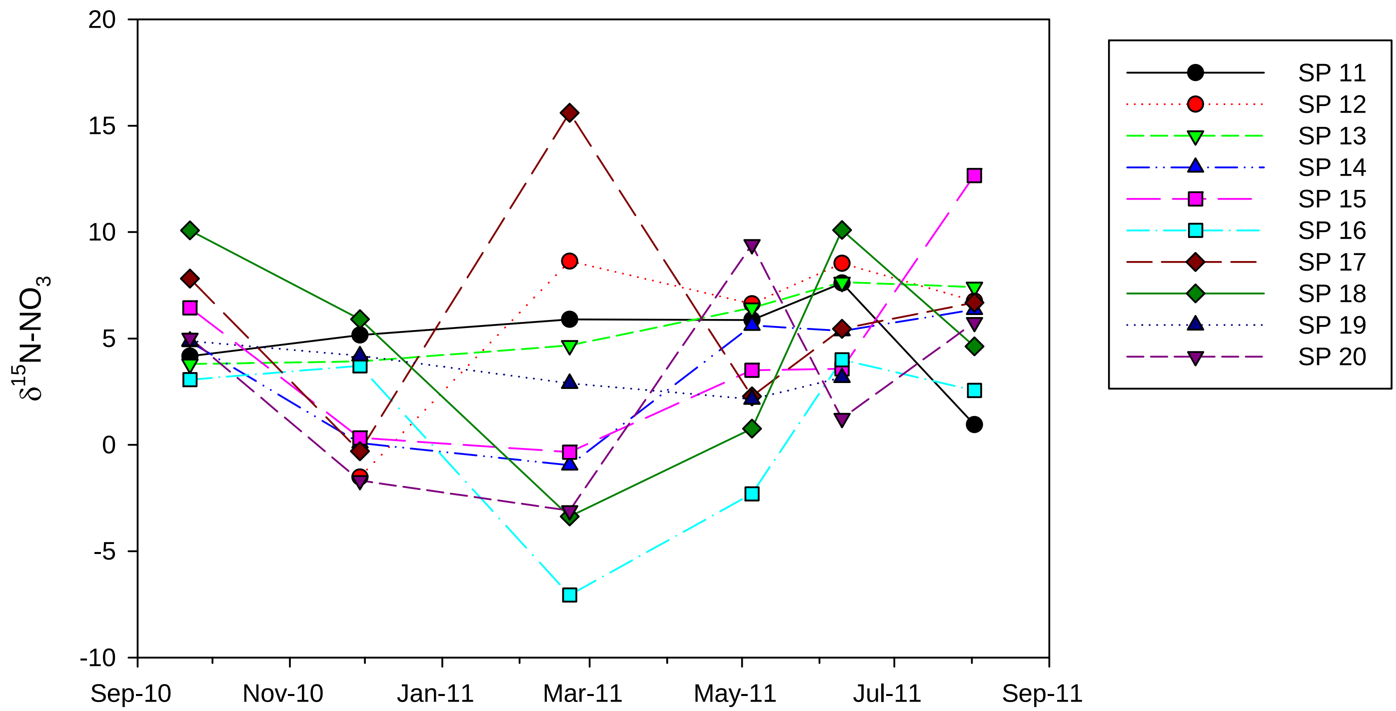
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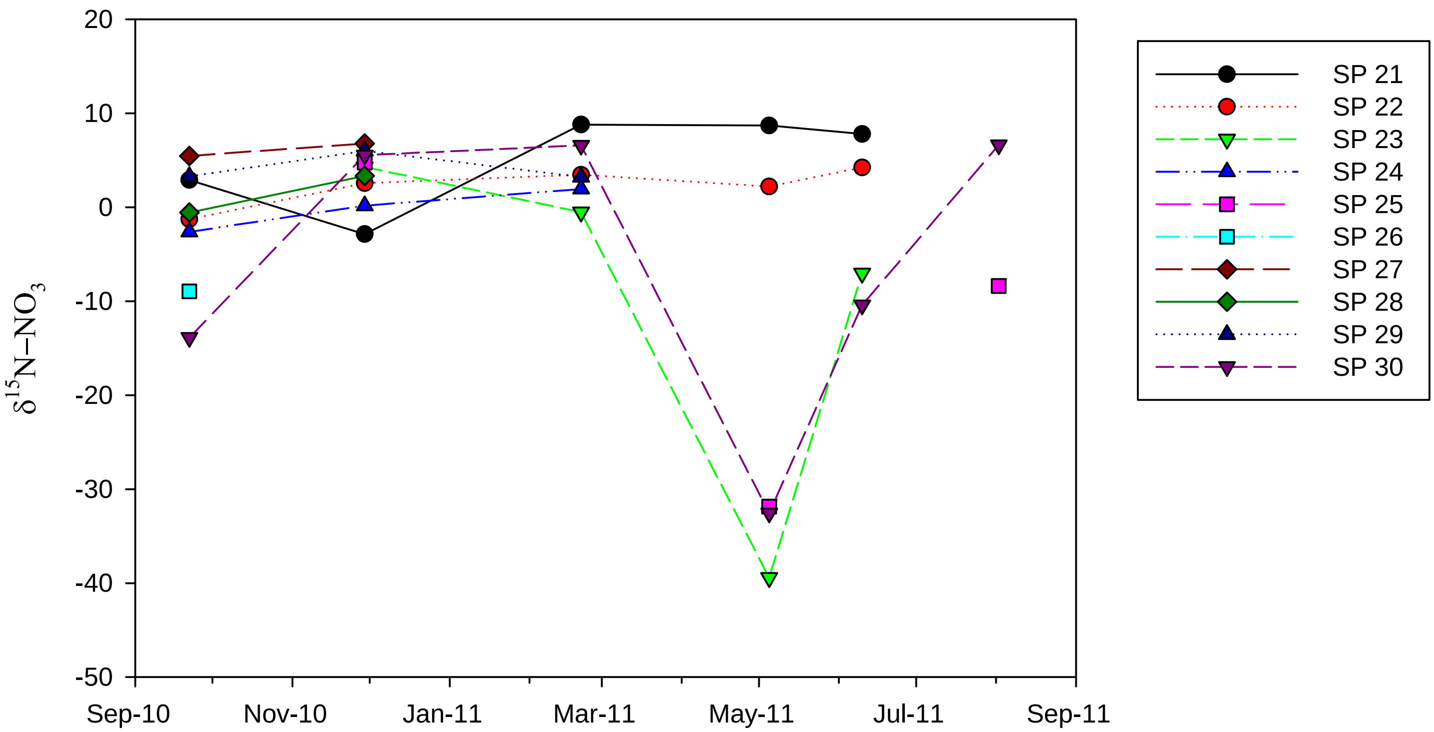

