# Queens Mirror Lake and the Triplet Chain-of-Lakes Hydrologic/Nutrient Budgets and Management Options

Final Report

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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 Casselberry (City) to develop hydrologic and nutrient budgets, along with a water quality management plan, for Queens Mirror Lake and the Triplet Chain-of-Lakes. A location map for Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 1-1. The study lakes are located near the center of the City of Casselberry in an area which is densely developed with a mixture of residential, commercial, and recreational land use activities. Many of the watershed areas were constructed prior to implementation of regulations requiring stormwater treatment and discharge untreated runoff directly into the lakes. Historical water quality in each of the lakes has been highly variable, ranging from oligotrophic to hypereutrophic conditions over the available period of record.

Queens Mirror Lake and the Triplet Chain-of-Lakes are located in the Gee Creek basin of the Lake Jesup watershed. An overview of the Gee Creek basin, including Queens Mirror Lake and the Triplet Chain-of-Lakes, is given on Figure 1-2. Lake Jesup is currently included on the Impaired Waters Verified List and is listed as impaired for nutrients and unionized ammonia. The primary objective of this project is to not only improve water quality in Queens Mirror Lake and the Triplet Chain-of-Lakes, but to also reduce loadings from the Gee Creek basin into Lake Jesup.

An overview of primary drainage patterns in Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 1-3. The primary flow direction within the system is from south to north, originating in Queens Mirror Lake which discharges to South Lake Triplet, Middle Lake Triplet, and North Lake Triplet. Discharges from North Lake Triplet form the headwaters of Gee Creek. Middle Lake Triplet also receives periodic inflows from Lost Lake, located east of Middle Lake Triplet. As a result, each of the lakes is not only impacted by inflows from the contributing sub-basin areas, but also significant volumetric transfers through the interconnected lake system.

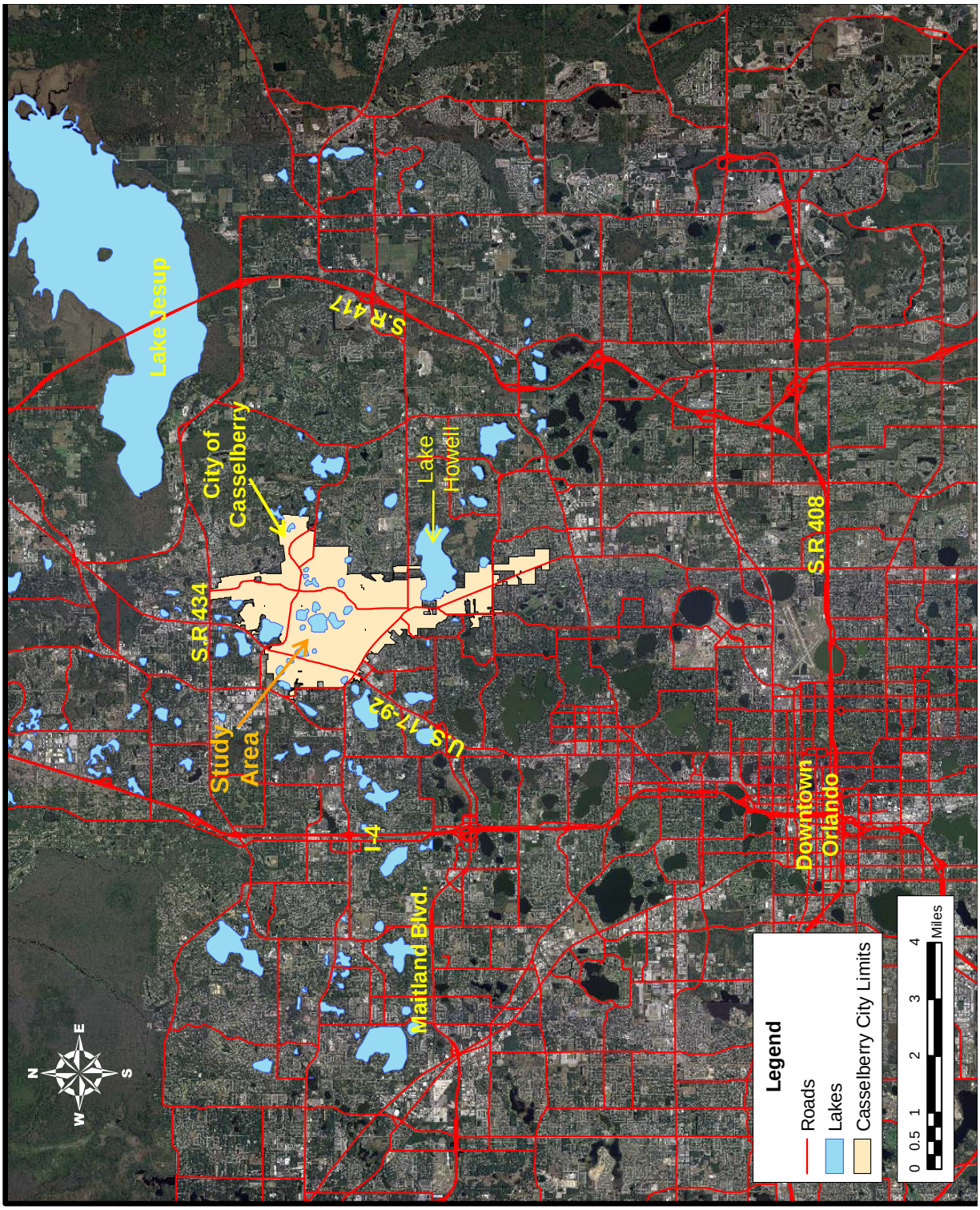



Figure 1-1. Location Map for Queens Mirror Lake and the Triplet Chain-of-Lakes.

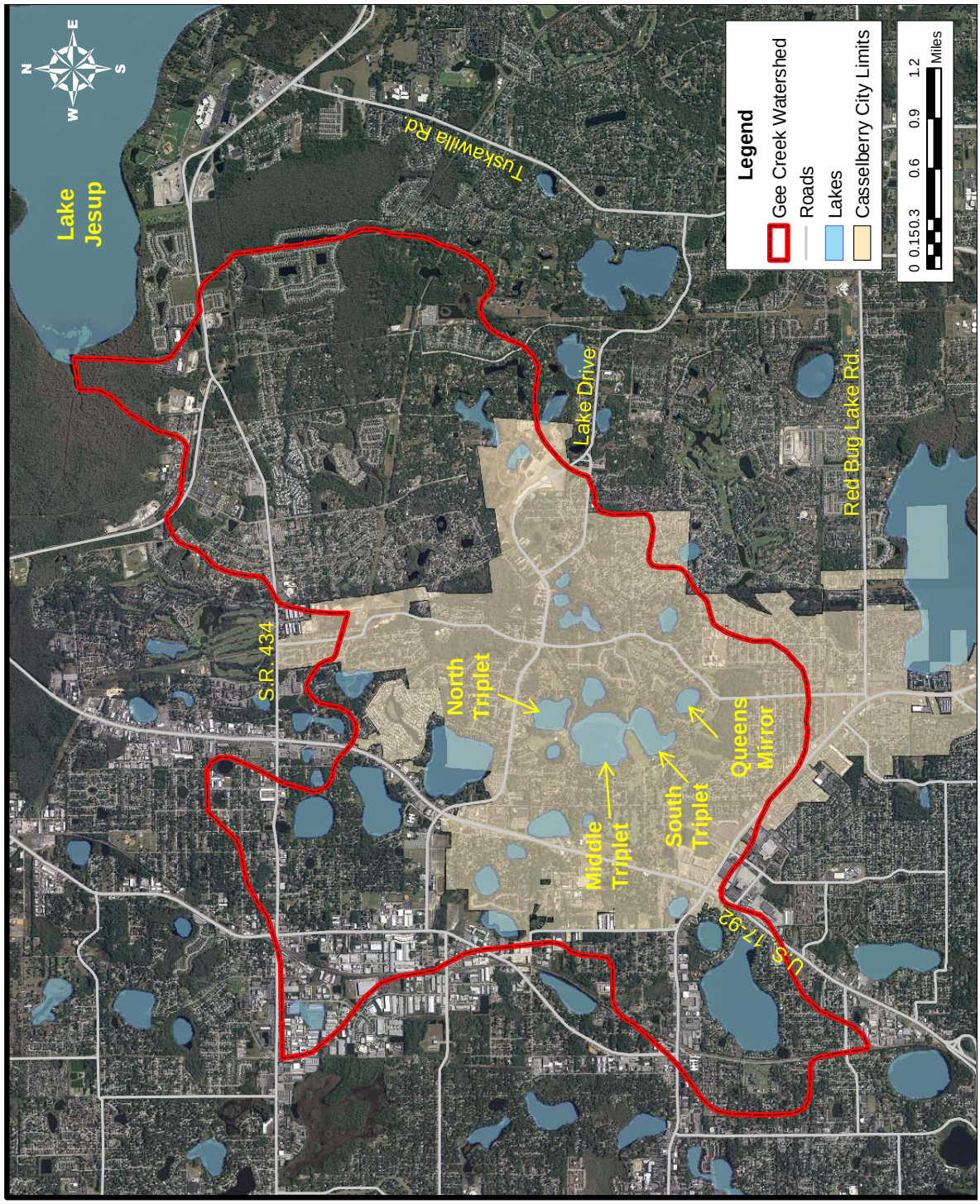



Figure 1-2. Location of Queens Mirror Lake and the Triplet Chain-of-Lakes in the Gee Creek Basin.

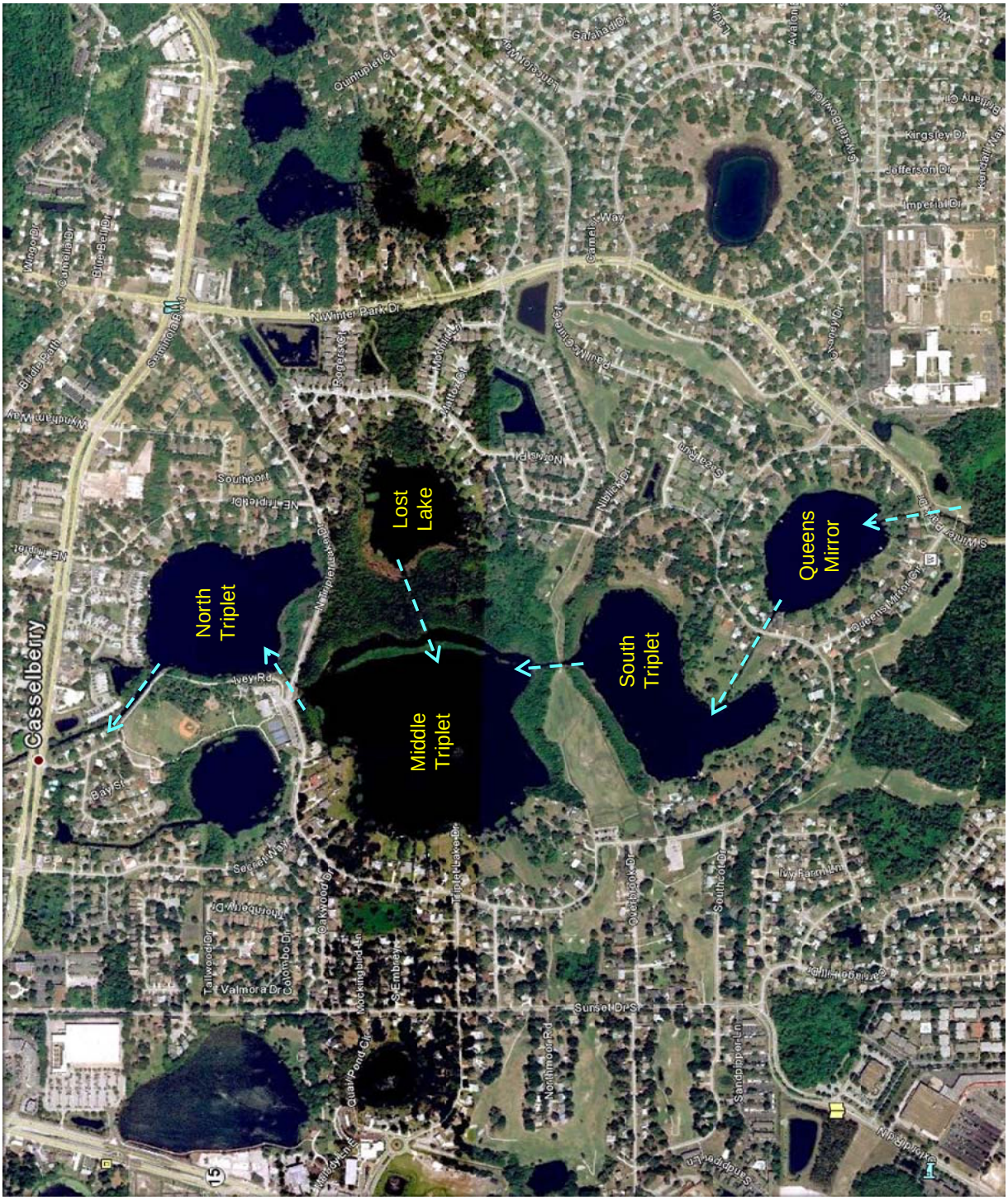



Figure 1-3. Overview of Primary Drainage Patterns in Queens Mirror Lake and the Triplet Chain-of-Lakes.

## 1.2 Work Efforts Performed by ERD

Work efforts were initiated on this project by ERD during September 2010. The primary objective of this project is to develop hydrologic and nutrient budgets for Queens Mirror Lake, North Lake Triplet, Middle Lake Triplet, and South Lake Triplet to identify significant pollutant sources and to provide a ranking of areas with respect to annual mass loadings and areal loadings

A field monitoring program was conducted by ERD from September 2010-June 2011 to collect hydrologic and water quality data for use in developing hydrologic and nutrient budgets for each of the lakes. The hydrologic budgets included estimated inputs from precipitation, groundwater seepage, and stormwater runoff. The nutrient budget included inputs from bulk precipitation, groundwater seepage, internal recycling, and stormwater runoff. Sediment core samples were also collected and used to identify sediment characteristics and potential impacts on water quality. The monitoring program was designed to include both dry and wet season conditions for development of hydrologic and nutrient budgets. The results of the hydrologic and nutrient budgets are used to identify nutrient sources to the lake and to make recommendations for water quality improvement projects. The work efforts described in this report were funded by the City of Casselberry through a Standard Consultant Agreement dated August 23, 2010.

This report has been divided into seven 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 and historical characteristics of the lakes are discussed in Section 2, including lake bathymetry, water quality, and sediment characteristics. A discussion of the drainage basin areas for each of the lakes is given in Section 3. Hydrologic budgets are presented in Section 4, with nutrient budgets included in Section 5. Alternatives for management of water quality in the lakes are discussed in Section 6. Cited references are listed in Section 7. Appendices are also attached which contain technical data and analyses used to support the analyses and conclusions contained within the report.

## SECTION 2

## PHYSICAL AND CHEMICAL CHARACTERISTICS OF QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES

### 2.1 Physical Characteristics

Hydrographic surveys of Queens Mirror Lake and the Triplet Chain-of-Lakes were conducted by the University of South Florida (USF) during 2001-2002. The hydrographic surveys were conducted using a differential GPS system combined with recording underwater sonar. A summary of characteristics of the bathymetric surveys conducted by USF is given in Table 2-1.

**TABLE 2-1**

**CHARACTERISTICS OF BATHYMETRIC SURVEYS FOR QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | SURVEY DATE | SURVEY ORGANIZATION | SURVEY METHOD | WATER ELEVATION ON SURVEY DATE (ft, NAVD88) |
|---|---|---|---|---|
| Queens Mirror Lake | 8/6/01 | USF[1] | DGPS-Sonar[2] | 49.68 |
| North Lake Triplet | 6/4/02 | USF | DGPS-Sonar | 48.76 |
| Middle Lake Triplet | 6/6/02 | USF | DGPS-Sonar | 48.59 |
| South Lake Triplet | 7/3/02 | USF | DGPS-Sonar | 48.83 |

1. USF: University of South Florida
2. DGPS-Sonar: Differential GPS combined with underwater sonar

Bathymetric contour maps for each of the four lakes were digitized by ERD and superimposed on a recent areal image of each lake. Water depth contours for Queens Mirror Lake are illustrated on Figure 2-1. Much of the central portion of Queens Mirror Lake ranges in depth from approximately 3-4 ft, with a small area extending to a water depth of approximately 6 ft. A tabular summary of depth-area-volume relationships for Queens Mirror Lake is given in Table 2-2. At a water surface elevation of 49.68 ft, the surface area of Queens Mirror Lake is approximately 12.53 ac, with a water volume of 33.6 ac-ft. The calculated mean depth in Queens Mirror Lake is approximately 2.7 ft.

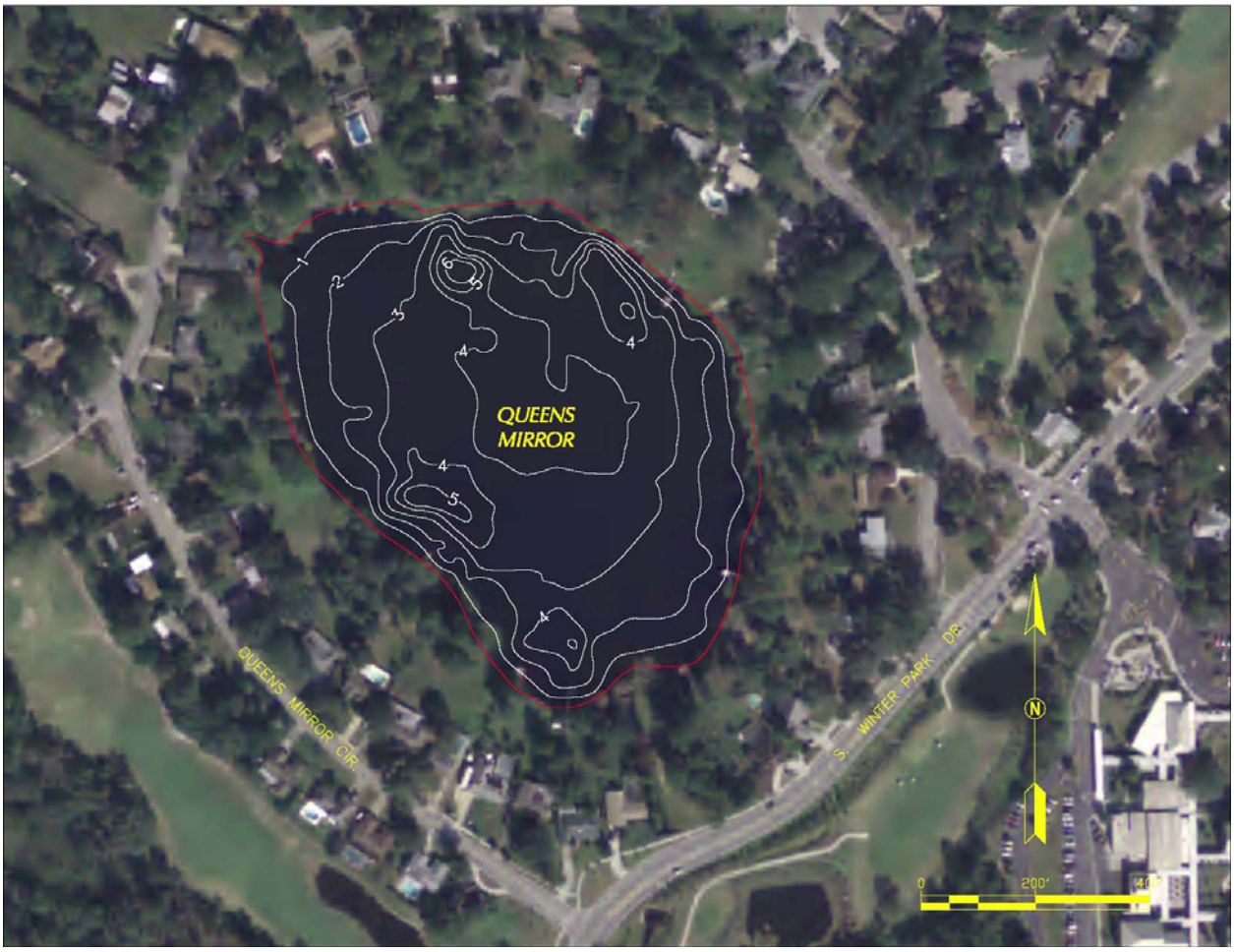



Figure 2-1. Water Depth Contours for Queens Mirror Lake.

**TABLE 2-2**

**DEPTH-AREA-VOLUME RELATIONSHIPS FOR QUEENS MIRROR LAKE (Elev. = 49.68 ft)**

| DEPTH (ft) | AREA (acres) | VOLUME (ac-ft) |
|---|---|---|
| 0 | 12.53 | 33.6 |
| 1 | 10.74 | 22.0 |
| 2 | 8.48 | 12.3 |
| 3 | 5.78 | 5.2 |
| 4 | 2.12 | 1.3 |
| 5 | 0.19 | 0.1 |
| 6 | 0.04 | 0.0 |

Water depth contours for South Lake Triplet are illustrated on Figure 2-2. The majority of South Lake Triplet is extremely shallow, with water depths ranging from approximately 2-4 ft. A deeper pocket with depths extending to approximately 8 ft is located in the southern lobe of the lake. Depth-area-volume relationships for South Lake Triplet are provided in Table 2-3. At a water surface elevation of 48.83 ft, the surface area of South Lake Triplet is approximately 23.29 ac, with a corresponding water volume of 47.4 ac-ft. The calculated mean water depth in South Lake Triplet is approximately 2.0 ft.

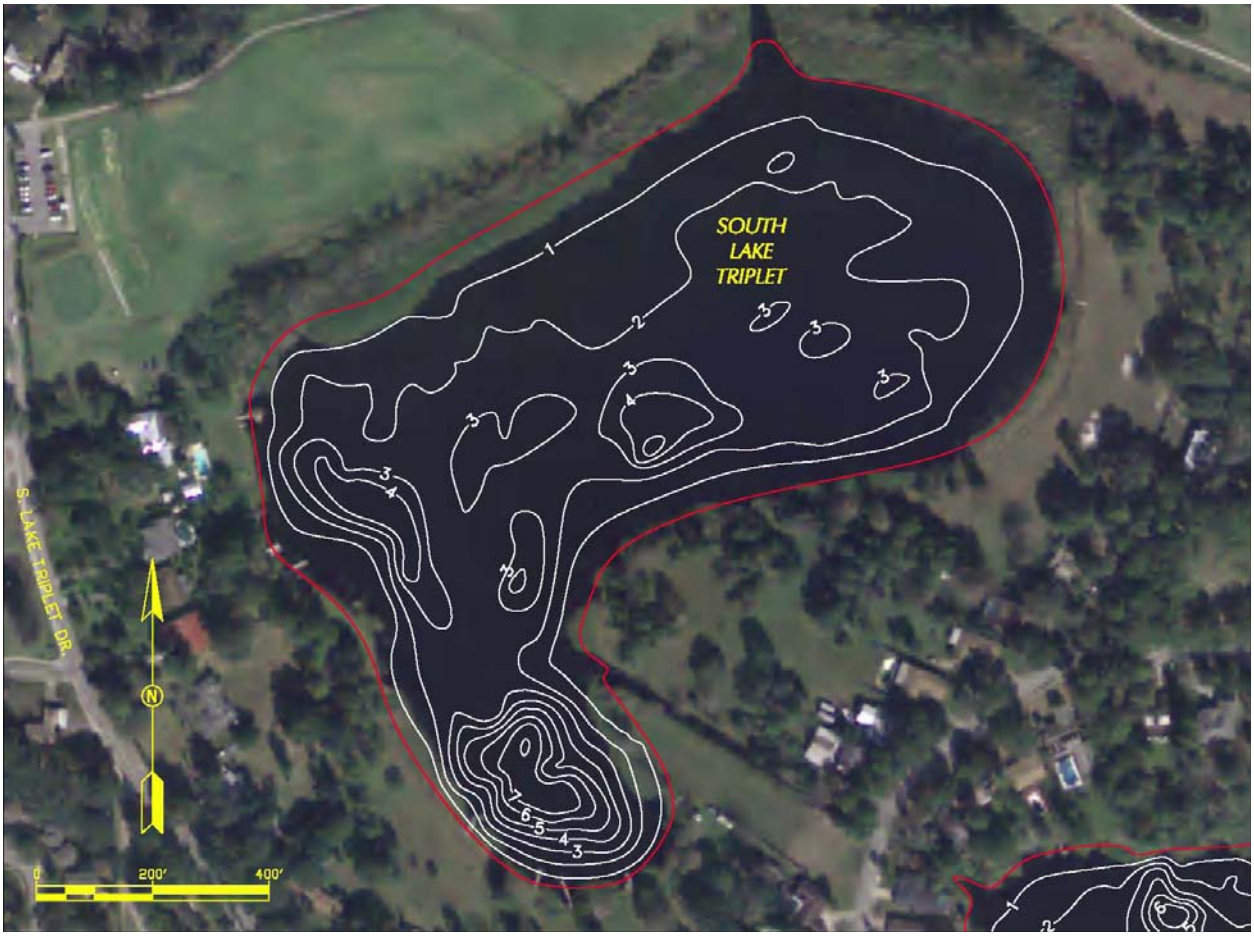



Figure 2-2. Water Depth Contours for South Lake Triplet.

Water depth contours for Middle Lake Triplet are illustrated on Figure 2-3. Central and eastern portions of Middle Lake Triplet are extremely shallow, with water depths ranging from approximately 1-3 ft. However, isolated deeper pockets are located around the southern and western perimeter of the lake, with water depths extending to approximately 11 ft. Based upon the shape and size of these pockets, it appears that these areas may have originated from dredging activities conducted to provide fill for upland areas. Depth-area-volume relationships for Middle Lake Triplet are given in Table 2-4 based upon a water surface elevation of 48.59 ft. At the water elevation present at the time of the bathymetric survey, the area of Middle Lake Triplet was approximately 44.59 ac, with a corresponding volume of 118 ac-ft. The calculated mean water depth in Middle Lake Triplet is approximately 2.6 ft.

## TABLE 2-3

## DEPTH-AREA-VOLUME RELATIONSHIPS FOR SOUTH LAKE TRIPLET (Elev. = 48.83 ft)

| DEPTH (ft) | AREA (acres) | VOLUME (ac-ft) |
|---|---|---|
| 0 | 23.29 | 47.4 |
| 1 | 17.76 | 26.9 |
| 2 | 11.48 | 12.3 |
| 3 | 3.53 | 4.8 |
| 4 | 1.57 | 2.2 |
| 5 | 0.74 | 1.1 |
| 6 | 0.45 | 0.5 |
| 7 | 0.24 | 0.1 |
| 8 | 0.01 | 0.0 |

## TABLE 2-4

## DEPTH-AREA-VOLUME RELATIONSHIPS FOR MIDDLE LAKE TRIPLET (Elev. = 48.59 ft)

| DEPTH (ft) | AREA (acres) | VOLUME (ac-ft) |
|---|---|---|
| 0 | 44.59 | 118.0 |
| 1 | 35.44 | 77.95 |
| 2 | 26.40 | 47.03 |
| 3 | 14.34 | 26.66 |
| 4 | 6.80 | 16.09 |
| 5 | 4.77 | 10.31 |
| 6 | 3.28 | 6.28 |
| 7 | 2.12 | 3.58 |
| 8 | 1.30 | 1.88 |
| 9 | 0.80 | 0.82 |
| 10 | 0.37 | 0.24 |
| 11 | 0.11 | 0.00 |

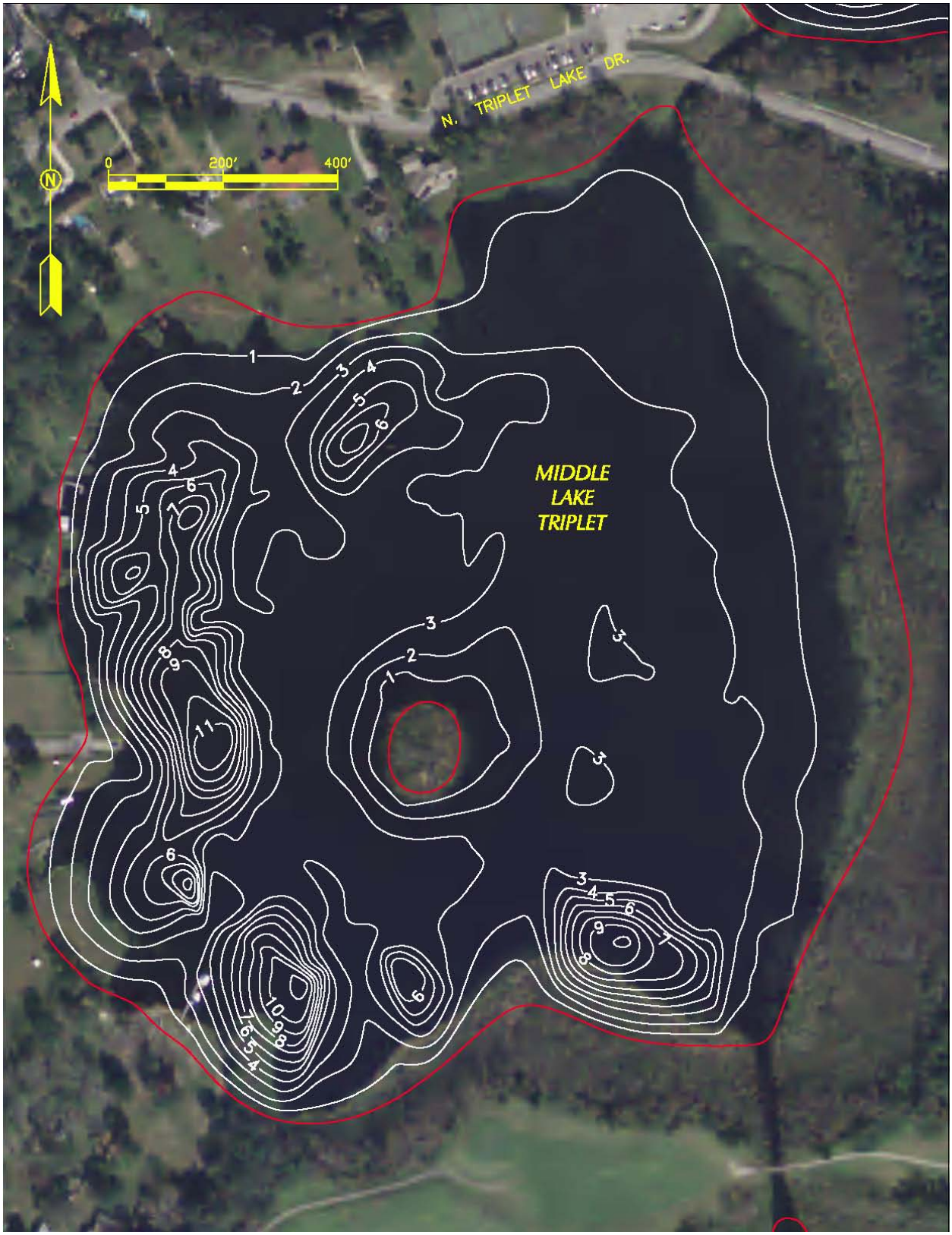



Figure 2-3. Water Depth Contours for Middle Lake Triplet.

Water depth contours for North Lake Triplet are illustrated on Figure 2-4. North Lake Triplet appears to be somewhat deeper than the remaining Triplet lakes, with water depths in central portions of the lake extending to approximately 6-7 ft. Several isolated pockets exhibit water depths ranging from approximately 11-12 ft. Based upon the shape and size of these pockets, it appears they may have originated as dredged areas used to generate soils for adjacent upland areas. Depth-area-volume relationships for North Lake Triplet, based upon the surface water elevation of 48.76 ft, are given on Table 2-5. At the water elevation present at the time of the bathymetric survey, the surface area in North Lake Triplet was approximately 21.47 ac, with a water volume of 103.9 ft, corresponding to a mean water depth of approximately 4.8 ft.

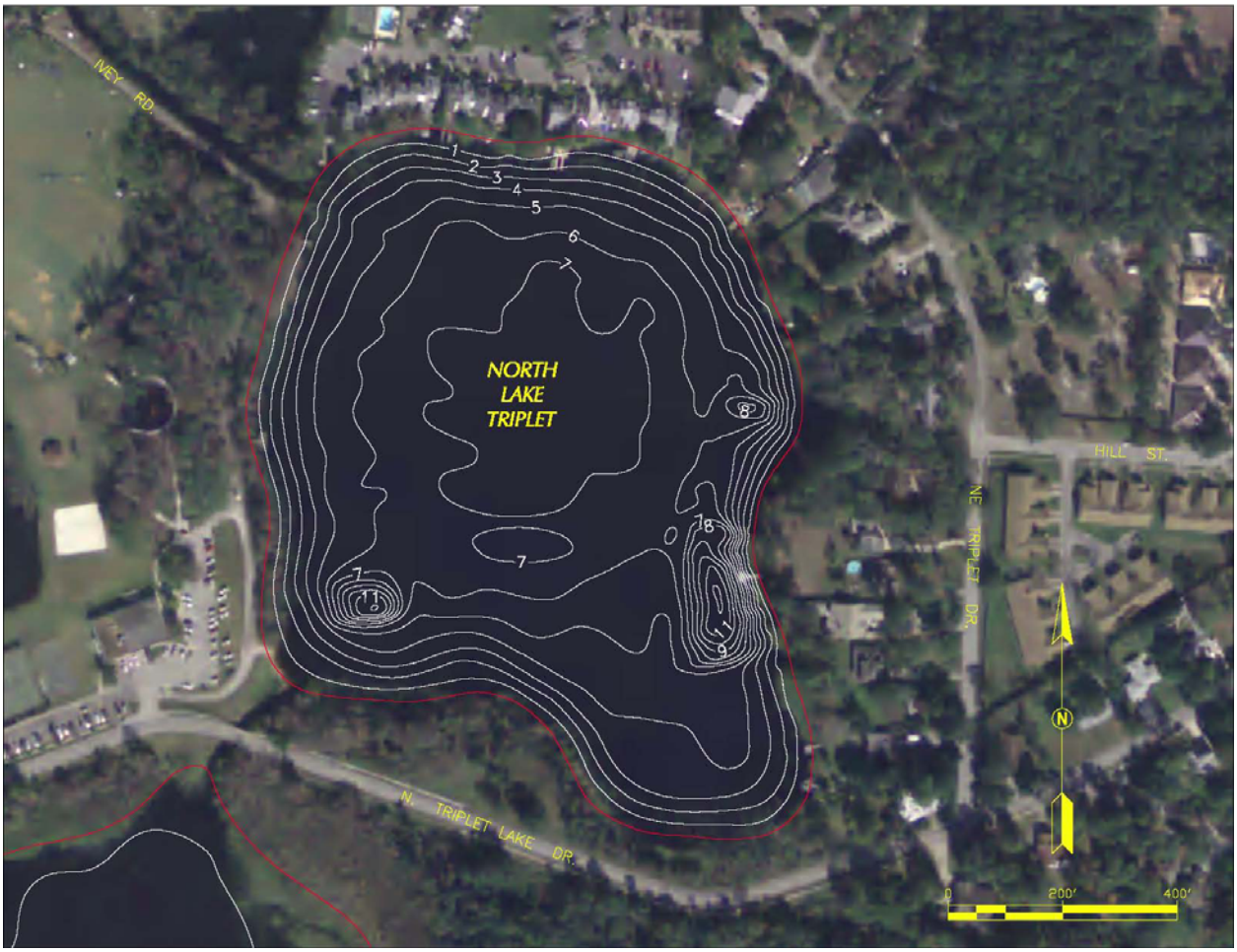



Figure 2-4. Water Depth Contours for North Lake Triplet.

A comparison of bathymetric characteristics of Queens Mirror Lake and the Triplet Chain-of-Lakes is given in Table 2-6. Surface areas of the lakes range from approximately 12.53 ac in Queens Mirror Lake to 44.59 ac in Middle Lake Triplet. Each of the lakes is extremely shallow, with mean water depths ranging from 2.0 ft in South Lake Triplet to 4.8 ft in North Lake Triplet.

## TABLE 2-5

## DEPTH-AREA-VOLUME RELATIONSHIPS FOR NORTH LAKE TRIPLET (Elev. = 48.76 ft)

| DEPTH (ft) | AREA (acres) | VOLUME (ac-ft) |
|---|---|---|
| 0 | 21.47 | 103.9 |
| 1 | 19.51 | 83.4 |
| 2 | 17.87 | 64.7 |
| 3 | 16.37 | 47.6 |
| 4 | 14.33 | 32.2 |
| 5 | 11.68 | 19.2 |
| 6 | 8.45 | 9.16 |
| 7 | 3.68 | 3.09 |
| 8 | 0.53 | 0.99 |
| 9 | 0.36 | 0.54 |
| 10 | 0.23 | 0.25 |
| 11 | 0.12 | 0.07 |
| 12 | 0.01 | 0.00 |

## TABLE 2-6

## COMPARISON OF BATHYMETRIC CHARACTERISTICS OF QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES

| PARAMETER | UNITS | QUEENS MIRROR LAKE | SOUTH LAKE TRIPLET | MIDDLE LAKE TRIPLET | NORTH LAKE TRIPLET |
|---|---|---|---|---|---|
| Area | acres | 12.53 | 23.29 | 44.59 | 21.47 |
| Volume | ac-ft | 67.2 | 94.8 | 118.0 | 103.9 |
| Maximum Depth | ft | 6 | 8 | 11 | 12 |
| Mean Depth | ft | 2.7 | 2.0 | 2.6 | 4.8 |
| Shoreline Length | ft | 2884 | 4659 | 5563 | 3853 |
| Shoreline Development | | 1.10 | 1.31 | 1.13 | 1.12 |

Information on shoreline length or lake perimeter is also provided near the bottom of Table 2-6 for each of the four lakes. This value is used to calculate the shoreline development index which is a measure of the regularity of the lake shoreline. The shoreline development index is a ratio of the perimeter of the lake to the perimeter of a lake with the same area that is a perfect circle. In general, lakes which exhibit a high degree of irregularity in the shoreline often provide a higher degree of habitat for aquatic organisms and often display a higher degree of diversity in the aquatic community. Shoreline development indices of approximately 2 or more are often considered to provide a high degree of habitat. As indicated on Table 2-6, shoreline development indices for the four lakes range from approximately 1.10-1.31, indicating fairly regular shoreline areas with shapes that approach a circular pattern. Based upon the shoreline development indices, each of the four lakes provides a relatively low degree of habitat compared with a lake with a highly irregular shoreline.

## 2.2 Water Quality Characteristics

### 2.2.1 Historical Water Quality Data

Relatively extensive historical water quality monitoring has been conducted in Queens Mirror Lake and the Triplet Chain-of-Lakes by a variety of sources. A summary of available historical water quality data for Queens Mirror Lake and the Triplet Chain-of-Lakes is given in Table 2-7. Water quality data in the four lakes have been collected by two primary sources, which include the ongoing City of Casselberry Lake Monitoring Program as well as the LAKEWATCH Program.

Routine water quality monitoring in the four lakes was initiated by the City of Casselberry during June 1993 and was continued on a quarterly basis until March 2001, with a total of 29 separate monitoring events conducted during this period. Quarterly monitoring was resumed in December 2003 and has been continued until the present, with an additional 29 quarterly monitoring events conducted in each of the four lakes.

Routine monitoring in each of the four lakes was initiated under the LAKEWATCH Program, operated by the University of Florida, during May 1996 and has continued on approximately a monthly basis until the present. This program has collected 113 monthly samples in Queens Mirror Lake and South Lake Triplet, with 119 monthly samples collected in Middle Lake Triplet and North Lake Triplet.

Water samples collected by the City of Casselberry Lake Monitoring Program are analyzed for general parameters, nutrients, microbiological parameters, metals, and demand parameters. Beginning in 1998, vertical field profiles of temperature, pH, conductivity, dissolved oxygen, and oxidation-reduction potential (ORP) were also conducted during each monitoring event. Samples collected and analyzed by the LAKEWATCH Program are analyzed for total nitrogen, total phosphorus, and chlorophyll-a, with Secchi disk measurements conducted at the time of sample collection. A complete listing of historical waster quality data collected in Queens Mirror Lake and the Triplet Chain-of-Lakes by the Casselberry Lake Water Monitoring Program is given in Appendix A.1, with data collected as part of the LAKEWATCH Program provided in Appendix A.2.

## TABLE 2-7

## SUMMARY OF AVAILABLE HISTORICAL WATER QUALITY DATA FOR QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES

| LAKE | DATA SOURCE | PERIOD OF RECORD | NUMBER OF SAMPLES | MONITORING FREQUENCY | PARAMETERS MEASURED |
|---|---|---|---|---|---|
| Queens Mirror Lake | Casselberry | 6/21/93-3/28/01<br>12/18/03-Present | 29<br>29 | Quarterly | General Parameters, Nutrients, Microbiological, Metals, Demand Parameters |
| | LAKEWATCH | 5/30/96-Present | 113 | Monthly | Total Nitrogen, Total Phosphorus, Secchi, Chlorophyll-a |
| South Lake Triplet | Casselberry | 6/21/93-3/28/01<br>12/18/03-Present | 29<br>29 | Quarterly | General Parameters, Nutrients, Microbiological, Metals, Demand Parameters |
| | LAKEWATCH | 5/30/96-Present | 113 | Monthly | Total Nitrogen, Total Phosphorus, Secchi, Chlorophyll-a |
| Middle Lake Triplet | Casselberry | 6/21/93-3/28/01<br>12/18/03-Present | 29<br>29 | Quarterly | General Parameters, Nutrients, Microbiological, Metals, Demand Parameters |
| | LAKEWATCH | 5/30/96-Present | 119 | Monthly | Total Nitrogen, Total Phosphorus, Secchi, Chlorophyll-a |
| North Lake Triplet | Casselberry | 6/21/93-3/28/01<br>12/18/03-Present | 29<br>29 | Quarterly | General Parameters, Nutrients, Microbiological, Metals, Demand Parameters |
| | LAKEWATCH | 5/30/96-Present | 119 | Monthly | Total Nitrogen, Total Phosphorus, Secchi, Chlorophyll-a |

Historical water quality characteristics in Queens Mirror Lake and the Triplet Chain-of-Lakes 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, trophic state index (TSI), and TN/TP ratio. Plots of temporal variability in concentrations of these parameters were developed for each lake using the historical water quality data. Mean annual average values for each 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. This line is obtained using linear regression techniques based on the average annual values for each parameter. 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 0.2 or less is generally considered to indicate a significant statistical trend, while p-values greater than 0.2 suggest an insignificant trend.

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 and indicates that inputs of phosphorus into the lake system should be controlled to regulate the growth of algal biomass within the lake.

Florida Trophic State Index (TSI) values were also calculated for each monitoring event in the four lakes over the period of historical data from 1993-2011. 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 are conducted for Queens Mirror Lake and the Triplet Chain-of-Lakes using measured concentrations of chlorophyll-a only according to the following relationship:

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

### 2.2.2 <u>Queens Mirror Lake</u>

A graphical summary of trends in measured concentrations of total nitrogen and total phosphorus in Queens Mirror Lake over the period of available historical data from 1993-2011 is given on Figure 2-5. Measured concentrations of total nitrogen in Queens Mirror Lake have been highly variable, ranging from approximately 500-2500 µg/l. However, the vast majority of nitrogen concentrations occur within the range of 500-1250 µg/l, reflecting low to moderate concentrations. Based upon the calculated p-value of 0.8615, no significant trend of either decreasing or increasing concentrations of total nitrogen is apparent in Queens Mirror Lake.

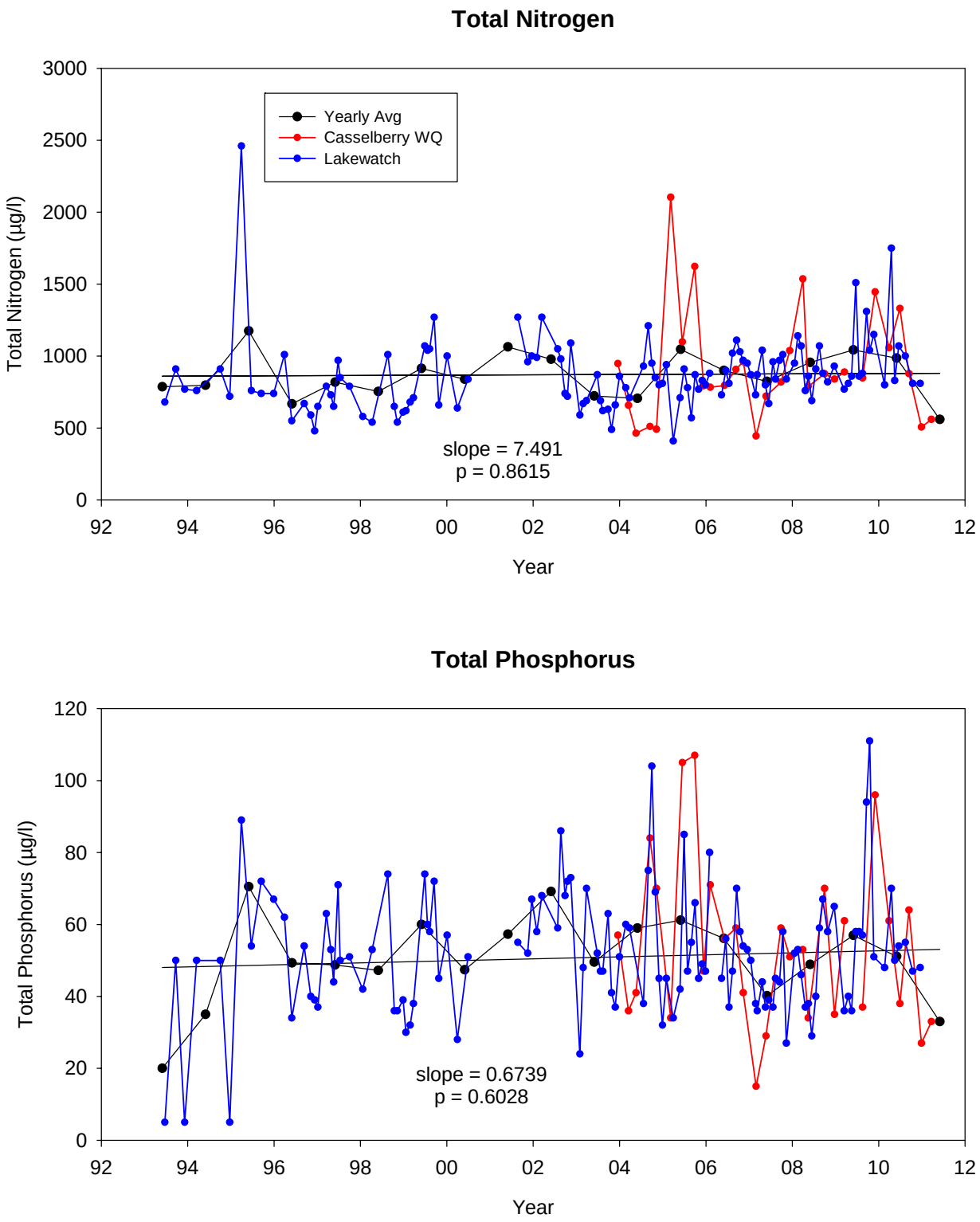



Figure 2-5. Trends in Concentrations of Total Nitrogen and Total Phosphorus in Queens Mirror Lake from 1993-2011.

Measured concentrations of total phosphorus in Queens Mirror Lake have also been highly variable over the available period of historical data, with measured concentrations ranging from approximately 5->100 μg/l. However, the vast majority of total phosphorus concentrations appear to occur within the range of approximately 30-70 μg/l, reflecting moderate to elevated concentrations. Based upon the calculated of 0.6028, no significant trend of either increasing or decreasing total phosphorus p-value concentrations is apparent in Queens Mirror Lake.

A graphical summary of trends in measured concentrations of chlorophyll-a and Secchi disk depth in Queens Mirror Lake over the period of available historical data from 1993-2011 is given on Figure 2-6. Measured concentrations of chlorophyll-a in Queens Mirror Lake have been highly variable over the period from 1993-2011, with a majority of the measured values ranging from approximately 10-70 $mg/m^3$. Variability in chlorophyll-a concentrations in Queens Mirror Lake appear to have increased over the past 5-10 years compared with the degree of variability observed prior to the year 2000. Based upon the calculated p-value of 0.0252, chlorophyll-a concentrations have exhibited a significant increase in Queens Mirror Lake over time at an average rate of 0.7 $mg/m^3$ per year.

A relatively high degree of variability has also been observed in measured Secchi disk depths in Queens Mirror Lake, with measured values ranging from approximately 0.3-1.7 m, although the vast majority of measured Secchi disk depths appear to fall within the range of approximately 0.7-1.2 m, reflecting moderate to poor water clarity. The regression line for the Secchi disk data indicates a significant negative slope, with a p-value of 0.0028, indicating that water clarity in Queens Mirror Lake is decreasing over time.

A graphical summary of trends in TSI values and TN/TP ratios in Queens Mirror Lake from 1993-2011 is given on Figure 2-7. Over the available period of record, TSI values in Queens Mirror Lake have ranged from oligotrophic to hypereutrophic, although the vast majority of the calculated TSI values appear to occur in the mesotrophic to hypereutrophic range. The regression trend line suggests an upward trend in TSI values, although the calculated p-value of 0.6283 indicates that the trend is not statistically significant.

Calculated TN/TP ratios in Queens Mirror Lake have ranged from nitrogen-limited to phosphorus-limited conditions, although the majority of ratios appear to suggest balanced nutrient conditions within the lake. The regression trend line suggests a trend of increasing TN/TP ratios, indicating that the lake is becoming more phosphorus-limited with time. The calculated p-value of 0.0354 indicates that the trend is statistically significant.

A graphical comparison of mean monthly concentrations of total phosphorus in Queens Mirror Lake from 1993-2011 is given on Figure 2-8. An evaluation of seasonal concentrations of total phosphorus in lake systems can be useful in identifying dominant phosphorus sources to a lake. If phosphorus concentrations in a lake peak during wet season conditions, then it can be assumed that runoff is the dominant contributor of phosphorus loadings to a lake. However, if phosphorus concentrations are substantially higher during dry season conditions, particularly during periods of the year when water column circulation would be expected, then internal processes (such as internal phosphorus recycling) may be more significant than runoff. As indicated on Figure 2-8, total phosphorus concentrations in Queens Mirror Lake appear to peak during wet season conditions, with lower phosphorus concentrations during other portions of the year, suggesting that runoff inputs into Queens Mirror Lake are more significant than internal processes.

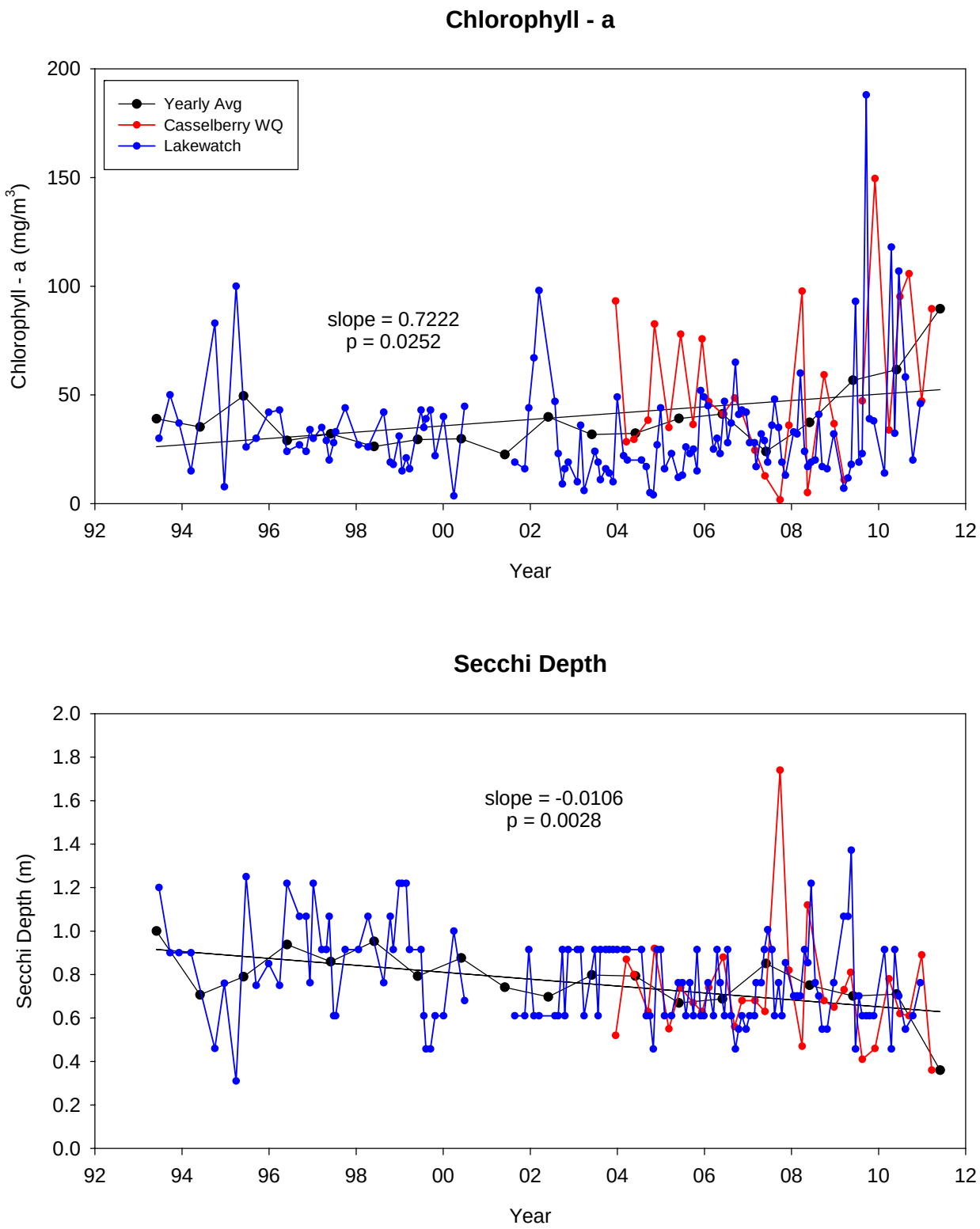
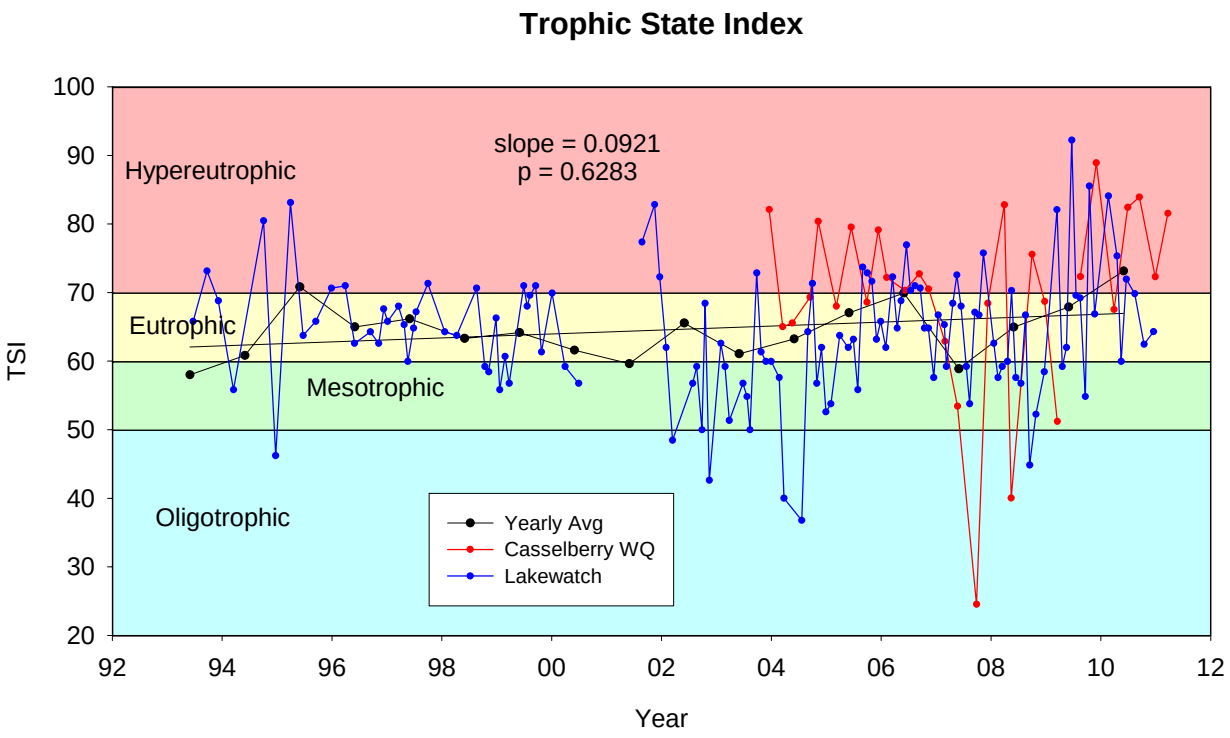



Figure 2-6. Trends in Concentrations of Chlorophyll-a and Secchi Disk Depth in Queens Mirror Lake from 1993-2011.



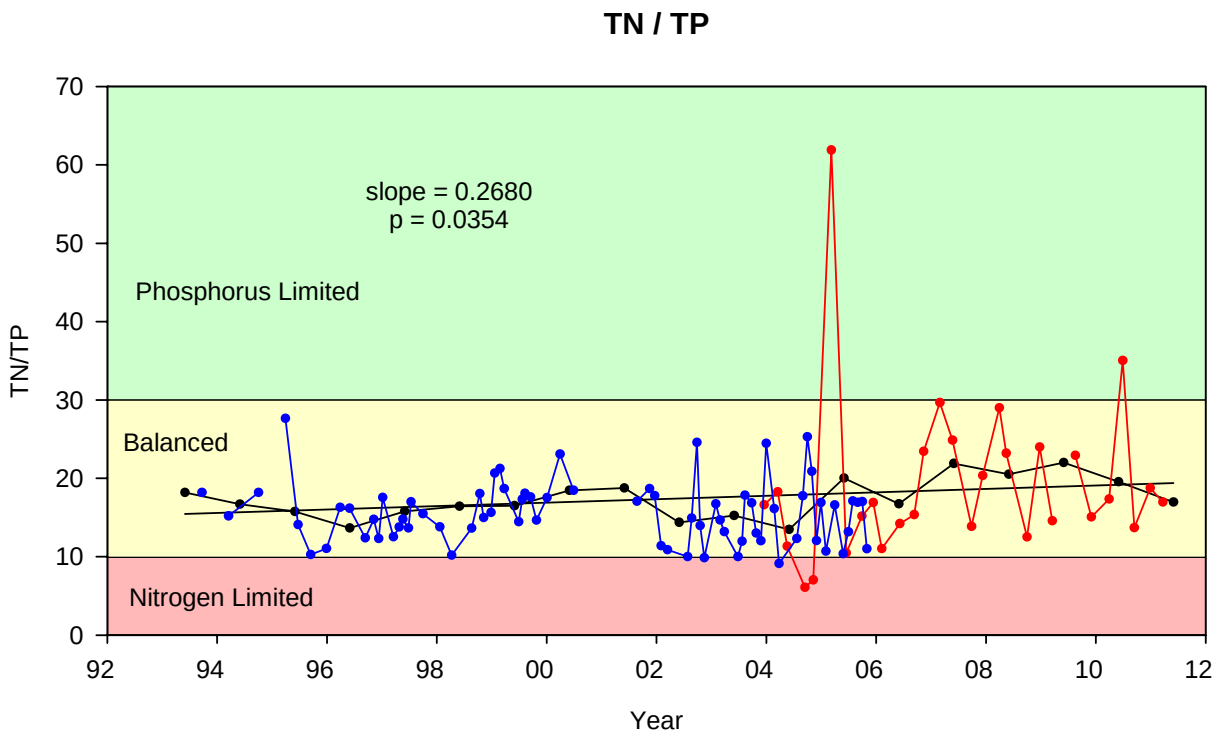




Figure 2-7. Trends in TSI and TN/TP Ratios in Queens Mirror Lake from 1993-2011.

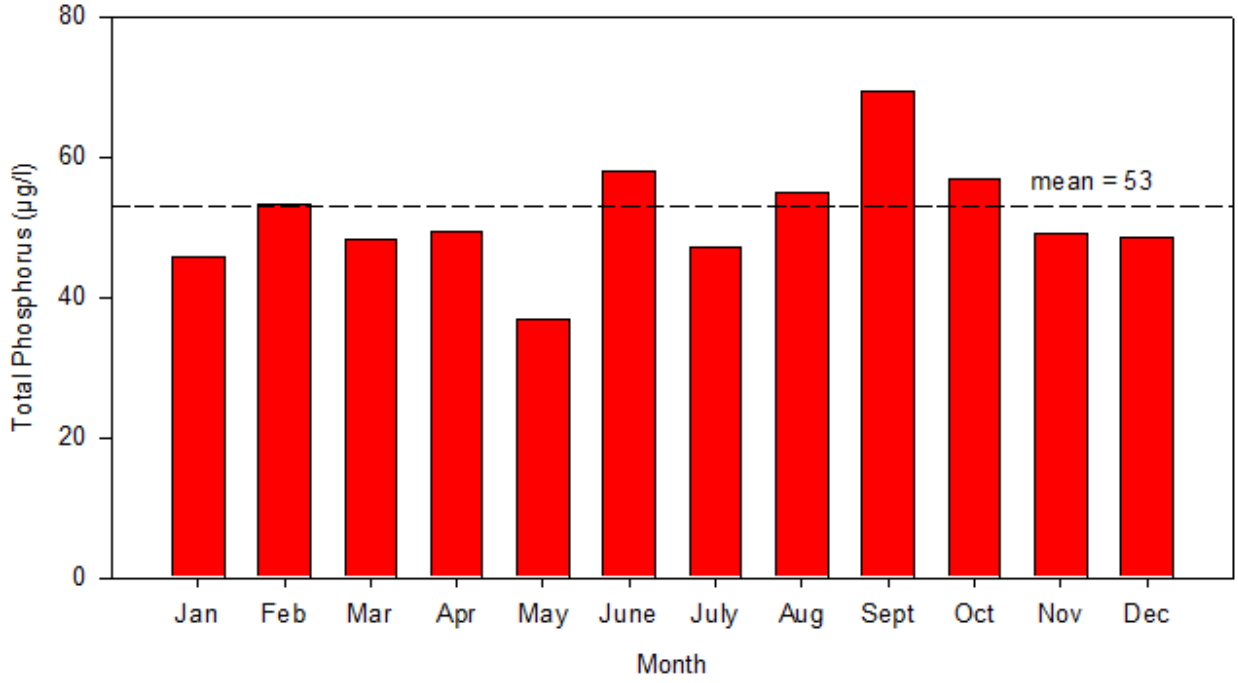



Figure 2-8. Mean Monthly Concentrations of Total Phosphorus in Queens Mirror Lake from 1993-2011.

A tabular summary of water quality characteristics in Queens Mirror Lake from 1993-2011 is given on Table 2-8. The data summarized in this table are based upon the extensive surface water monitoring program conducted by the City of Casselberry. Data collected by the LAKEWATCH Program are not included in Table 2-8 since the LAKEWATCH samples are analyzed for only a few parameters.

Surface water samples collected in Queens Mirror Lake have been neutral to slightly alkaline in pH. Measured alkalinity levels within the lake have ranged from moderately to poorly buffered, with the mean overall alkalinity value of 41.3 mg/l suggesting relatively poorly buffered conditions.

Measured concentrations of inorganic nitrogen species in Queens Mirror Lake have been highly variable, although on an average basis, the measured concentrations for ammonia and $NO_x$ are extremely low in value. The dominant nitrogen species in Queens Mirror Lake is organic nitrogen, consisting of dissolved and particulate organic nitrogen forms. On an average basis, organic nitrogen comprises more than 95% of the total nitrogen present in the water column.

Measured concentrations of soluble reactive phosphorus (SRP) have also been highly variable over the monitoring program. The overall mean concentration for SRP of 7 µg/l reflects a relatively elevated value for a lake system, since a majority of the lakes in Central Florida are characterized by SRP concentrations of 2-4 µg/l or less. Total phosphorus concentrations in Queens Mirror Lake have also been highly variable, ranging from low to extremely elevated. The overall mean total phosphorus concentration of 52 µg/l reflects an elevated total phosphorus level.

**TABLE 2-8**

**SUMMARY OF WATER QUALITY CHARACTERISTICS IN QUEENS MIRROR LAKE FROM 1993-2011 (Data Source: City of Casselberry)**

| PARAMETER | UNITS | MINIMUM | MAXIMUM | MEAN |
|---|---|---|---|---|
| pH | s.u. | 6.32 | 8.69 | 7.32 |
| Secchi Depth | m | 0.31 | 1.74 | 0.78 |
| Alkalinity | mg/l | 18.6 | 60.2 | 41.3 |
| $NH_3$-N | µg/l | <5 | 273 | 32 |
| $NO_x$-N | µg/l | <5 | 103 | 9 |
| Organic Nitrogen | µg/l | 440 | 2460 | 903 |
| Total Nitrogen | µg/l | 445 | 2460 | 914 |
| SRP | µg/l | <1 | 48 | 7 |
| Total Phosphorus | µg/l | 5 | 139 | 52 |
| Turbidity | NTU | 0.9 | 28.0 | 5.4 |
| Color | Co-Pt units | 27 | 308 | 112 |
| BOD | mg/l | <2 | 71 | 6.2 |
| Chlorophyll-a | $mg/m^3$ | 2.0 | 149 | 42.5 |
| Fecal Coliform | #/100 ml | 2 | 570 | 49 |
| Cadmium | µg/l | <1 | 3 | 1.2 |
| Chromium | µg/l | <5 | 9 | 2.8 |
| Copper | µg/l | <1 | 13 | 3.4 |
| Iron | µg/l | 2 | 570 | 167 |
| Lead | µg/l | < 3 | < 3 | < 3 |
| Zinc | µg/l | 2 | 89 | 10 |

Measured concentrations of turbidity, color, and BOD in Queens Mirror Lake have also been highly variable during the Casselberry lake monitoring program. However, on an average basis, surface water in Queens Mirror Lake is characterized by a moderate level of turbidity and a relatively high color concentration. The mean BOD concentration of 6.2 mg/l is also highly elevated compared with concentrations commonly observed in urban lakes. Measured chlorophyll-a concentrations in Queens Mirror Lake have also been highly variable, ranging from excellent to extremely poor, with the overall mean chlorophyll-a concentration of 42.5 $mg/m^3$ reflecting a highly elevated value. Measured fecal coliform counts in Queens Mirror Lake have been typically low in value, with only a few limited instances of samples exceeding the applicable criterion for Class III surface waters (recreational) of 200 organisms/100 ml.

In general, Queens Mirror Lake is characterized by extremely low levels of cadmium, chromium, copper, iron, lead, and zinc. Each of the mean metal concentrations easily meets the applicable water quality criteria for Class III surface waters.

A graphical comparison of mean seasonal vertical field profiles collected in Queens Mirror Lake during the Casselberry water quality monitoring program is given on Figure 2-9. Vertical field profiles collected within the lake were averaged on a seasonal basis to provide a general overview of seasonal variability within the lake. For purposes of this analysis, the months of January-March are assumed to reflect winter conditions, with April-June reflecting spring conditions, July-September reflecting summer conditions, and October-December reflecting fall seasonal conditions.

In general, water temperature decreased slowly with increasing depth in Queens Mirror Lake during virtually all of the field monitoring events. However, no significant thermal stratification was observed within the lake, presumably due to the relatively shallow water depth. A similar profile is apparent for pH, with a steady decrease in pH with increasing water depth. The most elevated pH values were observed during winter, fall, and spring conditions, with the lowest pH values observed during summer conditions. Measured conductivity values appear to be relatively uniform throughout the water column during a majority of the monitoring events. However, increases in conductivity were observed near the water-sediment interface during spring conditions, suggesting that internal recycling may be occurring during these events which is releasing ions from the sediments into the overlying water column. Dissolved oxygen concentrations in Queens Mirror Lake typically decrease relatively rapidly with increasing water depth. During the spring period, anoxic conditions appear to exist in lower portions of the water column which correspond to the depth of increased conductivity. Relatively aerobic conditions appear to exist within the majority of the water column during the remaining months of the year.

### 2.2.3 South Lake Triplet

Graphical trends in concentrations of total nitrogen and total phosphorus in South Lake Triplet from 1993-2011 are illustrated on Figure 2-10. Total nitrogen concentrations within the lake have ranged from approximately 400-1900 μg/l, although the majority of measured values appear to range from approximately 600-1200 μg/l, indicating low to moderate nitrogen concentrations. The regression trend line for total nitrogen concentrations over time suggests a downward trend in nitrogen values, and the p-value of 0.0886 indicates that the trend is statistically significant.

Measured total phosphorus concentrations in South Lake Triplet have ranged from low to elevated over the available period of record, although the majority of measured values fall within the range of approximately 20-80 μg/l. Phosphorus concentrations have been highly variable over time, with a high degree of variability observed within a given year. The regression trend line suggests a steady decline in phosphorus concentrations over time, although the calculated p-value of 0.4254 indicates that the trend is not statistically significant.

Trends in concentrations of chlorophyll-a and Secchi disk depth in South Lake Triplet from 1993-2011 are illustrated on Figure 2-11. Chlorophyll-a values in South Lake Triplet have been highly variable over time, ranging from approximately 5-130 $mg/m^3$. However, the majority of measured values appear to be within the range of approximately 10-60 $mg/m^3$, reflecting moderate to elevated values. The slope of the regression line suggests that chlorophyll-a concentrations have decreased over time, although the calculated p-value indicates that the trend is not statistically significant.

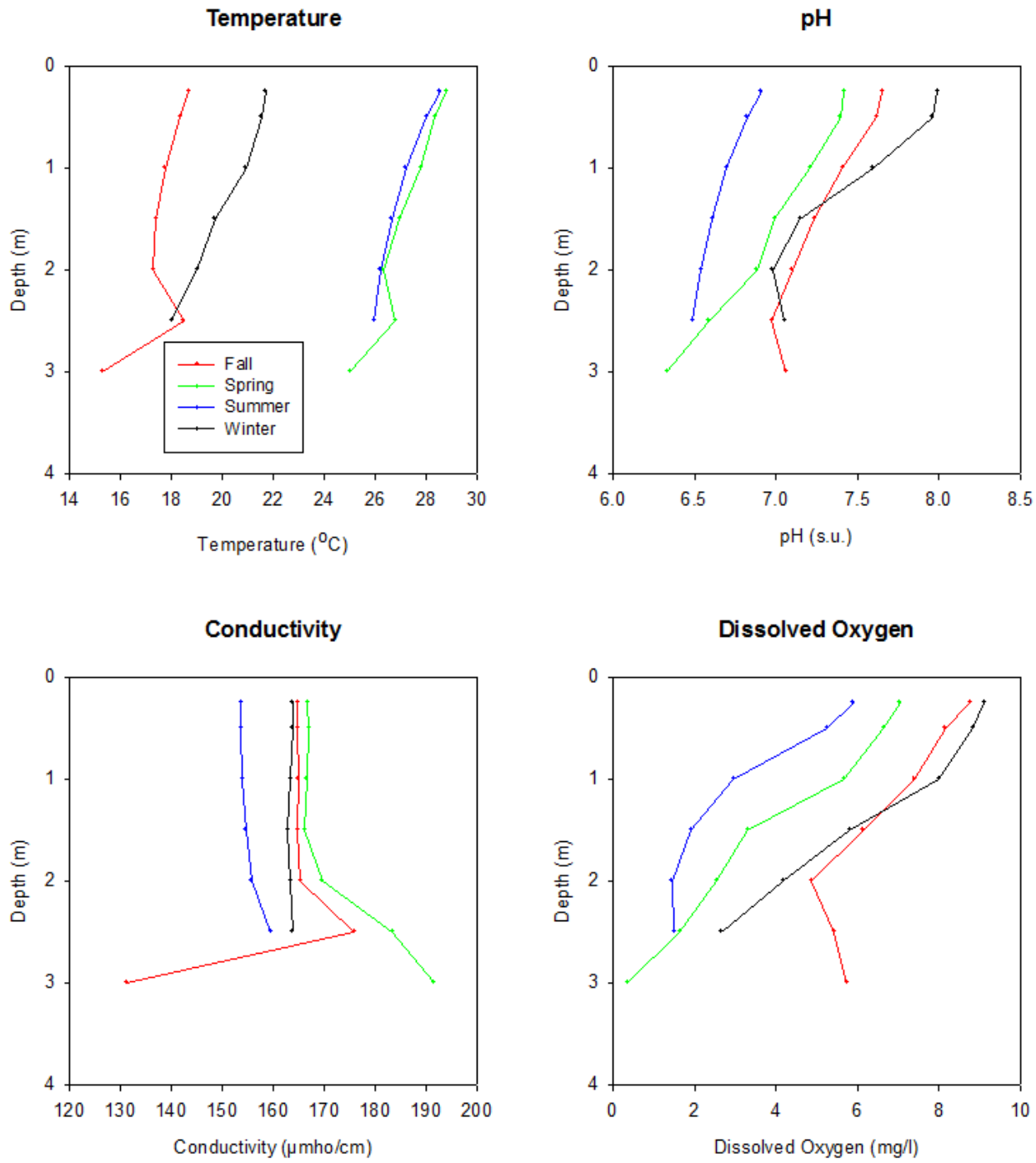
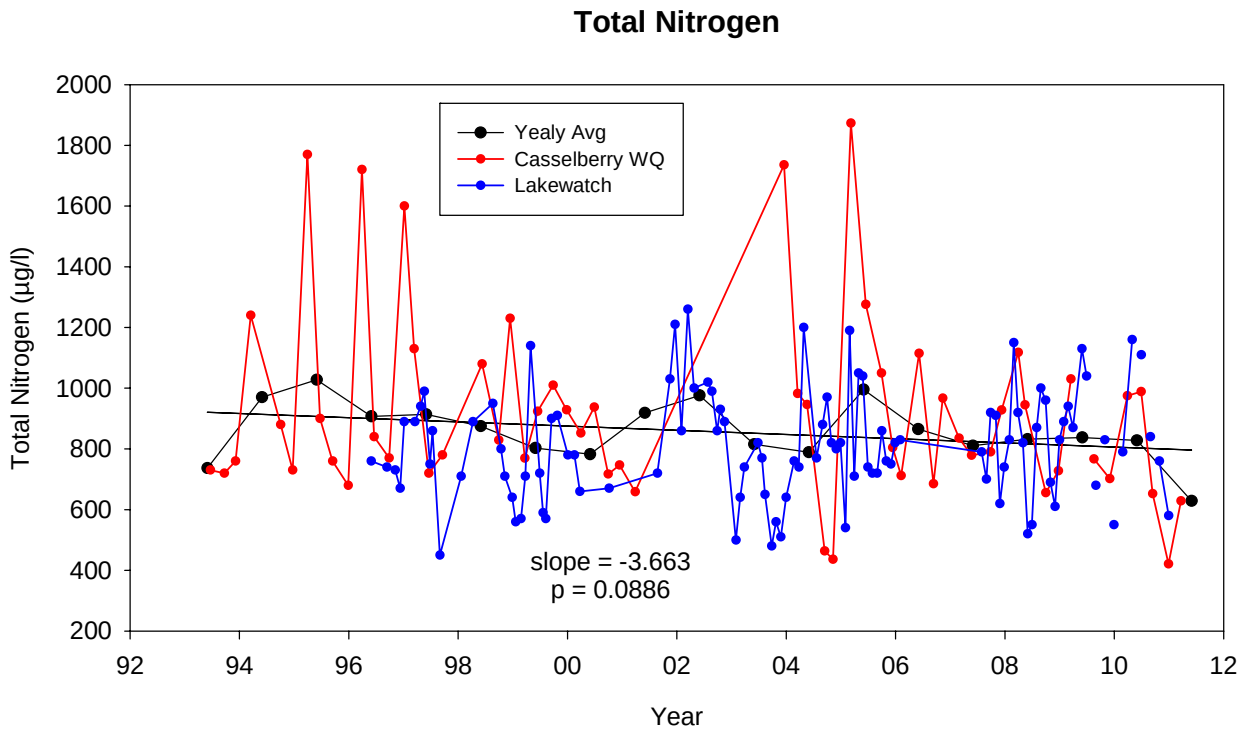



Figure 2-9. Mean Seasonal Vertical Field Profiles Collected in Queens Mirror Lake from 1998-2011.



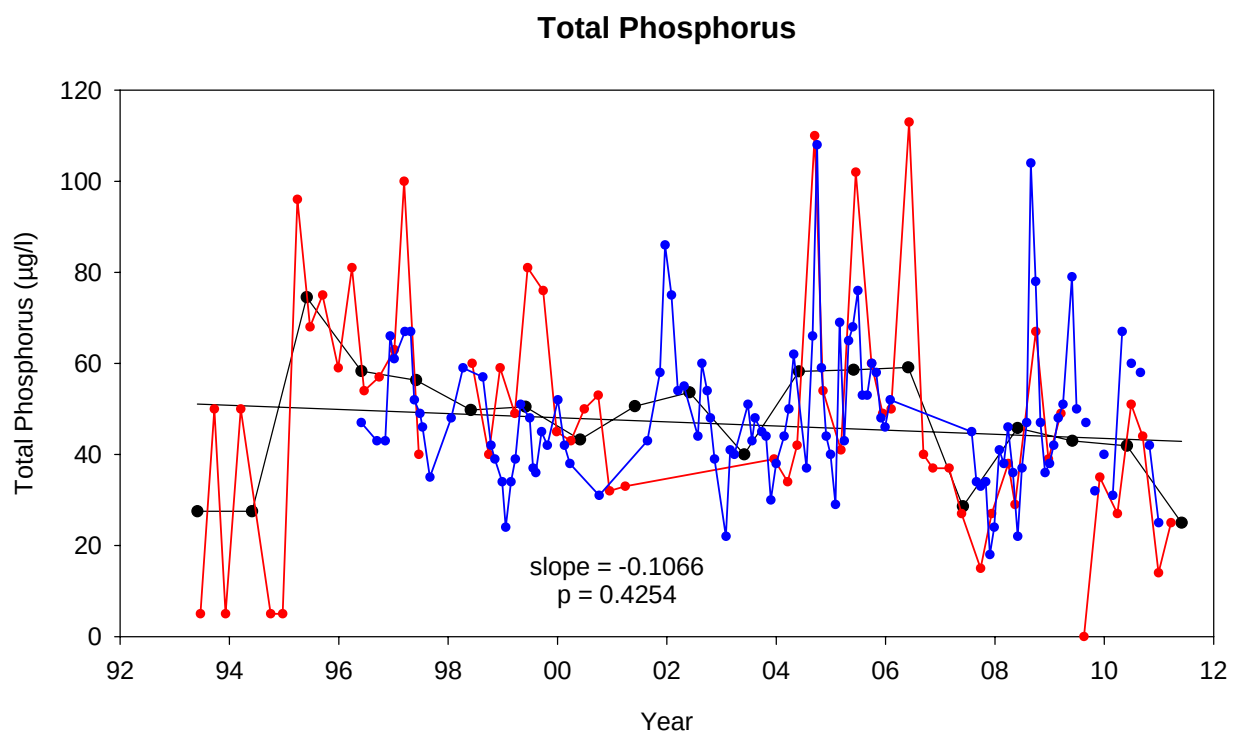
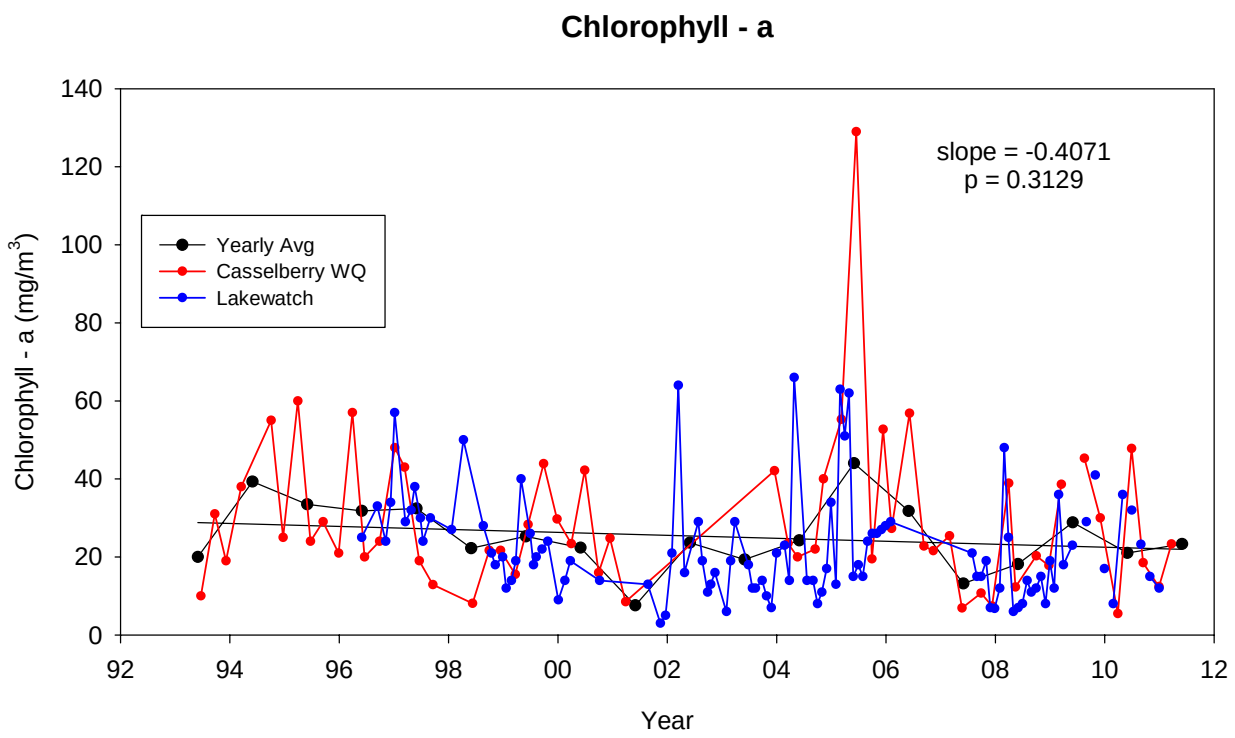




Figure 2-10. Trends in Concentrations of Total Nitrogen and Total Phosphorus in South Lake Triplet from 1993-2011.



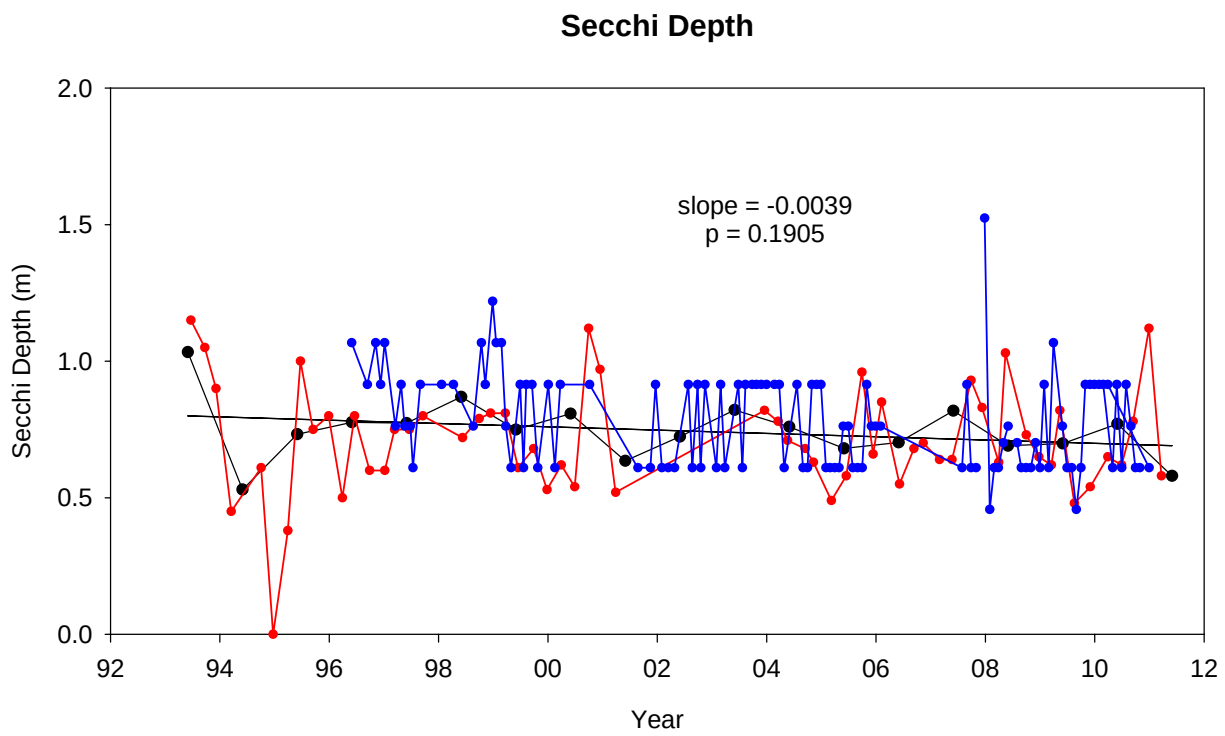




Figure 2-11. Trends in Concentrations of Chlorophyll-a and Secchi Disk Depth in South Lake Triplet from 1993-2011.

Measured Secchi disk depths in South Lake Triplet have been relatively consistent over time, with the majority of measured values ranging from approximately 0.5-1 m, reflecting poor to very poor water clarity. The negative slope of the regression line suggests a downward trend in Secchi disk depth within South Lake Triplet, and the calculated p-value of 0.1905 suggests that the relationship is marginally significant.

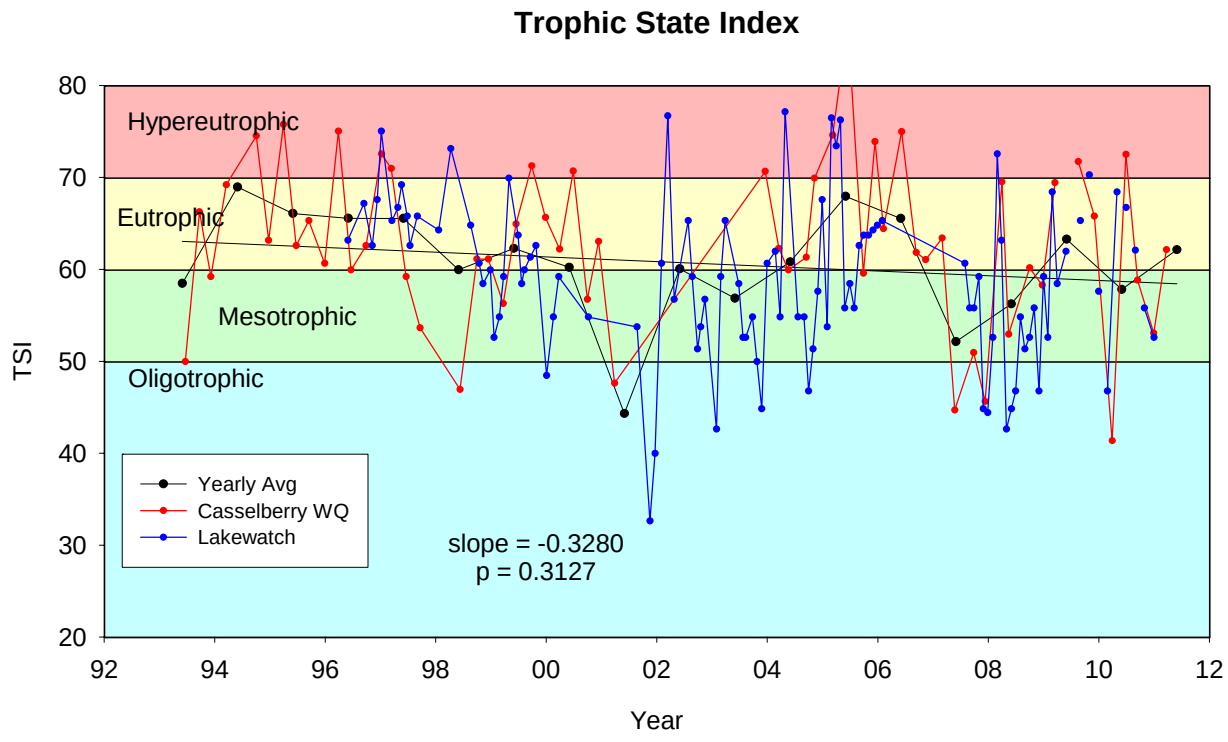
Trends in TSI and TN/TP ratios in South Lake Triplet from 1993-2011 are illustrated on Figure 2-12. Calculated TSI values for South Lake Triplet have been highly variable over time, ranging from oligotrophic to hypereutrophic conditions. However, the majority of measured values occur within the mesotrophic, eutrophic, and hypereutrophic categories. The negative slope of the regression line suggests that TSI values are decreasing slightly over time, although the calculated p-value of 0.3127 indicates that the trend is not statistically significant.

Calculated TN/TP ratios in South Lake Triplet have also been highly variable, ranging from nitrogen-limited to phosphorus-limited conditions. However, the vast majority of calculated ratios suggest nutrient-balanced conditions within the lake. The positive slope of the regression line suggests that South Lake Triplet is becoming more phosphorus-limited over time, and the calculated p-value of 0.0284 indicates that the increase is statistically significant.

A graphical comparison of mean monthly concentrations of total phosphorus in South Lake Triplet is given on Figure 2-13. Peaks in total phosphorus concentrations within the lake appear to occur during spring and wet season conditions, with lower phosphorus concentrations during remaining portions of the year. This pattern is somewhat unusual, and suggests that both runoff and internal recycling processes may be significant contributors to phosphorus loadings in South Lake Triplet.

A summary of water quality characteristics measured in South Lake Triplet from 1993-2011 as part of the City of Casselberry lake monitoring program is given in Table 2-9. Surface water collected in South Lake Triplet has been approximately neutral to slightly alkaline in pH, with values similar to those measured in Queens Mirror Lake. South Lake Triplet is also relatively poorly buffered, with a mean alkalinity value of only 36.2 mg/l, approximately 20% lower than alkalinity values measured in Queens Mirror Lake.

Similar to Queens Mirror Lake, South Lake Triplet is also characterized by variable but generally low values of ammonia and $NO_x$. Organic nitrogen is clearly the dominant nitrogen species in South Lake Triplet, comprising more than 90% of the total nitrogen present within the lake. South Lake Triplet is also characterized by highly variable concentrations of phosphorus species, although the mean concentrations for SRP and total phosphorus in South Lake Triplet are slightly lower than values measured in Queens Mirror Lake. The mean SRP concentration of 5 μg/l reflects a moderately elevated value for this parameter. The mean total phosphorus concentration of 47 μg/l is also somewhat elevated, although lower than the mean value measured in Queens Mirror Lake.



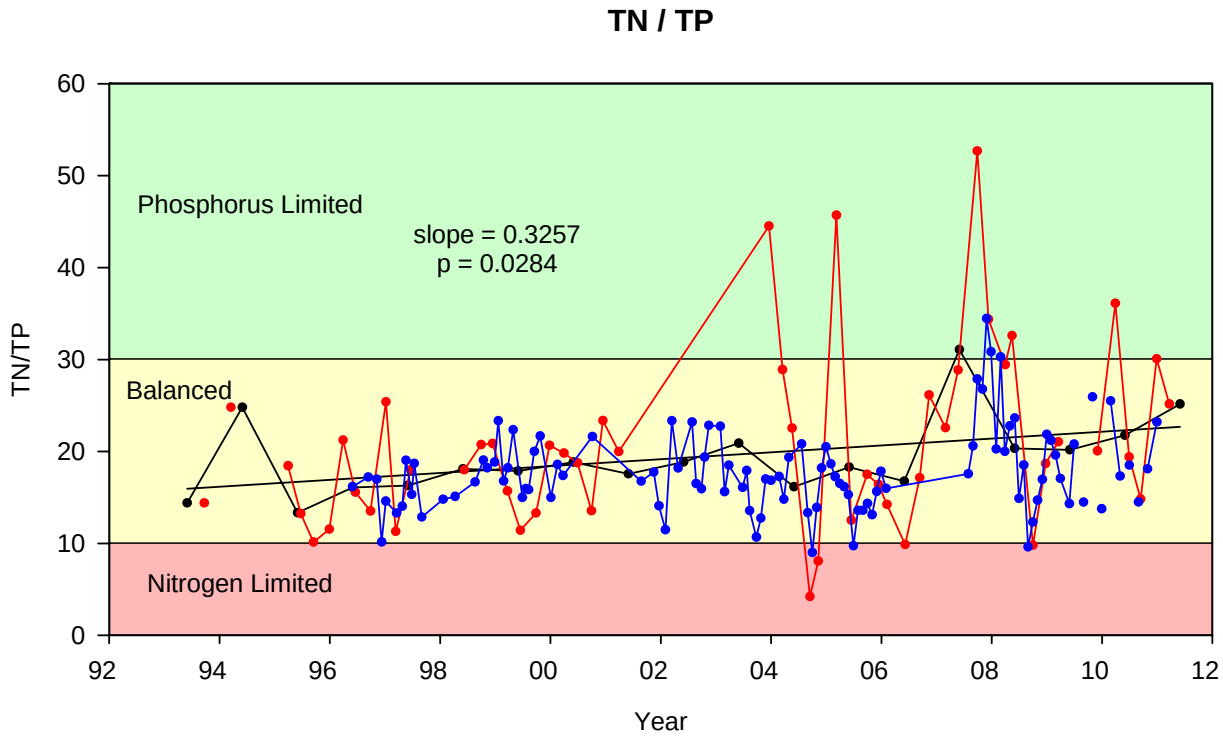




Figure 2-12. Trends in TSI and TN/TP Ratios in South Lake Triplet from 1993-2011.

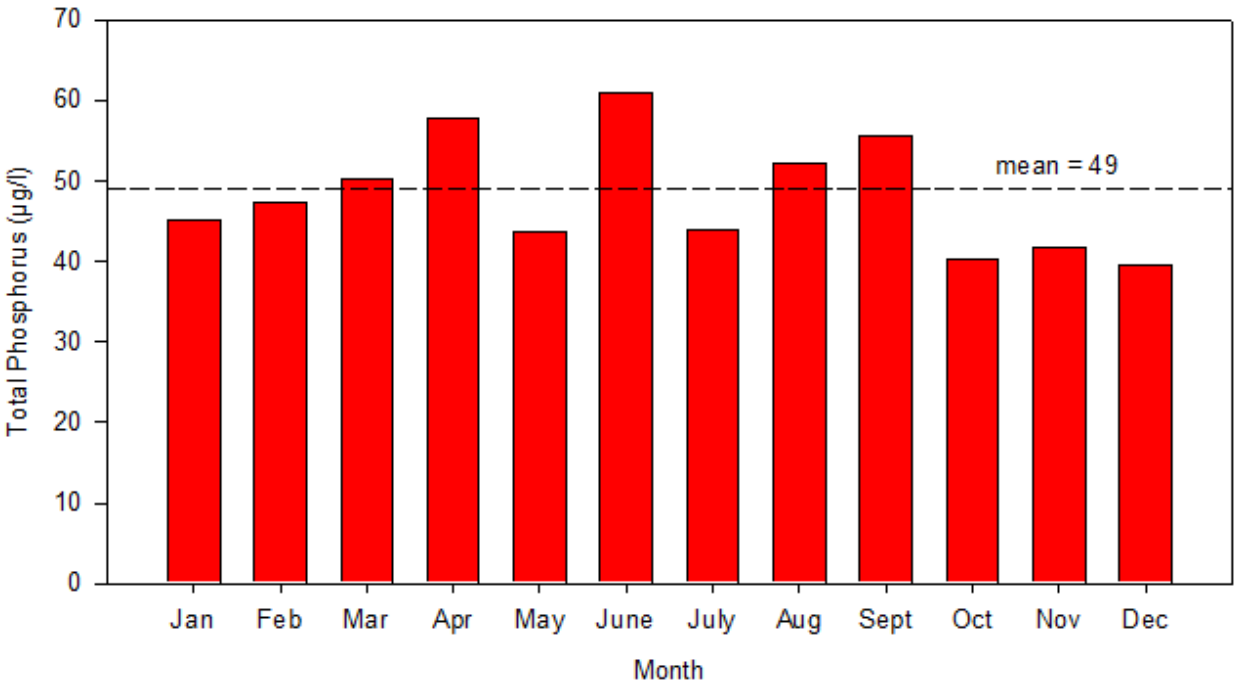



Figure 2-13. Mean Monthly Concentrations of Total Phosphorus in South Lake Triplet from 1993-2011.

South Lake Triplet is typically characterized by moderate levels of turbidity, high color, and a relatively high BOD value. Chlorophyll-a concentrations have been highly variable, ranging from moderate to extremely elevated. The mean chlorophyll-a concentration of 28.7 $mg/m^3$ is substantially lower than the mean chlorophyll-a value measured in Queens Mirror Lake, although still reflecting a relatively high value. Fecal coliform counts in South Lake Triplet have been highly variable, although virtually all measured values are less than the applicable Class III criterion for this parameter.

In general, South Lake Triplet has been characterized by extremely low levels for each of the measured heavy metals. The mean heavy metal concentrations summarized on Table 2-9 easily meet the applicable Class III criteria for these parameters.

A graphical summary of mean seasonal vertical field profiles collected in South Lake Triplet from 1998-2011 are given on Figure 2-14. In general, no significant thermal stratification has been observed in South Lake Triplet, with only a slight decrease in temperature with increasing water depth. A general trend of decreasing pH with increasing water depth has been observed in the lake during virtually all monitoring events. Similar to the pattern exhibited by Queens Mirror Lake, the most elevated pH levels are observed during fall, spring, and winter conditions, with the lowest pH values observed during summer conditions. In general, measured conductivity values in South Lake Triplet are uniform throughout the water column. However,

increases in conductivity at the water-sediment interface have been frequently observed during fall conditions, suggesting that internal recycling may be significant during this time. Dissolved oxygen concentrations in the lake typically decrease with increasing water depth. Dissolved oxygen concentrations are lowest near the water-sediment interface during spring and fall conditions, with mean dissolved oxygen concentrations of approximately 1mg/l or less during these periods.

**TABLE 2-9**

**SUMMARY OF WATER QUALITY CHARACTERISTICS IN SOUTH LAKE TRIPLET FROM 1993-2011 (Data Source: City of Casselberry)**

| PARAMETER | UNITS | MINIMUM | MAXIMUM | MEAN |
|---|---|---|---|---|
| pH | s.u. | 6.30 | 8.66 | 7.33 |
| Secchi Depth | m | 0.38 | 1.15 | 0.72 |
| Alkalinity | mg/l | 12.7 | 51.7 | 36.2 |
| $NH_3$-N | µg/l | <5 | 287 | 35 |
| $NO_x$-N | µg/l | <5 | 87 | 7 |
| Organic Nitrogen | µg/l | 408 | 1584 | 879 |
| Total Nitrogen | µg/l | 421 | 1873 | 923 |
| SRP | µg/l | <1 | 62 | 5 |
| Total Phosphorus | µg/l | 5 | 113 | 47 |
| Turbidity | NTU | 1.1 | 33.7 | 6.4 |
| Color | Co-Pt units | 21 | 284 | 93 |
| BOD | mg/l | <2 | 52 | 5.2 |
| Chlorophyll-a | $mg/m^3$ | 5.5 | 129 | 28.7 |
| Fecal Coliform | #/100 ml | 2 | 570 | 53 |
| Cadmium | µg/l | <1 | 3 | 0.8 |
| Chromium | µg/l | <5 | 9 | 3.0 |
| Copper | µg/l | <1 | 7 | 2.3 |
| Iron | µg/l | 2 | 570 | 177 |
| Lead | µg/l | < 3 | < 3 | < 3 |
| Zinc | µg/l | 1 | 150 | 14 |

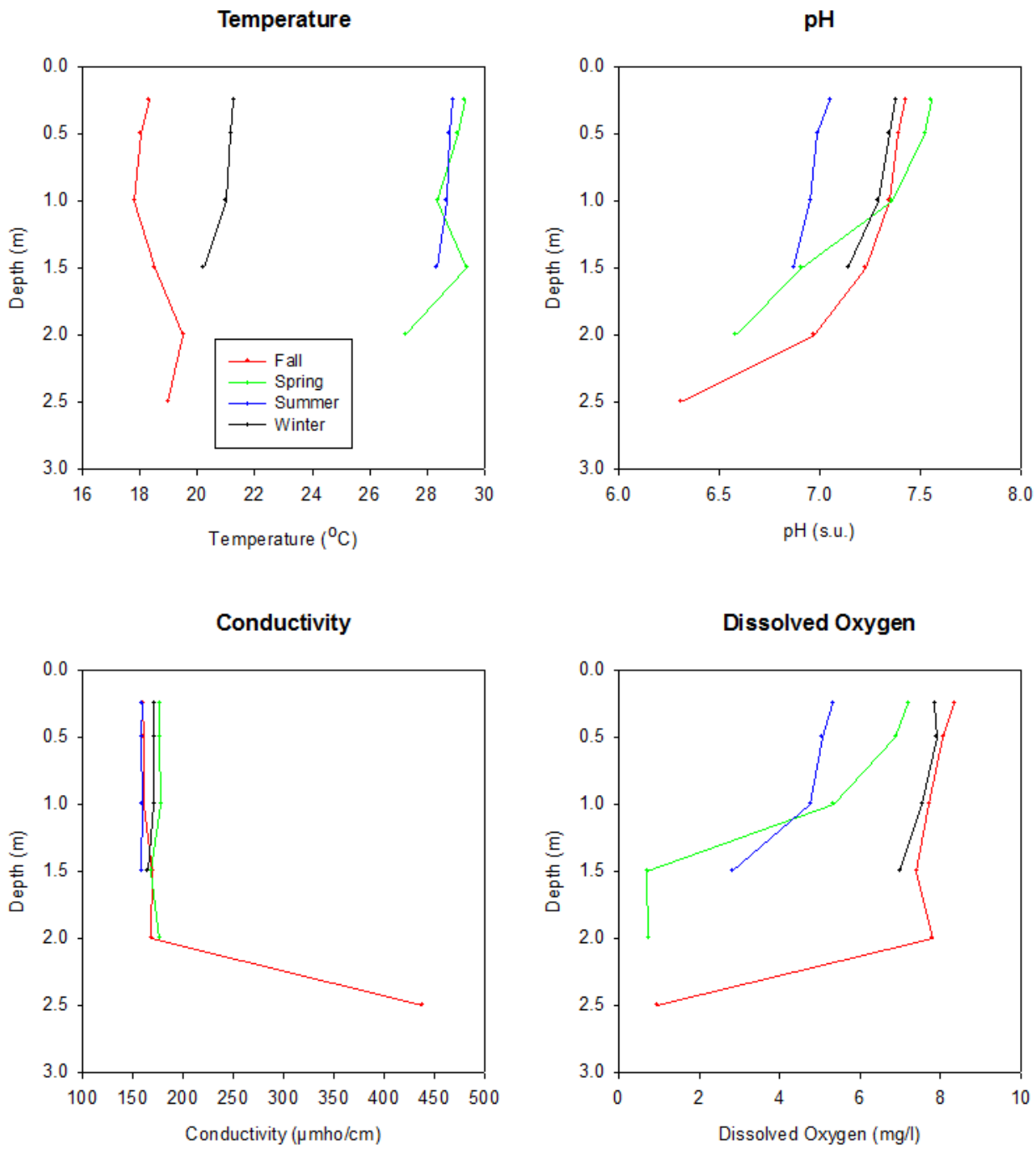



Figure 2-14. Mean Seasonal Vertical Field Profiles Collected in South Lake Triplet from 1998-2011.

### 2.2.4 Middle Lake Triplet

Trends in concentrations of total nitrogen and total phosphorus in Middle Lake Triplet from 1993-2011 are illustrated on Figure 2-15. Measured concentrations of total nitrogen in Middle Lake Triplet have ranged from approximately 500-1900 μg/l, although the majority of measured values appear to range from approximately 500-1200 μg/l, reflecting good to moderate nitrogen concentrations. The negative slope of the regression trend line indicates that total nitrogen concentrations are decreasing over time, and the calculated p-value of 0.0580 indicates that the trend is statistically significant.

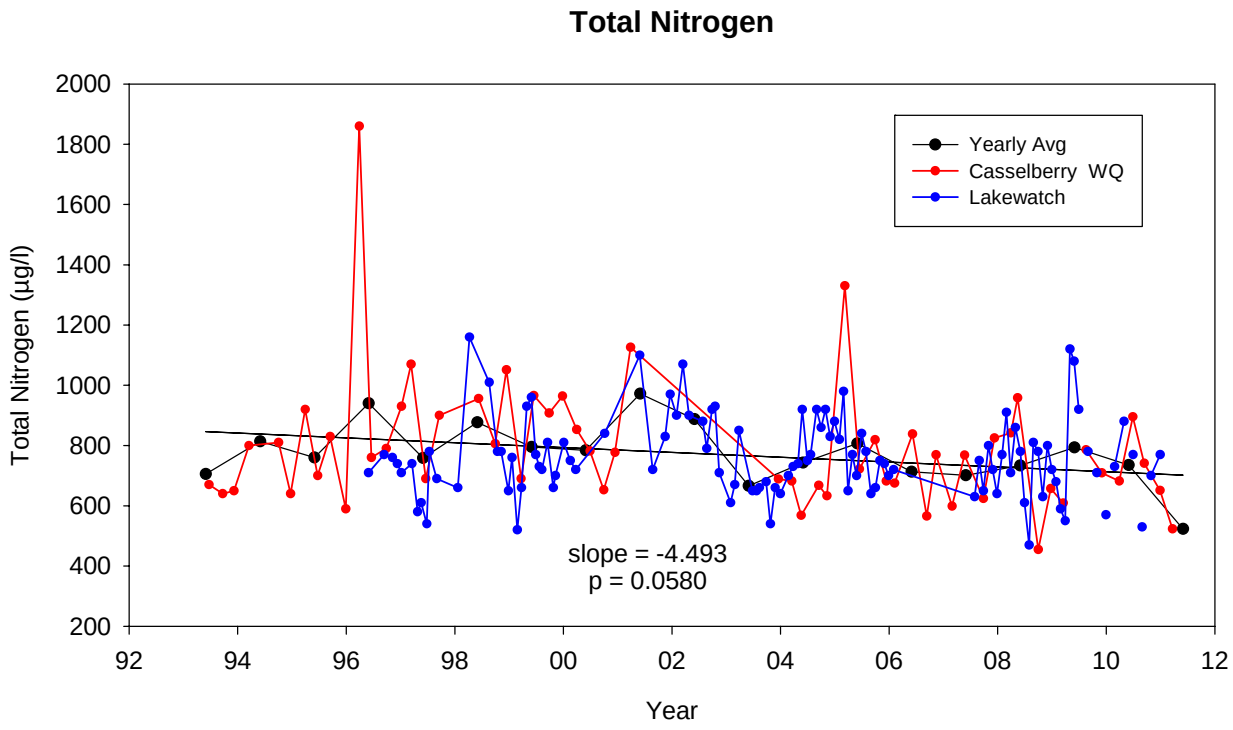
Total phosphorus concentrations in Middle Lake Triplet have been highly variable over time, ranging from approximately 5-95 μg/l. The vast majority of total phosphorus measurements appear to fall within the range of 20-60 μg/l, reflecting moderate to poor phosphorus concentrations. The negative slope of the regression line for the data suggests that total phosphorus concentrations in Middle Lake Triplet have decreased over time, and the calculated p-value of 0.0931 indicates that the trend is statistically significant.