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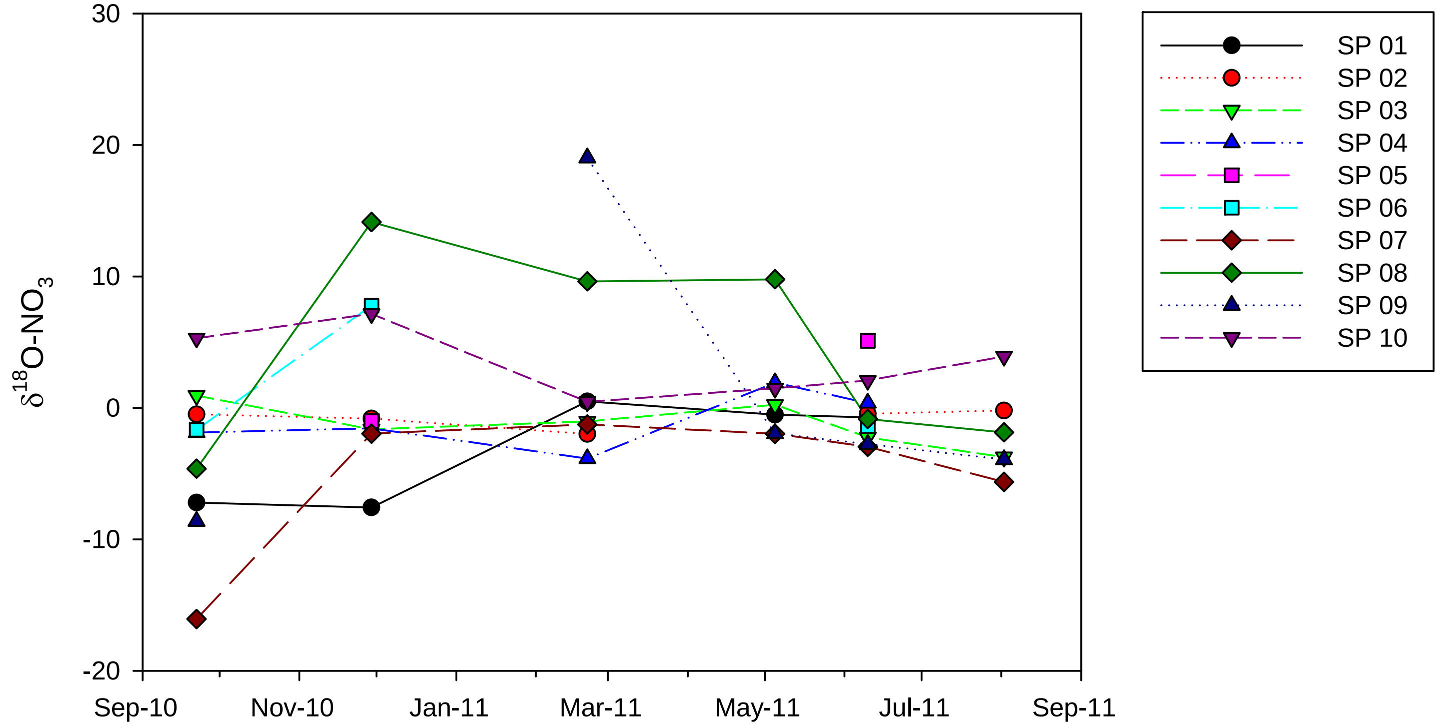