Trends in concentrations of chlorophyll-a and Secchi disk depth in Middle Lake Triplet from 1993-2011 are illustrated on Figure 2-16. Measured chlorophyll-a concentrations in Middle Lake Triplet have been highly variable over time, ranging from approximately 1-65 $mg/m^3$. However, the vast majority of measured chlorophyll-a concentrations appear to fall within the range of approximately 5-40 $mg/m^3$, reflecting good to poor concentration levels. The negative slope of the regression line suggests that chlorophyll-a concentrations in Middle Lake Triplet are decreasing over time, and the calculated p-value of 0.1022 indicates that the declining trend is statistically significant.

A relatively low degree of variability has been observed in measured Secchi disk depths in Middle Lake Triplet which have ranged from approximately 0.3-1.5 m. However, the vast majority of measured values appear to fall within the range of 0.6-1.2 m, reflecting poor to fair water clarity. The negative slope of the regression line suggests that Secchi disk depths in Middle Lake Triplet have decreased over time, although the calculated p-value of 0.6044 indicates that the trend is not statistically significant.

Trends in TSI and TN/TP ratios in Middle Lake Triplet from 1993-2011 are illustrated on Figure 2-17. Calculated TSI values in Middle Lake Triplet have ranged from oligotrophic to hypereutrophic, although the vast majority of measured values appear to fall within the range of oligotrophic to eutrophic. The TSI index in Middle Lake Triplet appears to be declining over time, and the calculated p-value of 0.0192 indicates that the declining trend is statistically significant.

Calculated TN/TP ratios in Middle Lake Triplet have been highly variable over the available period of record, ranging from nitrogen-limited to phosphorus-limited conditions. However, the vast majority of calculated ratios have indicated either balanced or phosphorus-limited conditions. The positive slope of the regression line suggests that Middle Lake Triplet is becoming more phosphorus-limited over time, and the calculated p-value of 0.0007 indicates that the increasing trend in TN/TP ratios is statistically significant.



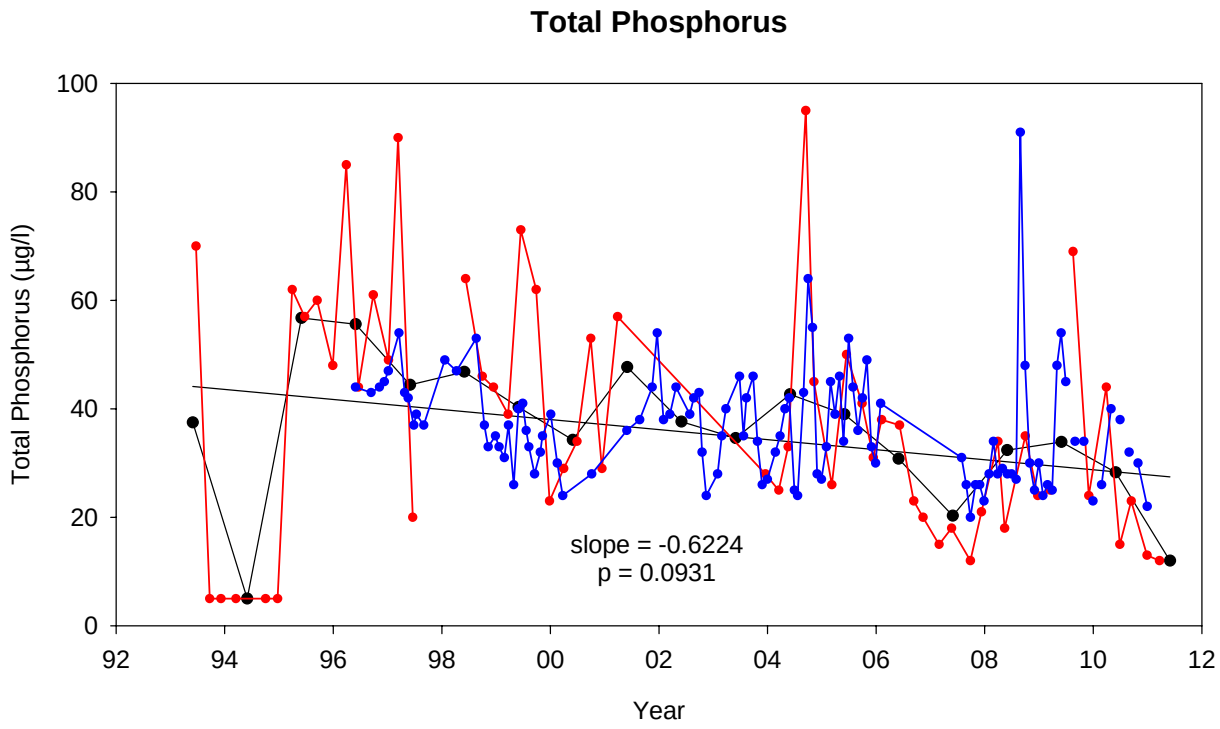




Figure 2-15. Trends in Concentrations of Total Nitrogen and Total Phosphorus in Middle Lake Triplet from 1993-2011.

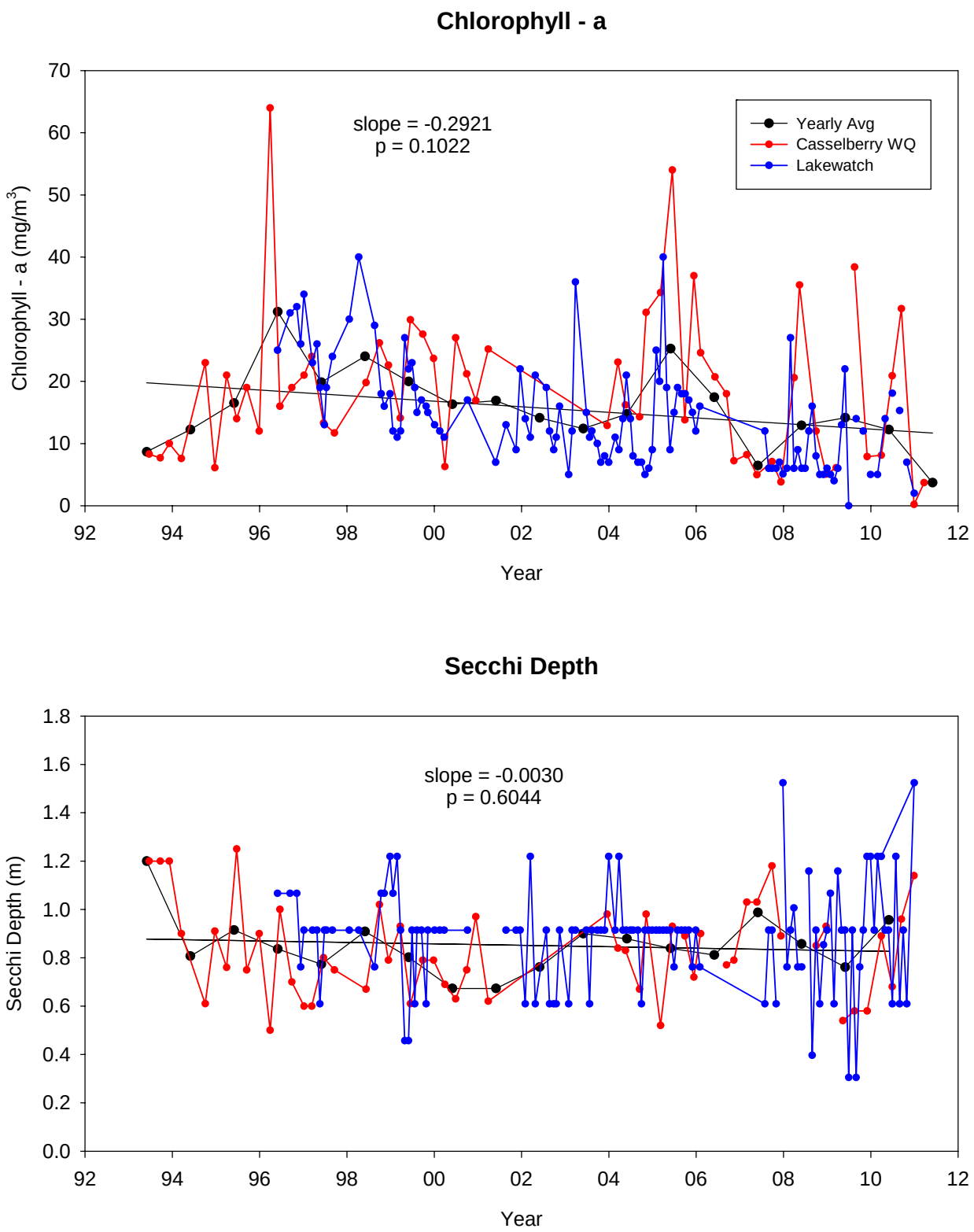
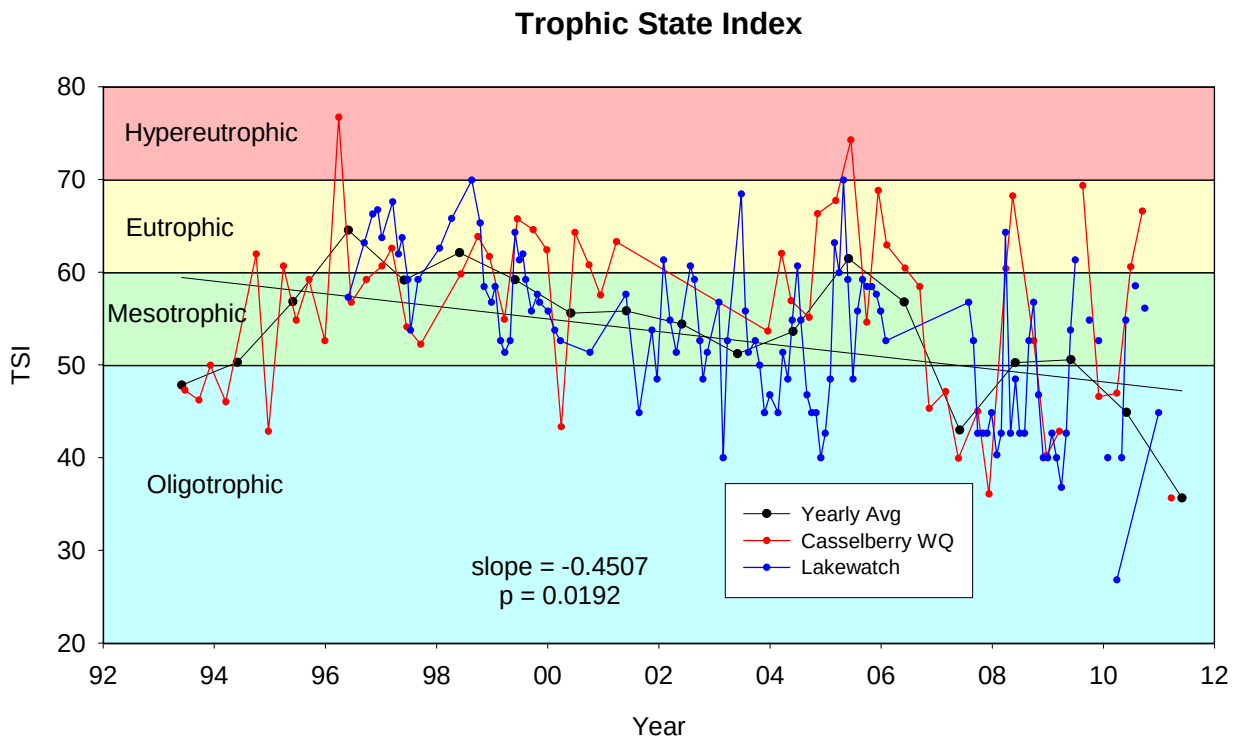



Figure 2-16. Trends in Concentrations of Chlorophyll-a and Secchi Disk Depth in Middle Lake Triplet from 1993-2011.



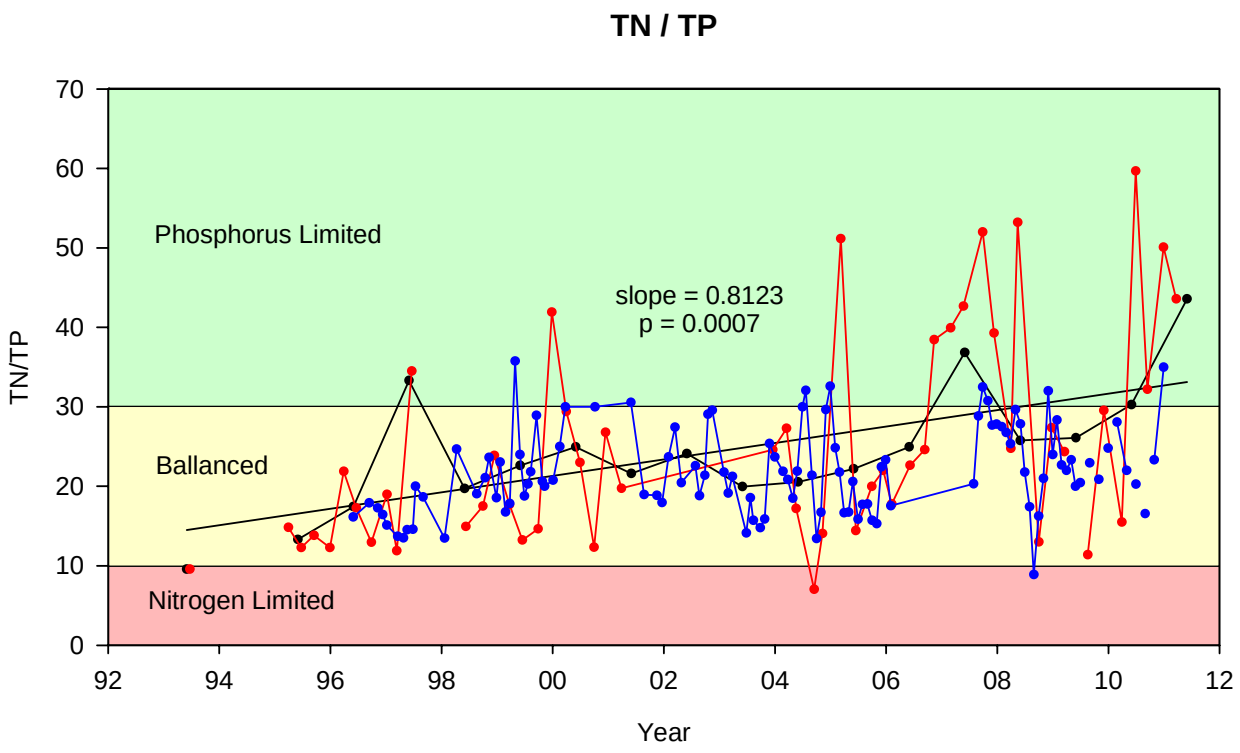




Figure 2-17. Trends in TSI and TN/TP Ratios in Middle Lake Triplet from 1993-2011.

A comparison of mean monthly concentrations of total phosphorus in Middle Lake Triplet from 1993-2011 is given on Figure 2-18. The trend in monthly concentrations of total phosphorus in Middle Lake Triplet is similar to the trend in monthly phosphorus concentrations observed in South Lake Triplet, with the most elevated levels of total phosphorus observed during spring and wet season conditions. These conditions suggest that both runoff and internal recycling may be significant contributors to phosphorus loadings in Middle Lake Triplet.

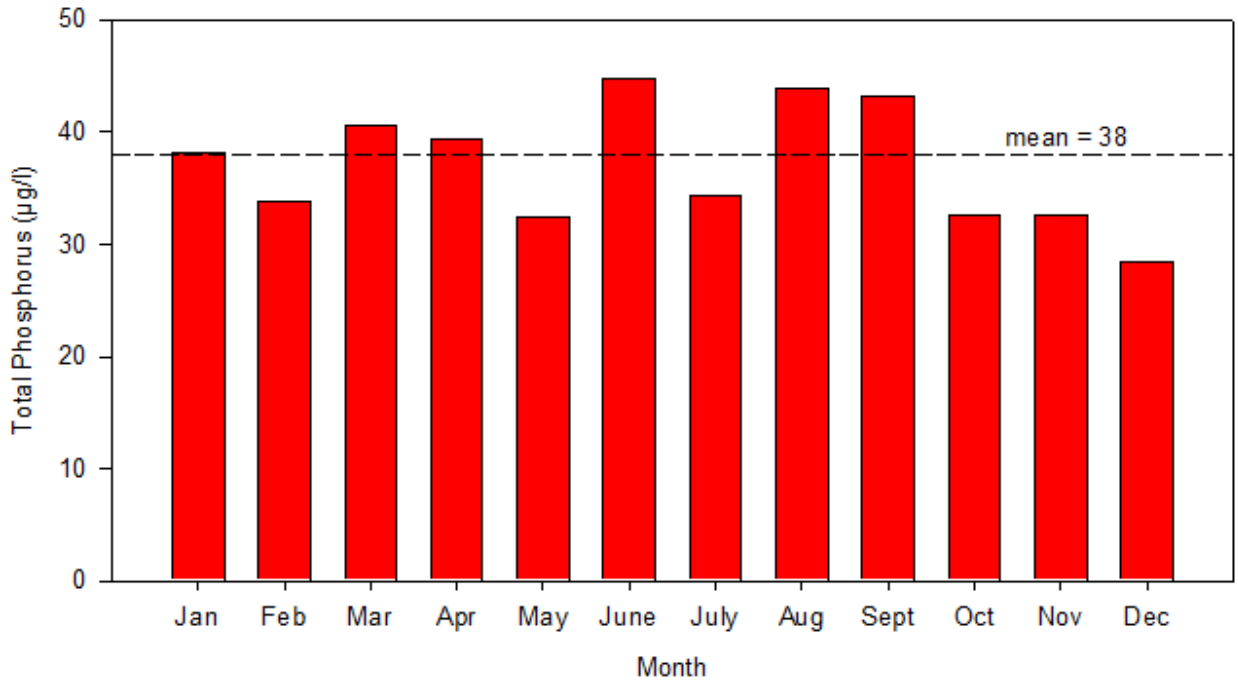



Figure 2-18. Mean Monthly Concentrations of Total Phosphorus in Middle Lake Triplet from 1993-2011.

A summary of water quality characteristics in Middle Lake Triplet from 1993-2011, based upon samples collected as part of the City of Casselberry lake monitoring program, is given on Table 2-10. Surface water in Middle Lake Triplet has ranged from neutral to slightly alkaline in pH, with pH values similar to those measured in South Lake Triplet and Queens Mirror Lake. Middle Lake Triplet also appears to be relatively poorly buffered, as reflected by the mean alkalinity value of 35.4 mg/l.

Similar to the trends observed in Queens Mirror Lake and South Lake Triplet, Middle Lake Triplet is characterized by highly variable but generally low levels of ammonia and $NO_x$. The dominant nitrogen species within the lake is organic nitrogen which comprises more than 95% of the total nitrogen present in the water column.

**TABLE 2-10**

**SUMMARY OF WATER QUALITY CHARACTERISTICS IN MIDDLE LAKE TRIPLET FROM 1993-2011 (Data Source: City of Casselberry)**

| PARAMETER | UNITS | MINIMUM | MAXIMUM | MEAN |
|---|---|---|---|---|
| pH | s.u. | 6.30 | 8.79 | 7.33 |
| Secchi Depth | m | 0.50 | 1.25 | 0.84 |
| Alkalinity | mg/l | 12.6 | 47.7 | 35.4 |
| $NH_3$-N | µg/l | <5 | 333 | 39 |
| $NO_x$-N | µg/l | <5 | 118 | 11 |
| Organic Nitrogen | µg/l | 453 | 1860 | 798 |
| Total Nitrogen | µg/l | 455 | 2050 | 817 |
| SRP | µg/l | <1 | 42 | 3 |
| Total Phosphorus | µg/l | 5 | 95 | 36 |
| Turbidity | NTU | 1.0 | 60.6 | 6.8 |
| Color | Co-Pt units | 21 | 230 | 85 |
| BOD | mg/l | <2 | 62 | 4.9 |
| Chlorophyll-a | $mg/m^3$ | 2.0 | 64.0 | 18.9 |
| Fecal Coliform | #/100 ml | 2 | 570 | 34 |
| Cadmium | µg/l | <1 | 3 | 0.8 |
| Chromium | µg/l | <5 | 9 | 3.4 |
| Copper | µg/l | <1 | 8 | 3.0 |
| Iron | µg/l | 2 | 570 | 136 |
| Lead | µg/l | < 3 | < 3 | < 3 |
| Zinc | µg/l | 2 | 149 | 10 |

Measured SRP concentrations in Middle Lake Triplet have been highly variable, although the mean SRP concentration of 3 µg/l reflects a low to moderate value. Total phosphorus concentrations have also varied from low to extremely elevated, with the mean concentration of 36 µg/l reflecting an elevated concentration.

Measured concentrations of turbidity, color, and BOD have also been highly variable in Middle Lake Triplet. The mean turbidity value of 6.8 NTU reflects a moderately high turbidity for a lake system. Middle Lake Triplet is also highly colored, with a mean color concentration of 85 Pt-Co units. The mean BOD concentration of 4.9 mg/l is a relatively high value for a lake system which typically are characterized by BOD concentrations of 2-3 mg/l or less.

Measured concentrations of chlorophyll-a in Middle Lake Triplet have ranged from low to elevated during the lake monitoring program. The overall mean chlorophyll-a concentration of 18.9 $mg/m^3$ reflects a moderately elevated value. Fecal coliform counts have also been variable in Middle Lake Triplet, although the vast majority of values easily meet the applicable Class III criteria.

In general, low levels of heavy metals have been observed in Middle Lake Triplet during virtually all of the field monitoring events. The mean values for heavy metals listed in Table 2-10 easily meet the applicable criteria for heavy metals in Class III recreational waters.

A graphical comparison of mean seasonal vertical field profiles collected in Middle Lake Triplet from 1998-2011 is given in Figure 2-19. In general, no significant thermal stratification was observed in Middle Lake Triplet during any of the field monitoring events, presumably due to the shallow water depth within the lake. A slight decrease in pH was observed with increasing water depth, similar to the trends observed in the previous lakes. Similar to the pattern observed in Queens Mirror Lake and South Lake Triplet, the most elevated pH levels in Middle Lake Triplet were observed during fall, spring, and winter conditions, with the lowest pH values observed during summer. Relatively uniform conductivity values were observed in Middle Lake Triplet during virtually all of the field monitoring events. Dissolved oxygen concentrations in the lake generally decrease slowly with increasing water depth. Well oxygenated conditions were observed in Middle Lake Triplet during fall, summer, and winter conditions. However, near-anoxic conditions were observed near the sediment-water interface during spring conditions.

### 2.2.5 North Lake Triplet

Trends in concentrations of total nitrogen and total phosphorus in North Lake Triplet from 1993-2011 are illustrated on Figure 2-20. A wide range of total nitrogen concentrations have been measured in North Lake Triplet, ranging from approximately 50-1700 μg/l. However, the vast majority of measured total nitrogen concentrations appear to fall within the range of 600-1200 μg/l, reflecting good to moderate nitrogen levels. The negative slope of the regression line suggests that total nitrogen concentrations are decreasing over time, and the calculated p-value of 0.0927 indicates that the declining trend is statistically significant.

Measured total phosphorus concentrations in North Lake Triplet have also been highly variable over time, ranging from approximately 5-120 μg/l. However, the vast majority of measured values appear to fall within the range of 20-60 μg/l, reflecting fair to poor total phosphorus concentrations. The negative slope of the regression line suggests that phosphorus concentrations in North Lake Triplet have decreased over time, although the calculated p-value of 0.6289 indicates that the declining trend is not statistically significant.

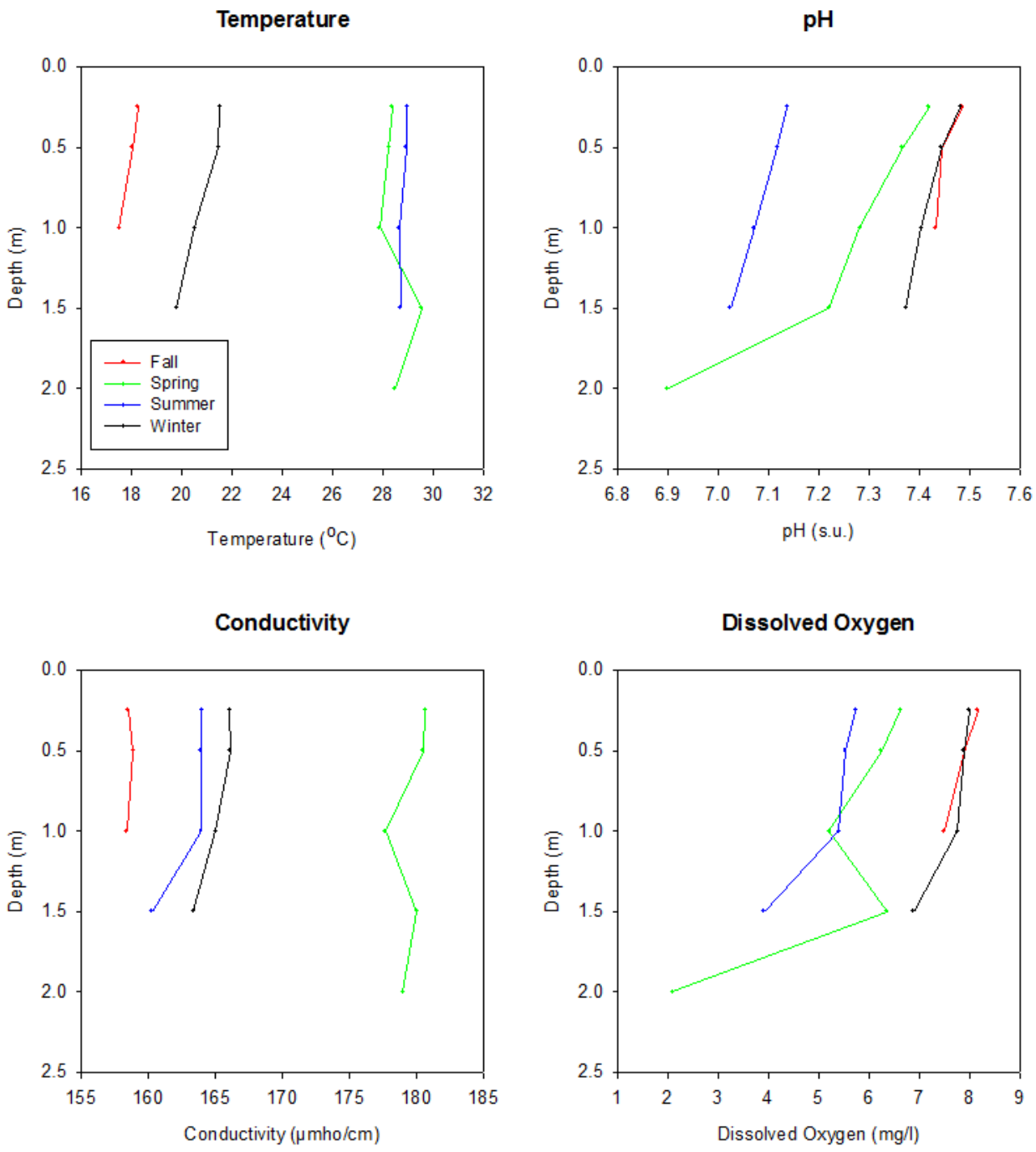
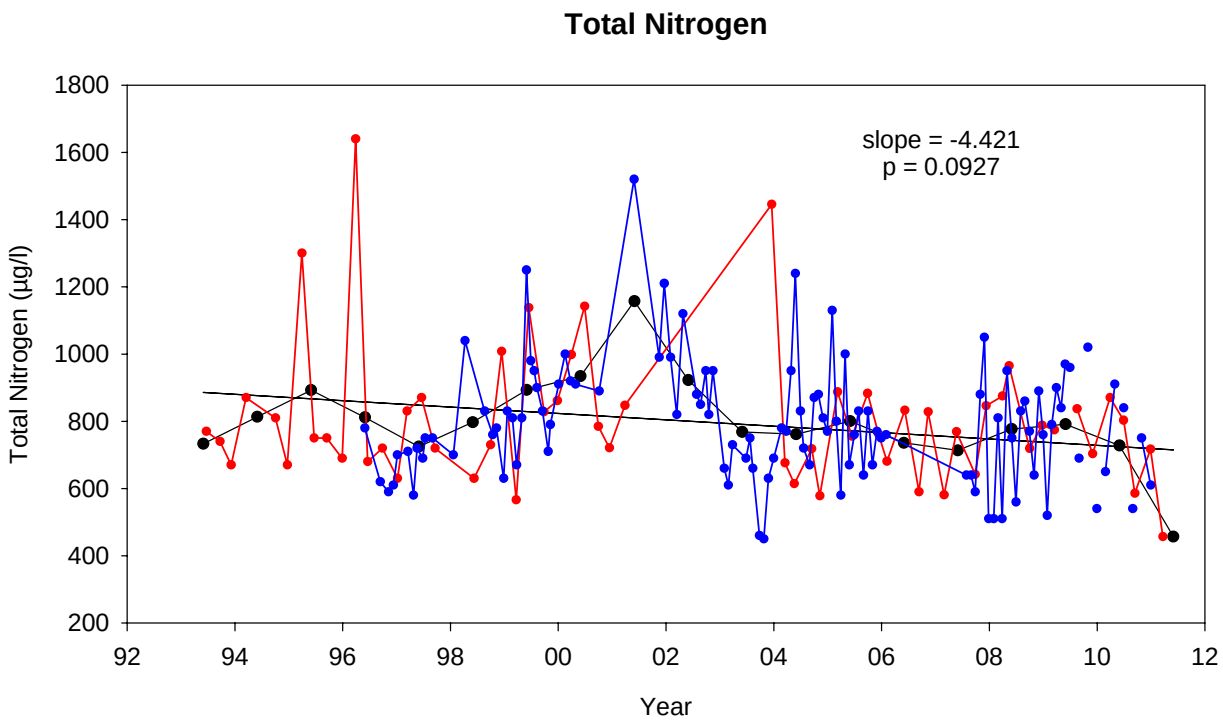



Figure 2-19. Mean Seasonal Vertical Field Profiles Collected in Middle Lake Triplet from 1998-2011.



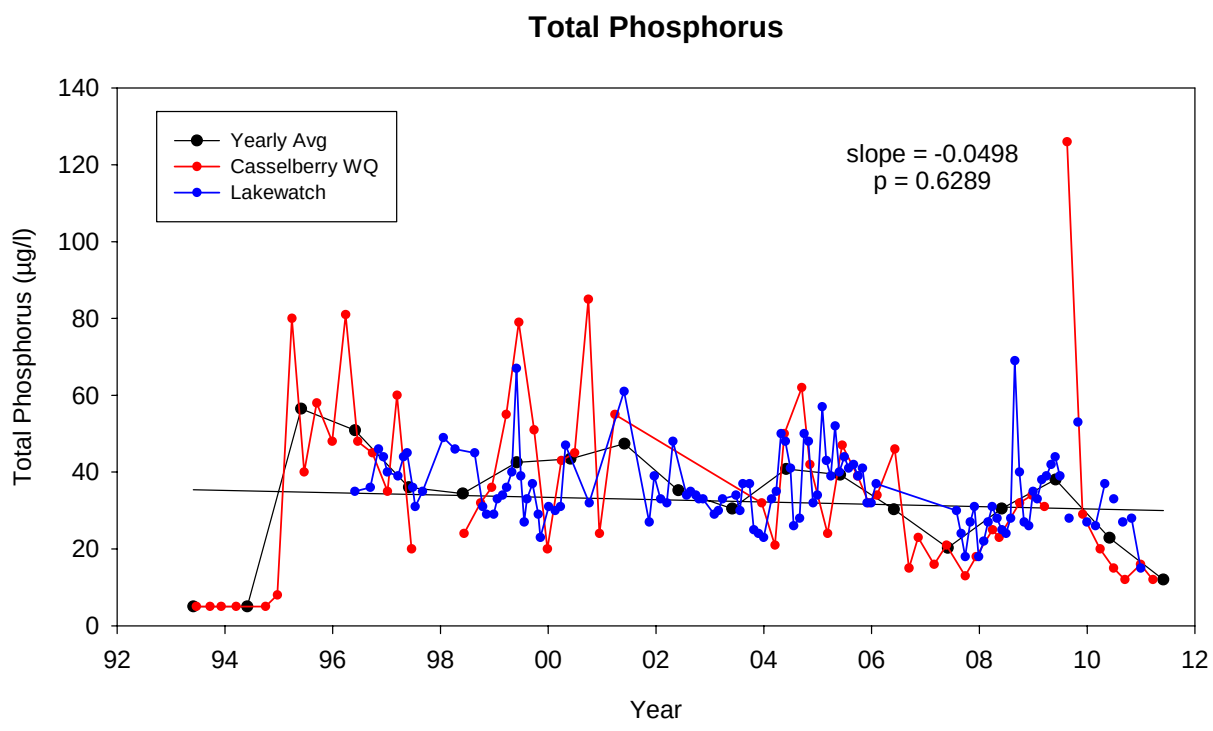




Figure 2-20. Trends in Concentrations of Total Nitrogen and Total Phosphorus in North Lake Triplet from 1993-2011.

Trends in measured concentrations of chlorophyll-a and Secchi disk depth in North Lake Triplet from 1993-2011 are illustrated on Figure 2-21. Chlorophyll-a concentrations within the lake have been highly variable over the period of record, ranging from approximately 2-70 $mg/m^3$. However, the vast majority of chlorophyll-a concentrations appear to fall within the range of approximately 5-40 $mg/m^3$, indicating good to poor water quality conditions. The negative slope of the regression line indicates a trend of declining chlorophyll-a concentrations over time, and the calculated p-value of 0.1384 indicates that the trend is statistically significant.

Similar to the trends observed in South Lake Triplet and Middle Lake Triplet, Secchi disk depths in North Lake Triplet have been relatively consistent over time, ranging from approximately 0.5-1.8 m, with the vast majority of measured values ranging from approximately 0.5-1.2 m. Secchi disk depth in this range are considered to reflect poor to moderate water clarity. The positive slope of the regression line suggests that Secchi disk depth is increasing in North Lake Triplet over time, and the calculated p-value of 0.0964 indicates that the increasing trend is statistically significant.

A summary of trends in TSI and TN/TP ratios in North Lake Triplet from 1993-2011 is given in Figure 2-22. TSI values in North Lake Triplet have ranged from oligotrophic to hypereutrophic over the available period of record. However, the vast majority of calculated TSI values fall within the range of oligotrophic to eutrophic. The negative slope of the regression line suggests that TSI values are decreasing in North Lake Triplet over time, and the calculated p-value of 0.0761 indicates that the declining trend is statistically significant.

Based upon the calculated TN/TP ratios, North Lake Triplet has exhibited nitrogen-limited, balanced, and phosphorus-limited conditions over the available period of record, although the vast majority of TN/TP ratios suggest balanced or phosphorus-limited conditions. The positive slope of the regression line suggests that North Lake Triplet is becoming more phosphorus-limited over time, and the calculated p-value of <0.0001 indicates that the trend is highly significant.

A comparison of mean monthly phosphorus concentrations in North Lake Triplet is given on Figure 2-23. Similar to the trends observed in Middle Lake Triplet and South Lake Triplet, North Lake Triplet appears to exhibit the highest phosphorus concentrations during spring and wet season conditions. This pattern suggests that both runoff and internal processes are responsible for regulating phosphorus concentrations in North Lake Triplet.

A tabular summary of water quality characteristics in North Lake Triplet from 1993-2011, collected as part of the City of Casselberry lake water monitoring program, is given in Table 2-11. Measured pH values in North Lake Triplet have ranged from neutral to slightly alkaline, with values similar to those observed in the previous lakes. The water column also appears to be relatively poorly buffered, with a mean alkalinity of 38.3 mg/l.

North Lake Triplet is characterized by variable but generally low values of ammonia and $NO_x$, with concentrations similar to those observed in each of the previous lakes. The dominant nitrogen species in North Lake Triplet is organic nitrogen which comprises well over 95% of the total nitrogen measured in the lake.

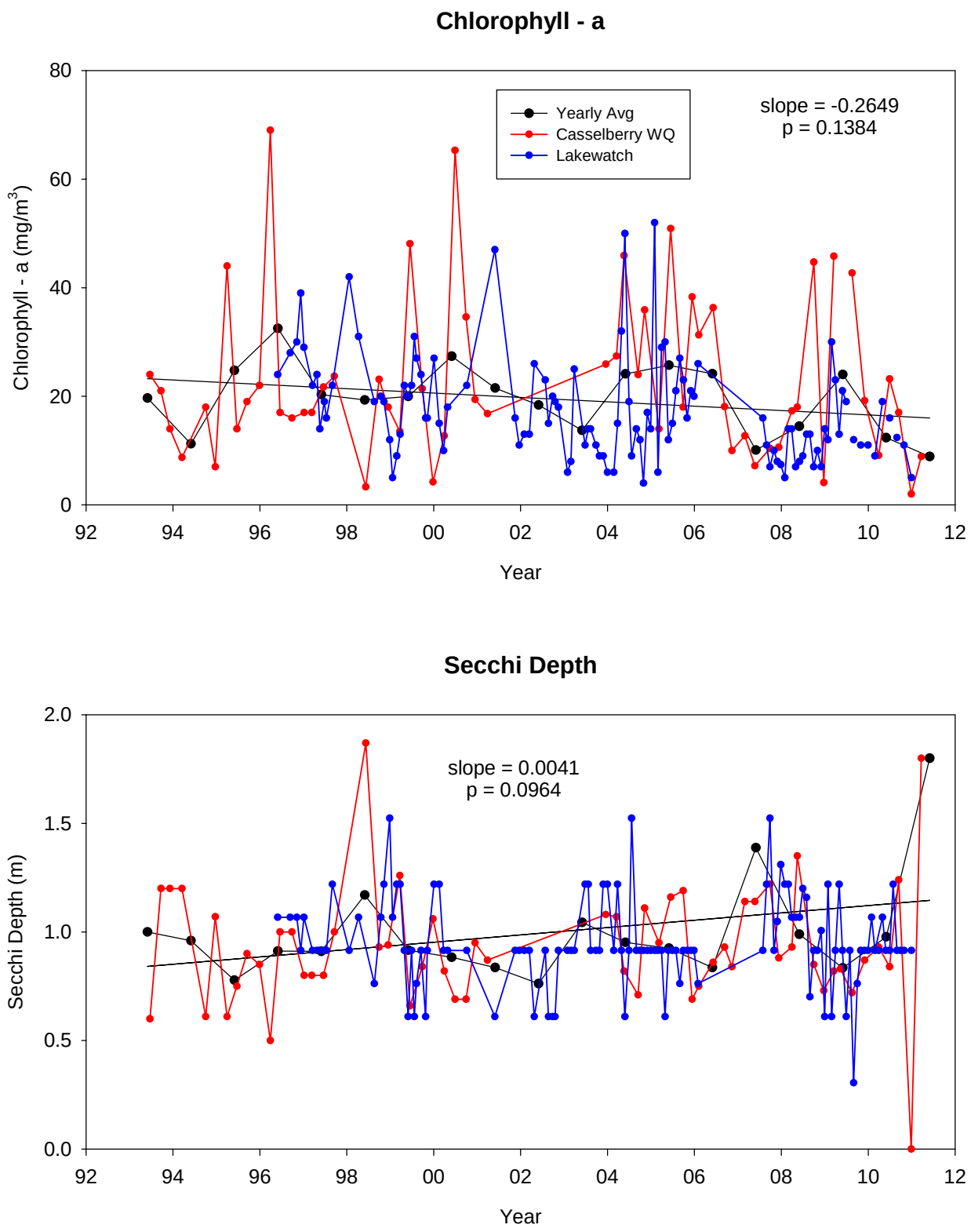



Figure 2-21. Trends in Concentrations of Chlorophyll-a and Secchi Disk Depth in North Lake Triplet from 1993-2011.

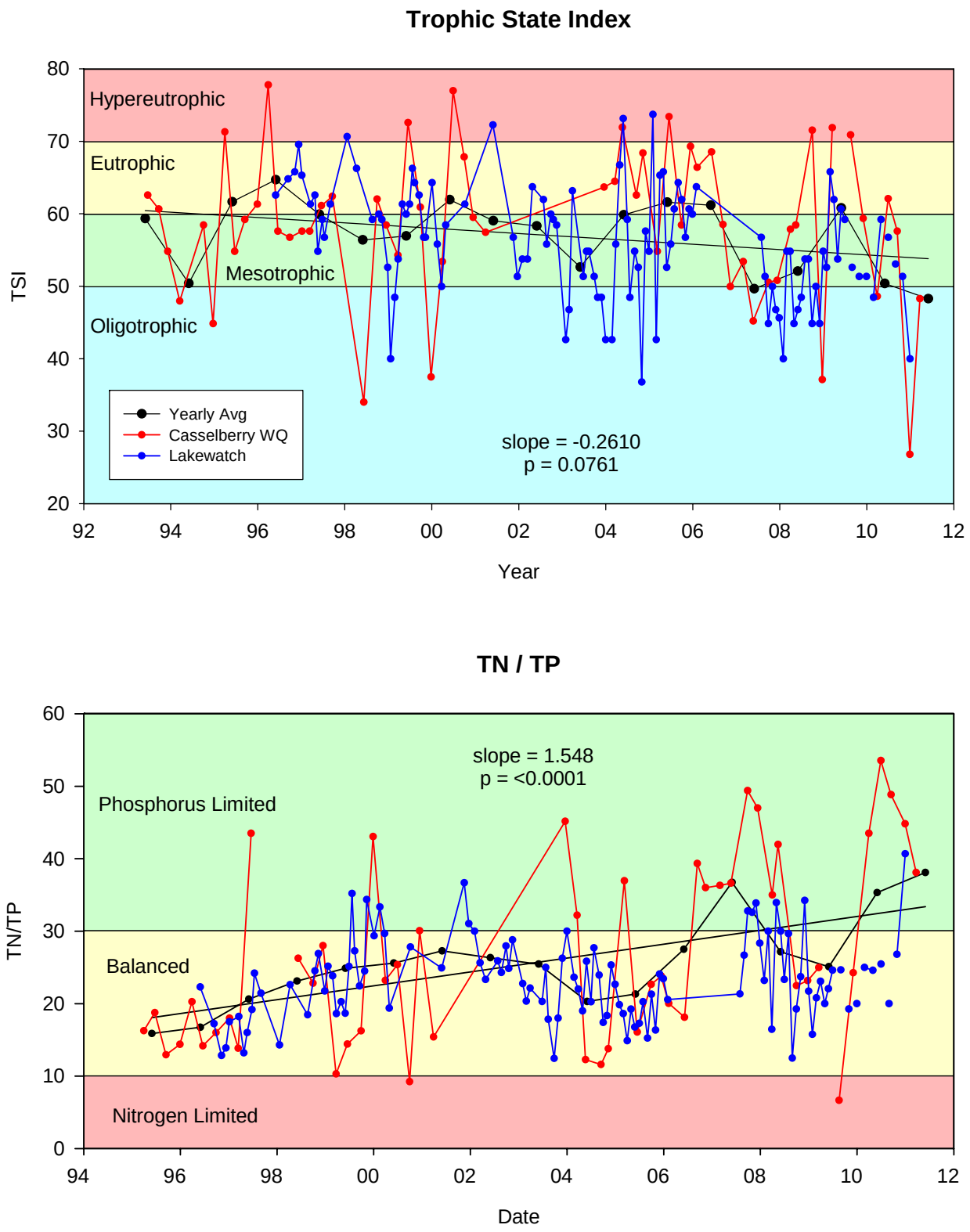



Figure 2-22. Trends in TSI and TN/TP Ratios in North Lake Triplet from 1993-2011.

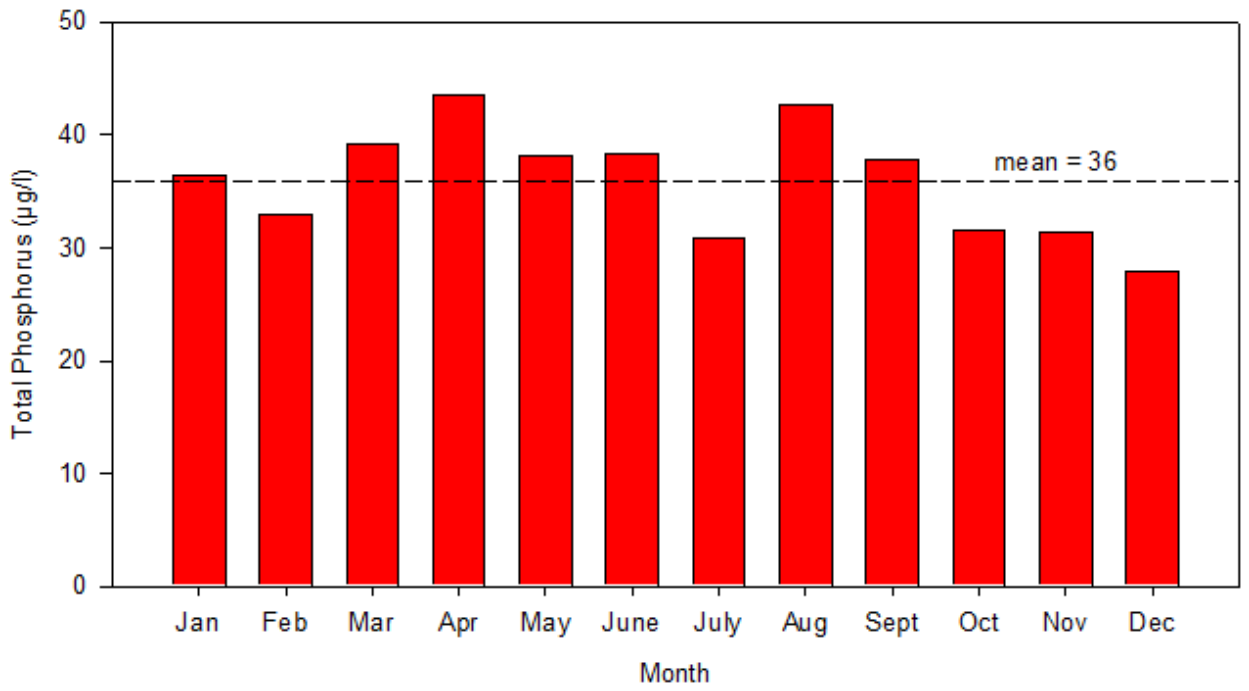



Figure 2-23. Mean Monthly Concentrations of Total Phosphorus in North Lake Triplet from 1993-2011.

Surface water in North Lake Triplet has been characterized by highly variable concentrations of both SRP and total phosphorus. However, the mean SRP concentration of 3 µg/l reflects a relatively low concentration for this parameter. The mean total phosphorus concentration of 33 µg/l reflects a moderately elevated concentration.

In general, measured concentrations of turbidity, color, and BOD have been highly variable in North Lake Triplet. However, on an average basis, surface water in North Lake Triplet is characterized by moderately elevated levels of turbidity and BOD. Water within the lake is also highly colored, although with lower color concentrations than observed in the upstream lakes. North Lake Triplet has also been characterized by highly variable concentrations of chlorophyll-a and fecal coliform bacteria. The mean chlorophyll-a concentration reflects a moderately elevated value, while the mean fecal coliform value is relatively low.

Surface water in North Lake Triplet is generally characterized by low levels of heavy metals during a majority of the monitoring events. The mean metal concentrations summarized on Table 2-11 easily meet the applicable Class III criteria for heavy metals.

**TABLE 2-11**

**SUMMARY OF WATER QUALITY CHARACTERISTICS IN NORTH LAKE TRIPLET FROM 1993-2011 (Data Source: City of Casselberry)**

| PARAMETER | UNITS | MINIMUM | MAXIMUM | MEAN |
|---|---|---|---|---|
| pH | s.u. | 6.12 | 8.6 | 7.42 |
| Secchi Depth | m | 0.50 | 1.87 | 0.95 |
| Alkalinity | mg/l | 14.0 | 62.4 | 38.3 |
| $NH_3$-N | µg/l | <5 | 265 | 41 |
| $NO_x$-N | µg/l | <5 | 151 | 13 |
| Organic Nitrogen | µg/l | 457 | 1640 | 805 |
| Total Nitrogen | µg/l | 457 | 1680 | 819 |
| SRP | µg/l | <1 | 46 | 3 |
| Total Phosphorus | µg/l | 5 | 85 | 33 |
| Turbidity | NTU | 0.9 | 18.0 | 4.2 |
| Color | Co-Pt units | 21 | 180 | 73 |
| BOD | mg/l | <2 | 67 | 4.5 |
| Chlorophyll-a | $mg/m^3$ | 2.0 | 69.0 | 22.7 |
| Fecal Coliform | #/100 ml | 2 | 570 | 24 |
| Cadmium | µg/l | <1 | 2 | 0.8 |
| Chromium | µg/l | <5 | 12 | 3.3 |
| Copper | µg/l | <1 | 13 | 3.3 |
| Iron | µg/l | 2 | 570 | 114 |
| Lead | µg/l | < 3 | < 3 | < 3 |
| Zinc | µg/l | 1 | 69 | 9 |

A graphical summary of mean seasonal vertical field profiles collected in North Lake Triplet from 1998-2011 is given on Figure 2-24. In general, no evidence of significant thermal stratification was observed in North Lake Triplet during any of the monitoring events. A slight decrease in pH was observed with increasing water depth, with higher pH values measured during fall, spring, and winter conditions, and slightly lower pH values observed during summer conditions. Measured conductivity values were relatively uniform in upper portions of the water column, with increases in conductivity observed near the water-sediment interface during spring and winter conditions, although the increase in conductivity was substantially more pronounced during spring conditions. In general, dissolved oxygen concentrations decreased slowly with increasing water depth, with aerobic conditions maintained throughout the water column during fall, summer, and winter conditions. Periods of low dissolved oxygen at the water-sediment interface were observed during spring conditions which appear to correspond with the increase in conductivity observed in this same portion of the lake.

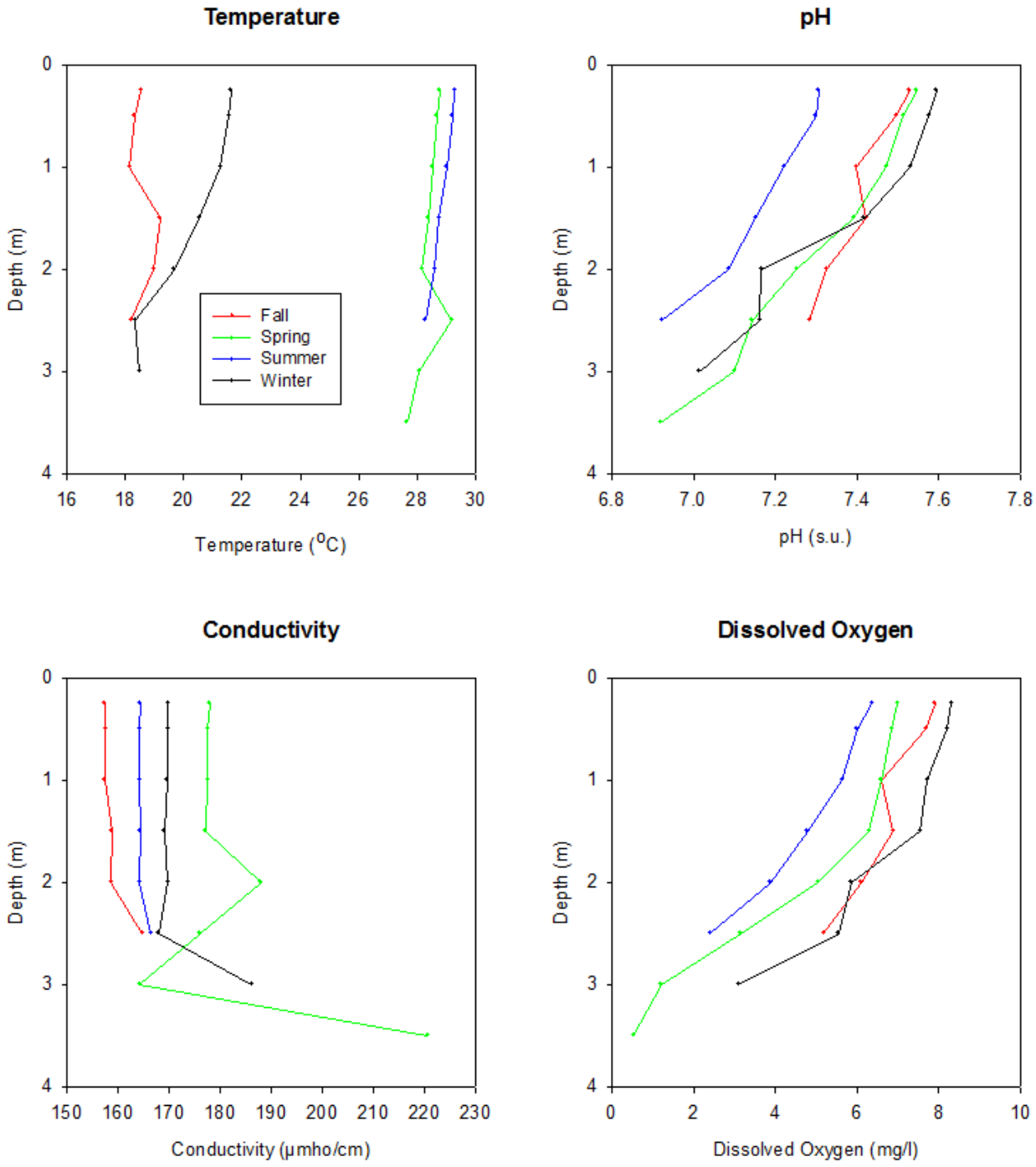



Figure 2-24. Mean Seasonal Vertical Field Profiles Collected in North Lake Triplet from 1998-2011.

### 2.2.6 Water Quality Comparison

A comparison of mean water quality characteristics in Queens Mirror Lake and the Triplet Chain-of-Lakes from 1993-2011 is given on Table 2-12. The data are arranged in columns which reflect the flow pattern from Queens Mirror Lake to South Lake Triplet to Middle Lake Triplet to North Lake Triplet. In general, concentrations of both total nitrogen and total phosphorus appear to decrease in a steady progression from Queens Mirror Lake to North Lake Triplet. In addition, measured Secchi disk depth appears to improve during migration through the chain-of-lakes. A pattern of decreasing color, BOD, chlorophyll-a, and fecal coliform bacteria is also apparent during migration through the chain, although the patterns are not as distinct as observed for nutrients. No distinct pattern of increasing or decreasing concentrations is apparent for heavy metals since the concentrations are already extremely low in value.