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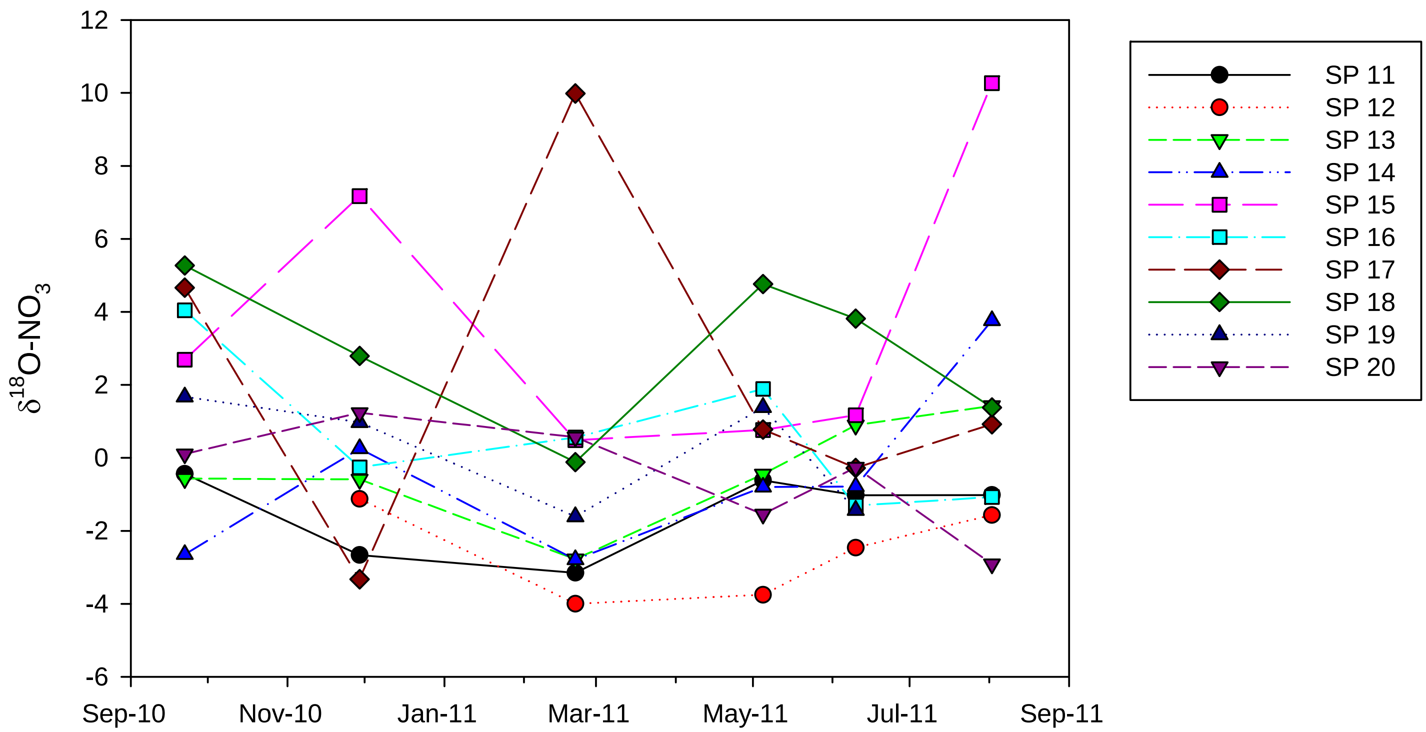

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