**TABLE 2-12**

**COMPARISON OF MEAN WATER QUALITY CHARACTERISTICS IN QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES FROM 1993-2011 (Data Source: City of Casselberry)**

| PARAMETER | UNITS | QUEENS MIRROR LAKE | SOUTH LAKE TRIPLET | MIDDLE LAKE TRIPLET | NORTH LAKE TRIPLET |
|---|---|---|---|---|---|
| pH | s.u. | 7.32 | 7.33 | 7.33 | 7.42 |
| Secchi Depth | m | 0.78 | 0.72 | 0.84 | 0.95 |
| Alkalinity | mg/l | 41.3 | 36.2 | 35.4 | 38.3 |
| $NH_3$-N | µg/l | 32 | 35 | 39 | 41 |
| $NO_x$-N | µg/l | 9 | 7 | 11 | 13 |
| Organic Nitrogen | µg/l | 903 | 879 | 798 | 805 |
| Total Nitrogen | µg/l | 914 | 923 | 817 | 819 |
| SRP | µg/l | 7 | 5 | 3 | 3 |
| Total Phosphorus | µg/l | 52 | 47 | 36 | 33 |
| Turbidity | NTU | 5.4 | 6.4 | 6.8 | 4.2 |
| Color | Co-Pt units | 112 | 93 | 85 | 73 |
| BOD | mg/l | 6.2 | 5.2 | 4.9 | 4.5 |
| Chlorophyll-a | $mg/m^3$ | 42.5 | 28.7 | 18.9 | 22.7 |
| Fecal Coliform | #/100 ml | 49 | 53 | 34 | 24 |
| Cadmium | µg/l | 1.2 | 0.8 | 0.8 | 0.8 |
| Chromium | µg/l | 2.8 | 3.0 | 3.4 | 3.3 |
| Copper | µg/l | 3.4 | 2.3 | 3.0 | 3.3 |
| Iron | µg/l | 167 | 177 | 136 | 114 |
| Lead | µg/l | < 3 | < 3 | < 3 | < 3 |
| Zinc | µg/l | 10 | 14 | 10 | 9 |

## 2.3 Sediment Characteristics

Sediment core samples were collected in Queens Mirror Lake and South Lake Triplet by ERD to evaluate the characteristics of existing sediments and potential impacts on water quality within the lakes. Sediment core samples were collected at 26 separate locations within the two lakes during December 2010 and February 2011 by ERD personnel, with 10 samples collected in Queens Mirror Lake and 16 samples collected in South Lake Triplet. Locations of sediment sampling sites in Queens Mirror Lake are illustrated on Figure 2-25. Based on the lake surface area of 12.53 acres, sediment samples were collected at a rate of one sample for every 1.25 acres of lake area. Locations of sediment sampling sites in South Lake Triplet are illustrated on Figure 2-26. Based on the lake surface area of 23.29 acres, sediment samples were collected at a rate of one sample for every 1.46 acres of lake area.

### 2.3.1 Sampling Techniques

Sediment samples were collected at each of the 26 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 26 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.

### 2.3.2 Sediment Characterization and Speciation Techniques

Each of the 26 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 2-13.

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on each of the 26 collected sediment samples. The modified 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.

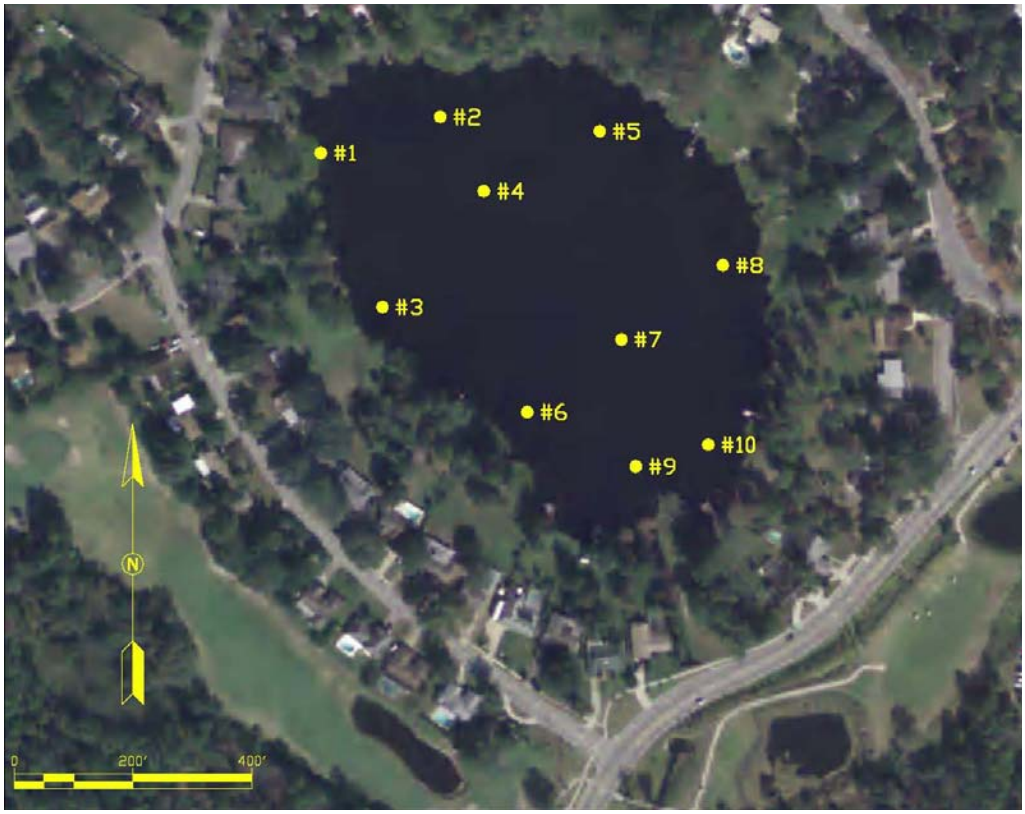



Figure 2-25. Locations of Sediment Monitoring Sites in Queens Mirror Lake.

Figure 2-26. Locations of Sediment Monitoring Sites in South Lake Triplet.

## TABLE 2-13

## 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.

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 2-27.

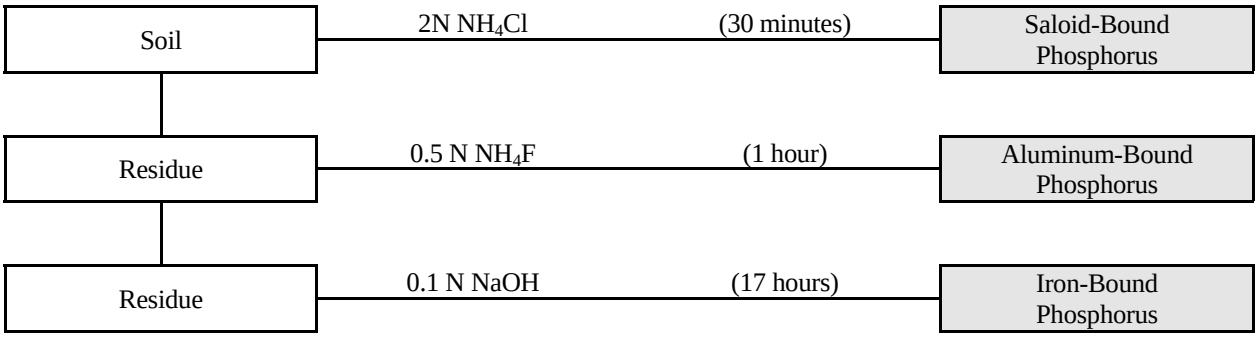



Figure 2-27. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

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.

### 2.3.3 Sediment Characteristics

#### 2.3.3.1 Visual Characteristics

Visual characteristics of sediment core samples were recorded for each of the 26 sediment samples collected in Queens Mirror Lake during February 2011, and in South Lake Triplet during December 2010. A summary of visual characteristics of sediment core samples collected in Queens Mirror Lake is given in Table 2-14. In general, a surficial layer of unconsolidated organic muck was observed in Queens Mirror Lake at each of the 10 sediment 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. Beneath this surficial layer, the sediments become more consolidated, with a consistency similar to pudding. These layers reflect older organic deposits in which most of the easily decomposable organic material has been oxidized, and the remaining organic deposits are resistant to further degradation. These layers typically do not resuspend into the water column except during relatively vigorous wind or boating activity on the lake. In most areas of the lake, fine brown sand is found beneath the consolidated muck layer, reflecting the parent material which forms the bottom of the lake. Photographs of typical sediment core characteristics in Queens Mirror Lake and South Lake Triplet are given on Figure 2-28.

Visual characteristics of sediment core samples collected in South Lake Triplet are given in Table 2-15. In general, a surficial layer of unconsolidated organic muck was observed in South Lake Triplet at 15 of the 16 monitoring sites, with measured depths ranging from 0-12 cm. This unconsolidated surficial layer is similar to the one observed in Queens Mirror Lake and is comprised primarily of fresh organic material. In most areas of the lake, the layer of unconsolidated organic muck lies on top of a layer of consolidated organic muck which extends from approximately 30-80 cm. The material beneath the consolidated muck layer consists of fine brown sand which forms the parent base material of the lake.

#### 2.3.3.2 General Sediment Characteristics

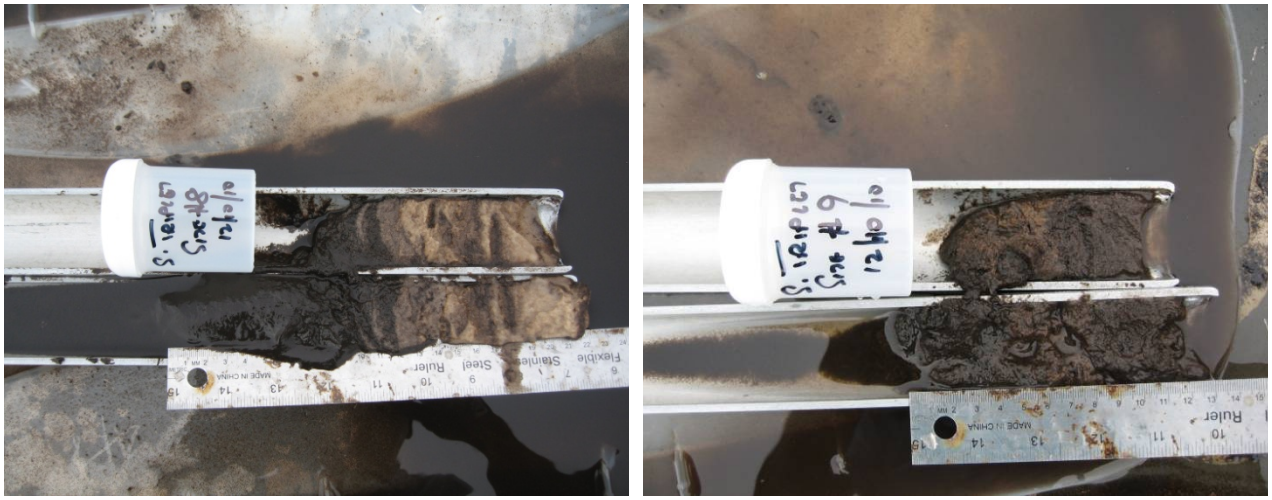
After return to the ERD Laboratory, the collected sediment core samples were evaluated for general sediment characteristics, including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphorus. A summary of general characteristics measured in each of the sediment core samples collected in Queens Mirror Lake and South Lake Triplet is given on Table 2-16.

## TABLE 2-14

## VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN QUEENS MIRROR LAKE ON FEBRUARY 4, 2011

| SITE NO. | LAYER (cm) | VISUAL APPEARANCE |
|---|---|---|
| 1 | 0 - 8 | Dark brown unconsolidated organic muck |
| | 8 - 51 | Dark brown consolidated organic muck |
| | > 51 | Brown fine sand with organics |
| 2 | 0 - 9 | Dark brown unconsolidated organic muck |
| | 9 - 46 | Dark brown consolidated organic muck |
| | > 46 | Brown fine sand with organics |
| 3 | 0 - 8 | Dark brown unconsolidated organic muck |
| | 8 - 26 | Dark brown consolidated organic muck |
| | > 26 | Brown fine sand with organics |
| 4 | 0 - 8 | Dark brown unconsolidated organic muck |
| | 8 - 44 | Dark brown consolidated organic muck |
| 5 | 0 - 4 | Dark brown unconsolidated organic muck |
| | 4 - 39 | Dark brown consolidated organic muck |
| | 39 - >48 | Brown fine sand with organics |
| 6 | 0 - 7 | Dark brown unconsolidated organic muck |
| | 7 - 30 | Dark brown consolidated organic muck |
| | 30 - >34 | Brown fine sand with organics |
| 7 | 0 - 8 | Dark brown unconsolidated organic muck |
| | 8 - 39 | Dark brown consolidated organic muck |
| | 39 - >44 | Brown fine sand with organics |
| 8 | 0 - 14 | Dark brown unconsolidated organic muck |
| | 14 - 51 | Dark brown consolidated organic muck |
| | 51 - >66 | Brown fine sand with organics |
| 9 | 0 - 1 | Dark brown unconsolidated organic muck |
| | 1 - 4 | Dark brown consolidated organic muck |
| | 4 - 12 | Brown fine sand with organics |
| | 12 - >35 | Brown fine sand with organics |
| 10 | 0 - 6 | Dark brown unconsolidated organic muck |
| | 6 - 49 | Dark brown consolidated organic muck |
| | 49 - >53 | Brown fine sand with organics |

Typical sediment core samples with deep organic muck deposits



Typical sediment core samples with thin organic muck deposits overlying sand

Figure 2-28. Photographs of Typical Sediment Characteristics in Queens Mirror Lake and South Lake Triplet.

# TABLE 2-15

## VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN SOUTH LAKE TRIPLET ON DECEMBER 10, 2010

| SITE NO. | LAYER (cm) | VISUAL APPEARANCE |
|---|---|---|
| 1 | 0 - 4 | Dark brown unconsolidated organic muck |
| | 4 - >66 | Dark brown consolidated organic muck |
| 2 | 0 - >21 | Brown fine sand with organics |
| 3 | 0 - 12 | Dark brown unconsolidated organic muck |
| | 12 - >74 | Dark brown consolidated organic muck |
| 4 | 0 - 14 | Dark brown unconsolidated organic muck |
| | 14 - >83 | Dark brown consolidated organic muck |
| 5 | 0 - 11 | Dark brown unconsolidated organic muck |
| | 11 - >81 | Dark brown consolidated organic muck |
| 6 | 0 - 16 | Dark brown unconsolidated organic muck |
| | 16 - 45 | Dark brown consolidated organic muck |
| | 45 - >57 | Brown fine sand with organics |
| 7 | 0 - 6 | Dark brown unconsolidated organic muck |
| | 6 - 48 | Dark brown consolidated organic muck |
| | 48 - >57 | Brown fine sand with organics |
| 8 | 0 - 9 | Dark brown unconsolidated organic muck |
| | 9 - >24 | Brown fine sand with organics |
| 9 | 0 - 2 | Dark brown unconsolidated organic muck |
| | 2 - >14 | Brown fine sand with organics |
| 10 | 0 - 3 | Dark brown unconsolidated organic muck |
| | 3 - 37 | Dark brown consolidated organic muck |
| | 37 - >61 | Brown fine sand with organics |
| 11 | 0 - 1 | Dark brown unconsolidated organic muck |
| | 1 - 46 | Dark brown consolidated organic muck |
| | 46 - >68 | Brown fine sand with organics |
| 12 | 0 - 3 | Dark brown unconsolidated organic muck |
| | 3 - 38 | Dark brown consolidated organic muck |
| | 38 - >51 | Brown fine sand with organics |
| 13 | 0 - 1 | Dark brown unconsolidated organic muck |
| | 1 - 30 | Dark brown consolidated organic muck |
| | 30 - >62 | Brown fine sand with organics |
| 14 | 0 - 2 | Dark brown unconsolidated organic muck |
| | 2 - >51 | Dark brown consolidated organic muck |
| 15 | 0 - 2 | Dark brown unconsolidated organic muck |
| | 2 - >38 | Dark brown consolidated organic muck |
| 16 | 0 - 2 | Dark brown unconsolidated organic muck |
| | 2 - >43 | Dark brown consolidated organic muck |

## TABLE 2-16

## GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN QUEENS MIRROR LAKE AND SOUTH LAKE TRIPLET

| LAKE | SITE | pH (s.u.) | MOISTURE CONTENT (%) | ORGANIC CONTENT (% dry wt.) | DENSITY ($g/cm^3$) | TOTAL NITROGEN ($\mu g/cm^3$) | TOTAL PHOSPHORUS ($\mu g/cm^3$) |
|---|---|---|---|---|---|---|---|
| Queens Mirror Lake | Site 1 | 6.07 | 94.3 | 76.1 | 1.02 | 824 | 140 |
| | Site 2 | 5.98 | 92.3 | 57.0 | 1.05 | 1266 | 100 |
| | Site 3 | 5.94 | 91.8 | 64.8 | 1.04 | 931 | 169 |
| | Site 4 | 5.69 | 93.5 | 62.7 | 1.04 | 1330 | 130 |
| | Site 5 | 5.57 | 93.2 | 63.9 | 1.04 | 1382 | 110 |
| | Site 6 | 5.74 | 88.7 | 45.2 | 1.09 | 1061 | 90 |
| | Site 7 | 5.63 | 92.9 | 61.0 | 1.04 | 1548 | 161 |
| | Site 8 | 5.79 | 92.7 | 70.0 | 1.03 | 801 | 156 |
| | Site 9 | 6.36 | 45.8 | 5.4 | 1.77 | 1342 | 57 |
| | Site 10 | 6.04 | 92.5 | 68.5 | 1.04 | 771 | 113 |
| | **Mean:** | **5.88** | **87.8** | **57.5** | **1.12** | **1126** | **123** |
| South Lake Triplet | Site 1 | 6.02 | 92.0 | 68.0 | 1.04 | 1402 | 166 |
| | Site 2 | 6.13 | 38.9 | 2.1 | 1.90 | 325 | 73 |
| | Site 3 | 5.93 | 92.4 | 66.7 | 1.04 | 1319 | 127 |
| | Site 4 | 5.94 | 90.0 | 70.2 | 1.04 | 2306 | 99 |
| | Site 5 | 6.01 | 91.9 | 66.4 | 1.04 | 2312 | 150 |
| | Site 6 | 6.16 | 93.4 | 69.1 | 1.03 | 2016 | 124 |
| | Site 7 | 6.07 | 93.2 | 67.4 | 1.03 | 1281 | 129 |
| | Site 8 | 6.29 | 85.5 | 23.9 | 1.17 | 745 | 111 |
| | Site 9 | 6.39 | 45.7 | 6.3 | 1.76 | 256 | 99 |
| | Site 10 | 5.99 | 92.5 | 67.7 | 1.04 | 1900 | 192 |
| | Site 11 | 6.07 | 90.4 | 63.2 | 1.05 | 952 | 155 |
| | Site 12 | 6.42 | 84.0 | 36.3 | 1.15 | 346 | 128 |
| | Site 13 | 6.02 | 89.2 | 48.1 | 1.08 | 883 | 139 |
| | Site 14 | 6.13 | 92.3 | 59.7 | 1.05 | 1162 | 126 |
| | Site 15 | 6.08 | 92.8 | 69.5 | 1.03 | 1768 | 130 |
| | Site 16 | 5.94 | 92.3 | 56.6 | 1.05 | 1886 | 158 |
| | **Mean:** | **6.10** | **84.8** | **52.6** | **1.16** | **1304** | **132** |

In general, sediments in both Queens Mirror Lake and South Lake Triplet were found to be slightly acidic in pH, with measured pH values ranging from 5.57-6.36 in Queens Mirror Lake, and from 5.93-6.42 in South Lake Triplet. These values are typical of pH measurements commonly observed in eutrophic urban lakes. Isopleths of pH in the top 10 cm of the sediments in Queens Mirror Lake and South Lake Triplet are illustrated on Figure 2-29. In general, northwestern and southeastern portions of Queens Mirror Lake are characterized by sediment pH values of approximately 6.0 or greater, with central portions of the lake characterized by pH values less than 6. In contrast, sediments in South Lake Triplet are characterized by pH values of approximately 6 or greater throughout virtually all portions of the lake. The observed differences in pH values between the two lake sediments may reflect a higher degree of decomposition occurring in Queens Mirror Lake compared with South Lake Triplet.

Measurements of sediment moisture content in Queens Mirror Lake and South Lake Triplet were found to be highly variable, with moisture contents ranging from 45.8-94.3% in Queens Mirror Lake, and from 38.9-93.4% in South Lake Triplet. Isopleths of sediment moisture content in Queens Mirror Lake and South Lake Triplet are illustrated on Figure 2-30. Areas of elevated moisture content are present in central and northern portions of Queens Mirror Lake, along with central and southern portions of South Lake Triplet. 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. Based upon the sediment moisture content isopleths illustrated on Figure 2-30, it appears that virtually all of the sediments in each of the two lakes consists primarily of organic muck.

Measured organic content in sediments within the two lakes were highly variable, ranging from 5.4-76.1% in Queens Mirror Lake, and from 2.1-70.2% in South Lake Triplet. Isopleths of sediment organic content in sediments of the two lakes are illustrated on Figure 2-31. 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, virtually all areas within Queens Mirror Lake and South Lake Triplet are characterized by organic muck sediments. The highest levels of organic content, ranging from approximately 50-70%, occur in central and northern portions of Queens Mirror Lake in areas which correspond with the elevated moisture content values illustrated on Figure 2-30. A similar pattern is also apparent in South Lake Triplet, with the most elevated organic contents observed in central and southern portions of the lake in areas which correspond to the areas of elevated moisture content illustrated on Figure 2-30.

Measured sediment density values can be useful in evaluating the general characteristics of sediments within a lake. Sediments with calculated wet density between 1.0-1.25 $g/cm^3$ are indicative of highly organic muck type sediments, while sediment densities of approximately 2.0 $g/cm^3$ or greater are indicative of sandy sediment conditions. Density values between 1.25-2.0 $g/cm^3$ are often indicative of mixtures of sand and muck. As indicated on Table 2-16, measured density values in Queens Mirror Lake ranged from 1.02-1.77 $g/cm^3$, reflecting sediments with characteristics of both muck and sandy muck. However, the overall mean sediment density of 1.12 $g/cm^3$ suggests that the sediments are primarily organic in nature. Measured sediment densities in South Lake Triplet ranged from 1.03-1.90 $g/cm^3$, with the mean density value of 1.16 $g/cm^3$ indicating primarily muck type sediments. Isopleths of sediment density in the two lakes are illustrated on Figure 2-32. Based upon the measured density values, sediments in central and northern portions of Queens Mirror Lake, as well as sediments in central and southern portions of South Lake Triplet, consist primarily of organic muck.

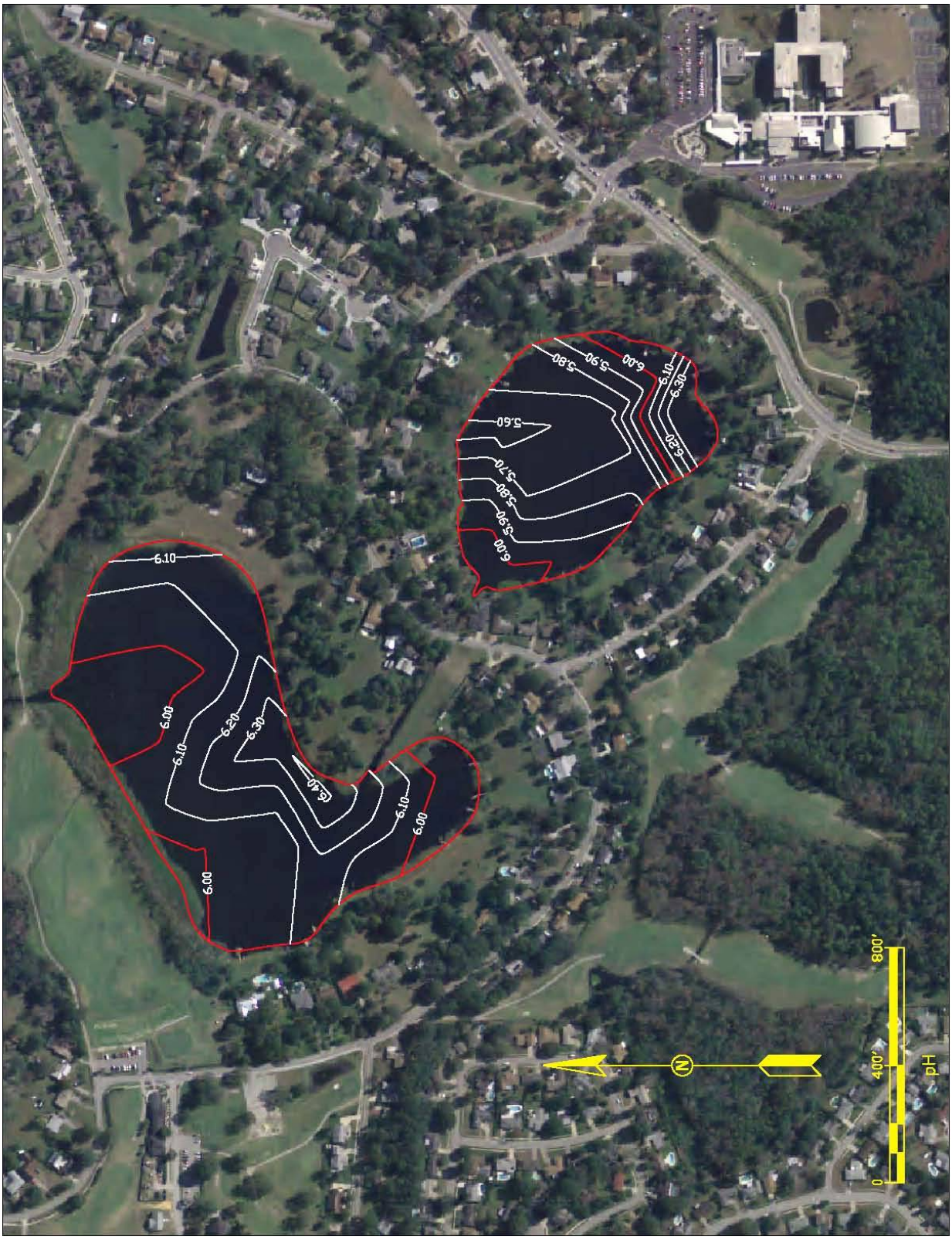



Figure 2-29. Isopleths of pH (s.u.) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

Figure 2-30. Isopleths of Moisture Content (%) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

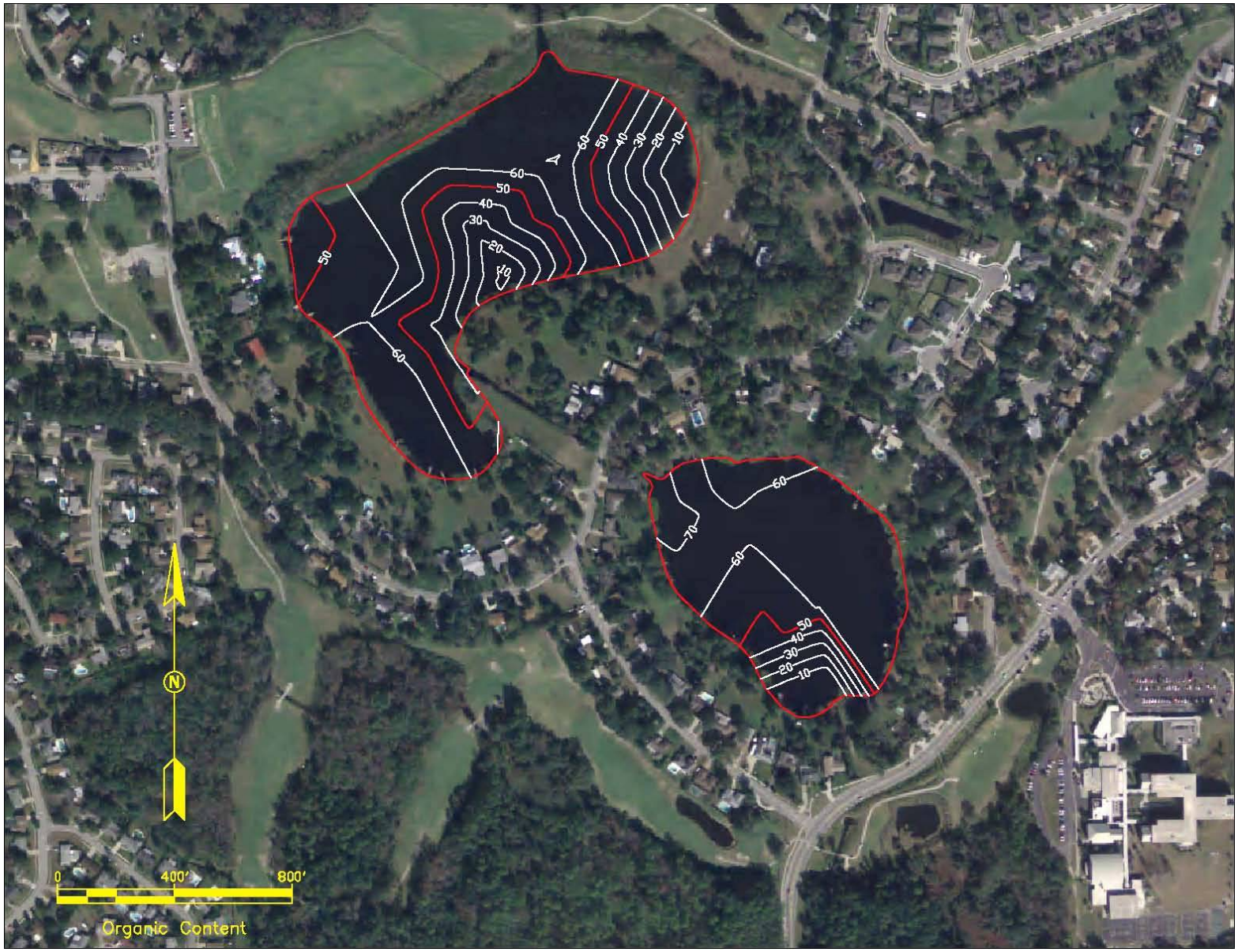



Figure 2-31. Isopleths of Organic Content (% of dry weight) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

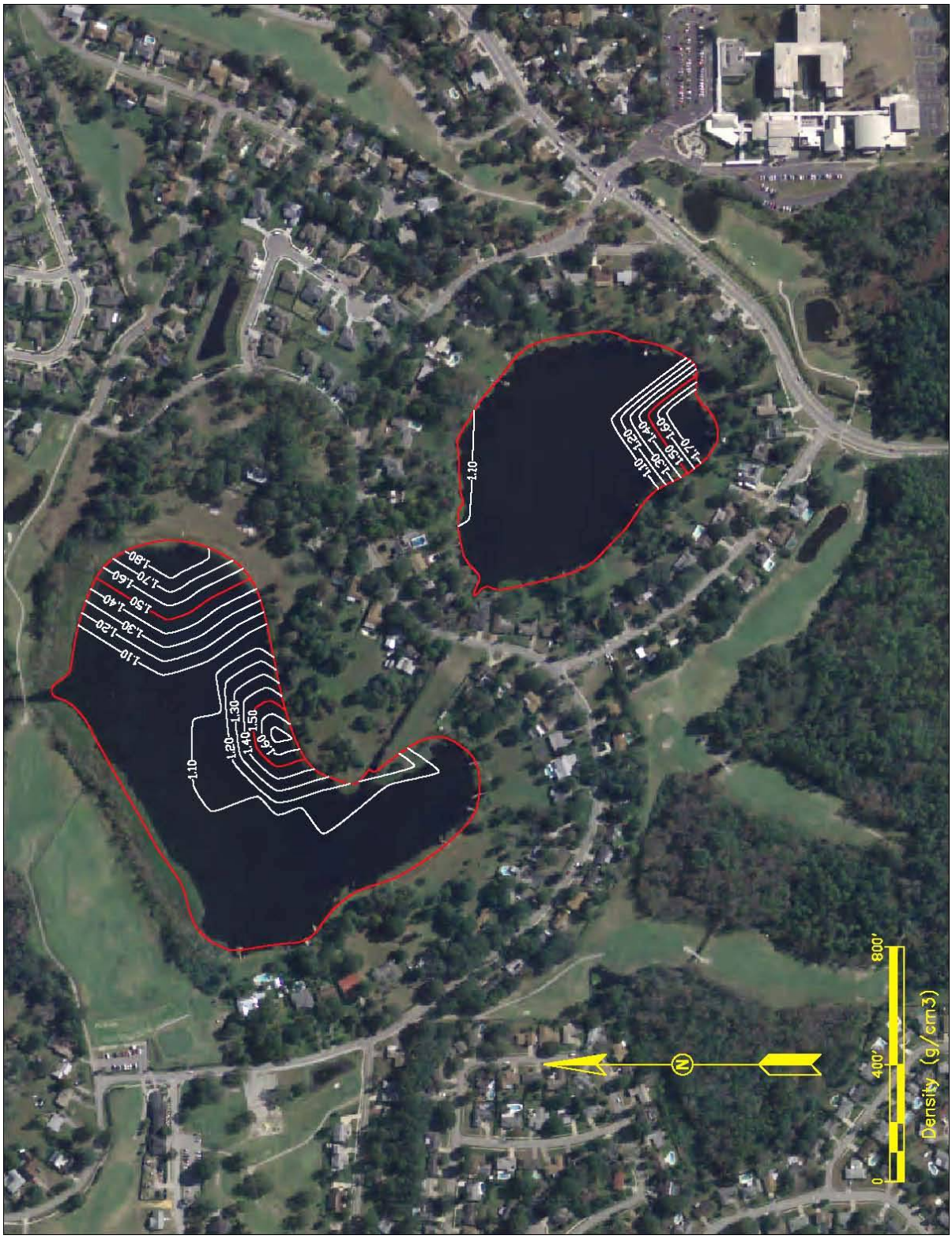



Figure 2-32. Isopleths of Bulk Density (g/cm$^3$) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

Measured concentrations of total nitrogen in sediments of the two lakes were found to be highly variable, with concentrations ranging from 771-1548 $\mu g/cm^3$ (wet weight basis) in Queens Mirror Lake, and from 256-2312 $\mu g/cm^3$ in South Lake Triplet. However, the mean total nitrogen concentration of 1126 $\mu g/cm^3$ in Queens Mirror Lake and 1304 $\mu g/cm^3$ in South Lake Triplet are slightly lower than nitrogen concentrations commonly observed in urban lakes which typically range from approximately 1500-2500 $\mu g/cm^3$. Isopleths of sediment nitrogen concentrations in Queens Mirror Lake and South Lake Triplet are illustrated on Figure 2-33. In general, the most elevated levels of total nitrogen occur in central portions of Queens Mirror Lake in areas which correspond to deep deposits of organic muck. The most elevated levels of total nitrogen in South Lake Triplet appear to occur in northern central and southern portions of the lake, where concentration isopleths range from approximately 1250-2000 $\mu g/cm^3$.

Sediment concentrations of total phosphorus were also highly variable within the two lakes, with sediment phosphorus concentrations ranging from 90-169 $\mu g/cm^3$ in Queens Mirror Lake, and from 73-192 $\mu g/cm^3$ in South Lake Triplet. The overall mean total phosphorus concentrations of 123 $\mu g/cm^3$ in Queens Mirror Lake and 132 $\mu g/cm^3$ in South Lake Triplet are somewhat lower than concentrations commonly observed in urban lakes which often range from approximately 250-500 $\mu g/cm^3$. Isopleths of total phosphorus concentrations in the two lakes are illustrated on Figure 2-34. Similar to the patterns exhibited by total nitrogen, the most elevated areas of total phosphorus occur in central portions of Queens Mirror Lake as well as central and southern portions of South Lake Triplet.

#### 2.3.3.3 Phosphorus Speciation

As discussed in Section 2.3.2, 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. This information is useful in evaluating the stability of phosphorus in sediments and the potential for release of phosphorus from the sediments under anoxic conditions.

A summary of phosphorus speciation in sediment core samples collected in Queens Mirror Lake and South Lake Triplet is given in Table 2-17. Saloid-bound phosphorus represents sediment phosphorus which is 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 2-17, saloid-bound phosphorus concentrations appear to be relatively uniform within the sediments of each of the two lakes, with an average saloid-bound phosphorus concentration of 4.2 $\mu g/cm^3$ in Queens Mirror Lake and 3.8 $\mu g/cm^3$ in South Lake Triplet. Saloid-bound phosphorus concentrations in this range are typical of values commonly observed in urban lakes. Isopleths of saloid-bound phosphorus in the sediments of the two lakes are illustrated on Figure 2-35. More elevated levels of saloid-bound phosphorus appear to correspond with areas of high sediment organic content in the two lakes.

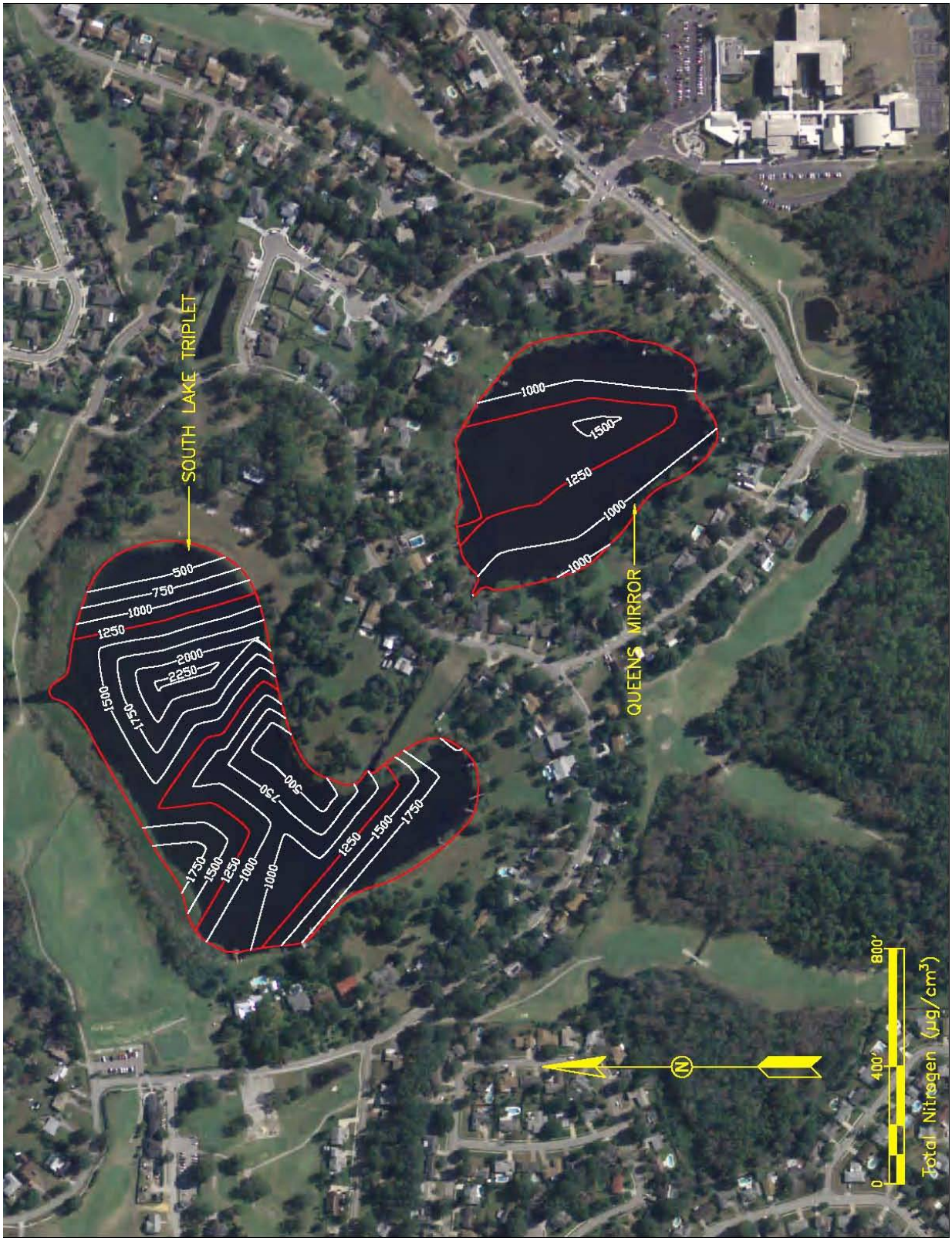



Figure 2-33. Isopleths of Total Nitrogen ($\mu g/cm^3$) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

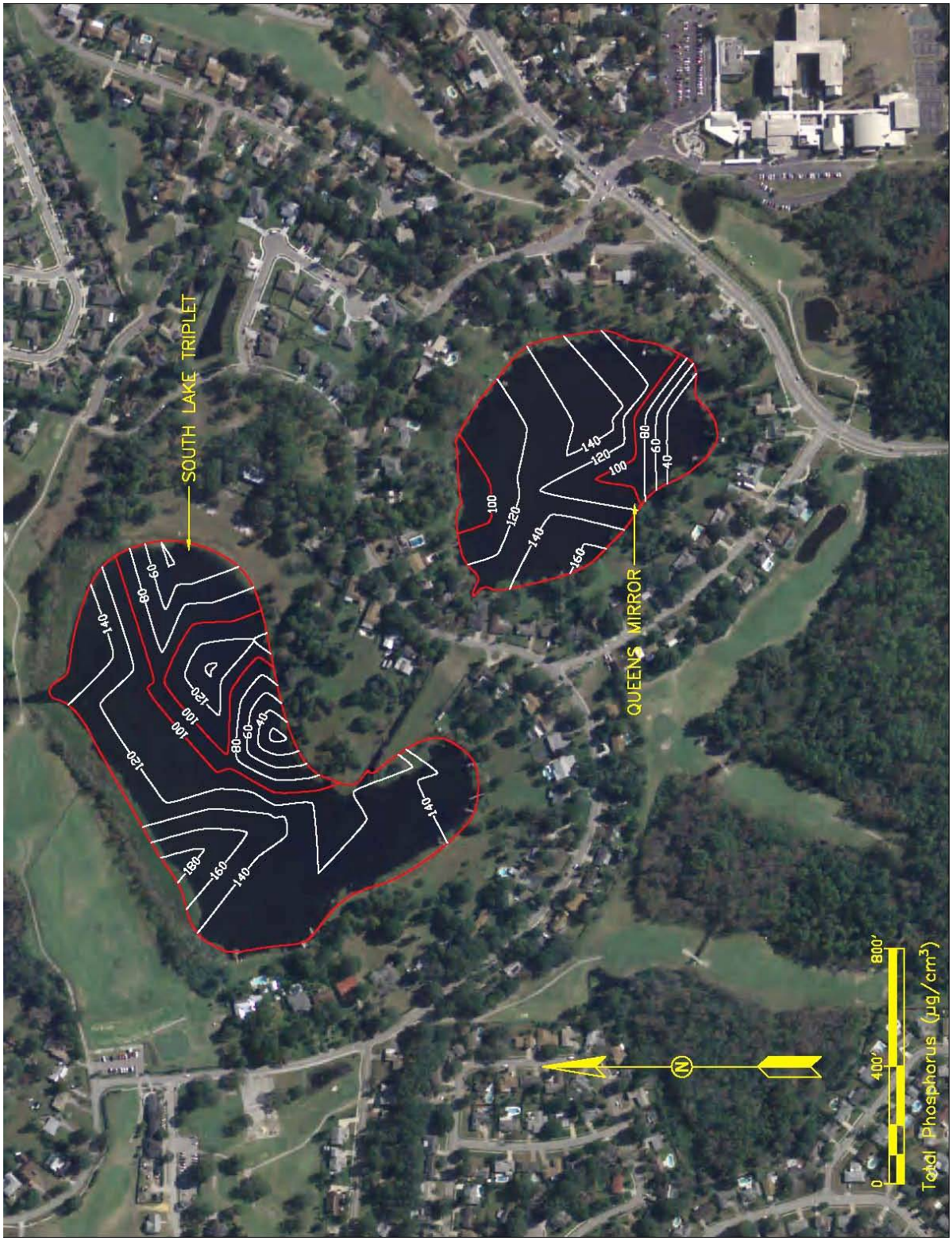



Figure 2-34. Isopleths of Total Phosphorus (µg/cm$^3$) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

## TABLE 2-17

## PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN QUEENS MIRROR LAKE AND SOUTH LAKE TRIPLET

| LAKE | SITE | SALOID-BOUND PHOSPHORUS ($\mu g/cm^3$) | IRON-BOUND PHOSPHORUS ($\mu g/cm^3$) | TOTAL AVAILABLE PHOSPHORUS ($\mu g/cm^3$) | PERCENT OF SEDIMENT PHOSPHORUS AVAILABLE (%) | ALUMINUM-BOUND PHOSPHORUS ($\mu g/cm^3$) |
|---|---|---|---|---|---|---|
| Queens Mirror Lake | Site 1 | 4.8 | 15 | 20 | 14 | 19 |
| | Site 2 | 3.3 | 39 | 42 | 42 | 27 |
| | Site 3 | 3.3 | 38 | 41 | 24 | 35 |
| | Site 4 | 5.1 | 59 | 64 | 49 | 44 |
| | Site 5 | 6.2 | 39 | 45 | 41 | 55 |
| | Site 6 | 2.9 | 60 | 63 | 69 | 46 |
| | Site 7 | 5.5 | 38 | 43 | 27 | 50 |
| | Site 8 | 3.6 | 35 | 39 | 25 | 38 |
| | Site 9 | 3.0 | 40 | 43 | 75 | 94 |
| | Site 10 | 2.6 | 38 | 40 | 36 | 33 |
| | **Mean:** | **4.0** | **40** | **44** | **40** | **44** |
| South Lake Triplet | Site 1 | 4.0 | 38 | 42 | 25 | 43 |
| | Site 2 | 2.8 | 4 | 7 | 10 | 20 |
| | Site 3 | 3.6 | 28 | 32 | 25 | 33 |
| | Site 4 | 5.3 | 54 | 59 | 60 | 90 |
| | Site 5 | 4.7 | 48 | 53 | 35 | 82 |
| | Site 6 | 2.9 | 23 | 26 | 21 | 41 |
| | Site 7 | 3.9 | 28 | 32 | 25 | 64 |
| | Site 8 | 3.3 | 36 | 39 | 35 | 63 |
| | Site 9 | 5.3 | 25 | 30 | 31 | 50 |
| | Site 10 | 4.8 | 99 | 104 | 54 | 106 |
| | Site 11 | 3.8 | 77 | 81 | 52 | 71 |
| | Site 12 | 3.9 | 42 | 46 | 36 | 68 |
| | Site 13 | 3.8 | 28 | 31 | 23 | 39 |
| | Site 14 | 4.7 | 15 | 20 | 16 | 59 |
| | Site 15 | 5.6 | 16 | 21 | 16 | 63 |
| | Site 16 | 7.6 | 41 | 48 | 31 | 125 |
| | **Mean:** | **4.4** | **38** | **42** | **31** | **64** |

Figure 2-35. Isopleths of Saloid-Bound Phosphorus (µg/cm$^3$) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

In general, iron-bound phosphorus associations in the sediments of Queens Mirror Lake and South Lake Triplet appear to be moderate 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 Queens Mirror Lake range from 15-60 $\mu g/cm^3$, with concentrations ranging from 4-99 $\mu g/cm^3$ in South Lake Triplet. The average iron-bound phosphorus concentrations of 40 $\mu g/cm^3$ in Queens Mirror Lake and 38 $\mu g/cm^3$ in South Lake Triplet reflect values which are similar to iron-bound phosphorus concentrations commonly observed in urban lake systems. Isopleths of iron-bound phosphorus in the sediments of the two lakes are illustrated on Figure 2-36.

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 iron-bound phosphorus can become available under reduced conditions, the sum of these species represents the total phosphorus which is potentially available for release from the sediments. This information can be utilized as a guide for future sediment inactivation procedures. In general, total available phosphorus concentrations in each of the two lakes appear to be moderate to low in value, with a mean of 44 $\mu g/cm^3$ in Queens Mirror Lake and 42 $\mu g/cm^3$ in South Lake Triplet. Isopleths of total available phosphorus in sediments of the two lakes are illustrated on Figure 2-37. Areas of more elevated total available phosphorus are apparent in central portions of Queens Mirror Lake and in central and southern portions of South Lake Triplet. The isopleths presented on Figure 2-37 can be utilized directly as a guide for future sediment inactivation activities.

Total available phosphorus can also be expressed as a percentage of the total phosphorus contained within the sediments. This value reflects the percentage of the total phosphorus within the sediments which is subject to potential release. As indicated on Table 2-17, potentially available phosphorus in the sediments of Queens Mirror Lake ranges from approximately 14-75% of the total sediment phosphorus, and from 10-54% of the total sediment phosphorus in South Lake Triplet. The mean value of 40% in Queens Mirror Lake and 31% in South Lake Triplet suggests that approximately one-third of the existing accumulations of phosphorus within the sediments of the two lakes is potentially available for release into the overlying water column.

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 ranges from an average of 44 $\mu g/cm^3$ in Queens Mirror Lake to an average of approximately 64 $\mu g/cm^3$ in South Lake Triplet. These values suggest that approximately one-third of the total phosphorus contained within the sediments of Queens Mirror Lake, and approximately one-half of the phosphorus contained within the sediments of South Lake Triplet, is bound with aluminum and is considered to be unavailable for release into the overlying water column. Isopleths of aluminum-bound phosphorus in the sediments of Queens Mirror Lake and South Lake Triplet are illustrated on Figure 2-38.

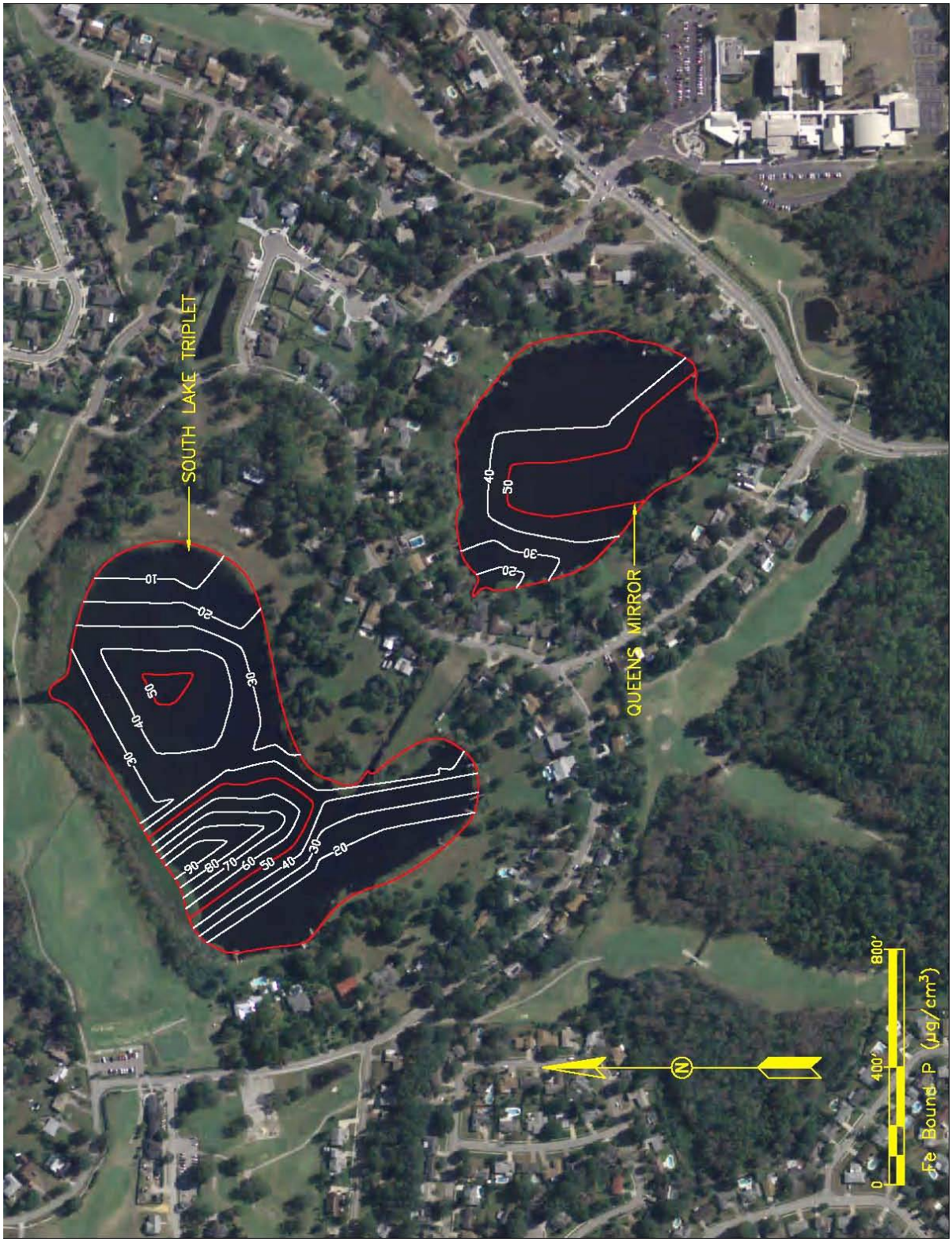



Figure 2-36. Isopleths of Iron-Bound Phosphorus (µg/cm$^3$) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

Figure 2-37. Isopleths of Total Available Phosphorus (µg/cm$^3$) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

Figure 2-38. Isopleths of Aluminum-Bound Phosphorus (µg/cm$^3$) in the Top 10 cm of Sediments in Queens Mirror Lake and South Lake Triplet.

## 2.4 Water Level Elevations

Information on historical water level elevations in Queens Mirror Lake and the Triplet Chain-of-Lakes was obtained from the Seminole County Water Atlas. Water level elevation data are available in Queens Mirror Lake and Middle Lake Triplet from August 1990 to the present, with water level measurements collected on approximately a monthly basis. Monitoring of water level elevations was initiated in North Lake Triplet during January 2003 and has continued to the present on approximately a monthly basis. Water level data for South Lake Triplet are available only from August 2004-July 2005, with a total of three separate measurements conducted during that period.

A graphical summary of historical water level elevations in Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 2-39. In general, water surface elevations in Queens Mirror Lake appear to be slightly higher than the Triplet Chain-of-Lakes during most of the monitoring dates. This trend seems logical since Queens Mirror Lake represents the most upstream waterbody in the system. Water level elevations in the remaining lakes mimic water elevations in Queens Mirror Lake relatively closely, with a few notable exceptions when water elevations in Middle Lake Triplet fall several feet lower than water level elevations in Queens Mirror Lake. It appears that the free-flowing connections between Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet become severed during these instances, resulting in substantial differences in water surface elevations between the isolated waterbodies.

A tabular summary of water surface elevations in Queens Mirror Lake and the Triplet Chain-of-Lakes, based upon available historical data, is given in Table 2-18. Water level information for South Lake Triplet is not included due to the limited amount of available data.

**TABLE 2-18**

**SUMMARY OF WATER SURFACE ELEVATIONS IN QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | DATES OF AVAILABLE DATA | MINIMUM LEVEL (ft) | MAXIMUM LEVEL (ft) | MEAN LEVEL (ft) |
|---|---|---|---|---|
| Queens Mirror Lake | 8/90 - Present | 47.80 | 54.40 | 50.37 |
| Middle Lake Triplet | 8/90 - Present | 46.71 | 53.00 | 50.21 |
| North Lake Triplet | 1/03 - Present | 48.65 | 52.86 | 50.10 |

Water surface elevations in Queens Mirror Lake have ranged approximately 6.6 ft between minimum and maximum values from 1990 to the present. A similar range of approximately 6.29 ft has been observed between minimum and maximum water surface elevations in Middle Lake Triplet. A range of 4.21 ft has been observed in North Lake Triplet between minimum and maximum values, but the period of data is substantially less. Mean water level elevations decrease progressively from Queens Mirror Lake to Middle Lake Triplet to North Lake Triplet which is consistent with the general flow direction within the Chain-of-Lakes.

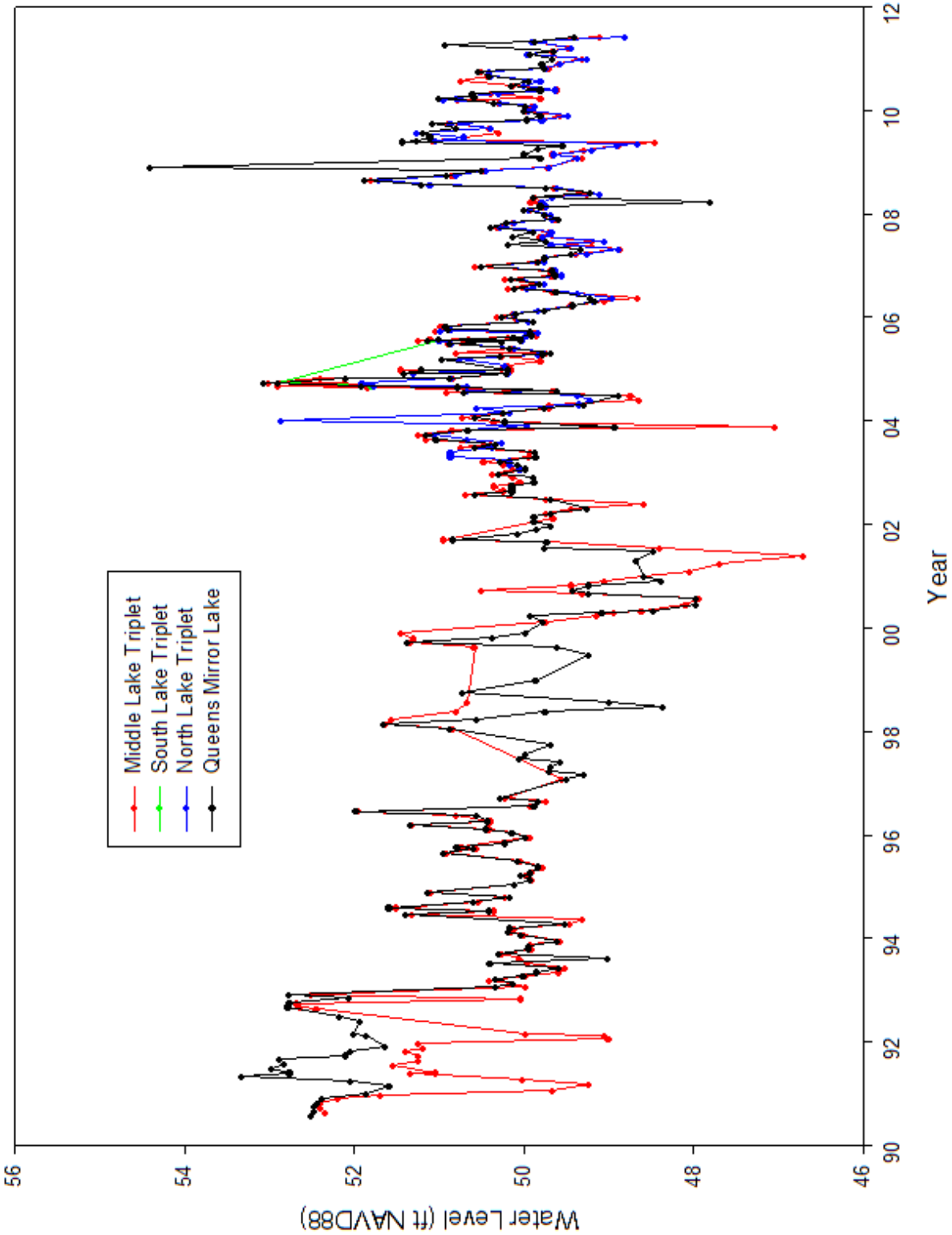



Figure 2-39. Historical Water Levels in Queens Mirror Lake and the Triplet Chain-of-Lakes.

# SECTION 3

# CHARACTERISTICS OF THE QUEENS MIRROR LAKE AND TRIPLET CHAIN-OF-LAKES DRAINAGE BASINS

Characteristics of the drainage basin areas for Queens Mirror Lake and the Triplet Chain-of-Lakes are summarized in this section, including information on drainage sub-basin delineations, land use characteristics, hydrologic characteristics, soil types, and existing stormwater treatment areas. A discussion of each of these elements is given in the following sections.

## 3.1 Watershed Characteristics

A delineation of contributing drainage basin areas discharging to Queens Mirror Lake and the Triplet Chain of Lakes was conducted by ERD as part of this project. Preliminary drainage basin boundaries were established based upon information contained in the Seminole County GIS system. The basin delineations provided by Seminole County included a separate basin for Queens Mirror Lake and a combined basin for the Triplet Chain-of-Lakes, including multiple interconnected waterbodies.

The Seminole County basin boundaries were modified, as appropriate, by reviewing one-foot contour elevation maps obtained from the St. Johns River Water Management District (SJRWMD) for the general area, along with field reconnaissance and observations of drainage patterns during significant storm events. The Casselberry stormsewer layer was also provided to ERD in a PDF format which contained approximate locations of pipes and significant drainage channels. This information was digitized onto an aerial base map along with the contour elevation data and preliminary basin delineations and used to refine the sub-basin areas for Queens Mirror Lake, as well as to delineate separate drainage basin boundaries for North Lake Triplet, Middle Lake Triplet, and South Lake Triplet. Basin delineations were also conducted for the series of interconnected lakes located east of Middle Lake Triplet and west of Queens Mirror Lake.

An overview of the drainage basin delineations for Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 3-1. The drainage sub-basin area discharging into Queens Mirror Lake extends south and west of the lake and is substantially larger than the sub-basin areas discharging into South Lake Triplet, Middle Lake Triplet, or North Lake Triplet. Queens Mirror Lake receives inflows from a series of interconnected lakes west of US 17-92 which includes Lake Maltbie, Pot Lake, Prairie Lake, Pearl Lake, and Grassy Lake, along with a series of interconnected wetlands east of US 17-92. Portions of the Queens Mirror drainage basin east of US 17-92 may overflow into the Middle Lake Triplet drainage basin during extreme high water level conditions, but the normal flow direction is into Queens Mirror Lake.

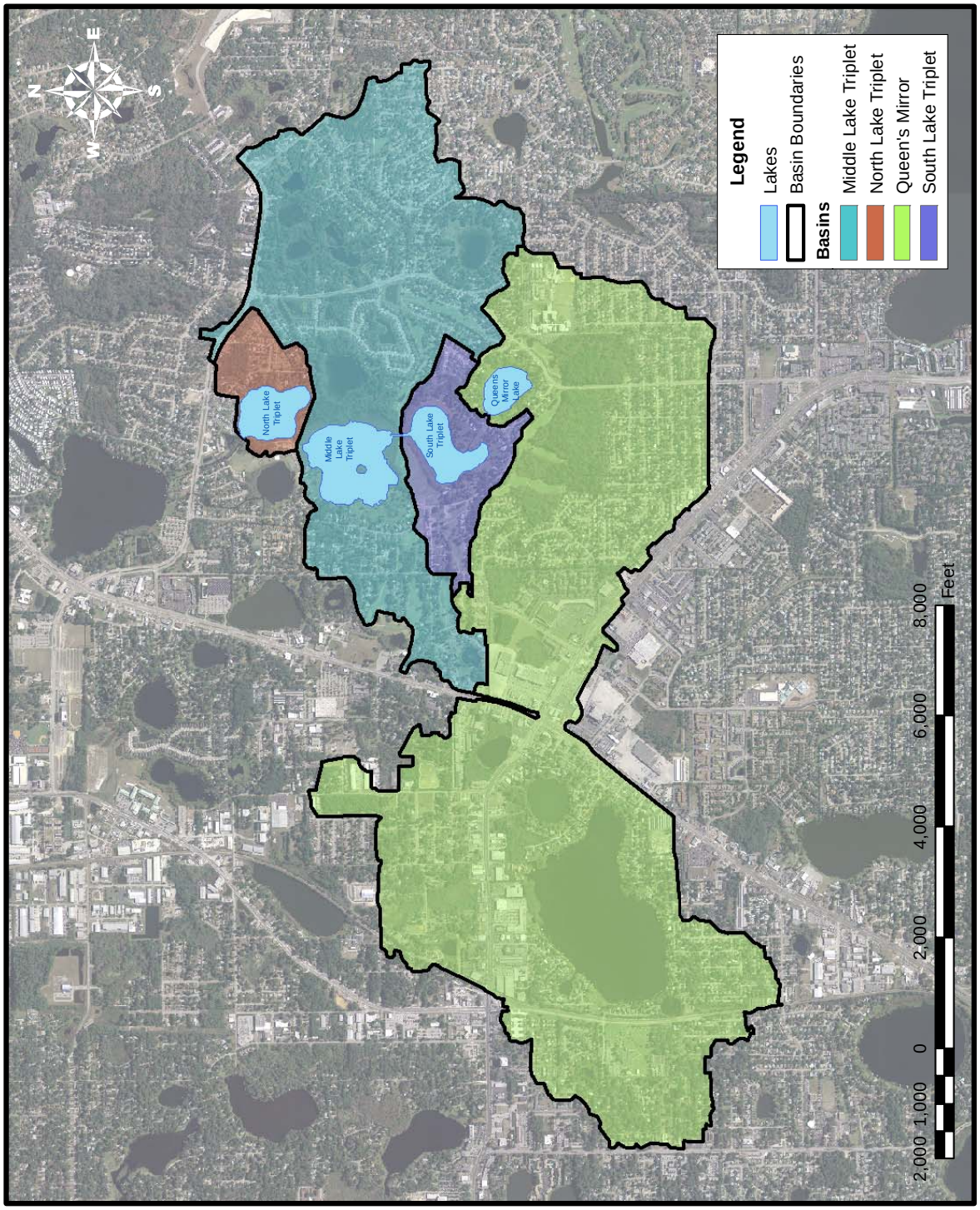



Figure 3-1. Drainage Basin Delineations for Queens Mirror Lake and the Triplet Chain-of-Lakes.

In addition to the directly connected sub-basin areas, Middle Lake Triplet also receives inflow from Lost Lake which receives inflow from six additional sub-basin areas which are identified as Lake Annette, Lake Emily, Lake Cecile, Lake Marie, Lake Yvonne, and Crystal Bowl Lake. Each of these lakes ultimately discharges to Lost Lake which then discharges into the west side of Middle Lake Triplet.

An overview of significant drainage channels and stormsewer pipes in the Queens Mirror and Triplet Chain-of-Lakes drainage basins is given on Figure 3-2. Runoff is conveyed within the various drainage basins using a combination of underground stormsewers and earthen canals and ditches.

Delineations of individual sub-basin areas discharging into each of the study lakes are given on Figure 3-3. Each of the identified sub-basin areas reflects a portion of the overall watershed which discharges through a defined stormsewer, canal, or ditch into either one of the evaluated lakes or an upstream interconnected waterbody. This information is used to estimate annual runoff volumes to each of the interconnected waterbodies to generate a hydrologic model for Queens Mirror Lake and the Triplet Chain-of-Lakes.

A tabular summary of sub-basin areas discharging to Queens Mirror Lake, the Triplet Chain-of-Lakes, and interconnected waterbodies is given on Table 3-1. The sub-basin areas summarized on Table 3-1 reflects the total area discharging to Queens Mirror Lake and each of the Triplet Chain-of-Lakes, including the area of interconnected lakes and the associated watersheds. However, surface areas for the open water for Queens Mirror Lake, South Lake Triplet, Middle Lake Triplet, and North Lake Triplet are not included in the sub-basin areas since these direct lake areas are not included in the hydrologic modeling discussed in a subsequent section.

Approximately 1,364 acres discharge into Queens Mirror Lake, with approximately 98% of the total sub-basin area discharging into the lake through the southern inflow canal, referred to as sub-basin QM-1. A relatively small area, identified as QM-2, discharges residential and street runoff from a 5.15-acre area adjacent to the lake, with approximately 22.5 acres of direct overland flow into the lake from adjacent parcels.

Six separate sub-basin areas were identified in the South Lake Triplet basin, with approximately 43% of the total basin area discharging directly into the lake by direct overland flow. The remaining sub-basins consist of residential and golf course areas.

Multiple sub-basin areas were identified which discharge into Middle Lake Triplet. The total sub-basin area discharging to Middle Lake Triplet is approximately 626.65 acres, with approximately 25% of the drainage basin area consisting of a series of interconnected lakes located east of Middle Lake Triplet which ultimately discharge into Lost Lake and then into Middle Lake Triplet through the Lost Lake canal. Two separate sub-basin areas were identified which discharge directly into North Lake Triplet, with the largest sub-basin area (identified as NLT-1) reflecting a residential land use located east of the lake.

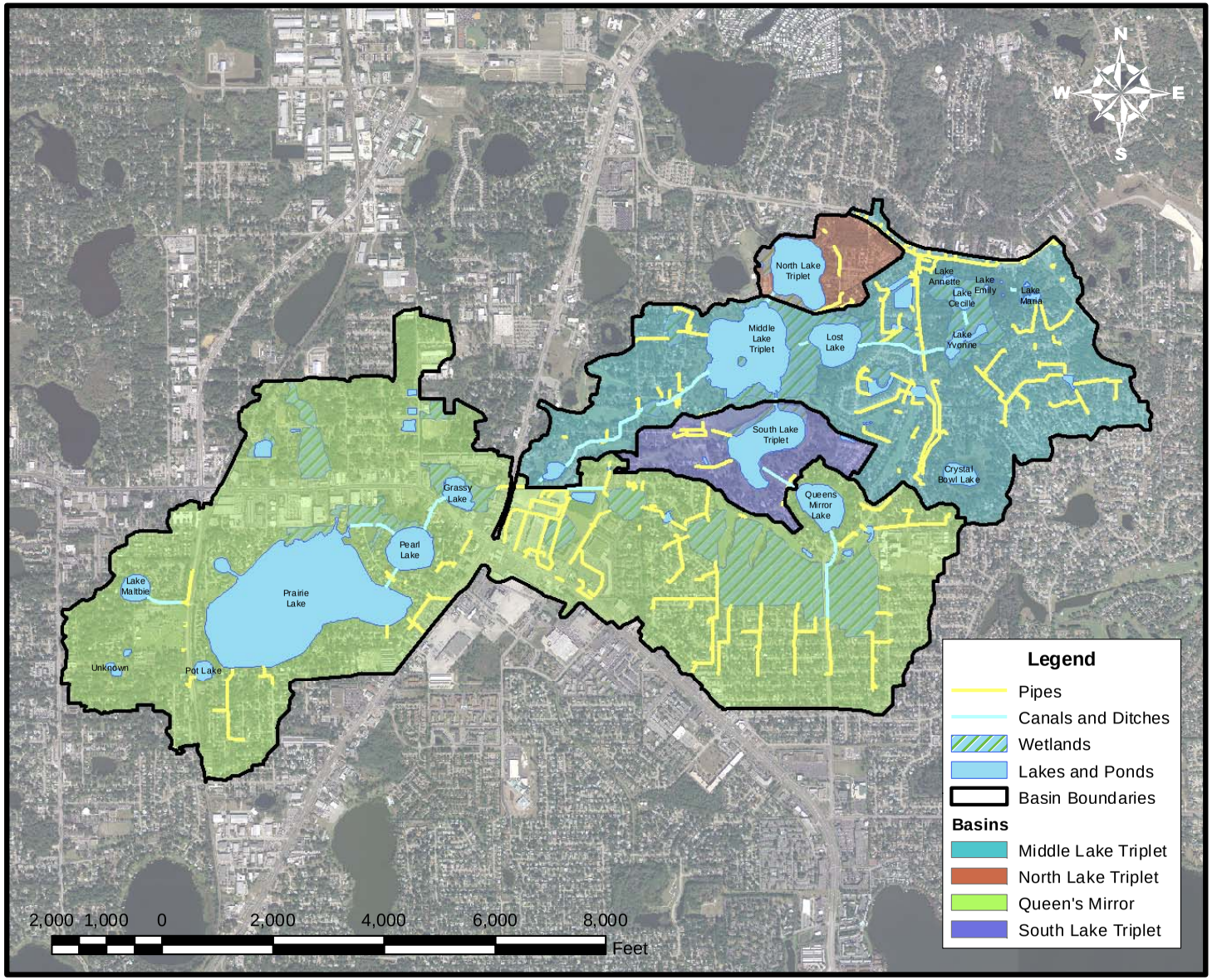



Figure 3-2. Locations of Significant Drainage Channels and Pipes in the Queens Mirror Lake and Triplet Chain-of-Lakes Drainage Basins.

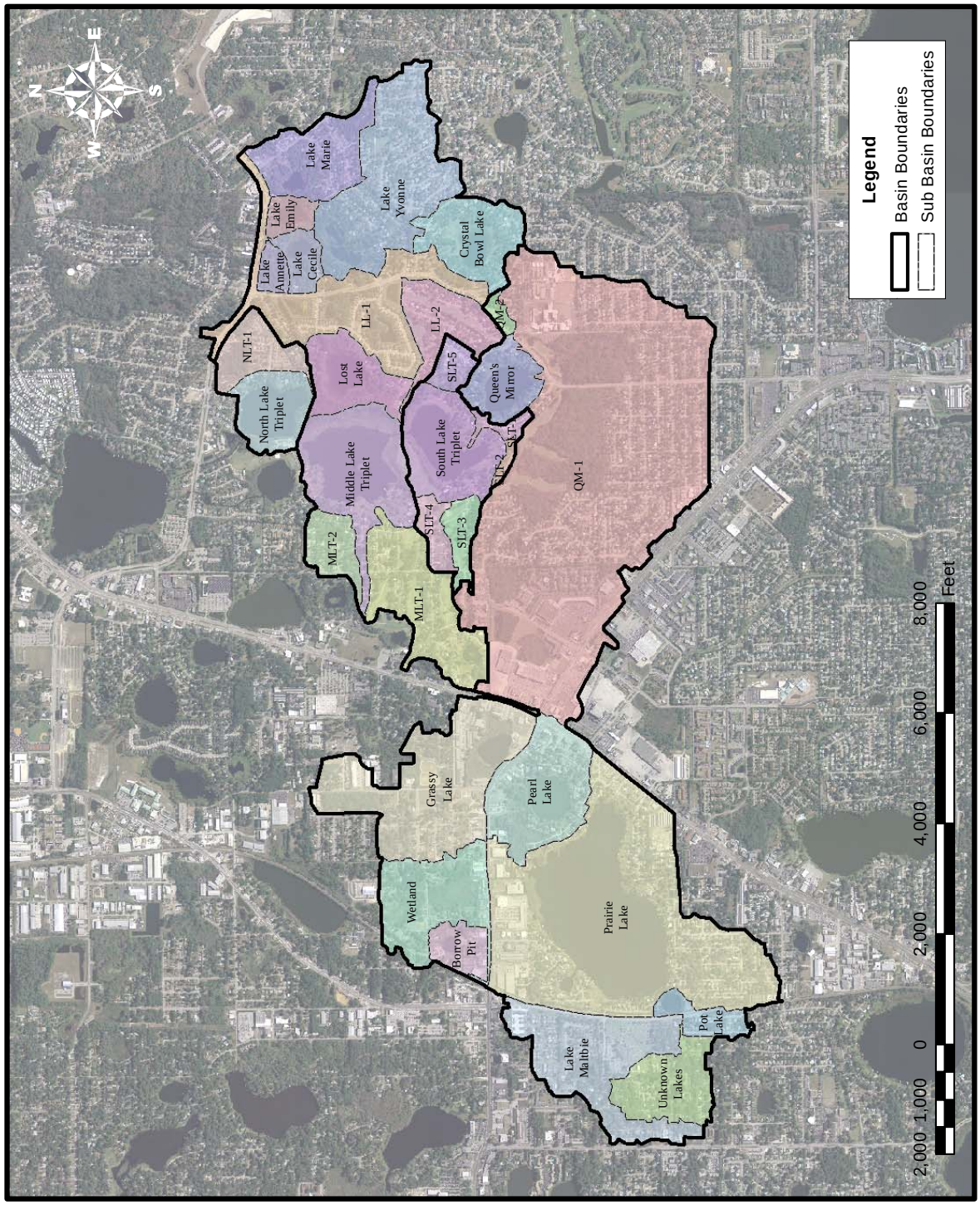



Figure 3-3. Drainage Sub-basin Delineations for Queens Mirror Lake, the Triplet Chain-of-Lakes, and Interconnected Waterbodies.

## TABLE 3-1

## SUMMARY OF SUB-BASIN AREAS DISCHARGING TO QUEENS MIRROR LAKE, THE TRIPLET CHAIN-OF-LAKES AND INTERCONNECTED WATERBODIES

| LAKE | SUB-BASIN | AREA (acres) | PERCENT OF TOTAL (%) | INPUT TYPE |
|---|---|---|---|---|
| Queens Mirror Lake | Borrow Pit | 14.23 | 1.0 | Ditch/Canal |
| | Grassy Lake | 142.39 | 10.2 | Ditch/Canal |
| | Lake Maltbie | 99.41 | 7.1 | Ditch/Canal |
| | Pearl Lake | 79.90 | 5.7 | Ditch/Canal |
| | Pot Lake | 19.13 | 1.4 | Ditch/Canal |
| | Prairie Lake | 330.27 | 23.8 | Ditch/Canal |
| | Un-Named Lake | 49.49 | 3.6 | Ditch/Canal |
| | Wetland | 76.68 | 5.5 | Ditch/Canal |
| | QM-1 | 552.61 | 39.7 | Ditch/Canal |
| | QM-2 | 5.15 | 0.4 | 15-inch RCP |
| | Direct | 22.49 | 1.6 | Overland flow |
| | **Totals:** | **1391.7** | **100.0** | **--** |
| South Lake Triplet | SLT-1 | 7.47 | 7.8 | Ditch/Canal |
| | SLT-2 | 3.73 | 3.8 | 18-inch RCP |
| | SLT-3 | 16.37 | 17.0 | 15-inch RCP |
| | SLT-4 | 14.38 | 14.9 | 24-inch ECMP |
| | SLT-5 | 12.96 | 13.5 | Unknown |
| | Direct | 41.39 | 43.0 | Overland flow |
| | **Totals:** | **96.30** | **100.0** | **--** |
| Middle Lake Triplet | Crystal Bowl | 53.79 | 8.6 | Ditch/Canal |
| | Lake Annette | 9.65 | 1.5 | Ditch/Canal |
| | Lake Cecile | 16.48 | 2.6 | Ditch/Canal |
| | Lake Emily | 12.64 | 2.0 | Ditch/Canal |
| | Lake Marie | 58.90 | 9.4 | Ditch/Canal |
| | Lake Yvonne | 126.08 | 20.1 | Ditch/Canal |
| | Lost Lake Direct | 44.89 | 7.2 | Ditch/Canal |
| | Lost Lake-1 | 108.48 | 17.3 | Ditch/Canal |
| | Lost Lake-2 | 42.56 | 6.8 | Ditch/Canal |
| | MLT-1 | 81.92 | 13.1 | Ditch/Canal |
| | MLT-2 | 24.76 | 4.0 | 15-inch RCP |
| | Direct | 46.50 | 7.4 | Overland flow |
| | **Totals:** | **626.65** | **100.0** | **--** |
| North Lake Triplet | NLT-1 | 31.82 | 64.3 | 15-inch RCP |
| | Direct | 17.68 | 35.7 | Overland flow |
| | **Totals:** | **49.50** | **100.0** | **--** |

A summary of drainage basin/lake area ratios for Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Table 3-2. Drainage basin/lake area ratios are often useful in evaluating the potential for runoff inputs to have a significant impact on water quality within a waterbody. Some researchers have suggested that drainage basin/lake area ratios less than 7 indicate lakes where nonpoint source pollution should have minimal impacts on lake water quality, while drainage basin/lake area ratios substantially in excess of 7 indicate waterbodies where nonpoint source runoff may have a significant impact on water quality. Based on the calculated drainage basin/lake area ratio for Queens Mirror Lake of 111, runoff inputs into Queens Mirror Lake would be expected to have a significant impact on water quality within the lake. A somewhat lower basin area/lake area ratio of 14.1 occurs for Middle Lake Triplet. Drainage basin/lake area ratios for South Lake Triplet and North Lake Triplet range from approximately 2.3-4.1, suggesting a much smaller potential for runoff impacts to these lakes compared to Queens Mirror Lake.

**TABLE 3-2**

**DRAINAGE BASIN / LAKE AREA RATIOS FOR QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | SURFACE AREA (acres) | DRAINAGE BASIN AREA (acres) | DRAINAGE BASIN/ LAKE AREA RATIO |
|---|---|---|---|
| Queens Mirror Lake | 12.53 | 1391.7 | 111 |
| South Lake Triplet | 23.29 | 96.30 | 4.1 |
| Middle Lake Triplet | 44.59 | 626.65 | 14.1 |
| North Lake Triplet | 21.47 | 49.50 | 2.3 |

## 3.2 Topography

Topographic elevation contours in the vicinity of Queens Mirror Lake and the Triplet Chain-of-Lakes are indicated on Figure 3-4 based upon one-foot contour maps obtained from SJRWMD. In general, elevations within the watersheds range from approximately 100 ft in upper portions of the sub-basin areas to approximately 45-50 ft in the vicinity of the lakes. This reflects an elevation drop of approximately 50 ft across the watershed, particularly in southwestern portions of the basin.

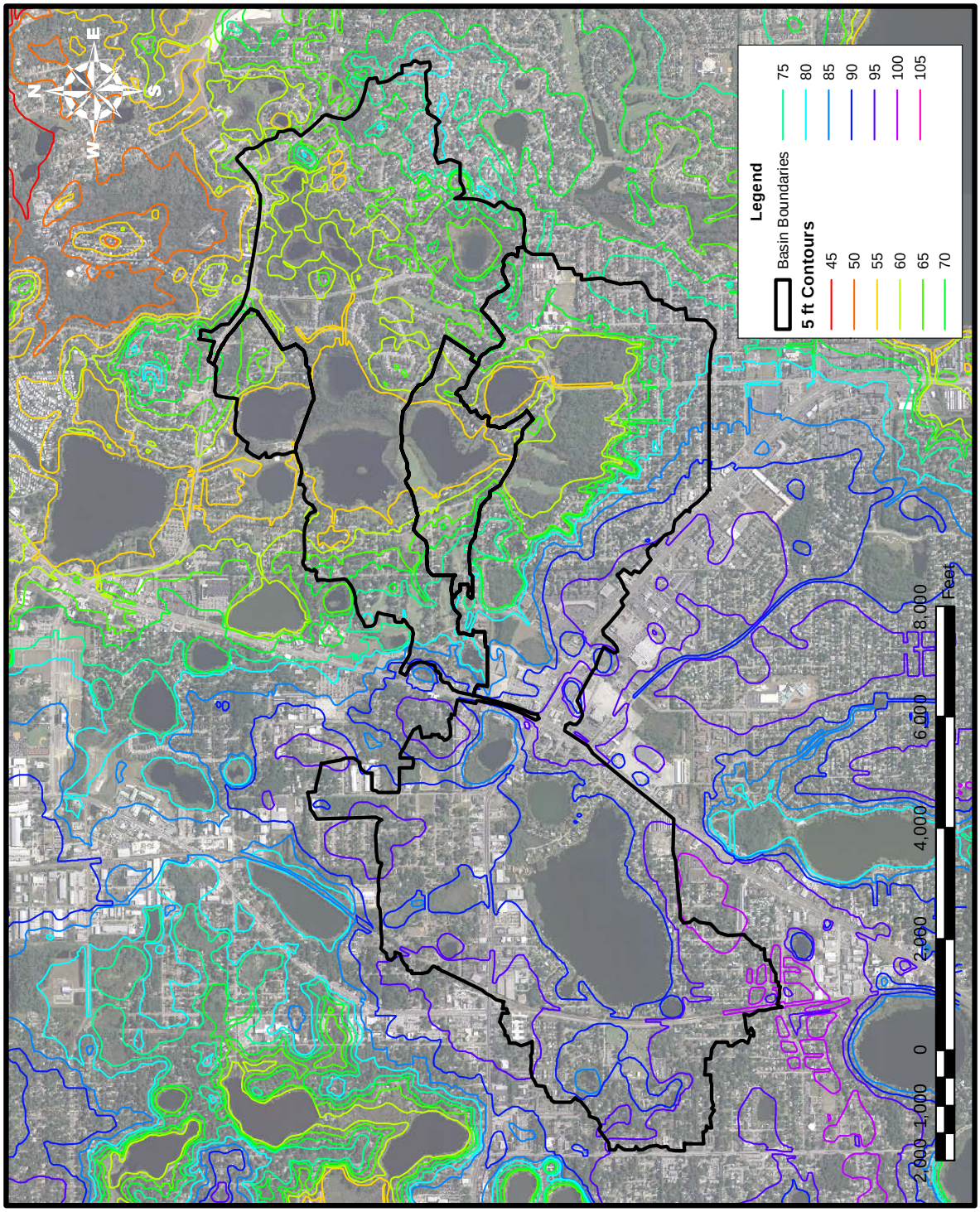



Figure 3-4. Topographic Contours in the Vicinity of Queens Mirror Lake and the Triplet Chain-of-Lakes.

## 3.3 Land Use

Land use information for the Queens Mirror Lake and Triplet Chain-of-Lakes drainage basins was originally obtained from the 2004 Land Use Inventory conducted by the Florida Department of Environmental Protection (FDEP). This information was obtained by ERD as a GIS shape file and was used as a baseline dataset. Minor changes to the land use data were identified using a combination of aerial photography and field reconnaissance, and applicable modifications were made to the 2004 land use to develop the land use data used for this analysis. Land use categories within the basin were combined into a series of general land use categories for which runoff characterization data are typically available. The resulting land use summary developed by ERD reflects conditions which currently exist within the Queens Mirror Lake and Triplet Chain-of-Lakes drainage basin.

An overview of general land use categories in the Queens Mirror Lake and Triplet Chain-of-Lakes drainage basin, including interconnected waterbodies, is given on Figure 3-5. The dominant land use category within the basins appears to be single-family residential followed by commercial, wetlands, and golf course areas. Small areas of open space and general recreational areas are also present within the various drainage basins.

A summary of land use characteristics in the Queens Mirror Lake and Triplet Chain-of-Lakes drainage basin, including interconnected waterbodies, is given in Table 3-3. The dominant land use category in each of the drainage basins is medium-density residential homes which comprises approximately 42% of the land area within the Queens Mirror Lake drainage basin, 50% of the land use within the South Lake Triplet drainage basin, 60% of the land use within the Middle Lake Triplet basin, and 40% of the land use within the North Lake Triplet drainage basin. Wetlands also occupy a significant portion of the drainage basin areas, comprising approximately 10% of the area within the Queens Mirror Lake basin, 4% of the area in the South Lake Triplet basin, 11% of the land area within the Middle Lake Triplet basin, and 12% of the land area within the North Lake Triplet basin. Other significant land use categories include commercial, high-density residential, and golf course activities. The land use characteristics summarized in Table 3-3 are used in a subsequent section to develop hydrologic and nutrient loadings for each of the identified sub-basin areas.

## 3.4 Soil Characteristics

Information on soil types within the Queens Mirror Lake and the Triplet Chain-of-Lakes drainage basin was obtained from the Seminole County 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 one of five 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 3-4.

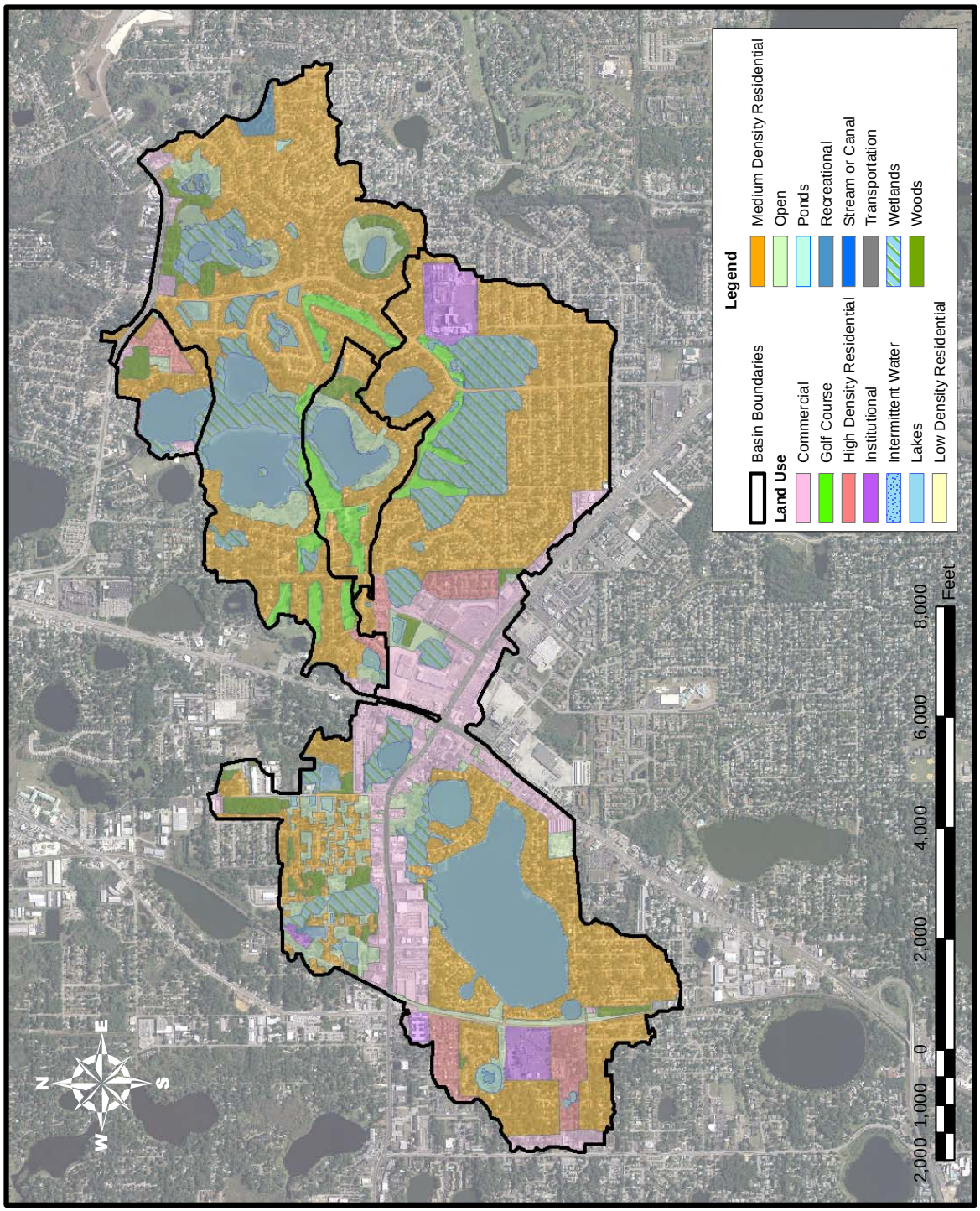



Figure 3-5. Current Land Use in the Queens Mirror Lake and Triplet Chain-of-Lakes Drainage Basins (Source: FDEP, 2004 Coverage).

# TABLE 3-3

## CURRENT LAND USE IN THE QUEENS MIRROR LAKE AND TRIPLET CHAIN-OF-LAKES DRAINAGE BASINS

| WATERBODY | LAND USE CATEGORY | AREA (acres) | PERCENT OF TOTAL (%) |
|---|---|---|---|
| Queens Mirror Lake | Single Family Residential | 587.21 | 42.2 |
| | Multi-Family | 60.35 | 4.3 |
| | Commercial | 214.99 | 15.4 |
| | Industrial | 10.85 | 0.8 |
| | Institutional | 54.93 | 3.9 |
| | Golf Course | 19.53 | 1.4 |
| | Recreational | 5.83 | 0.4 |
| | Transportation | 25.06 | 1.8 |
| | Open Space | 79.10 | 5.7 |
| | Lakes | 146.92 | 10.6 |
| | Woods | 31.90 | 2.3 |
| | Wetlands | 142.68 | 10.3 |
| | Ponds | 12.39 | 0.9 |
| | **Total:** | **1391.7** | **100.0** |
| South Lake Triplet | Single Family Residential | 48.31 | 50.2 |
| | Multi-Family | 0.08 | 0.1 |
| | Golf Course | 22.01 | 22.9 |
| | Open Space | 15.32 | 15.9 |
| | Woods | 5.94 | 6.2 |
| | Wetlands | 3.88 | 4.0 |
| | Ponds | 0.76 | 0.7 |
| | **Total:** | **96.30** | **100.0** |
| Middle Lake Triplet | Low Density Residential | 0.29 | < 0.1 |
| | Single Family Residential | 375.01 | 59.8 |
| | Multi-Family | 4.51 | 0.7 |
| | Commercial | 13.12 | 2.2 |
| | Golf Course | 35.81 | 5.7 |
| | Recreational | 7.42 | 1.2 |
| | Transportation | 11.69 | 1.9 |
| | Open Space | 45.94 | 7.3 |
| | Lakes | 25.76 | 4.1 |
| | Woods | 25.77 | 4.1 |
| | Wetlands | 70.71 | 11.3 |
| | Ponds | 10.62 | 1.7 |
| | **Total:** | **626.65** | **100.0** |
| North Lake Triplet | Single Family Residential | 19.79 | 40.0 |
| | Multi-Family | 11.86 | 24.0 |
| | Commercial | 4.10 | 8.3 |
| | Transportation | 0.18 | 0.4 |
| | Open Space | 2.24 | 4.5 |
| | Woods | 5.58 | 11.2 |
| | Wetlands | 5.75 | 11.6 |
| | **Total:** | **49.50** | **100.0** |

**TABLE 3-4**

**CHARACTERISTICS OF SCS HYDROLOGIC SOIL GROUP CLASSIFICATIONS**

| SOIL GROUP | DESCRIPTION | RUNOFF POTENTIAL | INFILTRATION RATE |
|---|---|---|---|
| A | Deep sandy soils | Very low | High |
| B / D | Shallow sandy soils over low permeability layer | Low in developed condition, high in undeveloped | High in developed condition, low in undeveloped |
| C | Sandy soil with high clay or organic content | Medium to high | Low |
| D | Clayey soils | Very high | Low to none |
| W | Water | -- | -- |

A graphical depiction of hydrologic soil groups in drainage basin areas for Queens Mirror Lake, the Triplet Chain-of-Lakes, and interconnected waterbodies is given on Figure 3-6. The dominant soil type within the overall drainage basin appears to be HSG D soils which have a low infiltration rate and a high runoff potential. However, the majority of soils listed in HSG D are designated as "Urban" in the original soil survey which includes areas that were developed at the time of the original survey which prevented an actual determination of the soil grouping. These "Urban" areas are often placed in HSG D regardless of the actual soil types. In some instances, this classification may not reflect the true runoff potential of a soil.

Central portions of the overall drainage basin area are occupied by HSG B/D soils which include soils with a high runoff potential in undeveloped conditions due to elevated water table conditions, and a low runoff potential in developed conditions. Small pockets of HSG A soils are scattered throughout the basin, reflecting soils with a low runoff potential and a high infiltration rate.

A tabular summary of hydrologic soil groups in the Queens Mirror Lake and Triplet Chain-of-Lakes drainage basins is given in Table 3-5. The dominant soil groups in the Queens Mirror Lake and Middle Lake Triplet drainage basins is HSG D soils which reflect a high runoff potential. However, the dominant soil type in the South Lake Triplet and North Lake Triplet basins is HSG A which reflects a low runoff potential. Soil types within the interconnected waterbodies are highly variable, but generally reflect soils with a moderate to high runoff potential.

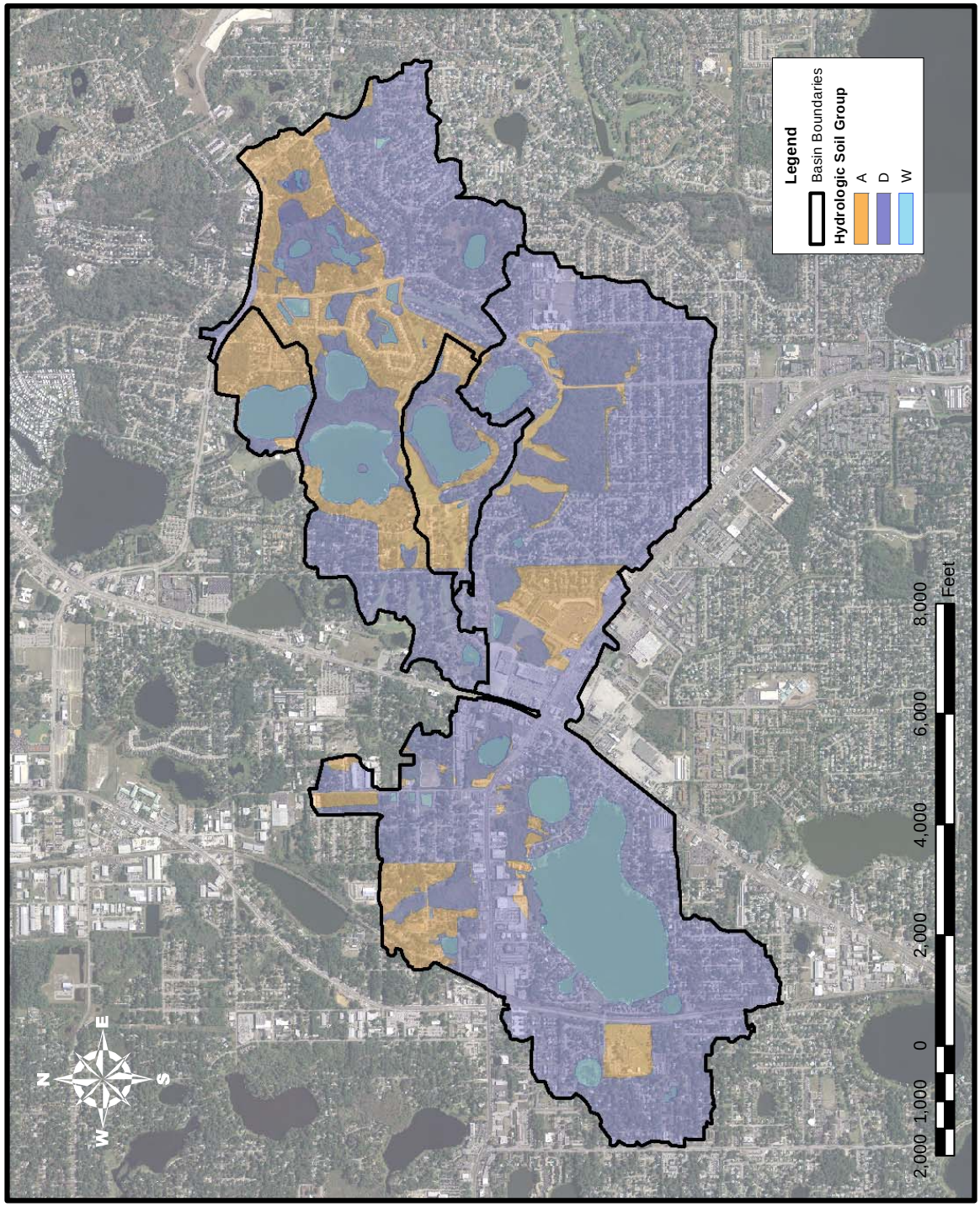



Figure 3-6. Hydrologic Soil Groups (HSG) in the Queens Mirror Lake and Triplet Chain-of-Lakes Drainage Basin.

**TABLE 3-5**

**HYDROLOGIC SOIL GROUPS IN THE QUEENS MIRROR LAKE AND TRIPLET CHAIN-OF-LAKES DRAINAGE BASINS**

| WATERBODY | HSG SOIL GROUP | AREA (acres) | PERCENT OF TOTAL (%) |
|---|---|---|---|
| Queens Mirror Lake | A | 117.67 | 8.5 |
| | A/D | 213.83 | 15.4 |
| | D | 913.31 | 65.6 |
| | W | 146.92 | 10.5 |
| | **Total:** | **1391.73** | **100.0** |
| South Lake Triplet | A | 43.46 | 45.1 |
| | A/D | 20.60 | 21.4 |
| | D | 32.24 | 33.5 |
| | W | 0.00 | 0.0 |
| | **Total:** | **96.30** | **100.0** |
| Middle Lake Triplet | A | 132.65 | 21.2 |
| | A/D | 133.29 | 21.2 |
| | D | 324.33 | 51.8 |
| | W | 36.38 | 5.8 |
| | **Total:** | **626.65** | **100.0** |
| North Lake Triplet | A | 33.90 | 68.5 |
| | A/D | 15.60 | 31.5 |
| | D | 0.00 | 0.0 |
| | W | 0.00 | 0.0 |
| | **Total:** | **49.50** | **100.0** |

## 3.5 Governmental Jurisdictions

A graphical overview of governmental jurisdictions in the Queens Mirror Lake and Triplet Chain-of-Lakes basins is given on Figure 3-7. The entire drainage basin areas for South Lake Triplet, Middle Lake Triplet, and North Lake Triplet are located within the City of Casselberry. Portions of the Queens Mirror Lake drainage basin located east of US 17-92 are located within the City of Casselberry. Portions of the Queens Mirror Lake drainage basin located west of US 17-92 are distributed approximately equally between the City of Altamonte Springs and unincorporated Seminole County, with a small portion of the basin area located in the vicinity of Grassy Lake contained within the City of Casselberry.

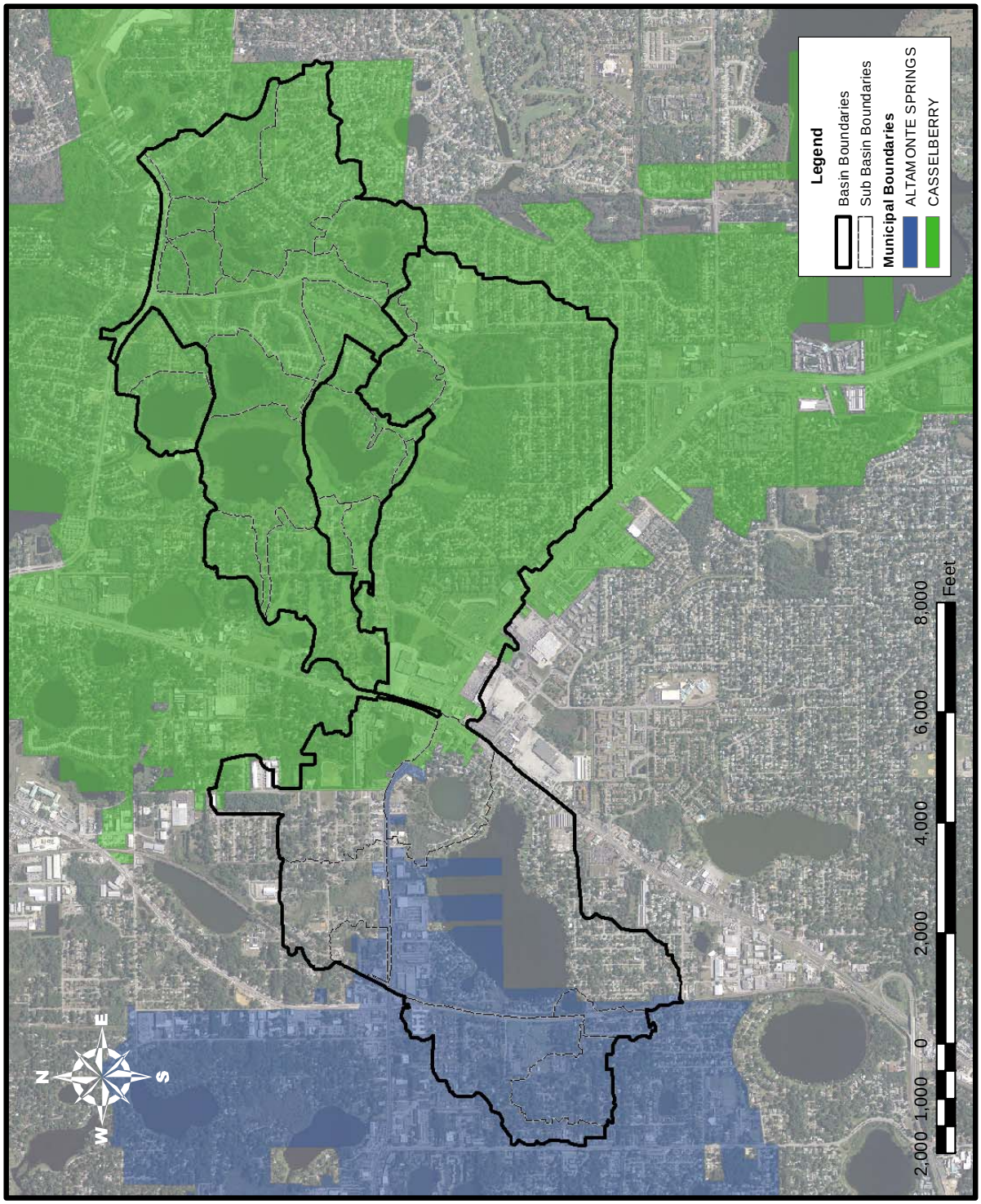



Figure 3-7. Governmental Jurisdictions in the Queens Mirror lake and Triplet Chain-of-Lakes Drainage Basins.

## 3.6 Hydrologic Characteristics

In addition to land use characteristics, information on hydrologic characteristics of the drainage sub-basin areas was developed by ERD for use in modeling inputs of stormwater runoff to Queens Mirror Lake and the Triplet Chain-of-Lakes. The initial step in evaluating hydrologic characteristics involved delineating pervious and impervious areas for typical land use categories within the drainage basin. Aerial photography of the drainage basin areas was obtained from FDEP in the form of digital orthoquad photography, dated 2004. Impervious areas within the drainage basin boundaries were digitally outlined for selected typical land use categories using GIS. The remaining land areas are assumed to represent pervious areas.