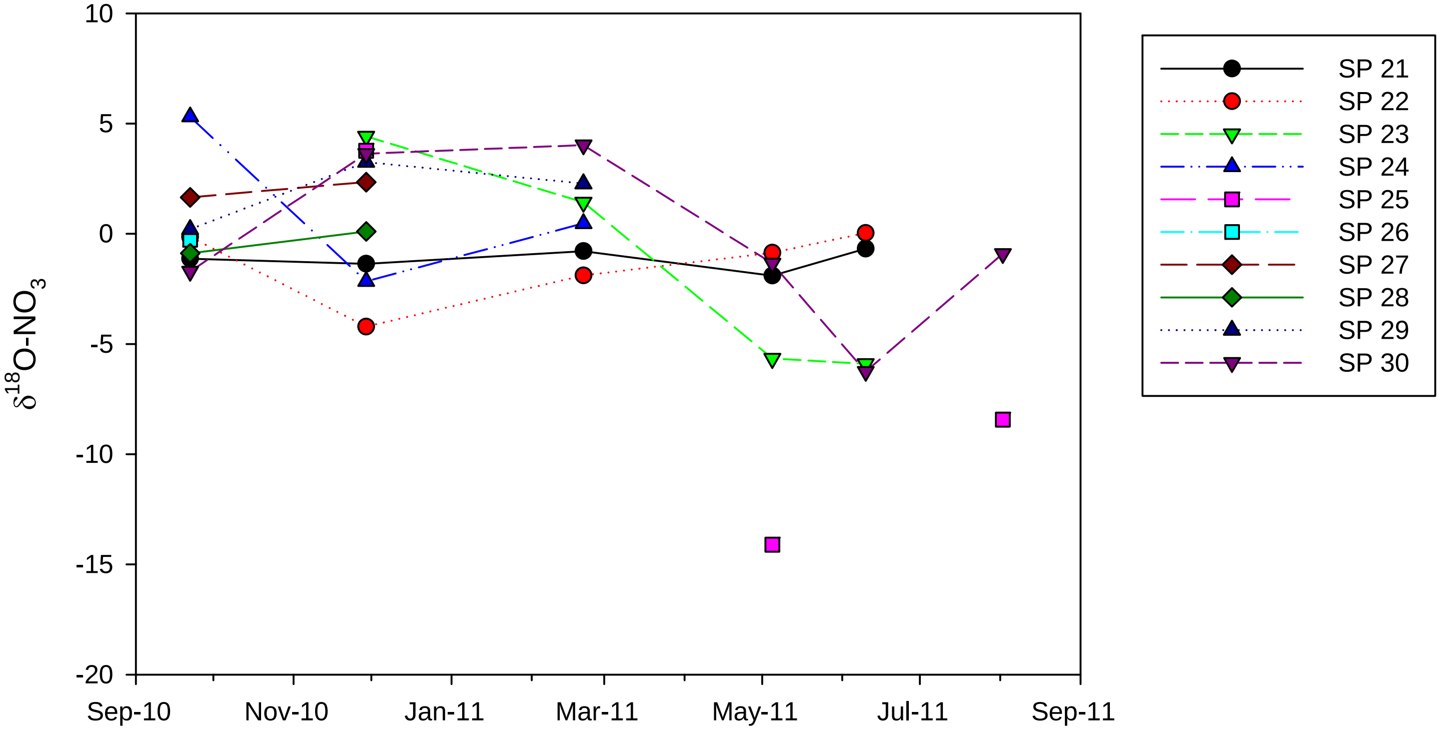

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