A tabular summary of hydrologic characteristics of drainage basin areas discharging to Queens Mirror Lake and the Triplet Chain-of-Lakes is given in Table 3-6. Hydrologic characteristics are provided for each individual land use category within each sub-basin area. In addition to the total area for each land use category, information is also provided on the percentage of directly connected impervious areas (DCIA) for each land use category within the basins. An area is considered to be directly connected if the drainage from the area discharges directly into the primary stormsewer system for the basin. In non-directly connected areas, the runoff from the impervious surface first migrates over a pervious area prior to entering the stormsewer system. This pervious area provides additional opportunities for soil infiltration of the runoff prior to reaching the receiving waterbody. Impervious areas meeting the definition of DCIA were identified by ERD using a combination of aerial photography and field reconnaissance. The DCIA and non-DCIA areas are modeled separately when performing estimates of runoff inputs from modeled storm events. A non-DCIA curve number value (CN) is also provided for each basin and land use category. This value is used to represent the runoff potential for the pervious areas as well as impervious areas which are not directly connected. The non-DCIA curve number is calculated by:

$$\textit{non-DCIA CN} = \frac{[(\textit{non-DCIA impervious area in acres}) \times 98] + [(\textit{pervious area in acres}) \times CN_p]}{(\textit{non-DCIA impervious area} + \textit{pervious area})}$$

where:

| | | |
|---|---|---|
| non-DCIA impervious area | = | total impervious area – DCIA (acres) |
| $CN_p$ | = | curve number for pervious areas based on soil types and land cover |

# TABLE 3-6

## HYDROLOGIC CHARACTERISTICS FOR LAND USE CATEGORIES IN THE QUEENS MIRROR LAKE, TRIPLET CHAIN-OF-LAKES, AND INTERCONNECTED WATERBODY DRAINAGE BASINS

| BASIN | LAND USE CATEGORY | AREA (acres) | DCIA (%) | NON-DCIA CN |
|---|---|---|---|---|
| Queens Mirror Lake | Commercial | 90.8 | 85.0 | 80.3 |
| | Industrial | 0.6 | 0.0 | 85.4 |
| | Institutional | 30.1 | 25.0 | 80.9 |
| | Transportation | 13.5 | 90.0 | 87.1 |
| | Medium Density Residential | 296.2 | 19.1 | 83.8 |
| | High Density Residential | 22.3 | 53.1 | 69.6 |
| | Golf Course | 19.6 | 0.0 | 72.0 |
| | Open | 5.9 | 0.0 | 65.8 |
| | Woods | 5.6 | 0.0 | 57.8 |
| | Wetlands | 100.5 | 0.0 | 76.7 |
| | Ponds | 2.8 | 100.0 | --- |
| | **Total:** | **587.9** | **28.6** | **80.3** |
| South Lake Triplet | Medium Density Residential | 48.7 | 11.4 | 76.4 |
| | High Density Residential | 0.1 | 60.0 | 84.5 |
| | Golf Course | 22.2 | 9.3 | 63.3 |
| | Open | 15.6 | 0.0 | 67.3 |
| | Woods | 5.9 | 0.0 | 74.9 |
| | Wetlands | 5.9 | 0.0 | 76.2 |
| | Ponds | 0.3 | 100.0 | --- |
| | **Total:** | **98.6** | **8.1** | **71.8** |
| Middle Lake Triplet | Commercial | 3.9 | 81.5 | 83.0 |
| | Low Density Residential | 0.3 | 0.0 | 83.6 |
| | Medium Density Residential | 85.6 | 20.0 | 81.5 |
| | High Density Residential | 4.8 | 60.0 | 84.5 |
| | Golf Course | 20.0 | 2.9 | 77.5 |
| | Open | 14.0 | 0.0 | 75.7 |
| | Woods | 0.2 | 0.0 | 77.0 |
| | Wetlands | 27.7 | 0.0 | 76.3 |
| | Ponds | 2.1 | 100.0 | --- |
| | **Total:** | **158.5** | **16.3** | **79.3** |
| North Lake Triplet | Commercial | 4.1 | 22.2 | 69.7 |
| | Transportation | 0.2 | 90.0 | 80.5 |
| | Medium Density Residential | 19.8 | 11.7 | 67.5 |
| | High Density Residential | 11.9 | 36.9 | 62.5 |
| | Open | 2.2 | 0.0 | 39.0 |
| | Woods | 5.6 | 0.0 | 30.0 |
| | Wetlands | 5.8 | 0.0 | 76.6 |
| | **Total:** | **49.5** | **15.7** | **61.5** |

## TABLE 3-6 -- CONTINUED

## HYDROLOGIC CHARACTERISTICS FOR LAND USE CATEGORIES IN THE QUEENS MIRROR LAKE, TRIPLET CHAIN-OF-LAKES, AND INTERCONNECTED WATERBODY DRAINAGE BASINS

| BASIN | LAND USE CATEGORY | AREA (acres) | DCIA (%) | NON-DCIA CN |
|---|---|---|---|---|
| Lost Lake | Commercial | 1.5 | 20.0 | 63.1 |
| | Transportation | 11.3 | 90.0 | 83.7 |
| | Medium Density Residential | 119.3 | 20.0 | 72.5 |
| | Golf Course | 16.0 | 0.0 | 72.6 |
| | Open | 2.7 | 0.0 | 58.8 |
| | Woods | 0.6 | 0.0 | 68.0 |
| | Wetlands | 24.1 | 0.0 | 76.8 |
| | Ponds | 7.6 | 100.0 | --- |
| | **Total:** | **183.1** | **22.9** | **73.0** |
| Lake Annette | Commercial | 2.7 | 60.0 | 70.8 |
| | Transportation | 0.0 | 90.0 | 86.0 |
| | Medium Density Residential | 1.1 | 20.0 | 70.3 |
| | Woods | 4.0 | 0.0 | 71.7 |
| | Wetlands | 1.1 | 0.0 | 74.5 |
| | **Total:** | **9.0** | **20.7** | **71.8** |
| Lake Cecile | Medium Density Residential | 2.1 | 20.0 | 71.1 |
| | Woods | 4.5 | 0.0 | 75.9 |
| | Wetlands | 7.6 | 0.0 | 77.0 |
| | **Total:** | **14.2** | **3.0** | **75.9** |
| Lake Emily | Commercial | 1.7 | 5.0 | 66.5 |
| | Medium Density Residential | 1.2 | 20.0 | 55.5 |
| | Open | 4.0 | 0.0 | 78.2 |
| | Woods | 3.7 | 0.0 | 57.2 |
| | Wetlands | 2.0 | 0.0 | 77.0 |
| | **Total:** | **12.6** | **2.6** | **68.4** |
| Lake Marie | Commercial | 3.0 | 18.8 | 53.5 |
| | Transportation | 0.3 | 90.0 | 68.5 |
| | Medium Density Residential | 33.5 | 20.0 | 71.8 |
| | Recreational | 6.9 | 0.0 | 69.9 |
| | Open | 10.0 | 0.0 | 47.6 |
| | Woods | 3.2 | 0.0 | 30.9 |
| | Wetlands | 2.0 | 0.0 | 59.2 |
| | **Total:** | **58.9** | **12.8** | **62.9** |
| Lake Yvonne | Medium Density Residential | 103.9 | 20.0 | 83.1 |
| | Recreational | 0.6 | 0.0 | 80.9 |
| | Open | 5.1 | 0.0 | 54.9 |
| | Woods | 0.9 | 0.0 | 70.3 |
| | Wetlands | 11.2 | 0.0 | 68.7 |
| | Ponds | 0.7 | 100.0 | --- |
| | **Total:** | **122.4** | **17.5** | **79.9** |
| Crystal Bowl Lake | Medium Density Residential | 28.6 | 20.0 | 84.5 |
| | Open | 12.1 | 0.0 | 80.0 |
| | Woods | 8.5 | 0.0 | 77.0 |
| | **Total:** | **49.2** | **11.6** | **81.8** |
| | **Grand Total:** | **1344.0** | **21.5** | **76.7** |

## 3.7 Stormwater Treatment

Watershed areas which currently receive stormwater treatment were identified by ERD within the Queens Mirror Lake, Triplet Chain-of-Lakes, and interconnected lakes drainage basins using a combination of aerial photography and field reconnaissance. A summary of the results of these evaluations is given on Figure 3-8.

Stormwater treatment within the Queens Mirror Lake, Triplet Chain-of-Lakes, and interconnected lakes drainage basins consists primarily of dry retention and wet detention. Developed areas which receive stormwater treatment by one of these two common mechanisms are indicated on Figure 3-8. Dry retention is a treatment mechanism which emphasizes infiltration of the runoff into the onsite soils, while wet detention provides stormwater treatment in a wet pond setting. Significant depressional areas are also indicated on Figure 3-8 since these areas retain a large portion of the generated runoff volume. Ponds associated with the golf course areas are indicated even though the ponds may not have been built using current design criteria. Small natural or man-made ponds within the watersheds which were not specifically constructed for stormwater treatment are also indicated on Figure 3-8 and assigned a treatment level based on the size of the pond relative to the contributing basin area.

The most common stormwater treatment technique within the drainage basins appears to be wet detention which is used extensively in eastern portions of the basin area. The Queens Mirror Lake drainage basin appears to contain a wet detention pond, along with a natural pond, a dry treatment pond, and several golf course ponds. The South Lake Triplet drainage basin contains a golf course pond along with a wet detention pond for recent development. The Middle Lake Triplet basin contains a depressional area along with a natural pond, with the North Lake Triplet basin containing only a dry pond for recent development. All of the remaining stormwater treatment systems are associated with the interconnected waterbodies which discharge into Lost Lake.

## 3.8 Wastewater Disposal

Information on sanitary sewage disposal within the Queens Mirror Lake and Triplet Chain-of-Lakes drainage basins was provided to ERD by the City of Casselberry. An aerial overview of methods of sanitary disposal in the vicinity of Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 3-9. Approximately 80% of the areas immediately adjacent to Queens Mirror Lake appear to be serviced by a sanitary sewer system, with the remaining areas serviced by individual on-site septic tanks. Approximately half of the developed parcels immediately adjacent to South Lake Triplet are serviced by on-site septic tanks, with the remaining areas serviced by existing sanitary sewer systems. Only a few parcels immediately adjacent to Middle Lake Triplet appear to be serviced by septic tanks, although a number of septic tanks are located in upland basin areas. Portions of the development on the east side of North Lake Triplet appear to be serviced by septic tanks, with remaining areas serviced by sanitary sewer systems.

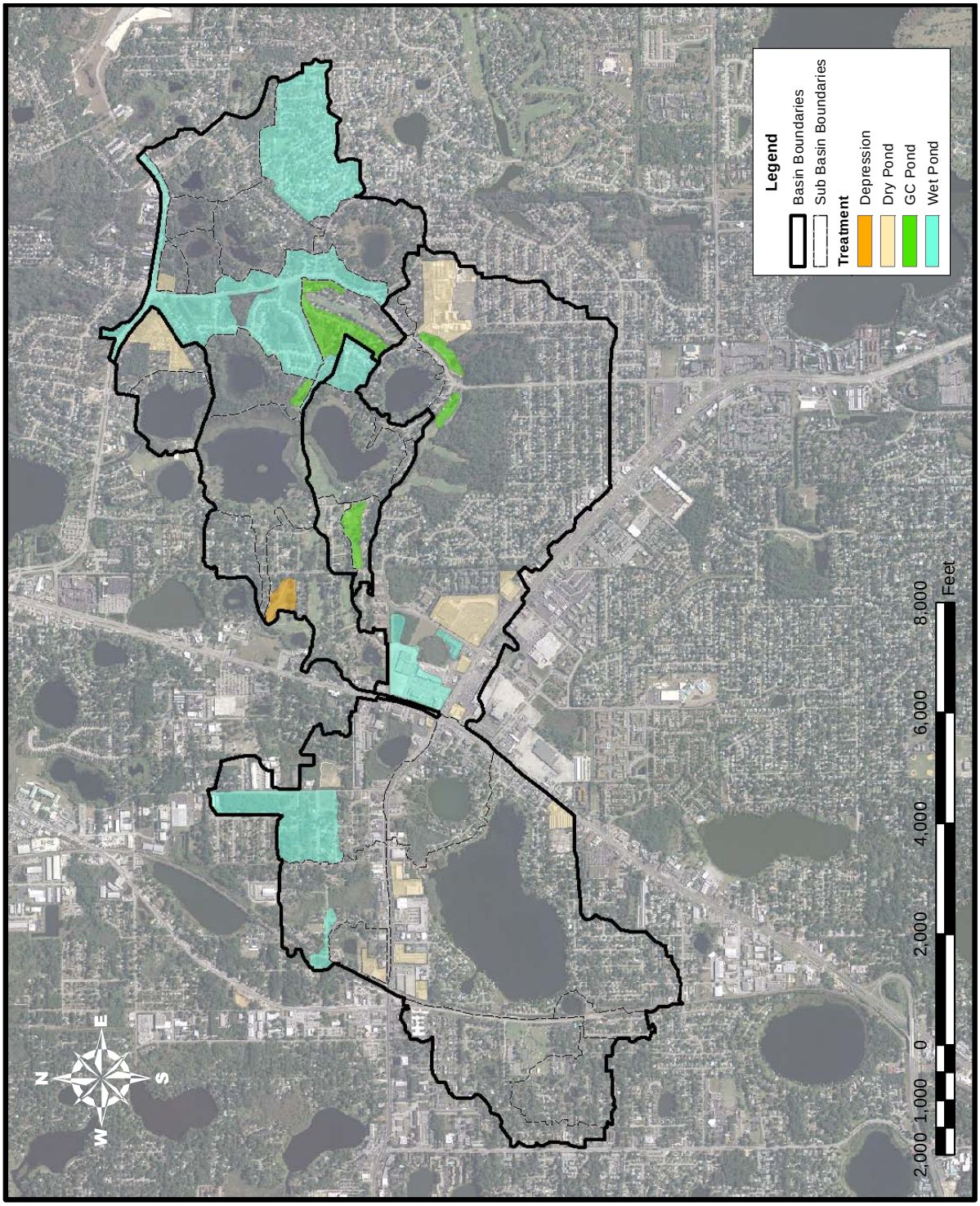



Figure 3-8. Stormwater Treatment Areas within the Queens Mirror Lake, Triplet Chain-of-Lakes, and Interconnected Waterbodies.

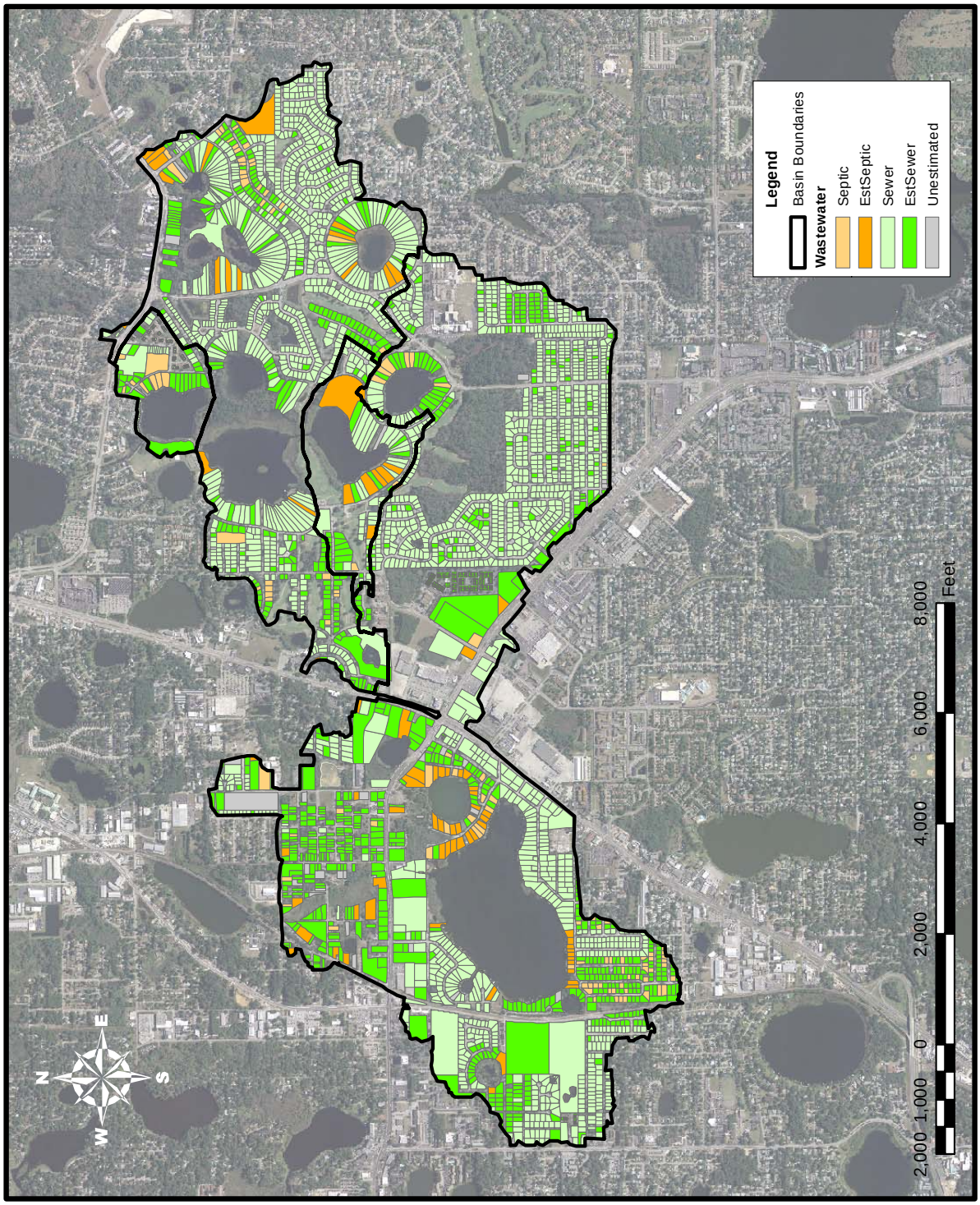



Figure 3-9. Sanitary Disposal Methods in the Vicinity of Queens Mirror Lake and the Triplet Chain-of-Lakes.

# SECTION 4

# HYDROLOGIC INPUTS AND LOSSES

An average annual hydrologic budget was developed for Queens Mirror Lake and the Triplet Chain-of-Lakes which includes inputs from direct precipitation, stormwater runoff, tributary inflow, and groundwater seepage. Hydrologic losses are estimated for evaporation, deep recharge, and outfall discharges between the interconnected lakes. The hydrologic budget is used as an input for development of a nutrient budget as well as estimation of hydraulic residence time. A discussion of identified hydrologic inputs and losses for Queens Mirror Lake and the Triplet Chain-of-Lakes is given in the following sections.

## 4.1 Hydrologic Inputs

### 4.1.1 Direct Precipitation

#### 4.1.1.1 Rainfall Characteristics

Hydrologic inputs from direct precipitation to Queens Mirror Lake and the Triplet Chain-of-Lakes 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.

#### 4.1.1.2 Hydrologic Inputs

Estimated monthly hydrologic inputs from direct precipitation into Queens Mirror Lake and the Triplet Chain-of-Lakes 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 areas for each of the lakes summarized in Table 2-6. A summary of estimated mean monthly hydrologic inputs to Queens Mirror Lake and the Triplet Chain-of-Lakes from direct precipitation is given in Table 4-2. During an average annual rainfall year, direct precipitation contributes approximately 52.24 ac-ft to Queens Mirror Lake, 97.10 ac-ft to South Lake Triplet, 185.9 ac-ft to Middle Lake Triplet, and 89.51 ac-ft to North Lake Triplet.

## TABLE 4-1

## SUMMARY OF MEAN MONTHLY RAINFALL IN THE ORLANDO AREA FROM 1942-2005

| 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** |

## TABLE 4-2

## ESTIMATED MEAN MONTHLY HYDROLOGIC INPUTS TO QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES FROM DIRECT PRECIPITATION

| MONTH | MONTHLY RAINFALL (inches) | INPUTS (ac-ft/month) | | | |
|---|---|---|---|---|---|
| | | Queens Mirror Lake | South Lake Triplet | Middle Lake Triplet | North Lake Triplet |
| January | 2.53 | 2.64 | 4.91 | 9.40 | 4.53 |
| February | 2.46 | 2.57 | 4.77 | 9.14 | 4.40 |
| March | 3.62 | 3.78 | 7.03 | 13.45 | 6.48 |
| April | 2.82 | 2.94 | 5.47 | 10.48 | 5.05 |
| May | 3.82 | 3.99 | 7.41 | 14.19 | 6.83 |
| June | 7.49 | 7.82 | 14.54 | 27.83 | 13.40 |
| July | 7.61 | 7.95 | 14.77 | 28.28 | 13.62 |
| August | 6.16 | 6.43 | 11.96 | 22.89 | 11.02 |
| September | 6.27 | 6.55 | 12.17 | 23.30 | 11.22 |
| October | 2.60 | 2.71 | 5.05 | 9.66 | 4.65 |
| November | 2.61 | 2.73 | 5.07 | 9.70 | 4.67 |
| December | 2.04 | 2.13 | 3.96 | 7.58 | 3.65 |
| **TOTALS:** | **50.03** | **52.24** | **97.10** | **185.9** | **89.51** |

### 4.1.2 Stormwater Runoff

Estimates of volumetric inputs from direct stormwater runoff were generated for each of the sub-basin areas discharging into Queens Mirror Lake, the Triplet Chain-of-Lakes. The estimated runoff volumes were calculated for average annual rainfall conditions based upon a statistical distribution of historical rainfall events. In addition to direct sub-basin areas which discharge into Queens Mirror Lake and the Triplet Chain-of-Lakes through individual stormsewer lines, ditches, or canals, Middle Lake Triplet also receives inflow from a series of interconnected lakes. Inflow from interconnected lake systems discharges to Lost Lake which then discharges into the east side of Middle Lake Triplet. A schematic of the overall drainage basin areas discharging to Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 4-1. Estimates of annual hydrologic inputs were generated for each of the lake system inflows as well as the direct sub-basin areas. The estimates of runoff inputs are utilized for development of hydrologic and nutrient budgets for Queens Mirror Lake and the Triplet Chain-of-Lakes. Details of evaluation methods and results of the runoff modeling efforts are given in the following sections.

A probability distribution of individual rain events during the period of record for the OIA meteorological site was developed by evaluating common rain events which occurred at the monitoring site. Hourly meteorological data was obtained from the NCDC for the OIA meteorological site, and the continuous hourly rainfall record was scanned to determine the total rainfall depth for individual rain events which occurred at the monitoring site over the period of record from 1942-2005. Only National Climatic Data Center (NCDC) valid rainfall years, defined as a year with valid data for all 12 months, were used in this analysis. Yearly periods which were missing one or more months of rainfall data were excluded from the data set.

For purposes of this analysis, a rain event is defined as a period of continuous rainfall. The US EPA typically uses a 6-hour separation for defining individual rain events. Using this criterion, rain episodes separated by less than six hours of dry conditions are considered to be one continuous event, while rain events separated by six hours or more of dry conditions are assumed to be separate events. The six-hour separation period is thought to be the minimum period of no rainfall required to restore the hydrologic characteristics of the site to pre-rain event conditions.

Although this definition may work well in the temperate climates present throughout much of the U.S., it fails to consider the small convective events which occur frequently within the State of Florida, particularly during the summer months. For rain events in the range of 0.25 inches or more, an inter-event separation period of approximately six hours seems adequate to restore hydrologic characteristics for a Florida watershed. However, for events less than 0.25 inches, hydrologic characteristics can be restored rapidly, often within several hours. Therefore, for purposes of this evaluation, a variable inter-event dry period is utilized. When the cumulative hourly rainfall is equal to 0.25 inches or more, an inter-event dry period of six hours is required to initiate the start of a new rain event. Rainfall which occurs less than six hours from the termination of the previous rainfall is assumed to be part of the original rainfall event. However, for rain events less than 0.25 inches, an inter-event dry period of three hours is used to indicate the start of a new independent runoff event.

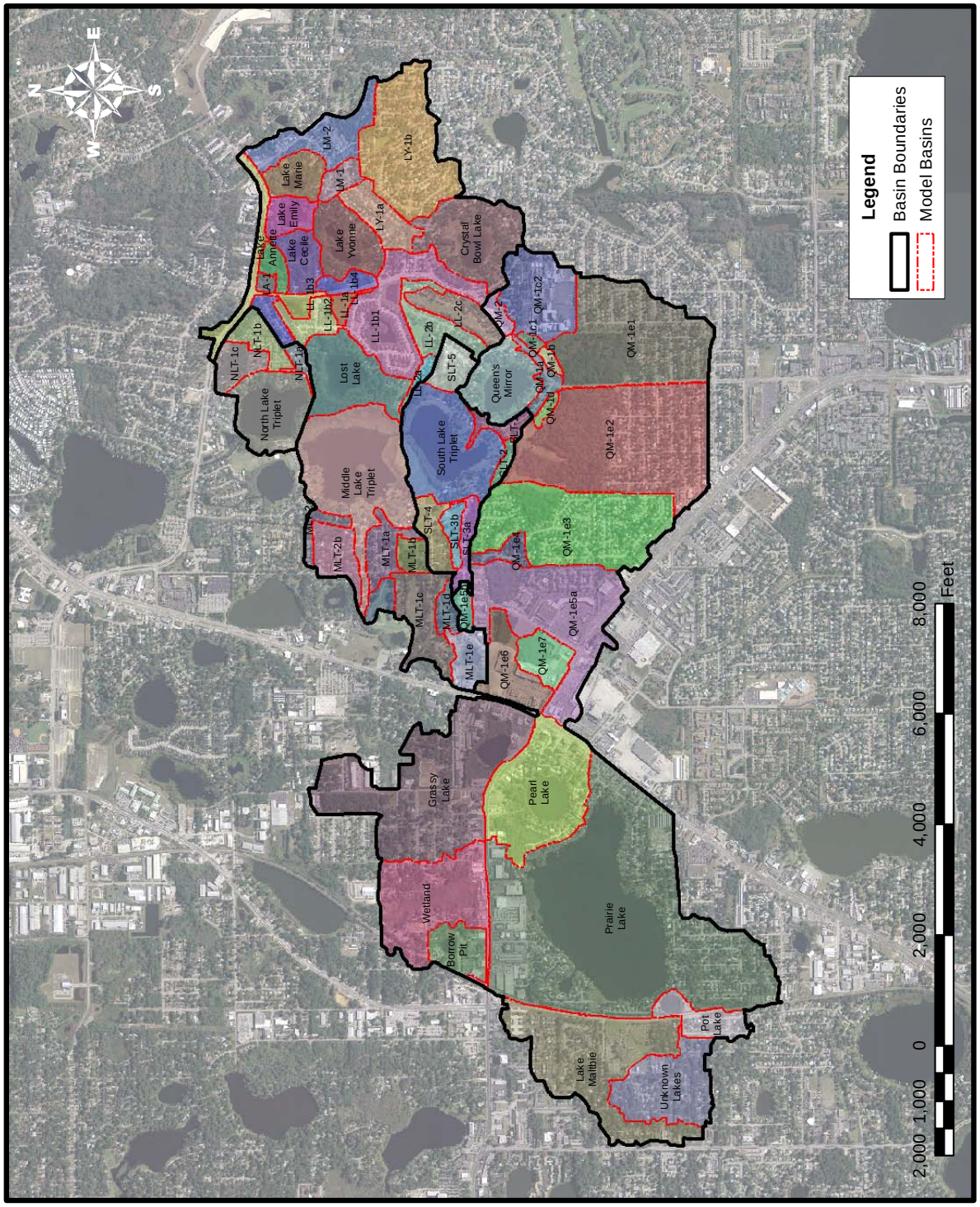



Figure 4-1. Drainage Basin Areas Discharging to Queens Mirror Lake and the Triplet Chain-of-Lakes.

The available data set for the OIA meteorological site was scanned and divided into individual rain events based upon the criteria outlined previously. Individual rainfall events at the monitoring site were divided into 19 rainfall event ranges which include 0.00-0.10 inches, 0.11-0.20 inches, 0.21-0.30 inches, 0.31-0.40 inches, 0.41-0.50 inches, 0.51-1.00 inch, 1.01-1.50 inches, 1.51-2.00 inches, 2.01-2.50 inches, 2.51-3.00 inches, 3.01-3.50 inches, 3.51-4.00 inches, 4.01-4.50 inches, 4.51-5.00 inches, 5.01-6.00 inches, 6.01-7.00 inches, 7.01-8.00 inches, 8.01-9.00 inches, and greater than 9 inches. For each rainfall event range, the median depth of rain events within the interval was calculated, as well as the average number of rain events, the mean rainfall duration, the mean antecedent dry period, the annual rainfall depth contributed by each interval, and the cumulative annual event volume.

A frequency distribution of typical rain events in the Orlando area from 1942-2005 is given in Table 4-3. During an average rainfall year, the Orlando area receives approximately 127 independent rain events. Approximately 43% of these events contribute approximately 0.1 inch of rainfall or less, with 58% contributing 0.2 inches or less and 76% contributing 0.5 inches or less.

**TABLE 4-3**

**FREQUENCY DISTRIBUTION OF RAIN EVENTS IN THE ORLANDO AREA FROM 1942-2005**

| RAINFALL EVENT RANGE (inches) | NUMBER OF ANNUAL EVENTS IN RANGE | MEDIAN INTERVAL RAINFALL DEPTH (inches) | RAINFALL EVENT RANGE (inches) | NUMBER OF ANNUAL EVENTS IN RANGE | MEDIAN INTERVAL RAINFALL DEPTH (inches) |
|---|---|---|---|---|---|
| 0.00-0.10 | 54.85 | 0.041 | 3.01-3.50 | 0.39 | 3.271 |
| 0.11-0.20 | 18.52 | 0.152 | 3.51-4.00 | 0.31 | 3.721 |
| 0.21-0.30 | 10.37 | 0.252 | 4.01-4.50 | 0.18 | 4.218 |
| 0.31-0.40 | 6.79 | 0.353 | 4.51-5.00 | 0.06 | 4.703 |
| 0.41-0.50 | 5.79 | 0.456 | 5.01-6.00 | 0.20 | 5.485 |
| 0.51-1.00 | 16.39 | 0.716 | 6.01-7.00 | 0.03 | 6.255 |
| 1.01-1.50 | 7.03 | 1.225 | 7.01-8.00 | 0.04 | 7.590 |
| 1.51-2.00 | 3.24 | 1.725 | 8.01-9.00 | 0.02 | 8.190 |
| 2.01-2.50 | 1.65 | 2.228 | >9.00 | 0.03 | 12.310 |
| 2.51-3.00 | 0.82 | 2.702 | | | |

A continuous simulation model was developed for the Queens Mirror Lake, Triplet Chain-of-Lakes, and interconnected lakes sub-basin areas which uses the statistical distribution of historical rain events summarized in Table 4-3 as the precipitation input data. This model provides an estimate of runoff inputs to each waterbody from the delineated sub-basins during average annual rainfall conditions. The SCS curve number methodology was used to provide estimates of the runoff volumes generated within each delineated drainage sub-basin area for rainfall events listed in Table 4-3. 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 field reconnaissance of the watershed areas. This information was discussed previously in Section 3.5.

After estimating the hydrologic characteristics of the 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:

$$Soil\ Storage, S = \frac{1000}{nDCIA\ CN} - 10$$

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

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

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:

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

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 of the rainfall events listed in Table 4-3. The sum of runoff generated by each of the modeled events is equivalent to the estimated annual runoff volume. This methodology was developed by ERD for FDEP for use in the Statewide Stormwater Rule.

The methodology outlined above provides an estimate of the “generated” runoff volume for each sub-basin area. However, significant portions of the generated runoff volume may be attenuated during migration through stormwater management systems, wetlands, ponds, or depressional areas 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 dry or 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. Wetland systems may retain large portions of the incoming runoff through infiltration and evapotranspiration.

The watershed model includes estimates of the types of stormwater management systems utilized within each sub-basin area, along with other likely attenuation processes, and the amount of developed area treated by each stormwater management type or attenuation process. 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 annual volumetric removal efficiencies for stormwater management and attenuation systems in the Queens Mirror Lake, Triplet Chain-of-Lakes, and interconnected waterbody drainage sub-basins is given in Table 4-4. These volumetric removals are based on previous research conducted by ERD on the performance efficiencies of stormwater management systems used in the State of Florida. Developed areas treated by dry ponds are assumed to have a volumetric loss of approximately 80% for runoff inputs due to infiltration and evaporation within the pond. Wet ponds are assumed to have a volumetric loss of approximately 20%, due primarily to evaporation and infiltration through the pond bottom. The information summarized in Table 4-4 is combined with information on stormwater management systems (Figure 3-8) to assist in calculation of estimated runoff inflow from sub-basin areas into the lakes.

**TABLE 4-4**

**ESTIMATED VOLUMETRIC REMOVAL EFFICIENCIES FOR STORMWATER MANAGEMENT SYSTEMS IN THE QUEENS MIRROR LAKE AND TRIPLET CHAIN-OF-LAKES DRAINAGE SUB-BASINS**

| SYSTEM TYPE | ANNUAL RUNOFF VOLUME REDUCTION (%) |
|---|---|
| Dry Pond | 80 |
| Wet Detention Pond | 20 |

In addition to volumetric removals which occur in stormwater management systems and wetlands within the various basins, several depressional areas were also identified in the Middle Lake Triplet drainage basin which attenuate a large portion of the annual runoff volume generated in areas discharging to these depressions. An overview of elevation contours in the vicinity of the depressional areas, located west of Middle Lake Triplet and east of US 17-92, is given on Figure 4-2. For purposes of estimating annual runoff discharges, an attenuation of 80% is assumed for runoff generated within these basins.

Additional significant depressional areas were also identified within the system of interconnected lakes located northeast of Queens Mirror Lake and the Triplet Chain-of-Lakes. An overview of elevation contours in the vicinity of these depressional areas is given on Figure 4-3. The identified depressional areas are associated with Lake Annette, Lake Cecile, Lake Emily, Lake Marie, and Lake Yvonne. Based upon the available contour information and a

review of historical aerial photography, it appears that these waterbodies frequently exist in a low water condition with only small pockets of water existing within the areas of the lake basin. These lakes exist as a system of interconnected waterbodies which ultimately discharge from Lake Yvonne into Lost Lake. However, it appears that the water elevations within the lakes rarely exceeds the elevations necessary to create a discharge through Lost Lake, indicating that a very large proportion of the incoming runoff flow is retained within the basins of the lakes. For purposes of estimating annual runoff discharges from these lakes to downstream waterbodies, an attenuation of 90% is assumed for runoff generated within these basins.

Volumetric losses were also included for water lost as a result of evapotranspiration (ET) in wetland areas scattered throughout the various drainage basins. Based upon satellite imagery of ET rates in the general vicinity of Queens Mirror Lake and the Triplet Chain-of-Lakes, the estimated annual actual ET lost from wetlands is approximately 45.7 inches/year. Therefore, an additional volumetric loss of 45.7 inches is assumed to occur over each of the identified wetland areas.

A relatively large annual runoff volume is generated within the series of interconnected waterbodies located west of US 17-92. Runoff generated within these sub-basins discharges from Grassy Lake beneath US 17-92 and into the QM-1 sub-basin. However, a high level hydraulic connection also exists from the QM-1 sub-basin to the Middle Lake Triplet MLT-1 sub-basin. As a result, inflows from Grassy Lake can also discharge to Sub-basin MLT-1 under high water level conditions, although this pattern of water movement is thought to be relatively rare. For purposes of this analysis, it is assumed that approximately 90% of the cumulative discharges from Grassy Lake remains within the QM-1 sub-basin, with 10% discharging to the MLT-1 sub-basin on an annual basis. This proportion is reflected in the hydrologic summary discussed in the next section.

#### 4.1.2.1 Hydrologic Inputs

A summary of calculations used to estimate annual runoff inputs to Queens Mirror Lake, the Triplet Chain-of-Lakes, and interconnected waterbodies is given in Appendix B, and a tabular summary of modeled runoff inputs is given on Table 4-5. This table provides a summary of runoff inputs for each lake and delineated sub-basin area. For each sub-basin, the generated runoff volume is listed, which reflects the modeled runoff volume generated within the sub-basin area prior to attenuation in stormwater systems, wetlands, or depressional areas. An estimate of the volume which is attenuated within the sub-basin is also provided based upon the methods discussed previously. The difference between the generated runoff volume and the attenuated runoff volume is the estimated annual volume which discharges to each of the modeled lake systems. Calculated C-values are also provided for each sub-basin area based on the volume which actually discharges to each waterbody from an individual sub-basin area.

The most significant sub-basin area discharging to Queens Mirror Lake is Sub-basin QM-1 which includes the series of upstream lakes and contributes approximately 97.0% of the total runoff volume which reaches the lake on an annual basis. This sub-basin receives runoff from all of the interconnected lakes located west of US 17-92 which discharge into the wetland system south of Queens Mirror Lake and ultimately through the southern inflow canal. Relatively small contributions occur from Sub-basin QM-2 and direct overland flow, ranging from 0.6-2.3%.

The most significant area discharging into South Lake Triplet is direct overland flow, which comprises approximately 46.9% of the annual runoff inputs. Runoff contributions from Sub-basins SLT-1, SLT-3, and SLT-4 are relatively similar, ranging from 10.3-16.0%, with only 5.5% of the annual runoff inputs contributed by Sub-basin SLT-2.

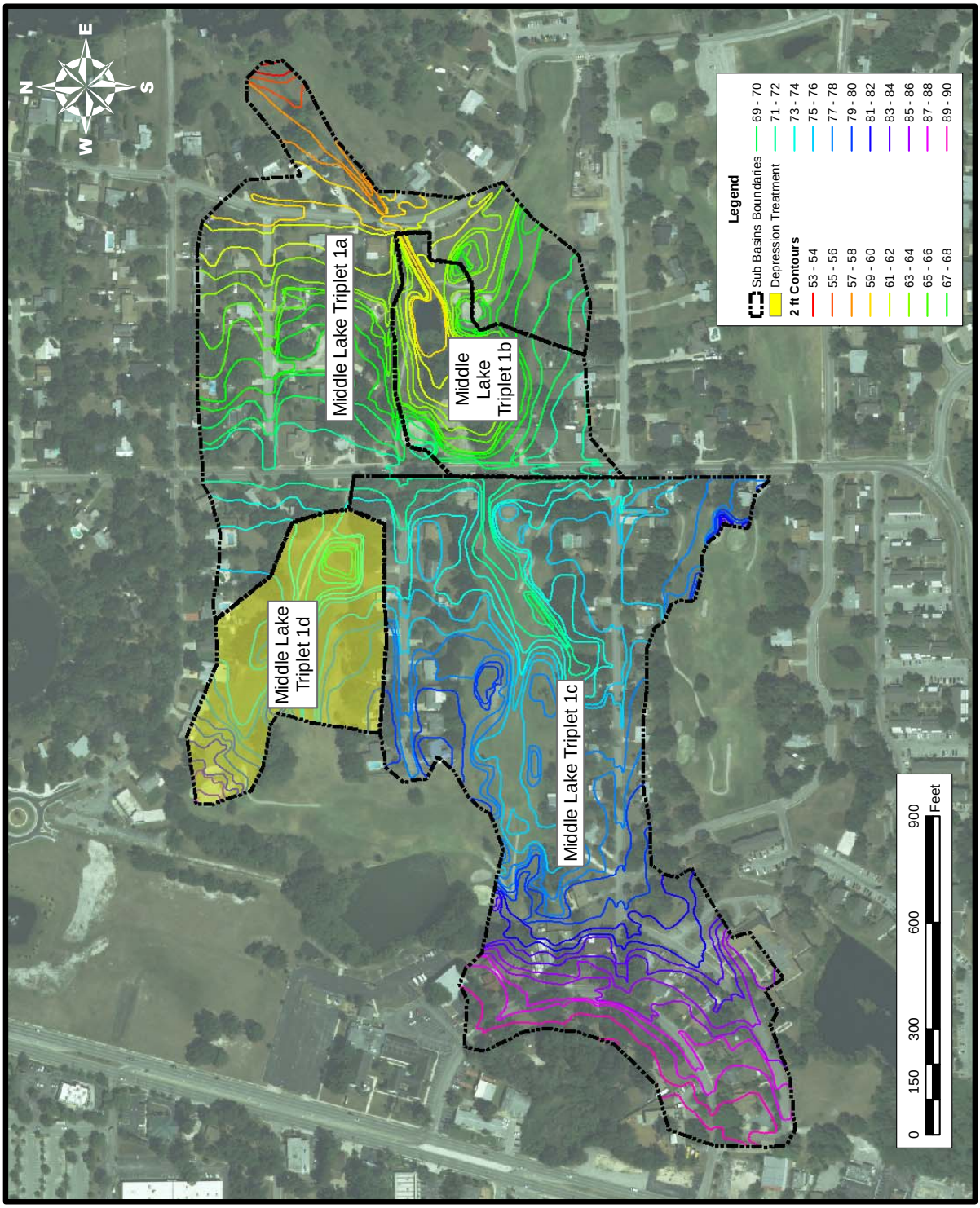



Figure 4-2. Isolated Depressional Areas in the Middle Lake Triplet Drainage Basin.

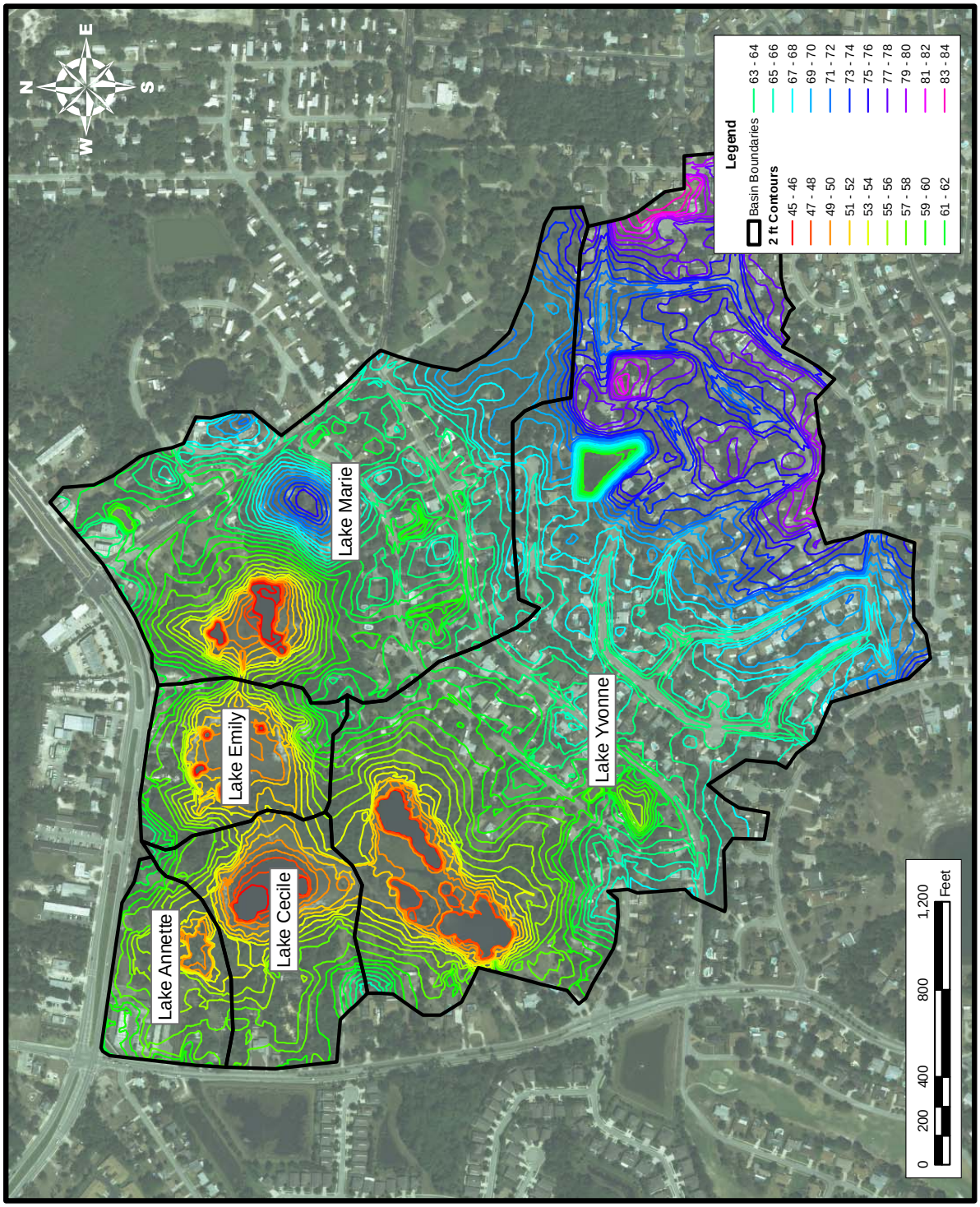



Figure 4-3. Isolated Depressional Areas in the Lake Annette, Lake Cecile, Lake Emily, Lake Marie, and Lake Yvonne Drainage Basins.

# TABLE 4-5

## MODELED RUNOFF INPUTS TO QUEENS MIRROR LAKE, THE TRIPLET CHAIN-OF-LAKES, AND INTERCONNECTED WATERBODIES

| LAKE | SUB-BASIN | BASIN AREA (acres) | GENERATED RUNOFF VOLUME (ac-ft/yr) | VOLUME ATTENUATED (ac-ft/yr) | VOLUME DISCHARGED TO LAKE (ac-ft/yr) | PERCENT OF TOTAL VOLUME (%) | ANNUAL C-VALUE |
|---|---|---|---|---|---|---|---|
| Grassy Lake Basin | Borrow Pit | 14.23 | 26.22 | 13.90 | 12.32 | 1.8 | 0.208 |
| | Wetland | 76.68 | 69.81 | 51.79 | 18.02 | 2.6 | 0.056 |
| | Un-named Lake | 49.49 | 66.13 | 52.91 | 13.22 | 1.9 | 0.064 |
| | Pot Lake | 19.13 | 21.37 | 4.27 | 17.1 | 2.5 | 0.214 |
| | Lake Maltbie | 99.41 | 130.0 | 0.00 | 130.0 | 19.1 | 0.314 |
| | Prairie Lake | 330.27 | 316.0 | 49.04 | 267.0 | 39.2 | 0.194 |
| | Pearl Lake | 79.90 | 113.4 | 33.81 | 79.58 | 11.7 | 0.239 |
| | Grassy Lake | 142.39 | 200.1 | 56.50 | 143.6 | 21.1 | 0.242 |
| | **Totals:** | 811.50 | 943.1 | 262.2 | 680.8 | 100.0 | 0.201 |
| Queens Mirror Lake | QM-1 | 1364.06 | 1629.7 [a] | 706.1 | 923.6 [a] | 97.0 | 0.162 |
| | QM-2 | 5.15 | 6.14 | 0.00 | 6.14 | 0.6 | 0.286 |
| | Direct | 22.49 | 22.00 | 0.00 | 22.00 | 2.3 | 0.235 |
| | **Totals:** | 1391.7 | 1657.9 | 706.1 | 951.7 | 100.0 | 0.164 |
| South Lake Triplet | SLT-1 | 7.47 | 8.32 | 0.00 | 8.32 | 10.3 | 0.267 |
| | SLT-2 | 3.73 | 4.48 | 0.00 | 4.48 | 5.5 | 0.288 |
| | SLT-3 | 16.37 | 13.72 | 0.76 | 12.96 | 16.0 | 0.190 |
| | SLT-4 | 14.38 | 9.93 | 0.00 | 9.93 | 12.2 | 0.166 |
| | SLT-5 | 12.96 | 9.22 | 1.84 | 7.38 | 9.1 | 0.137 |
| | Direct | 41.39 | 38.04 | 0.00 | 38.04 | 46.9 | 0.220 |
| | **Totals:** | 96.30 | 83.71 | 2.60 | 81.11 | 100.0 | 0.202 |
| Lost Lake Basin | Lake Marie | 58.90 | 50.92 | 33.87 | 17.05 | 8.7 | 0.069 |
| | Lake Emily | 12.64 | 9.59 | 7.77 | 1.82 | 0.9 | 0.035 |
| | Lake Annette | 9.65 | 9.86 | 9.09 | 0.77 | 0.4 | 0.019 |
| | Lake Cecile | 16.48 | 11.58 | 8.92 | 2.66 | 1.4 | 0.039 |
| | Lake Yvonne | 126.08 | 134.1 | 116.9 | 17.21 | 8.7 | 0.033 |
| | Crystal Bowl | 53.79 | 52.91 | 50.27 | 2.64 | 1.3 | 0.012 |
| | Lost Lake | 183.15 | 178.0 | 116.4 | 61.67 | 31.3 | 0.081 |
| | **Totals:** | 460.69 | 446.99 | 343.17 | 103.82 | 52.77 | 0.054 |
| Middle Lake Triplet | MLT-1 | 81.92 | 186.8 [b] | 42.14 | 144.6 [b] | 73.5 | 0.213 |
| | MLT-2 | 24.76 | 28.09 | 13.80 | 14.29 | 7.3 | 0.138 |
| | Direct | 91.05 | 37.80 | 0.00 | 37.80 | 19.2 | 0.100 |
| | **Totals:** | 197.73 | 252.68 | 55.94 | 196.73 | 100.00 | 0.169 |
| North Lake Triplet | NLT-1 | 31.82 | 15.94 | 0.00 | 15.94 | 54.6 | 0.120 |
| | Direct | 17.68 | 13.27 | 0.00 | 13.27 | 45.4 | 0.180 |
| | **Totals:** | 49.50 | 29.21 | 0.00 | 29.21 | 100.0 | 0.142 |

a. Includes 90% of discharge from Grassy Lake
b. Includes 10% of discharge from Grassy Lake

Runoff inputs into Middle Lake Triplet are contributed primarily by Sub-basin MLT-1 which contributes 48.1% on an annual basis, including the assumed periodic inflows from Grassy Lake under high water level conditions. However, direct runoff contributes approximately 12.6% of the annual runoff inputs, with 4.8% contributed by Sub-basin MLT-2. Approximately 34.6% of the annual runoff inputs originate from Lost Lake and the series of interconnected upstream lakes. Runoff inputs into North Lake Triplet are contributed approximately equally by runoff from Sub-basin NLT-1 and direct overland flow.

Calculated annual C-values are also provided for each of the modeled sub-basin areas discharging to Queens Mirror Lake and the Triplet Chain-of-Lakes. Annual runoff C-values for the individual sub-basins range from approximately 0.012-0.314. However, weighted average annual C-values for the lakes range from 0.142 in North Lake Triplet to 0.202 in South Lake Triplet. These C-values suggest that only approximately 15-20% of the annual generated runoff volume actually reaches Queens Mirror Lake and the Triplet Chain-of-Lakes. The information summarized in Table 4-5 is used to estimate total hydrologic inputs to each of the lakes as well as generate estimated annual nutrient loadings.

A nodal diagram for runoff generation and transport in the Queens Mirror Lake, Triplet Chain-of-Lakes, and interconnected waterbodies is given on Figure 4-4 which reflects the net effects of the runoff generation and attenuation processes discussed previously. The diagram provides the estimated runoff volume generated within each sub-basin area (listed in **blue** type) which is then routed into applicable stormwater management system, wetlands, or depressional areas. Appropriate attenuation factors are applied for the treatment processes, and the resulting net runoff volume (listed in **green** type) is transported to the next downstream basin or waterbody. This process is repeated for each sub-basin and treatment system combination within each of the evaluated lake drainage basins. Cumulative discharges from a lake to a downstream waterbody are listed in **red** type. The result of this process is an estimate of the annual runoff volume which actually reaches Queens Mirror Lake, South Lake Triplet, Middle Lake Triplet, and North Lake Triplet from drainage sub-basin areas and interconnected waterbodies.

### 4.1.3 Flow Between Interconnected Waterbodies

A field monitoring program was conducted by ERD from September 2010-January 2011 to quantify discharge rates between each of the four interconnected waterbodies. Locations of the flow monitoring sites are indicated on Figure 4-5. Flow monitoring was conducted on approximately a weekly basis at each of the canals which connect the four lakes. In addition, discharge measurements were also conducted on the canal from Lost Lake to Middle Lake Triplet, and at the discharge from North Lake Triplet.

ERD field personnel performed field measurements of discharge rates at each of the five monitoring sites using the velocity/cross-sectional area method. Velocity measurements were performed at known distances across each channel cross-section using a Sontek Acoustic Doppler Velocity (ADV) meter. The spacing between the velocity measurements was determined in the field such that not more than 10% of the total flow is represented by any one vertical cross-section. The depth at each section was also simultaneously measured using a graduated rod. A graduated tape was stretched across each channel so that reference locations could be determined for each simultaneous measurement of velocity and water depth.

If the water depth was less than 2.5 ft at a measurement point, the velocity was measured at 60% of the total water depth. If the water column depth exceeded 2.5 ft at a measurement point, velocity measurements were performed at 20% and 80% of the total water depth, with the mean section velocity determined by taking the average of the two measurements. The velocities were then integrated over each of the cross-sectional areas to determine the total discharge through the section on each monitoring date.

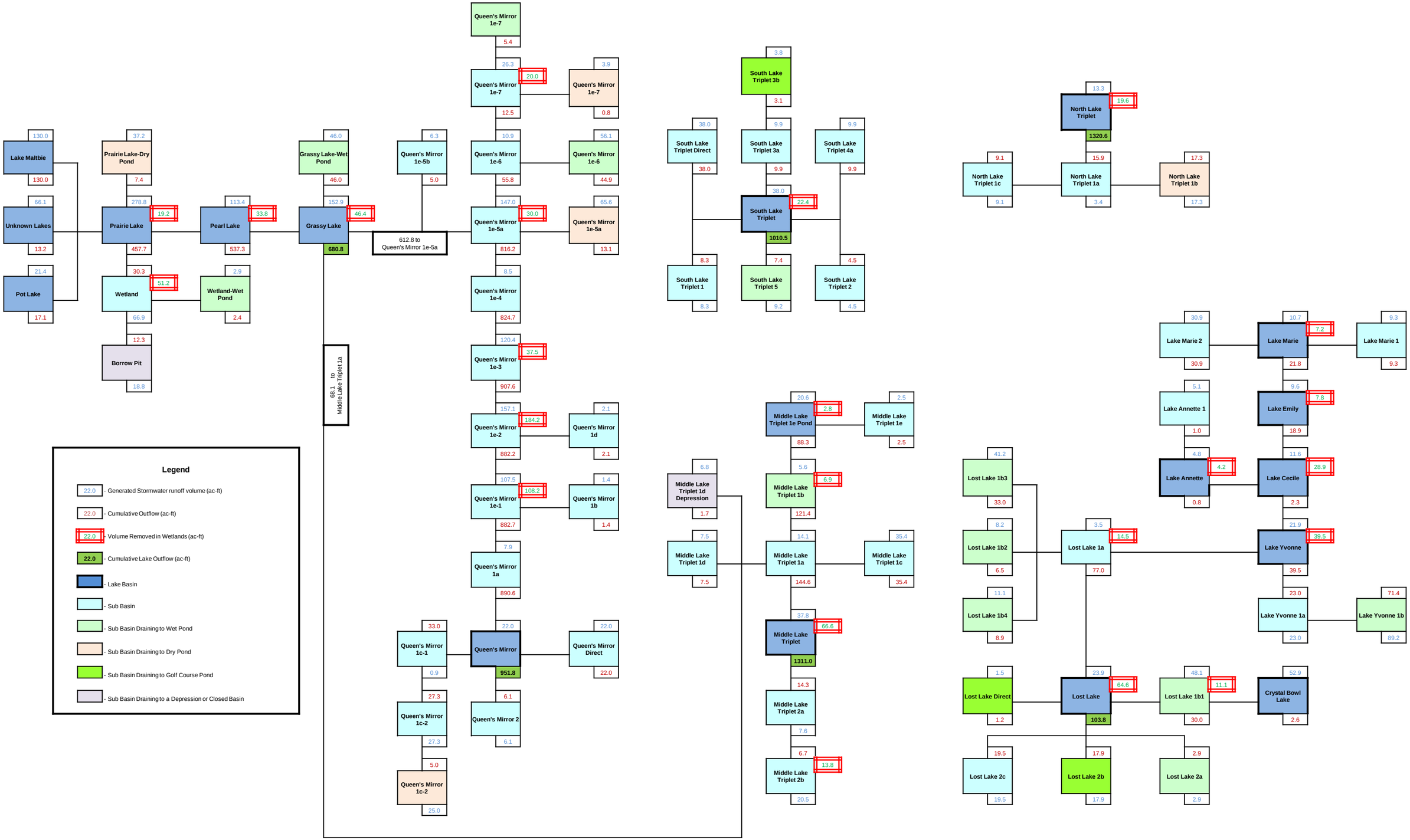



Figure 4-4. Nodal Diagram for Runoff Generation and Transport in Queens Mirror Lake, Triplet Chain-of-Lakes, and Interconnected Waterbodies.

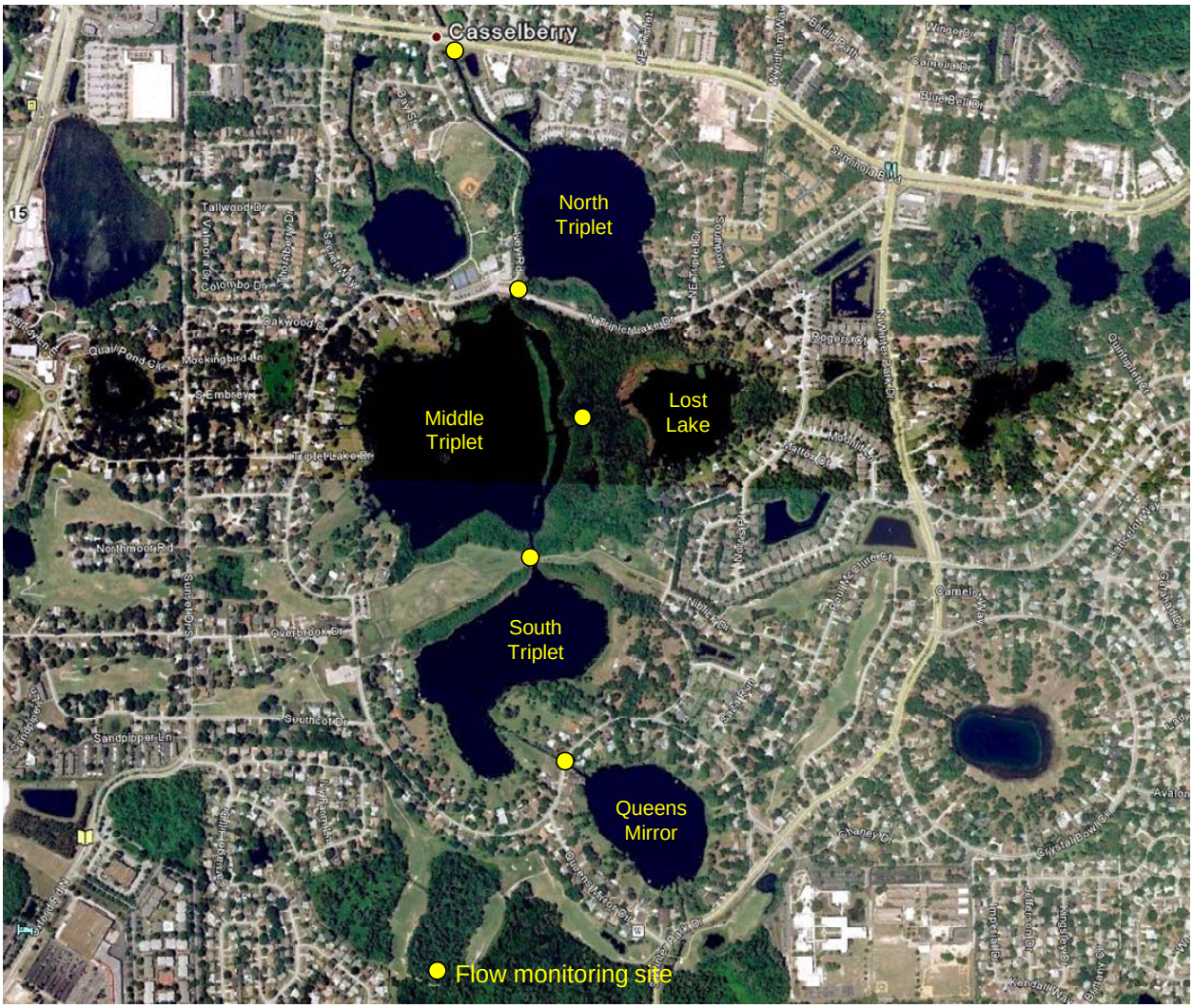



Figure 4-5. Flow Monitoring Sites for Queens Mirror Lake and the Triplet Chain-of-Lakes.

A graphical summary of measured discharge rates between Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 4-6. In general, inflow from Lost Lake to Middle Lake Triplet was relatively low throughout the field monitoring program, with measured discharges ranging from 0 cfs to approximately 2 cfs. Discharge from Lost Lake appears to occur only during relatively wet season conditions, with dry conditions observed within the canal during other portions of the year.

In general, discharge rates appear to increase with increasing distance downstream from Queens Mirror Lake. The general flow pattern between Queens Mirror Lake and the Triplet Chain-of-Lakes is south to north, with the final discharge occurring through the outfall channel from North Lake Triplet. Measured discharges increased steadily from Queens Mirror Lake to South Lake Triplet to Middle Lake Triplet to North Lake Triplet. Discharges from Middle Lake Triplet to North Lake Triplet and from North Lake Triplet to the outfall canal appear to be relatively similar throughout much of the field monitoring program. The data illustrated on Figure 4-6 are used to verify the general magnitude of discharges between the interconnected waterbodies. Annual volumes of water discharging between the interconnected lobes are discussed in a subsequent section.

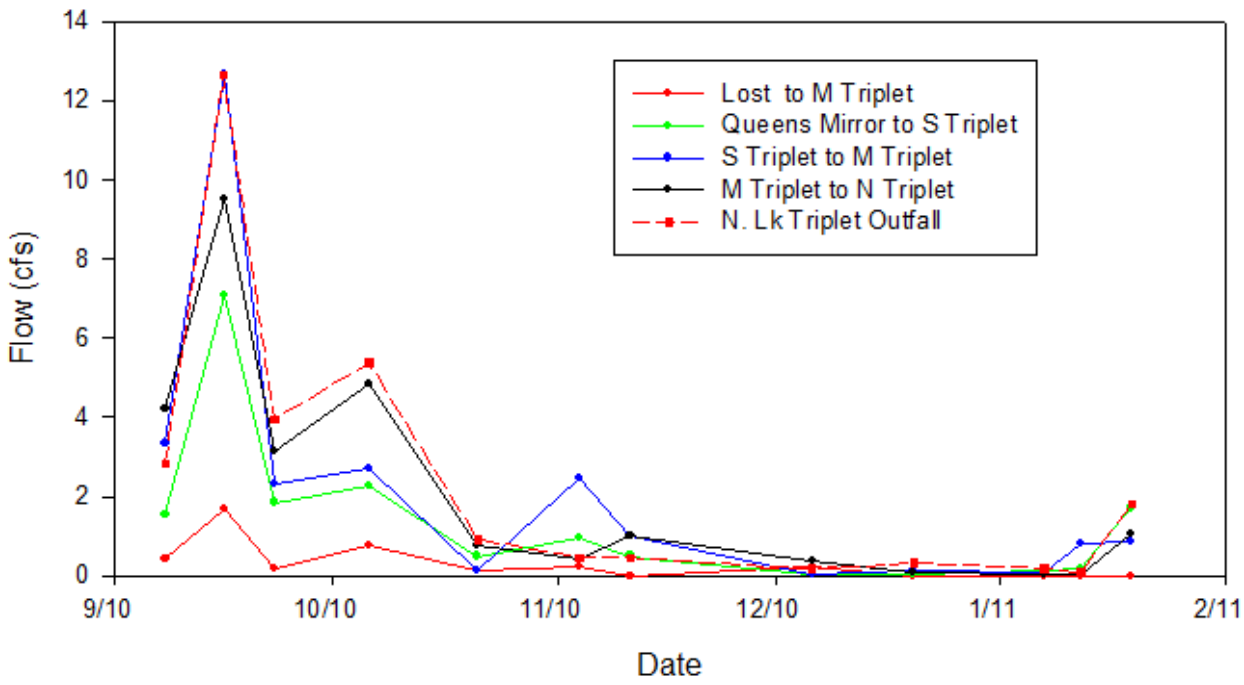



Figure 4-6. Measured Discharge Rates Between Queens Mirror Lake and the Triplet Chain-of-Lakes.

### 4.1.4 Shallow Groundwater Seepage

Field investigations were performed by ERD to evaluate the quantity and quality of shallow groundwater seepage entering Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet during an 8-month monitoring program from September 2010-May 2011. Seepage monitoring was not conducted in North Lake Triplet due to budget constraints. Groundwater seepage was quantified using a series of underwater seepage meters installed at selected locations throughout the three lakes. 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.

#### 4.1.4.1 Seepage Meter Construction and Locations

A schematic of a typical seepage meter installation used for this study is given in Figure 4-7. 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 inches of water was trapped inside the seepage meter above the lake bottom.

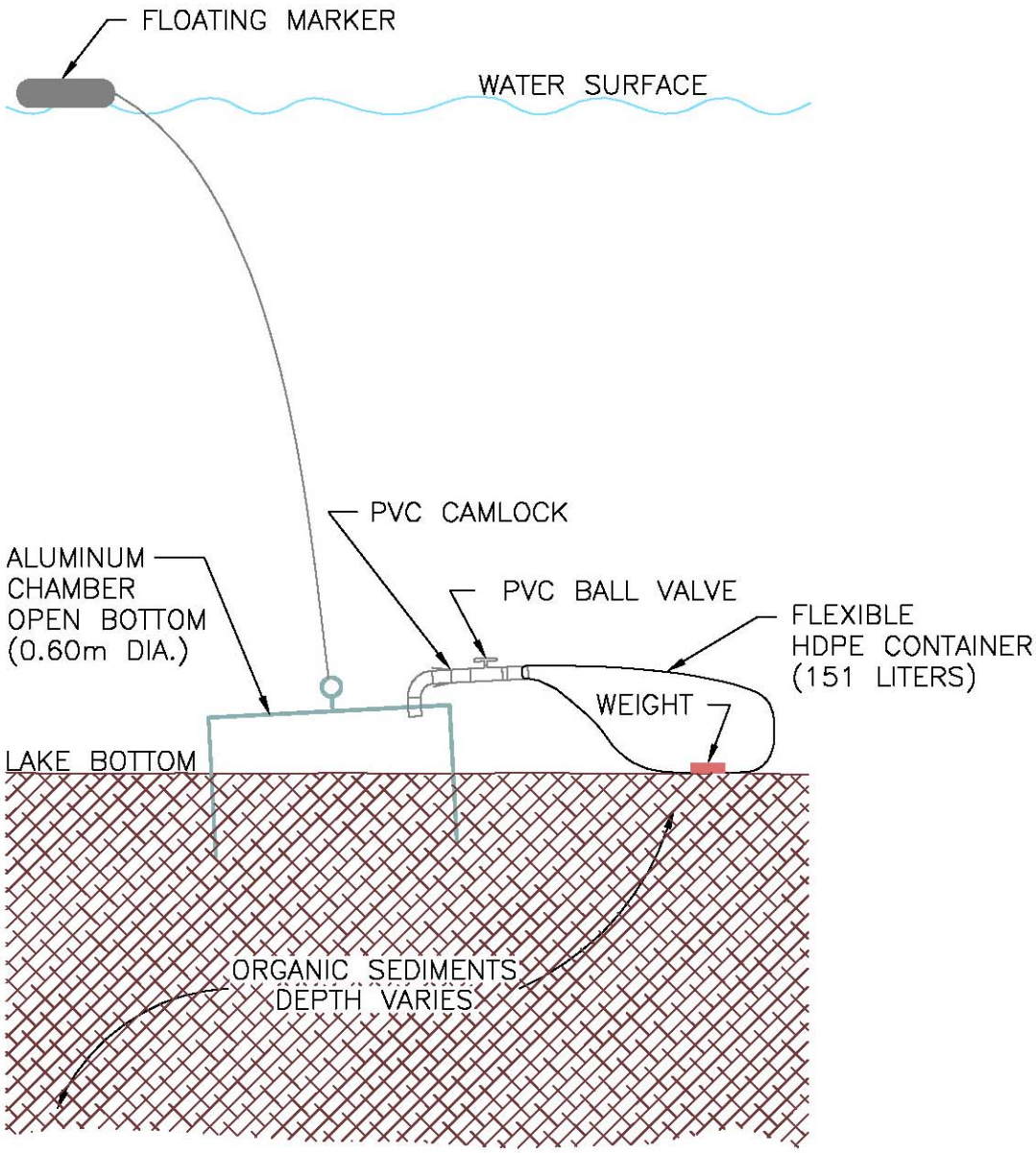



Figure 4-7 Typical Seepage Meter Installation.

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.

Thirteen seepage meters were installed in Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet on August 30, 2010. Locations for the seepage meters are indicated on Figure 4-8. 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 3-4 ft. Seepage meters were also installed in the central portion of each lake.

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 September 2010-May 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 collected for analysis of seepage characteristics. Six separate seepage monitoring events were conducted for evaluation of seepage quantity, with five events conducted to evaluate seepage quality at each of the monitoring sites. A total of 45 samples was collected between the 13 sites over the 255-day monitoring program.

#### 4.1.4.2 Seepage Meter Sampling Procedures

After the initial installation of collection bags, site visits were performed at monthly to bi-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.

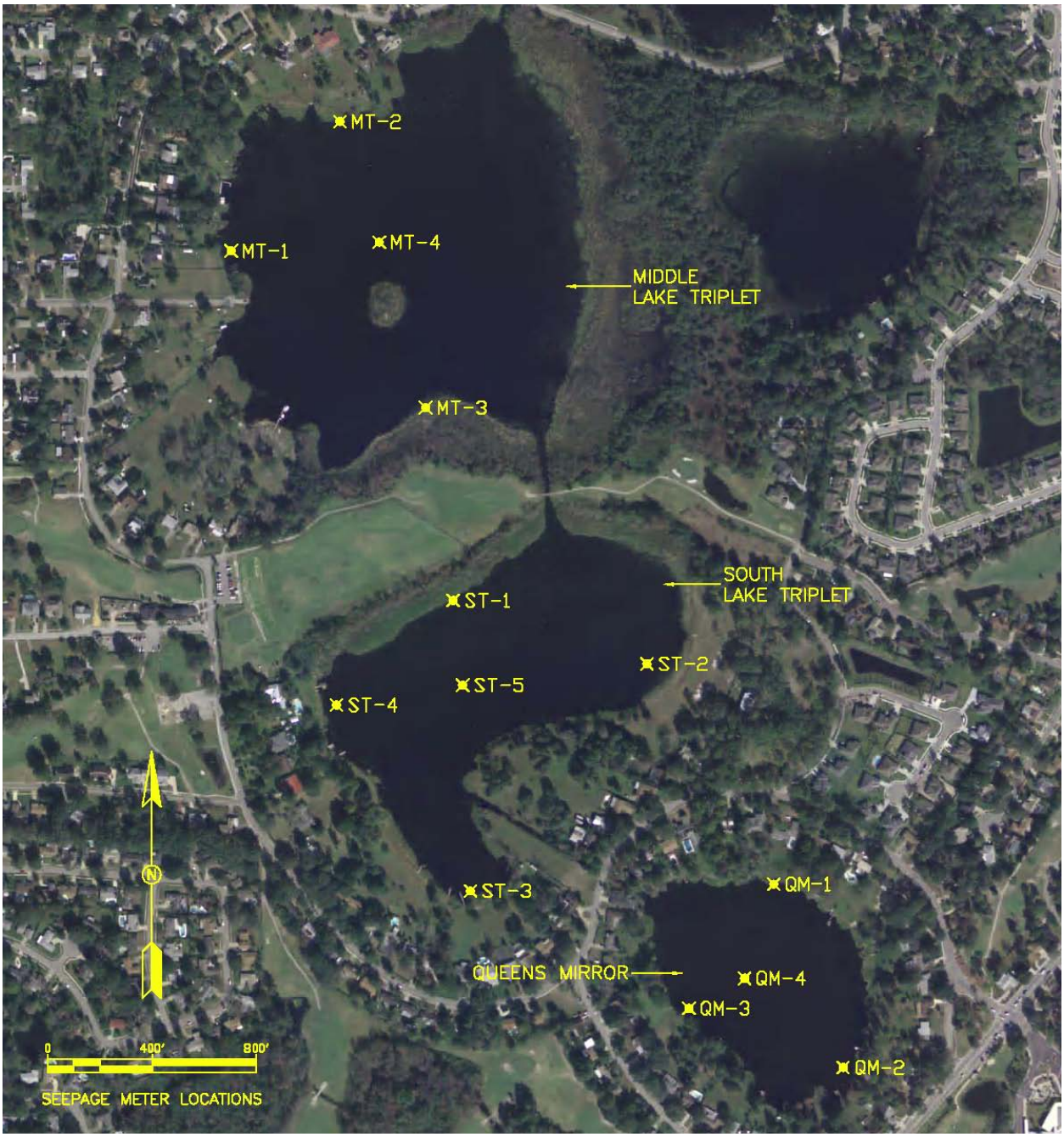



Figure 4-8. Seepage Monitoring Sites in Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet.

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 September 2010-May 2011 is given in Appendix C.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 C.1, several seepage meter sites contain missing data for one or more events as a result of missing or damaged collection bags and seepage meters, particularly in central portions of the lake. Periodic damage to these seepage meters resulted in missing samples for some of the monitoring sites. Damaged seepage meters were repaired or replaced at the time of the monitoring event. The most serious damage occurred at Site MT-4, located in the central portion of Middle Lake Triplet. The seepage meter at this site was repeatedly stolen and, as a result, no samples were collected at this site. Repeated seepage meter disturbance was also observed at shoreline sites in Middle Lake Triplet as well. A total of 58 samples was collected out of a potential of 65 samples (13 sites x 5 samples/site) for a collection percentage of 89%.

#### 4.1.4.3 Seepage Inflow

A statistical summary of seepage inflow measurements collected in Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet is given in Table 4-6. Mean seepage inflow measured in the individual lakes ranged from 0.72-0.83 liters/$m^2$-day, reflecting relatively low seepage values. For comparison, the mean seepage inflow rate measured by ERD in over 35 lakes in Central Florida is approximately 2.0 liters/$m^2$-day.

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 three lakes using the Autodesk Land Desktop 2007 Module for AutoCAD. Isopleths of mean seepage inflow into Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011 are given on Figure 4-9. The range of seepage values indicated on this figure is from 0.5-1.3 liters/$m^2$-day. In general, the lakes appear to exhibit low seepage inflow, with the majority of areas exhibiting seepage of approximately 1 liter/$m^2$-day or less. The seepage inflow isopleths indicated on Figure 4-9 are substantially lower than seepage rates commonly observed in Central Florida lakes.

A graphical comparison of seasonal variability in mean seepage inflow rates to Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet is given on Figure 4-10. Seepage inflow rates for the three lakes were greatest during the October 2010 monitoring event which typically reflects the end of wet season conditions. Seepage rates then declined substantially until the next monitoring event conducted during February 2011. A slight increase in seepage inflow rates was observed during March 2011, with another subsequent decline during the May 2011 monitoring event. In general, seepage inflow rates within the three lakes appear to track very closely throughout the field monitoring program.

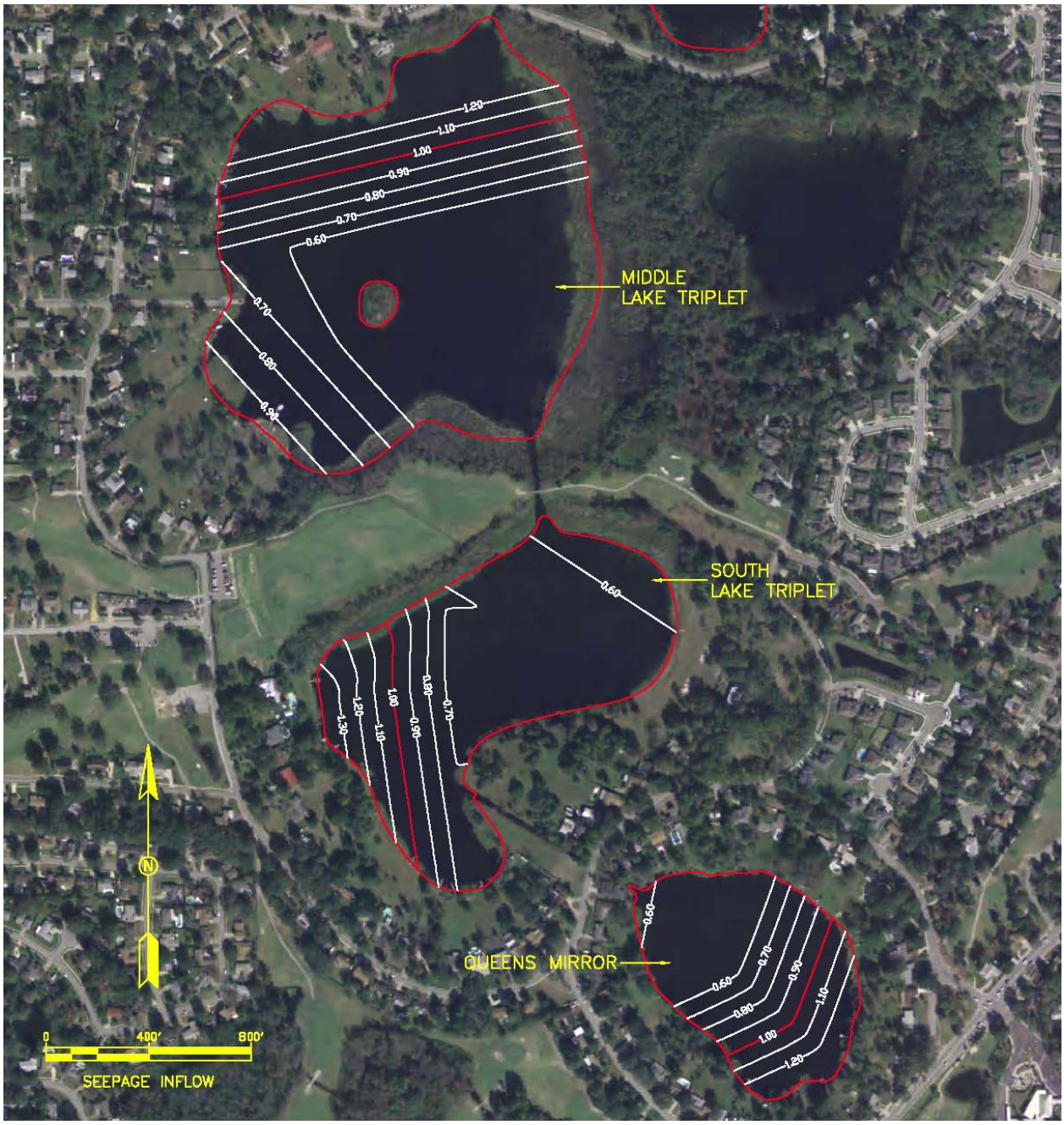



Figure 4-9. Mean Seepage Inflow Isopleths (liters/m$^2$-day) for Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011.

The seepage isopleths indicated on Figure 4-9 were graphically integrated to obtain estimates of mean daily seepage influx into each lake. Estimates of daily seepage inflow were calculated for each lake over the monitoring period from September 2010-May 2011. Since this period included both wet and dry season conditions, the mean daily seepage inflow values are assumed to reflect annual average daily inflow. The measured daily seepage inflow was then converted to an annual value by multiplying the mean daily seepage inflow by 365 days/year.

**TABLE 4-6**

**STATISTICAL SUMMARY OF SEEPAGE INFLOW TO QUEENS MIRROR LAKE, SOUTH LAKE TRIPLET, AND MIDDLE LAKE TRIPLET FROM SEPTEMBER 2010-MAY 2011**

| LAKE | SITE | MEAN VALUE (liters/m$^2$-day) | RANGE OF VALUES (liters/m$^2$-day) | NUMBER OF SAMPLES |
|---|---|---|---|---|
| Queens Mirror Lake | 1 | 0.51 | 0.32-1.85 | 5 |
| | 2 | 1.27 | 0.69-3.10 | 5 |
| | 3 | 0.56 | 0.31-2.28 | 5 |
| | 4 | 0.55 | 0.35-1.31 | 5 |
| South Lake Triplet | 1 | 0.71 | 0.04-2.50 | 5 |
| | 2 | 0.65 | 0.49-1.00 | 4 |
| | 3 | 0.77 | 0.45-1.47 | 5 |
| | 4 | 1.35 | 0.69-3.13 | 5 |
| | 5 | 0.65 | 0.29-1.90 | 5 |
| Middle Lake Triplet | 1 | 0.67 | 0.39-1.57 | 5 |
| | 2 | 1.29 | 1.07-1.79 | 2 |
| | 3 | 0.55 | 0.23-1.90 | 4 |
| | 4 | 0.51 | 0.36-1.04 | 3 |

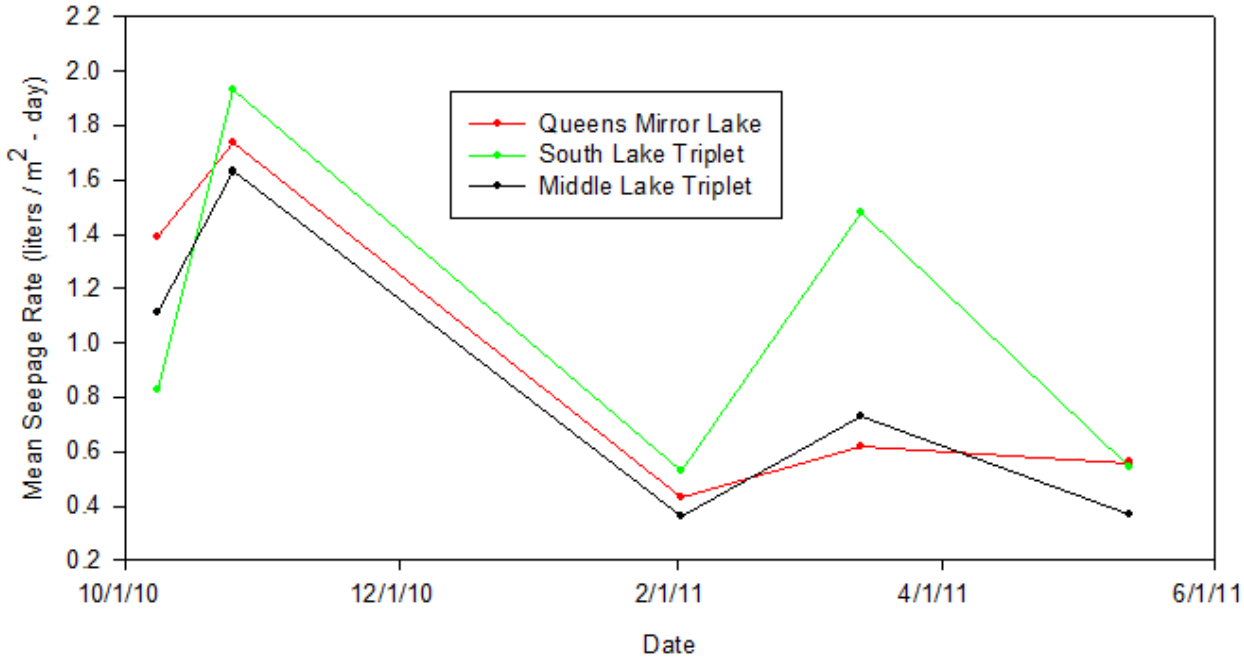



Figure 4-10. Seasonal Variability in Mean Seepage Inflow Rates to Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet.

A summary of estimated annual seepage inflow to Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet is given on Table 4-7. On an annual basis, seepage inflow to Queens Mirror Lake contributes approximately 12.3 ac-ft of water each year which equates to a water depth over the lake surface of approximately 0.98 ft. This inflow is approximately 58% lower than the seepage inflow rate of 2.36 ft/yr measured by ERD in Lake Howell.

**TABLE 4-7**

**ESTIMATED ANNUAL SEEPAGE INFLOW TO QUEENS MIRROR LAKE, SOUTH LAKE TRIPLET, AND MIDDLE LAKE TRIPLET**

| LAKE | ANNUAL SEEPAGE INFLOW | | |
|---|---|---|---|
| | liters/m$^2$-day[1] | ac-ft/yr | ft/yr |
| Queens Mirror Lake | 0.82 | 12.3 | 0.98 |
| South Lake Triplet | 0.78 | 21.8 | 0.93 |
| Middle Lake Triplet | 0.77 | 41.1 | 0.92 |
| North Lake Triplet | 0.79[2] | 20.3 | 0.95 |

1. Weighted mean inflow values
2. Estimated value - mean of values for Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet

On an annual basis, seepage inflow to South Lake Triplet contributes approximately 21.8 ac-ft of water each year which equates to a water depth over the lake surface of approximately 0.93 ft. This inflow is approximately 58% lower than the seepage inflow rate measured by ERD in Lake Howell. Seepage inflow to Middle Lake Triplet contributes approximately 41.1 ac-ft of water per year, which equates to a water depth over the lake surface of approximately 0.92 ft. Seepage monitoring was not conducted in North Lake Triplet, but a seepage inflow value is estimated as the mean of the seepage values measured in Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet. Using this estimated value, seepage inflow contributes approximately 20.3 ac-ft of water each year to North Lake Triplet which is equivalent to approximately 0.95 ft over the entire lake surface.

## 4.2 Hydrologic Losses

Hydrologic losses were estimated for Queens Mirror Lake and the Triplet Chain-of-Lakes resulting from evaporation, deep recharge, and discharges through lake outfall. Estimated losses from evaporation, deep recharge, and outfall discharges are summarized in the following sections.

### 4.2.1 Evaporation Losses

Estimates of monthly evaporation from Queens Mirror Lake and the Triplet Chain-of-Lakes 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 40 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 4-8. For purposes of this project, the mean evaporation measured at the Lake Alfred site is assumed to be similar to evaporation in the Casselberry area. 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 4-8**

**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 annual average evaporation losses from Queens Mirror Lake and the Triplet Chain-of-Lakes is given in Table 4-9. The values summarized in this table were obtained by multiplying the lake surface areas (summarized in Table 2-6) times the monthly estimated lake evaporation. The assumed annual average lake evaporation is 49.98 inches which is equivalent to a total annual evaporation loss of 52.2 ac-ft/yr in Queens Mirror Lake, 97.0 ac-ft/yr in South Lake Triplet, 186 ac-ft/yr in Middle Lake Triplet, and 89.4 ac-ft/yr in North Lake Triplet. This information is utilized in a subsequent section for estimation of hydrologic budgets for the lakes.

**TABLE 4-9**

**ESTIMATED EVAPORATION LOSSES FROM QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| MONTH | LAKE EVAPORATION (inches) | EVAPORATION LOSSES (ac-ft) | | | |
|---|---|---|---|---|---|
| | | Queens Mirror Lake | South Lake Triplet | Middle Lake Triplet | North Lake Triplet |
| January | 2.43 | 2.54 | 4.72 | 9.03 | 4.35 |
| February | 2.95 | 3.08 | 5.73 | 11.0 | 5.28 |
| March | 4.38 | 4.57 | 8.50 | 16.3 | 7.84 |
| April | 5.32 | 5.55 | 10.3 | 19.8 | 9.52 |
| May | 5.93 | 6.19 | 11.5 | 22.0 | 10.6 |
| June | 5.36 | 5.60 | 10.4 | 19.9 | 9.59 |
| July | 5.30 | 5.53 | 10.3 | 19.7 | 9.48 |
| August | 5.01 | 5.23 | 9.72 | 18.6 | 8.96 |
| September | 4.40 | 4.59 | 8.54 | 16.4 | 7.87 |
| October | 3.86 | 4.03 | 7.49 | 14.3 | 6.91 |
| November | 2.79 | 2.91 | 5.41 | 10.4 | 4.99 |
| December | 2.25 | 2.35 | 4.37 | 8.36 | 4.03 |
| **TOTALS:** | **49.98** | **52.2** | **97.0** | **186** | **89.4** |

### 4.2.2 Deep Recharge

A portion of the annual hydrologic inputs to Queens Mirror Lake and the Triplet Chain-of-Lakes 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.

According to the SJRWMD GIS recharge map for the Middle St. Johns River Basin, deep recharge to the Floridan Aquifer in the vicinity of Queens Mirror Lake and the Triplet Chain-of-Lakes is estimated to be approximately 0-4 inches/year. An overview of estimated recharge rates in the vicinity of Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 4-11. For purposes of this analysis, an annual recharge of 2 inches/year is assumed. This implies that a volume equivalent to 2 inches over the lake surfaces would be lost as a result of recharge into deeper aquifers. Based upon the lake surface areas listed in Table 2-6 and an assumed recharge loss of 2 inches/year, the estimated annual hydrologic losses as a result of deep recharge are approximately 2.09 ac-ft/yr in Queens Mirror Lake, 3.88 ac-ft/yr in South Lake Triplet, 7.43 ac-ft/yr in Middle Lake Triplet, and 3.58 ac-ft/yr in North Lake Triplet. This information is summarized in Table 4-10.

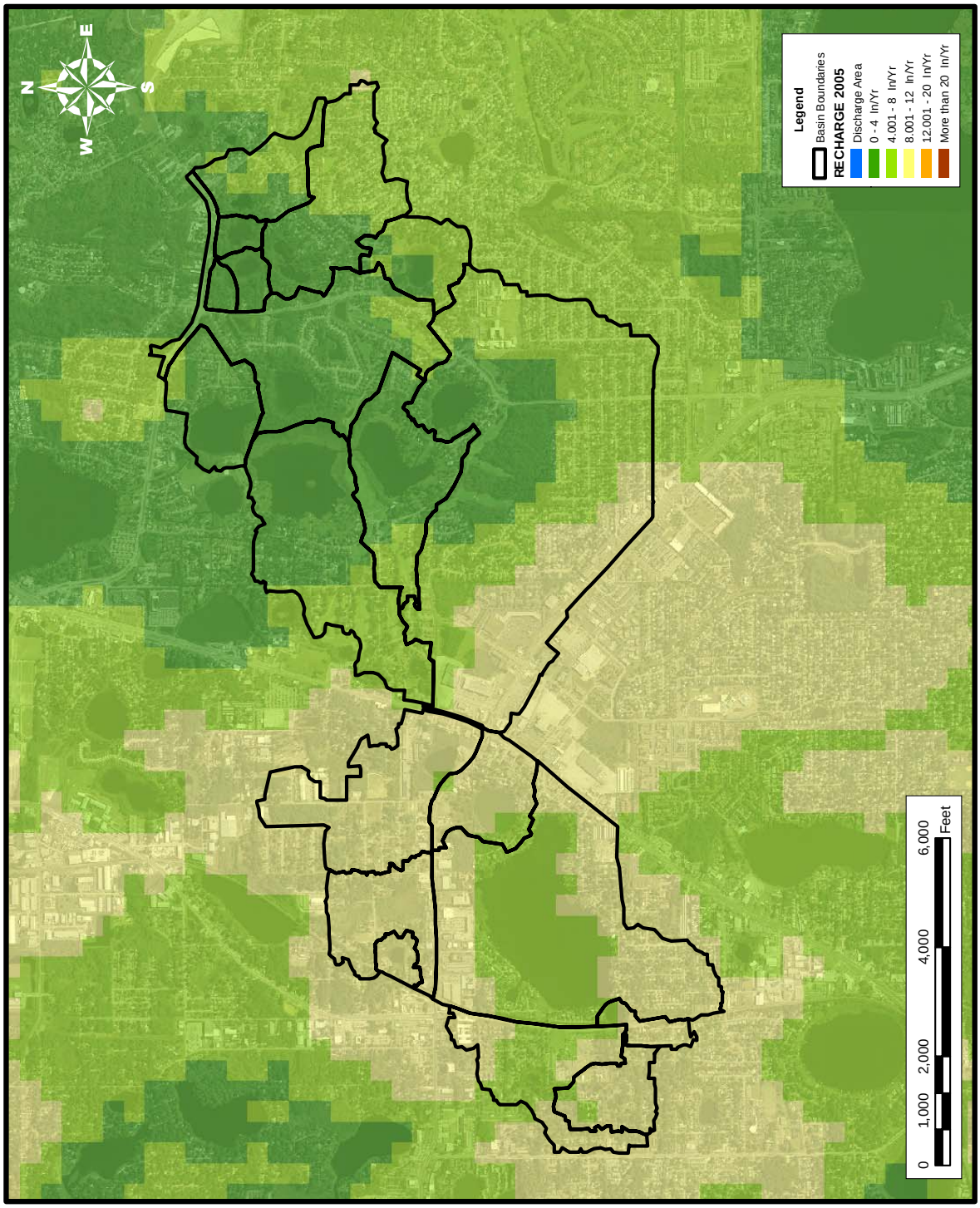



Figure 4-11. Estimated Annual Aquifer Recharge Rates in the Vicinity of Queens Mirror Lake and the Triplet Chain-of-Lakes. (Source: SJRWMD)

**TABLE 4-10**

**ESTIMATED ANNUAL DEEP RECHARGE LOSSES FROM QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | ESTIMATED DEEP RECHARGE LOSS | |
|---|---|---|
| | inches/year | ac-ft/yr |
| Queens Mirror Lake | 2 | 2.09 |
| South Lake Triplet | 2 | 3.88 |
| Middle Lake Triplet | 2 | 7.43 |
| North Lake Triplet | 2 | 3.58 |

### 4.2.3 Outflow from the Interconnected Lakes

For purposes of this analysis, discharges from the interconnected lakes are calculated as the difference between inputs and outputs for each lake on an annual basis according to the following relationship:

$$\textit{Lake Outflow} = (\textit{Precip} + \textit{Runoff Inputs} + \textit{Seepage}) - (\textit{Evap} + \textit{Recharge})$$

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

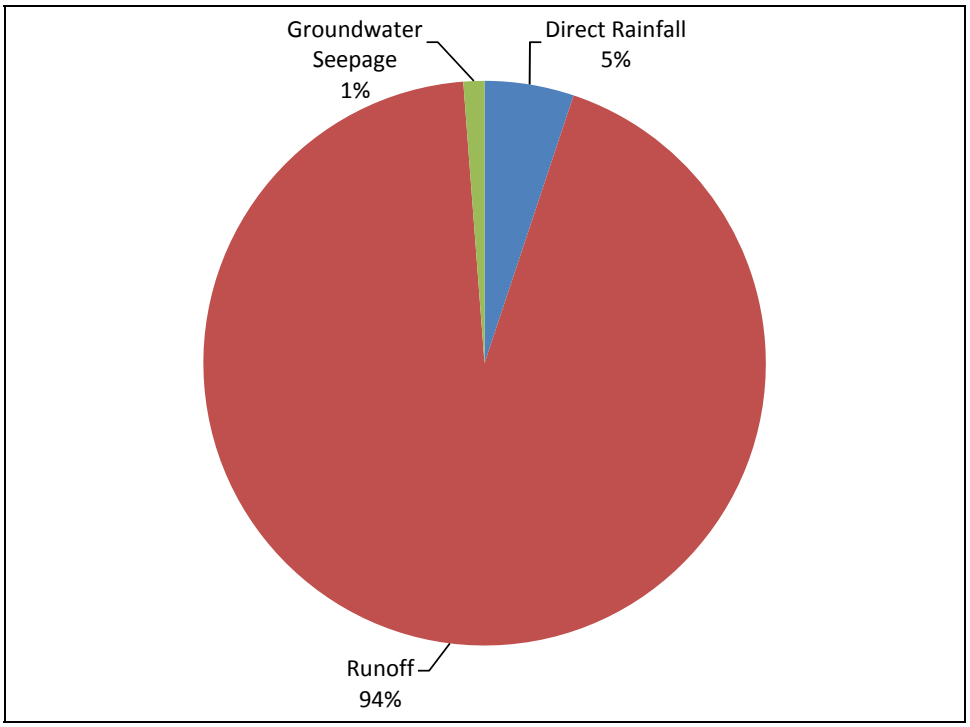
## 4.3 Hydrologic Budget

### 4.3.1 Hydrologic Inputs

A summary of estimated annual hydrologic inputs to Queens Mirror Lake and the Triplet Chain-of-Lakes, based upon the information summarized in the previous sections, is given in Table 4-11. Queens Mirror Lake receives hydrologic inputs from direct rainfall, stormwater runoff, and groundwater seepage. Approximately 94% of the hydrologic inputs are contributed by stormwater runoff, with 5% by direct rainfall and 1% by groundwater seepage.

South Lake Triplet receives hydrologic inputs from direct rainfall, stormwater runoff, and groundwater seepage, but also receives inflow resulting from discharges from Queens Mirror Lake. Estimates of discharges from Queens Mirror Lake were generated by subtracting evaporation losses (summarized in Table 4-9) and groundwater recharge losses (summarized in Table 4-10) from the total estimated annual hydrologic inputs to Queens Mirror Lake of 1016.2 ac-ft. The resulting inflow to South Lake Triplet calculated using this methodology is 961.9 ac-ft. On an annual basis, inflow from Queens Mirror Lake reflects about 83% of the hydrologic inputs to South Lake Triplet, with 8% contributed by direct rainfall, 7% by stormwater runoff, and 2% by groundwater seepage. A graphical comparison of hydrologic inputs to Queens Mirror Lake and South Lake Triplet is given on Figure 4-12.

Queens Mirror Lake Hydrologic Inputs




South Lake Triplet Hydrologic Inputs

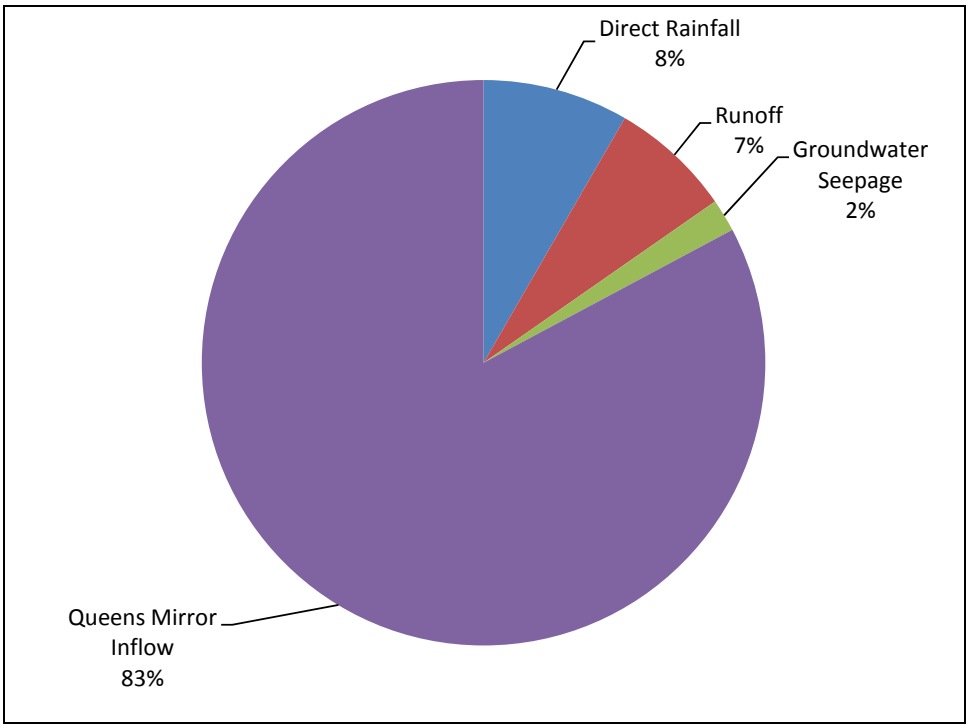



Figure 4-12. Comparison of Mean Annual Hydrologic Inputs to Queens Mirror Lake and South Lake Triplet.

**TABLE 4-11**

**SUMMARY OF ESTIMATED AVERAGE ANNUAL HYDROLOGIC INPUTS TO QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | INPUT SOURCE | ANNUAL VOLUME (ac-ft/yr) | PERCENT OF TOTAL |
|---|---|---|---|
| Queens Mirror Lake | Direct Rainfall | 52.2 | 5 |
| | Runoff | 951.7 | 94 |
| | Groundwater Seepage | 12.3 | 1 |
| | **Total** | **1016** | **100** |
| South Lake Triplet | Direct Rainfall | 97.1 | 8 |
| | Runoff | 81.1 | 7 |
| | Groundwater Seepage | 21.8 | 2 |
| | Queens Mirror Lake Inflow | 961.9 | 83 |
| | **Total** | **1162** | **100** |
| Middle Lake Triplet | Direct Rainfall | 185.9 | 12 |
| | Runoff | 196.7 | 12 |
| | Groundwater Seepage | 41.1 | 3 |
| | South Lake Triplet Inflow | 1061 | 66 |
| | Lost Lake Inflow | 103.8 | 7 |
| | **Total** | **1559** | **100** |
| North Lake Triplet | Direct Rainfall | 89.5 | 6 |
| | Runoff | 29.2 | 2 |
| | Groundwater Seepage | 20.3 | 2 |
| | Middle Lake Triplet Inflow | 1395 | 90 |
| | **Total** | **1534** | **100** |

Middle Lake Triplet receives hydrologic inputs from direct rainfall, stormwater runoff, and groundwater seepage, but also receives significant inflows as a result of inflows from South Lake Triplet and Lost Lake. Inflow from South Lake Triplet was calculated by subtracting annual evaporation losses and deep recharge losses from the sum of the hydrologic inputs to South Lake Triplet. Inflow from Lost Lake was modeled as part of the hydrologic modeling discussed in Section 4.1.2. For Lost Lake and the interconnected upstream waterbodies, precipitation inputs are assumed to be 50.03 inches/year (Table 4-2), with 49.98 inches/year of evaporation (Table 4-8). Inputs from groundwater seepage are approximately offset by losses to deep aquifer recharge. The total estimated annual inputs to Middle Lake Triplet are approximately 1559 ac-ft/yr, with 67% contributed by inflow from South Lake Triplet, 12% by direct rainfall, 6% by Lost Lake inflow, 12% by direct runoff, and 3% by groundwater seepage.

North Lake Triplet receives hydrologic inflows from direct rainfall, stormwater runoff, and groundwater seepage in addition to inflow from Middle Lake Triplet. Inflows from Middle Lake Triplet were approximated by subtracting evaporation losses and deep recharge losses from the total annual hydrologic inputs of 1534 ac-ft/yr to Middle Lake Triplet. Based upon this analysis, inflow from Middle Lake Triplet contributes 91% of the annual hydrologic inputs to North Lake Triplet, with 6% contributed by direct rainfall, 2% by stormwater runoff, and 1% by groundwater seepage. A graphical comparison of hydrologic inputs to Middle Lake Triplet and North Lake Triplet is given on Figure 4-13.

### 4.3.2 Hydrologic Losses

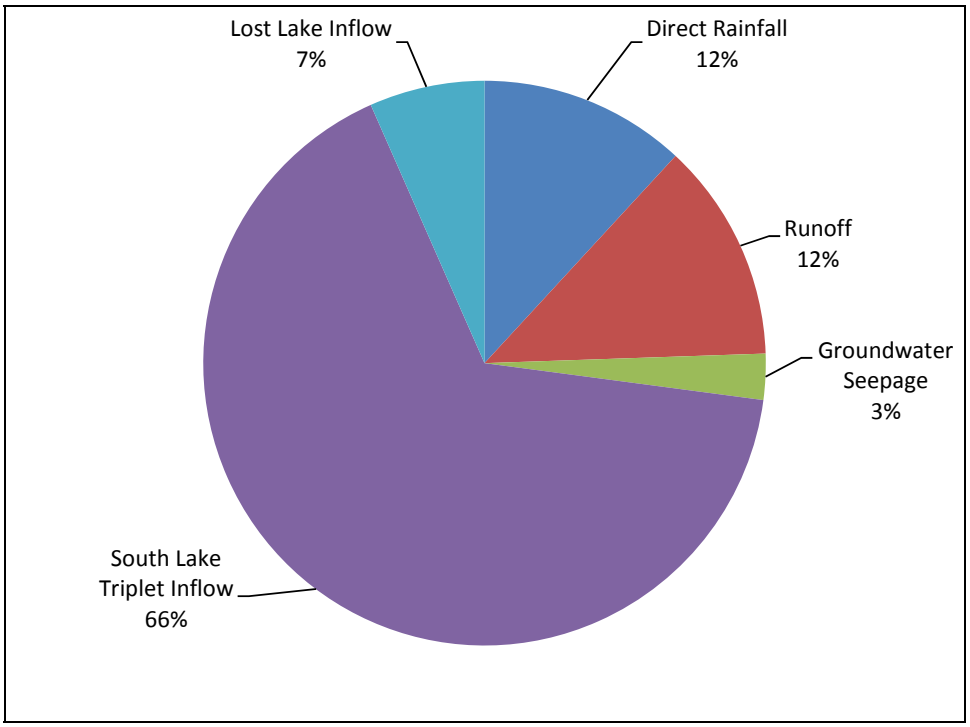
A summary of estimated annual hydrologic losses for Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Table 4-12. On an average annual basis, approximately 95% of the hydrologic losses for Queens Mirror Lake occur as a result of discharge to South Lake Triplet, with 5% lost from evaporation and <1% lost to deep recharge. Approximately 91% of the annual hydrologic inputs to South Lake Triplet are lost as a discharge to Middle Lake Triplet, with 8% lost to evaporation and <1% lost to deep recharge. A similar pattern is apparent for Middle Lake Triplet and North Lake Triplet as well, with 88% of the hydrologic inputs to Middle Lake Triplet discharging from the lake to North Lake Triplet, and 94% of the hydrologic inputs to North Lake Triplet discharging through the northern outfall canal.

**TABLE 4-12**

**SUMMARY OF ESTIMATED AVERAGE ANNUAL HYDROLOGIC LOSSES TO QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | SOURCE | ANNUAL VOLUME (ac-ft/yr) | PERCENT OF TOTAL |
|---|---|---|---|
| Queens Mirror Lake | Evaporation | 52.2 | 5 |
| | Deep Recharge | 2.09 | < 1 |
| | Discharge to South Lake Triplet | 961.9 | 95 |
| | **Total** | **1016** | **100** |
| South Lake Triplet | Evaporation | 97.0 | 8 |
| | Deep Recharge | 3.88 | < 1 |
| | Discharge to Middle Lake Triplet | 1061 | 91 |
| | **Total** | **1162** | **100** |
| Middle Lake Triplet | Evaporation | 186 | 12 |
| | Deep Recharge | 7.43 | < 1 |
| | Discharge to North Lake Triplet | 1395 | 88 |
| | **Total** | **1559** | **100** |
| North Lake Triplet | Evaporation | 89.4 | 6 |
| | Deep Recharge | 3.58 | < 1 |
| | Canal Discharge | 1441 | 94 |
| | **Total** | **1534** | **100** |

Middle Lake Triplet Hydrologic Inputs




North Lake Triplet Hydrologic Inputs

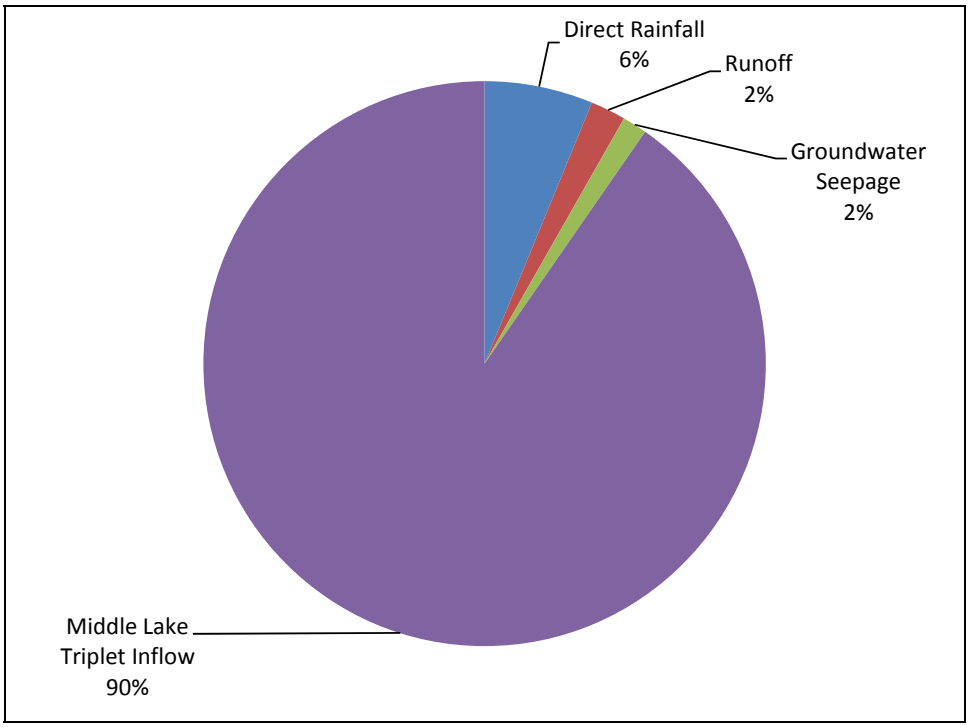



Figure 4-13. Comparison of Mean Annual Hydrologic Inputs to Middle Lake Triplet and North Lake Triplet.

## 4.4 Water Residence Time

Estimated annual hydraulic residence times were calculated for Queens Mirror Lake and the Triplet Chain-of-Lakes based upon the mean annual hydrologic budgets summarized in Section 4.3. The residence time is calculated by dividing the estimated water volume for each lake (summarized in Table 2-6) by the estimated annual hydrologic inputs (summarized in Table 4-11). A summary of this analysis is given in Table 4-13. Based upon this analysis, the calculated annual residence time in Queens Mirror Lake is approximately 24 days, with a residence time of 30 days in South Lake Triplet, 28 days in Middle Lake Triplet, and 25 days in North Lake Triplet. These estimated annual residence times are much lower than values commonly observed in urban lakes.

**TABLE 4-13**

**CALCULATED ANNUAL AVERAGE RESIDENCE TIMES IN QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | LAKE VOLUME (ac-ft) | ANNUAL HYDROLOGIC INPUTS (ac-ft/yr) | RESIDENCE TIME | |
|---|---|---|---|---|
| | | | Years | Days |
| Queens Mirror Lake | 67.2 | 1016 | 0.066 | 24 |
| South Lake Triplet | 94.8 | 1162 | 0.082 | 30 |
| Middle Lake Triplet | 118.0 | 1559 | 0.076 | 28 |
| North Lake Triplet | 103.9 | 1534 | 0.068 | 25 |

# SECTION 5

# NUTRIENT INPUTS AND LOSSES

Queens Mirror Lake and the Triplet Chain-of-Lakes receive nutrient inputs from a variety of sources which include stormwater runoff, interconnected lake inflow, shallow groundwater seepage, and bulk precipitation. 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 in each of the lakes.

## 5.1 Characteristics of Nutrient Inputs

### 5.1.1 Bulk Precipitation

#### 5.1.1.1 Chemical Characteristics

ERD has performed several evaluations of the characteristics of bulk precipitation in the Central Florida area. The most extensive of these evaluations was conducted as part of the Butler Chain-of-Lakes study. Bulk precipitation samples were collected by ERD on a continuous basis from December 2004-November 2005 at a monitoring site located adjacent to the Keene's Point boat ramp on Lake Isleworth. Twenty-nine bulk precipitation samples were collected at the monitoring site and analyzed for general parameters, nutrients, and TSS. A summary of the mean characteristics of measured concentrations for nitrogen, phosphorus, and TSS in bulk precipitation at the Butler Chain-of-Lakes monitoring site is given in Table 5-1. For purposes of this evaluation, it is assumed that the bulk precipitation characteristics summarized in Table 5-1 are similar to bulk precipitation which falls on Queens Mirror Lake and the Triplet Chain-of-Lakes.

**TABLE 5-1**

**MEAN CHARACTERISTICS OF BULK PRECIPITATION IN THE CENTRAL FLORIDA AREA**

| PARAMETER | UNITS | CONCENTRATION |
|---|---|---|
| Nitrogen | µg/l | 770 |
| Phosphorus | µg/l | 61 |
| TSS | mg/l | 17.3 |

#### 5.1.1.2 Mass Loadings

Estimates of annual mass loadings from bulk precipitation to Queens Mirror Lake and the Triplet Chain-of-Lakes 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 the lakes from bulk precipitation is given in Table 5-2.

**TABLE 5-2**

**ESTIMATED MEAN ANNUAL LOADINGS TO QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES FROM BULK PRECIPITATION**

| PARAMETER | MASS LOADINGS (kg/yr) | | | |
|---|---|---|---|---|
| | Queens Mirror Lake | South Lake Triplet | Middle Lake Triplet | North Lake Triplet |
| Total N | 49.6 | 92.2 | 177 | 85.0 |
| Total P | 3.93 | 7.30 | 14.0 | 6.73 |
| TSS | 1,115 | 2,072 | 3,966 | 1,910 |

### 5.1.2 Stormwater Runoff

#### 5.1.2.1 Field Monitoring Program

A field monitoring program was conducted by ERD from September 2010-February 2011 to provide runoff characterization data for two significant inflows into Queens Mirror Lake and the Triplet Chain-of-Lakes. This monitoring was conducted to provide site-specific runoff characteristics for discharges into the lakes to increase the accuracy of the runoff loading calculations in comparison with using standard literature-based values. Runoff field monitoring was conducted at two separate sites, indicated on Figure 5-1. The first site, referred to as the Winter Park Drive site, reflects the inflow from the large wetland area located south and west of Queens Mirror Lake. The monitoring site was located in the channel just downstream of Winter Park Drive. This inflow provides drainage for a sub-basin area of approximately 1,364 acres which is the largest sub-basin area within the Queens Mirror Lake and Triplet Chain-of-Lakes system.

The second field runoff monitoring site was located in Middle Lake Triplet sub-basin 1 which has an approximate area of 81.92 acres and is the second largest sub-basin area discharging to Queens Mirror Lake and the Triplet Chain-of-Lakes system. The monitoring site was located at the intersection of the drainage ditch and South Triplet Lake Drive on the downstream side of the roadway. The drainage basin for this area consists of a combination of residential homes and golf course areas which are similar to other sub-basin areas which discharge to South Lake Triplet and Queens Mirror Lake. The sub-basin area included with this monitoring site contains a number of interconnected ponds, ditches, wetlands, and drainage swales. Roadway drainage within this sub-basin is conveyed by both conventional curb and gutter systems and grassed roadside swales.

Figure 5-1. Locations of Inflow Monitoring Sites.

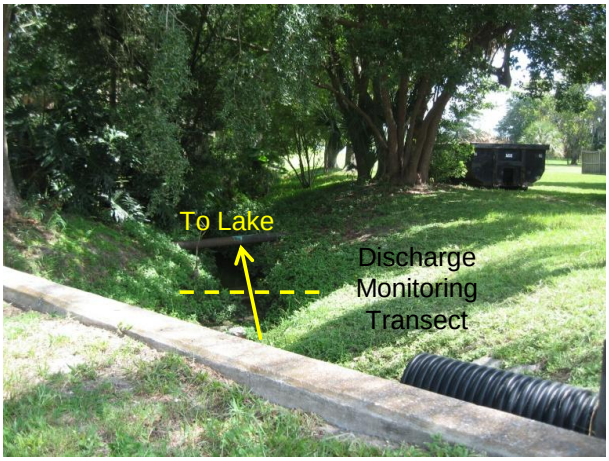
Field monitoring was conducted at each of the two sites on approximately a weekly basis or immediately following significant rain events within the sub-basins. Due to the size of the sub-basin areas, particularly sub-basin QM-1, the sub-basins store a large amount of runoff during rain events which is released slowly as a gradual baseflow over time. Field monitoring conducted by ERD consisted of field measurements of discharge rates through each of the two inflow channels and collection of a surface water sample for laboratory analyses. Photographs of the two inflow monitoring sites are given on Figure 5-2. Field monitoring was conducted during each weekly visit if measurable flow was present within either of the two inflows. If measurable flow was not present, no sample was collected for laboratory analyses.

a. Culverts Under Winter Park Drive

b. Channel to Queens Mirror Lake

Winter Park Drive Inflow Monitoring Site

c. Culverts Under South Lake Triplet Drive




d. Channel to Middle Lake Triplet

South Triplet Lake Drive Monitoring Site

Figure 5-2. Photographs of the Inflow Monitoring Sites.

A graphical comparison of measured discharge rates at the Winter Park Drive and South Triplet Lake Drive monitoring sites is given on Figure 5-3. Measured discharge rates at the Winter Park Drive inflow site, which reflects inflow from the 1,364-acre wetland area south of Queens Mirror Lake, ranged from approximately 0.1-4.8 cfs during the field monitoring program. Measurable flow was observed at this site during each of the weekly monitoring events over the period from September 2010-February 2011, reflecting both wet season and dry season conditions. Measured discharge rates at the South Triplet Lake Drive monitoring site were substantially lower, ranging from 0.02-0.25 cfs. In general, discharge at this site was observed only during wet season conditions, with little or no observed discharge during the period from November 2010-February 2011.

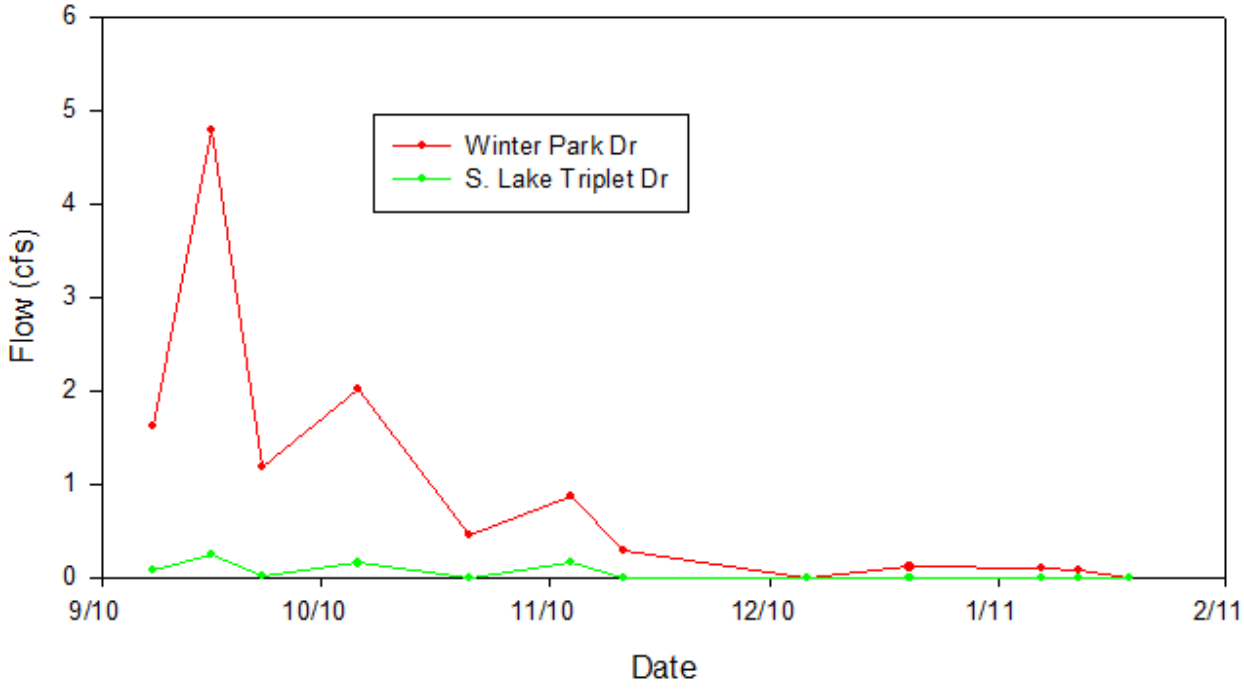



Figure 5-3. Measured Discharge Rates at the Winter Park Drive and South Triplet Lake Drive sites.

#### 5.1.2.2 Characteristics of Monitored Inflow Samples

A complete listing of water quality characteristics measured on runoff inflow samples collected at the Winter Park Drive and South Triplet Lake Drive monitoring sites is given in Appendix D. A total of 12 inflow samples were collected at the Winter Park Drive monitoring site which exhibited a constant discharge throughout most of the field monitoring program. In contrast, only 5 inflow samples were collected at the South Triplet Lake Drive site which typically exhibited inflow only during relatively wet season conditions.

A summary of chemical characteristics of runoff inflow samples collected at the Winter Park Drive and South Triplet Lake Drive monitoring sites is given in Table 5-3. Information is provided for the minimum, maximum, and mean value for each of the measured parameters at each monitoring site. The listed mean values reflect log-normal mean values since the data exhibit a log-normal distribution.

## TABLE 5-3

## SUMMARY OF CHEMICAL CHARACTERISTICS OF RUNOFF INFLOW SAMPLES COLLECTED AT THE WINTER PARK DRIVE AND SOUTH TRIPLET LAKE DRIVE MONITORING SITES

| PARAMETER | UNITS | WINTER PARK DRIVE | | | SOUTH TRIPLET LAKE DRIVE | | |
|---|---|---|---|---|---|---|---|
| | | Minimum Value | Maximum Value | Mean | Minimum Value | Maximum Value | Mean |
| pH | s.u. | 6.23 | 7.15 | 6.56 | 6.23 | 6.76 | 6.54 |
| Alkalinity | mg/l | 30 | 54.6 | 43.1 | 34 | 52.8 | 45.9 |
| Conductivity | µmho/cm | 145 | 181 | 164 | 229 | 308 | 281 |
| $NH_3$-N | µg/l | 21 | 132 | 72 | 68 | 737 | 154 |
| $NO_X$-N | µg/l | 6 | 62 | 24 | 19 | 80 | 54 |
| Diss. Org. N | µg/l | 110 | 389 | 239 | 51 | 919 | 216 |
| Particulate N | µg/l | 26 | 631 | 100 | 6 | 289 | 77 |
| Total N | µg/l | 265 | 1081 | 501 | 343 | 1171 | 723 |
| SRP | µg/l | 13 | 100 | 39 | 48 | 163 | 86 |
| Diss. Org. P | µg/l | 7 | 97 | 25 | 9 | 87 | 21 |
| Part. P | µg/l | 1 | 20 | 7 | 1 | 21 | 7 |
| Total P | µg/l | 34 | 147 | 79 | 62 | 209 | 123 |
| Turbidity | NTU | 0.8 | 3.2 | 1.7 | 0.4 | 2.5 | 1.3 |
| Color | Pt-Co | 80 | 205 | 140 | 67 | 93 | 79 |
| TSS | mg/l | 1.3 | 3.5 | 1.9 | 1.5 | 8.4 | 3.2 |

Samples collected at the Winter Park Drive inflow site, which reflect discharges from the large wetland system south of Queens Mirror Lake, were neutral to slightly acidic in pH and relatively poorly buffered, with a mean alkalinity of 43.1 mg/l. Measured conductivity in the inflow samples was also relatively low, with an overall mean of 164 µmho/cm. A large degree of variability was observed in measured concentrations of nitrogen species, although in general, measured concentrations for nitrogen species were generally low in value. Ammonia concentrations in the inflow samples were less than 100 µg/l in the majority of the samples, while $NO_x$ concentrations were typically less than 50 µg/l, each of which reflects low values. The dominant nitrogen species measured at this site was dissolved organic nitrogen which comprised approximately 50% of the overall total nitrogen concentration. The dominance of dissolved organic nitrogen is consistent with the origin of the inflow from a wetland area. Relatively low levels of particulate nitrogen were also observed at this site in the majority of the measured samples. Overall, the mean total nitrogen concentration of 501 µg/l reflects a relatively low inflow concentration.

A relatively high degree of variability was also observed in measured concentrations of phosphorus species. The dominant phosphorus species in the inflow samples appeared to be SRP (soluble reactive phosphorus) which contributed approximately 50% of the observed total phosphorus concentration. SRP is a readily available form of phosphorus which is capable of stimulating algal growth. The mean inflow SRP concentration of 39 μg/l reflects a continuing influx of available phosphorus to Queens Mirror Lake. The second most dominant phosphorus species appears to be dissolved organic phosphorus which is consistent with the wetland origin of the inflow. Particulate phosphorus in the inflow appears to be extremely low in value. Overall, the mean total phosphorus concentration of 79 μg/l reflects a relatively low concentration, but a relatively large mass loading since inflow at this site occurs throughout most of the year.

Inflow samples at the Winter Park Drive site were characterized by relatively low levels of both turbidity and TSS. However, the inflow at this site was highly colored, with measured color concentrations ranging from 80-205 Pt-Co units and an overall mean of 140 Pt-Co units.

The South Triplet Lake Drive monitoring site reflects an inflow to Middle Lake Triplet which drains a predominantly residential area with a relatively small amount of golf course activity. The physical characteristics of the drainage basin which discharges through this tributary is similar to drainage basins in the vicinity of South Lake Triplet and Queens Mirror Lake. Inflow samples collected at this site were found to be slightly acidic and relatively poorly buffered, with a mean alkalinity of only 45.9 mg/l. Inflows at this site were characterized by moderate levels of conductivity, with an overall mean of 281 μmho/cm.

Measured concentrations of nitrogen species at the South Triplet Lake Drive site were highly variable, with low to moderate concentrations, depending upon the species. Measured concentrations of ammonia were moderate in value, with an overall mean of 154 μg/l. However, concentrations of $NO_x$ were generally low in value, with a mean of only 54 μg/l. The dominant nitrogen species at this site was dissolved organic nitrogen which comprised approximately 40% of the total nitrogen measured. Particulate nitrogen was generally low in value in virtually all samples. Overall, the mean total nitrogen concentration of 723 μg/l is relatively low for urban runoff and likely reflects the pre-treatment effects of the series of interconnected treatment ponds located in upstream portions of the basin.

Measured concentrations of phosphorus species exhibited a relatively high degree of variability at the South Triplet Lake Drive site. The dominant phosphorus species was SRP which comprised approximately 65% of the total phosphorus measured. The mean SRP concentration of 86 μg/l reflects a readily available source of phosphorus as it discharges into Middle Lake Triplet. Particulate phosphorus concentrations at this site were low in value and appear to reflect pre-treatment systems within the basin. The overall total phosphorus concentration of 123 μg/l is low to moderate in value and approximately half of the value normally associated with residential subdivision areas which utilize curb and gutter drainage systems.

Measured concentrations of turbidity and TSS were typically low in value in virtually all samples collected at this site. The collected samples exhibited a moderate to high degree of color, with a mean color concentration of 79 Pt-Co units.

A statistical summary of measured concentrations of general parameters at the inflow monitoring sites is given in Figure 5-4 in the form of Tukey box plots, also often “box and whisker plots”. The bottom line of the box portion of each plot represents the lower quartile, with 25% of the data points falling below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data falling above this value. The **blue** horizontal line within the box represents the median value, with 50% of the data falling both above and below this value. The **red** horizontal line within the box represents the mean of the data points. The vertical lines, also known as "whiskers", represent the 5 and 95 percentiles for the data sets. Individual values which fall outside of the 5-95 percentile range, sometimes referred to as “outliers”, are indicated as **red dots**.

Inflow samples collected at the two monitoring sites appear to be relatively similar in pH and alkalinity. However, the South Triplet Lake Drive site is characterized by a substantially higher measured conductivity value than observed at the Winter Park Drive site. Measured TSS values at the South Triplet Lake Drive site were also higher in value and exhibited a higher degree of variability than observed at the Winter Park Drive site.

A statistical summary of measured concentrations of nitrogen species in samples collected at the South Triplet Lake Drive and Winter Park Drive inflow sites is given in Figure 5-5. In general, concentrations of ammonia, $NO_x$, and total nitrogen appear to be both more variable and higher in concentration at the South Lake Triplet Drive site than observed at the Winter Park Drive site. The low degree of variability in nitrogen species observed at the Winter Park Drive site is likely related to the impacts of the large wetland area which provides attenuation and treatment for inflows prior to discharging into Queens Mirror Lake.

A statistical summary of measured phosphorus species in samples collected at the South Triplet Lake Drive and Winter Park Drive inflow sites is given on Figure 5-6. Similar to the trends observed for nitrogen species, samples collected at the South Triplet Lake Drive site appear to exhibit both higher concentrations and a higher degree of variability for concentrations of SRP, particulate phosphorus, and total phosphorus. The lack of variability observed for phosphorus species at the Winter Park Drive site is likely related to pre-treatment effects within the large wetland system.

A statistical summary of measured concentrations of turbidity and color in samples collected at the inflow monitoring sites is given on Figure 5-7. Measured turbidity concentrations at these two inflow monitoring sites appear to be relatively similar. However, the Winter Park Drive inflow is characterized by a substantially higher color concentration which is characteristic of the wetland origin for this inflow.

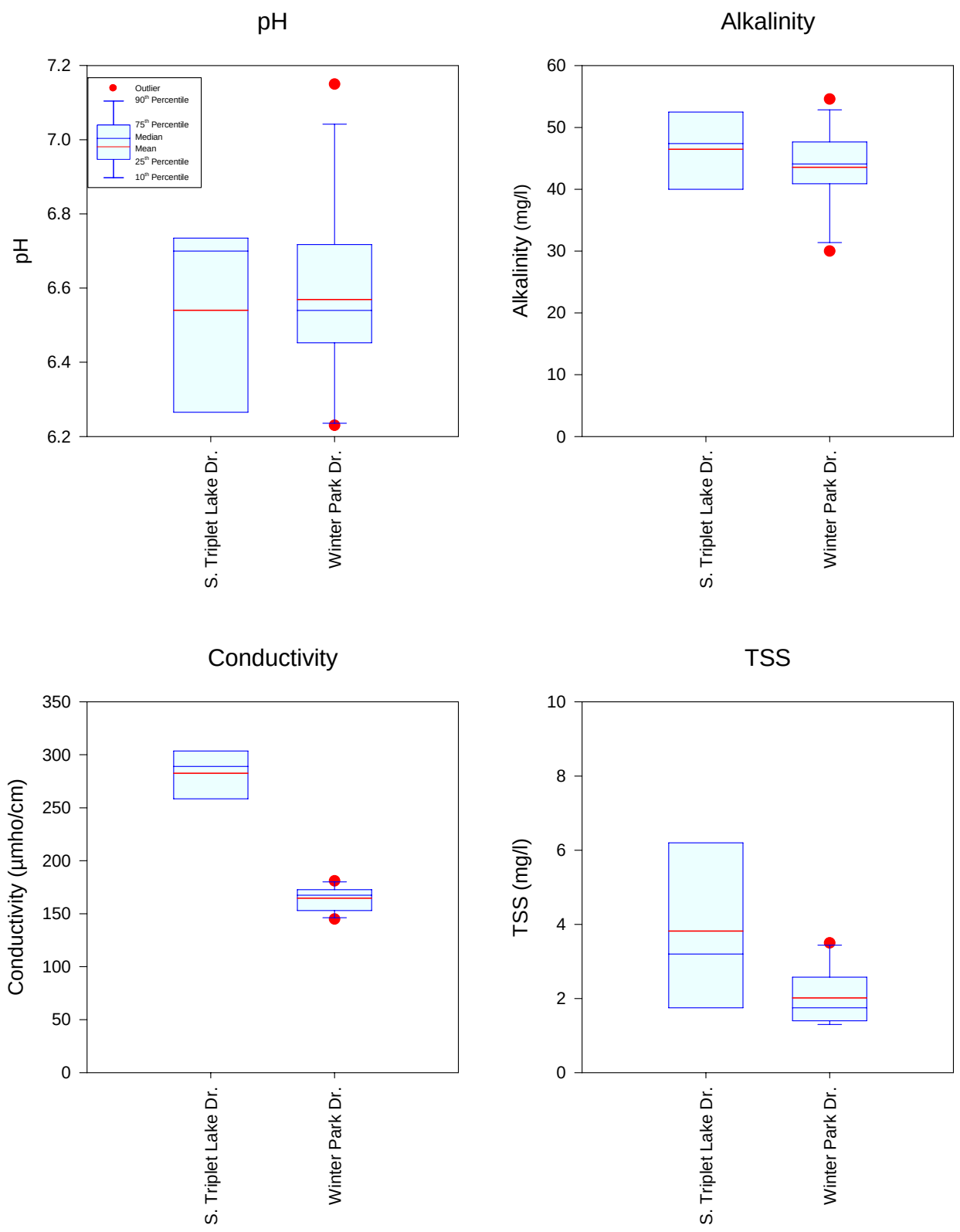



Figure 5-4. Box and Whisker Plots of General Parameters Measured at the Inflow Monitoring Sites.

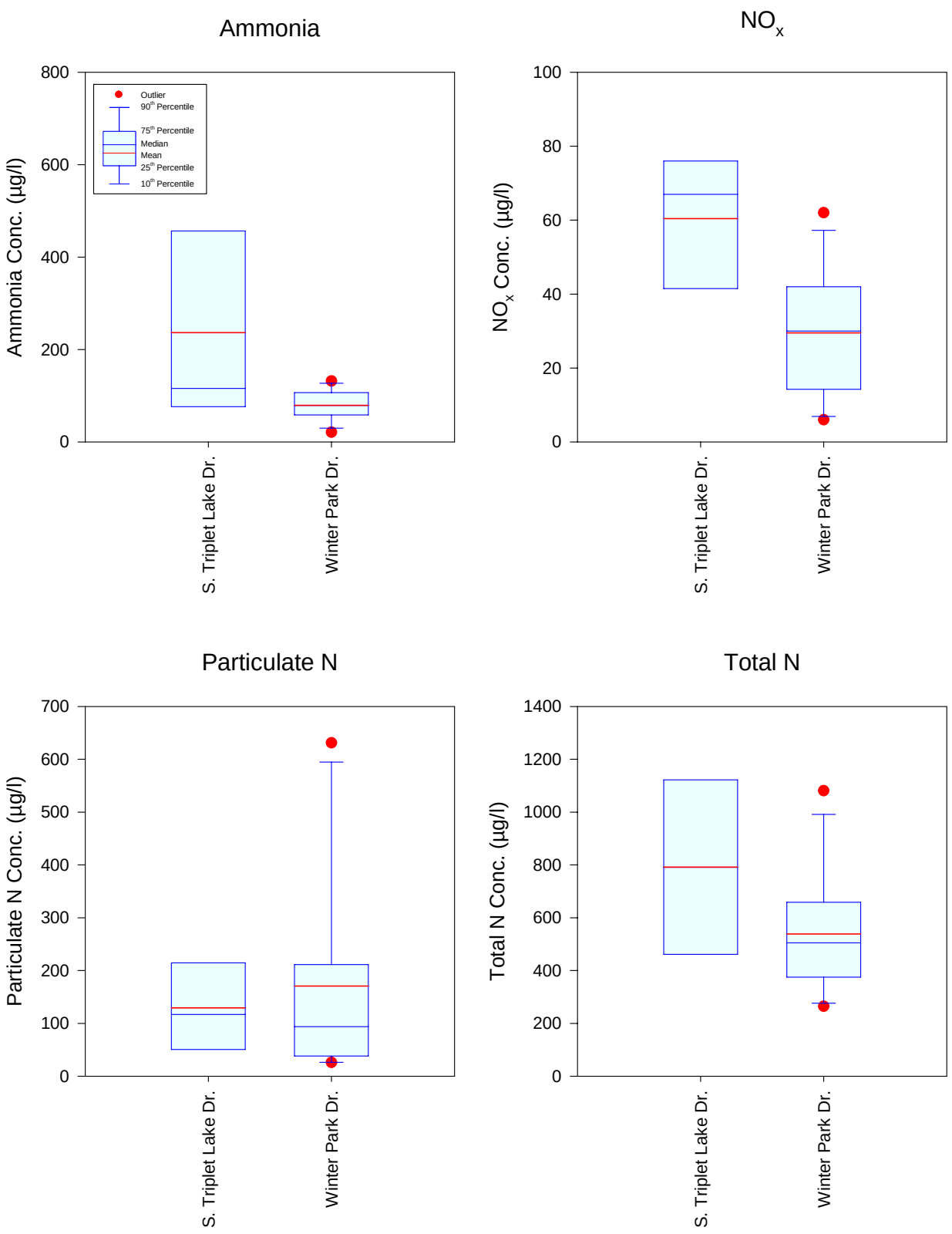



Figure 5-5. Box and Whisker Plots of Nitrogen Species Measured at the Inflow Monitoring Sites.

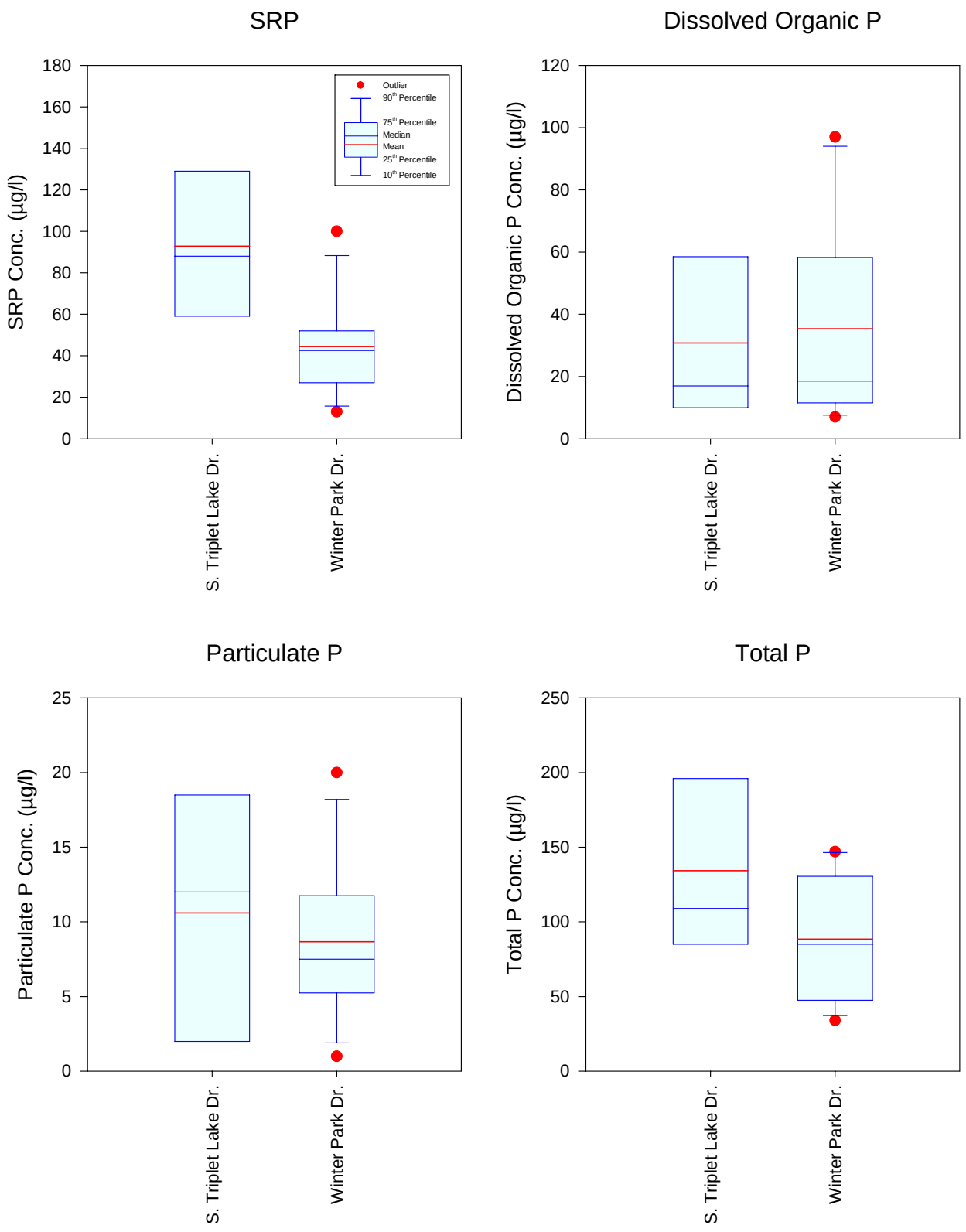



Figure 5-6. Box and Whisker Plots of Phosphorus Species Measured at the Inflow Monitoring Sites.

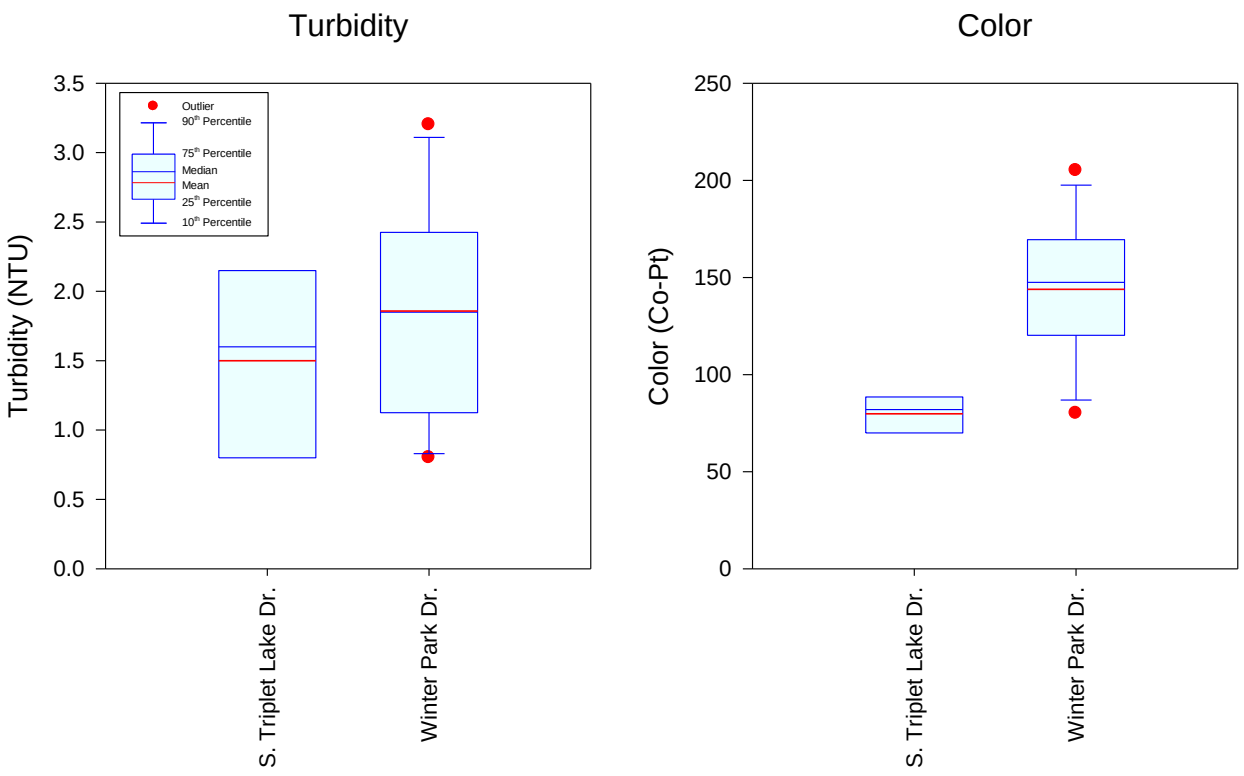



Figure 5-7. Box and Whisker Plots of Turbidity and Color Measured at the Inflow Monitoring Sites.

### 5.1.2.3 Mass Loadings

Estimates of annual mass loadings of total nitrogen, total phosphorus, and TSS were calculated for each of the sub-basin areas discharging into Queens Mirror Lake and the Triplet Chain-of-Lakes. These calculations reflect annual loadings of direct runoff inputs to each of the lakes from the identified sub-basin areas. The estimated mass loadings are calculated by multiplying the volume discharged to the lake from each sub-basin area (as summarized in Table 4-5) times assumed runoff characteristics for each sub-basin inflow.

Chemical characteristics for Queens Mirror Lake sub-basin QM-1, which reflects inflow from the 1,364-acre sub-basin south of Queens Mirror Lake, are assumed to be reflected by the characteristics summarized in Table 5-3 for the Winter Park Drive site. This area is the single largest sub-basin which discharges into either Queens Mirror Lake or the Triplet Chain-of-Lakes. For this sub-basin, a total nitrogen concentration of 501 µg/l (0.501 mg/l) and a total phosphorus concentration of 79 µg/l (0.079 mg/l) are assumed to be representative of the inflow from the sub-basin.

Inflows from the remaining Queens Mirror Lake and Triplet Chain-of-Lakes sub-basin inflows are assumed to be similar to the values measured at the South Triplet Lake Drive inflow monitoring site. The watershed area for this inflow is similar to land use activities in sub-basin areas in the vicinity of Middle Lake Triplet, South Lake Triplet, and Queens Mirror Lake. This sub-basin area is also similar to most of the sub-basin areas which discharge into North Lake Triplet. Therefore, for purposes of estimating runoff generated mass loadings, sub-basin areas other than QM-1 are assumed to be characterized by a total nitrogen concentration of 723 µg/l (0.723 mg/l) and a total phosphorus concentration of 123 µg/l (0.123 mg/l).

A summary of estimated runoff generated mass loadings to Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Table 5-4. Estimates of annual mass loadings of total nitrogen and total phosphorus are calculated for each sub-basin area using the estimated volume discharge to the lake from each sub-basin summarized on Table 4-5. The annual runoff discharge is multiplied by the assumed runoff concentrations to obtain the estimated mass loading from each sub-basin area to each of the four lakes. The basin areas reflect the "effective" area which includes all areas, including interconnected waterbodies, which discharge through a given sub-basin.

## TABLE 5-4

## ESTIMATED RUNOFF GENERATED MASS LOADINGS TO QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES

| LAKE | SUB-BASIN | EFFECTIVE BASIN AREA (acres) | DISCHARGE TO LAKE (ac-ft/yr) | RUNOFF CONCENTRATION (mg/l) | | MASS LOADING (kg/yr) | | AREAL LOADING (kg/ac-yr) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Total N | Total P | Total N | Total P | Total N | Total P |
| Queens Mirror Lake | QM-1 | 1282.96 | 923.6 | 501 | 79 | 570.7 | 90.0 | 0.44 | 0.07 |
| | QM-2 | 5.15 | 6.14 | 732 | 123 | 5.5 | 0.9 | 1.08 | 0.18 |
| | Direct | 22.49 | 22.00 | 732 | 123 | 19.9 | 3.3 | 0.88 | 0.15 |
| | **Total:** | **1310.60** | **951.7** | | | **596.1** | **94.3** | **0.80** | **0.13** |
| South Lake Triplet | SLT-1 | 7.47 | 8.32 | 732 | 123 | 7.5 | 1.3 | 1.01 | 0.17 |
| | SLT-2 | 3.73 | 4.48 | 732 | 123 | 4.0 | 0.7 | 1.08 | 0.18 |
| | SLT-3 | 16.37 | 12.96 | 732 | 123 | 11.7 | 2.0 | 0.71 | 0.12 |
| | SLT-4 | 14.38 | 9.93 | 732 | 123 | 9.0 | 1.5 | 0.62 | 0.10 |
| | SLT-5 | 12.96 | 7.38 | 732 | 123 | 6.7 | 1.1 | 0.51 | 0.09 |
| | Direct | 41.39 | 38.04 | 732 | 123 | 34.3 | 5.8 | 0.83 | 0.14 |
| | **Total:** | **96.30** | **81.11** | | | **73.2** | **12.3** | **0.80** | **0.13** |
| Middle Lake Triplet | MLT-1 | 163.07 | 144.6 | 732 | 123 | 130.6 | 21.9 | 0.80 | 0.13 |
| | MLT-2 | 24.76 | 14.29 | 732 | 123 | 12.9 | 2.2 | 0.52 | 0.09 |
| | Direct | 91.05 | 37.80 | 732 | 123 | 34.1 | 5.7 | 0.37 | 0.06 |
| | **Total:** | **278.88** | **196.7** | | | **177.6** | **29.8** | **0.57** | **0.10** |
| North Lake Triplet | NLT-1 | 31.82 | 15.94 | 732 | 123 | 14.4 | 2.4 | 0.45 | 0.08 |
| | Direct | 17.68 | 13.27 | 732 | 123 | 12.0 | 2.0 | 0.68 | 0.11 |
| | **Total:** | **49.50** | **29.21** | | | **26.37** | **4.43** | **0.57** | **0.09** |

The single largest sub-basin inflow to the lakes is Queens Mirror Lake sub-basin QM-1 which is by far the largest contributor of both total nitrogen and total phosphorus to the interconnected lakes. The second largest influx of total nitrogen and total phosphorus occurs from Middle Lake Triplet sub-basin MLT-1 which is the sub-basin monitored at the South Triplet Lake Drive site. Relatively large loadings of total nitrogen and total phosphorus are also generated in Middle Lake Triplet sub-basin MLT-2 and Middle Lake Triplet direct runoff. Mass loadings from the remaining sub-basin areas appear to be relatively low in comparison.

Calculated areal loading rates for total nitrogen and total phosphorus are also provided in the final column of Table 5-4 in units of kg/ac-yr. Queens Mirror Lake sub-basin QM-1 exhibits a relatively low areal loading rate although this sub-basin is by far the largest contributor of overall mass loadings. Higher than normal areal loading rates appear to occur in Queens Mirror Lake sub-basin QM-2, Queens Mirror Lake direct runoff, and South Lake Triplet sub-basin SLT-1 and SLT-2.

### 5.1.3 Interconnected Lake Discharges

As discussed in Section 4, Queens Mirror Lake and the Triplet Chain-of-Lakes consist of an interconnected lake system which flows from south to north, beginning with Queens Mirror Lake and ending with North Lake Triplet. Estimates of annual discharges between the interconnected lakes were discussed in Section 4.3 and are summarized in Table 4-11. These annual volumetric discharges also transfer significant loadings of nitrogen and phosphorus. Estimates of mass loadings resulting from the interconnected lake discharges were calculated by multiplying the discharge volumes summarized in Tables 4-11 and 4-12 times the mean ambient water column concentrations of total nitrogen and total phosphorus in Queens Mirror Lake and the Triplet Chain-of-Lakes, as summarized in Table 2-12.

However, in addition to inflow between Queens Mirror Lake and the Triplet Chain-of-Lakes, Middle Lake Triplet also receives inflow from Lost Lake and the interconnected lake system which provides input to Lost Lake. A summary of mean water quality characteristics of Lost Lake from 2003-2011 is given in Table 5-5. The information summarized in this table is based upon the quarterly ambient lake monitoring program conducted by the City of Casselberry. During the period from 2003-2011, Lost Lake has been characterized by a mean total nitrogen concentration of 681 μg/l and a mean total phosphorus concentration of 16 μg/l. These values are assumed to reflect concentrations in discharges from Lost Lake to Middle Lake Triplet.

A summary of estimated mass loadings exchanged between Queens Mirror Lake and the Triplet Chain-of-Lakes by interconnected lake transfer is given in Table 5-6. Annual volumetric exchange between the lakes was obtained from the information summarized in Section 4.3. Mean characteristics for the exchanged water are assumed to be reflected by water quality in the upstream lake. Estimates of mass loadings exchanged between the lakes on an annual basis is summarized in the final columns of Table 5-6. This information is used in a subsequent section to develop an overall mass loading budget for each of the lakes.

**TABLE 5-5**

**SUMMARY OF MEAN WATER QUALITY CHARACTERISTICS OF LOST LAKE FROM 2003-2011**

| PARAMETER | UNITS | MEAN VALUE |
|---|---|---|
| Alkalinity | mg/l | 39.1 |
| $NH_3$-N | µg/l | 61 |
| $NO_x$-N | µg/l | 35 |
| Organic Nitrogen | µg/l | 600 |
| Total Nitrogen | µg/l | 681 |
| Total Phosphorus | µg/l | 16 |
| Color | Pt-Co | 50 |

**TABLE 5-6**

**ESTIMATED MASS LOADINGS EXCHANGED BETWEEN QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES BY INTERCONNECTED LAKE TRANSFER**

| LOCATION | ANNUAL VOLUME (ac-ft) | MEAN CONCENTRATION (µg/l) | | MASS LOADING (kg/yr) | |
|---|---|---|---|---|---|
| | | Total N | Total P | Total N | Total P |
| Queens Mirror Lake to South Lake Triplet | 961.9 | 914 | 52 | 1084 | 61.7 |
| South Lake Triplet to Middle Lake Triplet | 1061 | 923 | 47 | 1208 | 61.5 |
| Lost Lake to Middle Lake Triplet | 103.8 | 681 | 16 | 87.2 | 2.05 |
| Middle Lake Triplet to North Lake Triplet | 1395 | 817 | 36 | 1406 | 61.9 |
| North Lake Triplet Outfall | 1441 | 819 | 33 | 1455 | 58.6 |

### 5.1.4 Groundwater Seepage

#### 5.1.4.1 Chemical Characteristics

Nutrient influx from groundwater seepage was quantified using a total of 13 seepage meters installed at locations throughout Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet. Five separate monitoring events were conducted over the period from September 2010-May 2011, and the collected groundwater seepage samples were analyzed in the ERD Laboratory for pH, conductivity, alkalinity, total nitrogen, and total phosphorus. A complete listing of laboratory measurements conducted on seepage samples collected at each of the 13 monitoring sites is given in Appendix C.2.

A summary of mean chemical characteristics of seepage samples collected in Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011 is given in Table 5-7. Seepage collected in each of the three lakes was found to be approximately neutral in pH, poorly buffered, and relatively low in specific conductivity. The only exception appears to be monitoring site MLT-1 which is located on the west side of Middle Lake Triplet. Seepage collected at this site was characterized by a slightly higher pH value and substantially higher concentrations for alkalinity and conductivity. Apparently, seepage at this site is impacted by factors which do not impact seepage at the other sites.

**TABLE 5-7**

**MEAN CHARACTERISTICS OF GROUNDWATER SEEPAGE SAMPLES COLLECTED IN QUEENS MIRROR LAKE, SOUTH LAKE TRIPLET, AND MIDDLE LAKE TRIPLET FROM SEPTEMBER 2010-MAY 2011**

| LAKE | SAMPLE LOCATION | pH (s.u.) | ALK. (mg/l) | COND. (µmho/cm) | $NH_3$-N (µg/l) | $NO_x$-N (µg/l) | ORG. N (µg/l) | TOTAL N (µg/l) | SRP (µg/l) | ORG. P (µg/l) | TOTAL P (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Queens Mirror Lake | QM-1 | 6.64 | 43.7 | 207 | 197 | 280 | 80 | 925 | 56 | 32 | 103 |
| | QM-2 | 6.32 | 26.5 | 166 | 35 | 412 | 212 | 883 | 35 | 19 | 60 |
| | QM-3 | 6.65 | 35.4 | 169 | 64 | 75 | 308 | 541 | 28 | 12 | 44 |
| | QM-4 | 6.81 | 48.7 | 197 | 228 | 370 | 429 | 1203 | 181 | 28 | 215 |
| South Lake Triplet | SLT-1 | 6.62 | 34.3 | 180 | 253 | 440 | 391 | 1599 | 85 | 23 | 111 |
| | SLT-2 | 6.74 | 41.2 | 191 | 95 | 1167 | 232 | 1868 | 93 | 21 | 117 |
| | SLT-3 | 6.61 | 34.8 | 178 | 97 | 967 | 616 | 1903 | 189 | 18 | 226 |
| | SLT-4 | 6.63 | 36.0 | 179 | 81 | 269 | 344 | 882 | 82 | 34 | 126 |
| | SLT-5 | 6.67 | 34.7 | 170 | 83 | 173 | 702 | 1056 | 39 | 26 | 66 |
| Middle Lake Triplet | MLT-1 | 7.26 | 150 | 487 | 807 | 5726 | 987 | 9371 | 766 | 914 | 2076 |
| | MLT-2 | 6.49 | 29.8 | 211 | 312 | 6131 | 420 | 6863 | 1535 | 192 | 1727 |
| | MLT-3 | 6.75 | 41.5 | 179 | 111 | 389 | 686 | 1242 | 72 | 41 | 114 |
| | MLT-4 | 7.02 | 40.5 | 189 | 163 | 507 | 1135 | 1924 | 131 | 127 | 288 |

In general, seepage samples were characterized by moderate to low levels of ammonia, with the exception of site MLT-1 which was characterized by a relatively elevated ammonia concentration of approximately 807 µg/l. Measured $NO_x$ concentrations were highly variable, although the majority of samples exhibited concentrations of approximately 1000 µg/l or less. Two exceptions to this generality were observed at monitoring sites MLT-1 and MLT-2, both of which exhibited extremely elevated $NO_x$ concentrations ranging from 5700-6100 µg/l. Dissolved organic nitrogen concentrations at each of the monitoring sites were relatively low in value, with a majority of measured values less than approximately 1000 µg/l. In general, measured total nitrogen concentrations were approximately 2000 µg/l or less at each of the monitoring sites, with the exception of MLT-1 and MLT-2, both of which exhibited extremely elevated concentrations of total nitrogen.

In general, relatively low concentrations of SRP and organic phosphorus were observed at each of the seepage meter monitoring sites, with the exceptions of MLT-1 and MLT-2 which exhibited extremely elevated concentrations for both parameters. A similar pattern was also observed for total phosphorus, with relatively low phosphorus concentrations observed at the majority of the monitoring sites and substantially elevated concentrations at MLT-1 and MLT-2. It appears obvious that factors are affecting the seepage quality at sites MLT-1 and MLT-2 which does not impact seepage at the remaining sites. Since seepage originates from upland portions of the watershed, the elevated phosphorus concentrations observed at MLT-1 and MLT-2 could be related to fertilizer use, septic tanks, hydric soils, or other sources.

Mean isopleths of total nitrogen concentrations in groundwater seepage entering Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011 is given on Figure 5-8. Nitrogen concentrations in Queens Mirror Lake and South Lake Triplet range from approximately 1000-1500 μg/l, reflecting moderate to low concentrations. However, substantially more elevated concentrations of total nitrogen were observed in groundwater seepage entering Middle Lake Triplet, particularly along the western side of the lake. Total nitrogen contours in Middle Lake Triplet range from 1500-9000 μg/l.

Mean isopleths of total phosphorus in groundwater seepage entering Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011 are illustrated on Figure 5-9. As discussed previously, seepage entering Queens Mirror Lake and South Lake Triplet was found to be relatively low in value, with concentration contours ranging from 100-200 μg/l. However, substantially higher concentrations of total phosphorus were measured entering Middle Lake Triplet, with concentration contours ranging from 200-2000 μg/l.

#### 5.1.4.2 <u>Mass Loadings</u>

Mean isopleths of nitrogen influx, in terms of $\mu g/m^2$-day, entering Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet are given in Figure 5-10. These isopleths were generated by combining the concentration isopleths for total nitrogen (provided on Figure 5-8) with the hydrologic isopleths for groundwater seepage (summarized on Figure 4-9). This procedure results in estimates of nitrogen influx in terms of mass of nitrogen per $m^2$ of lake surface per day. For purposes of this analysis, the term “influx” or “flux” is defined as the areal mass input or loading per unit of time. Nitrogen influx in Queens Mirror Lake ranges from approximately 500-1000 $\mu g/m^2$-day, with nitrogen influx in South Lake Triplet ranging from 1000-1500 $\mu g/m^2$-day. However, substantially higher nitrogen influx is observed in Middle Lake Triplet, with nitrogen flux contours ranging from 1000-8500 $\mu g/m^2$-day.

Mean seepage phosphorus influx isopleths for Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet are summarized on Figure 5-11. These isopleths were generated by combining the phosphorus concentration isopleths (provided on Figure 5-9) with the seepage inflow isopleths (summarized on Figure 4-9). In general, seepage phosphorus influx into Queens Mirror Lake is equivalent to approximately 100 $\mu g/m^2$-day or less. Phosphorus seepage influx in South lake Triplet ranges from 100-200 $\mu g/m^2$-day. However, a substantially higher rate of seepage influx was observed in Middle Lake Triplet, with influx contours ranging from 100-2200 $\mu g/m^2$-day.

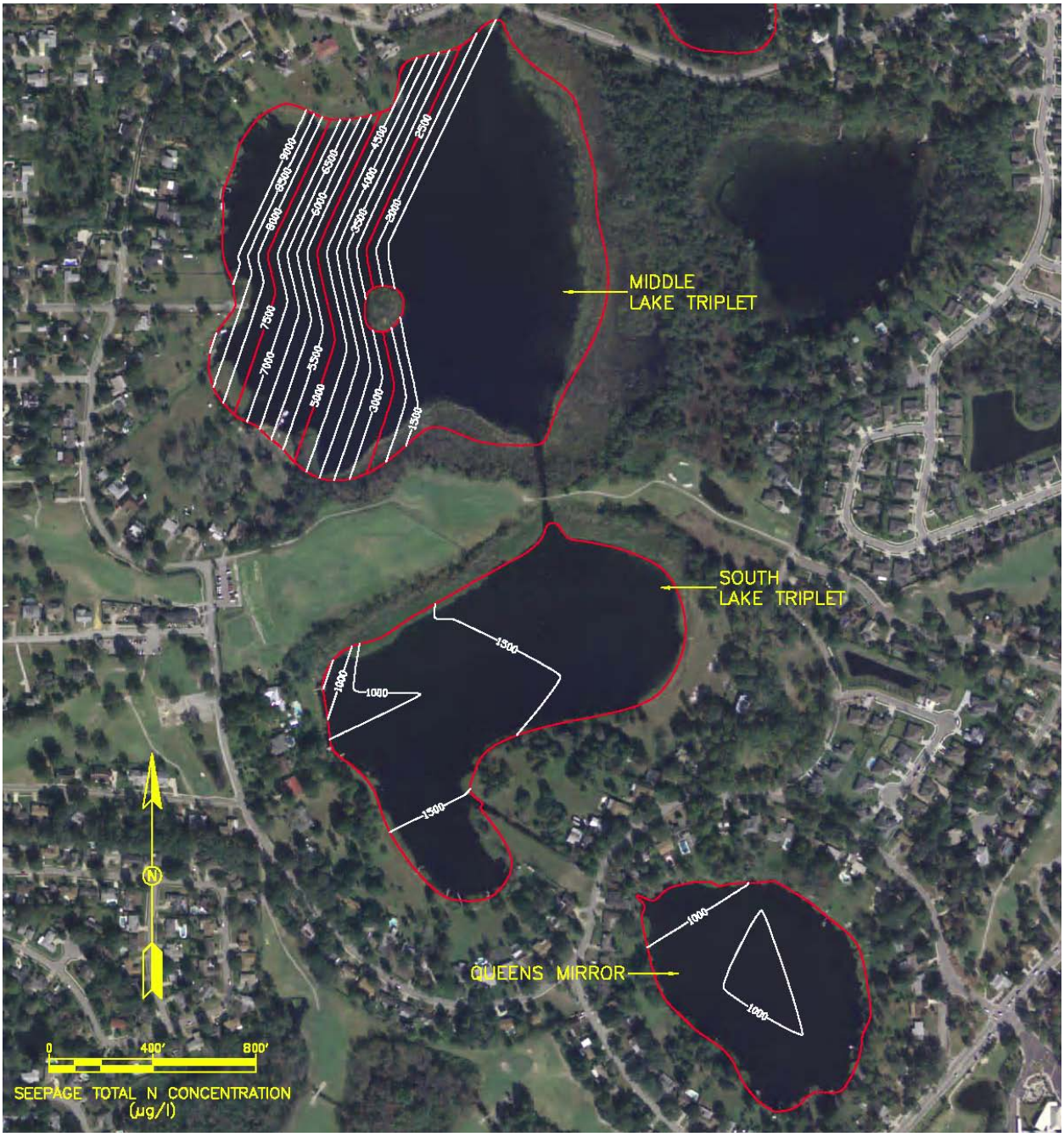



Figure 5-8. Mean Isopleths of Total Nitrogen (µg/l) in Groundwater Seepage Entering Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011.

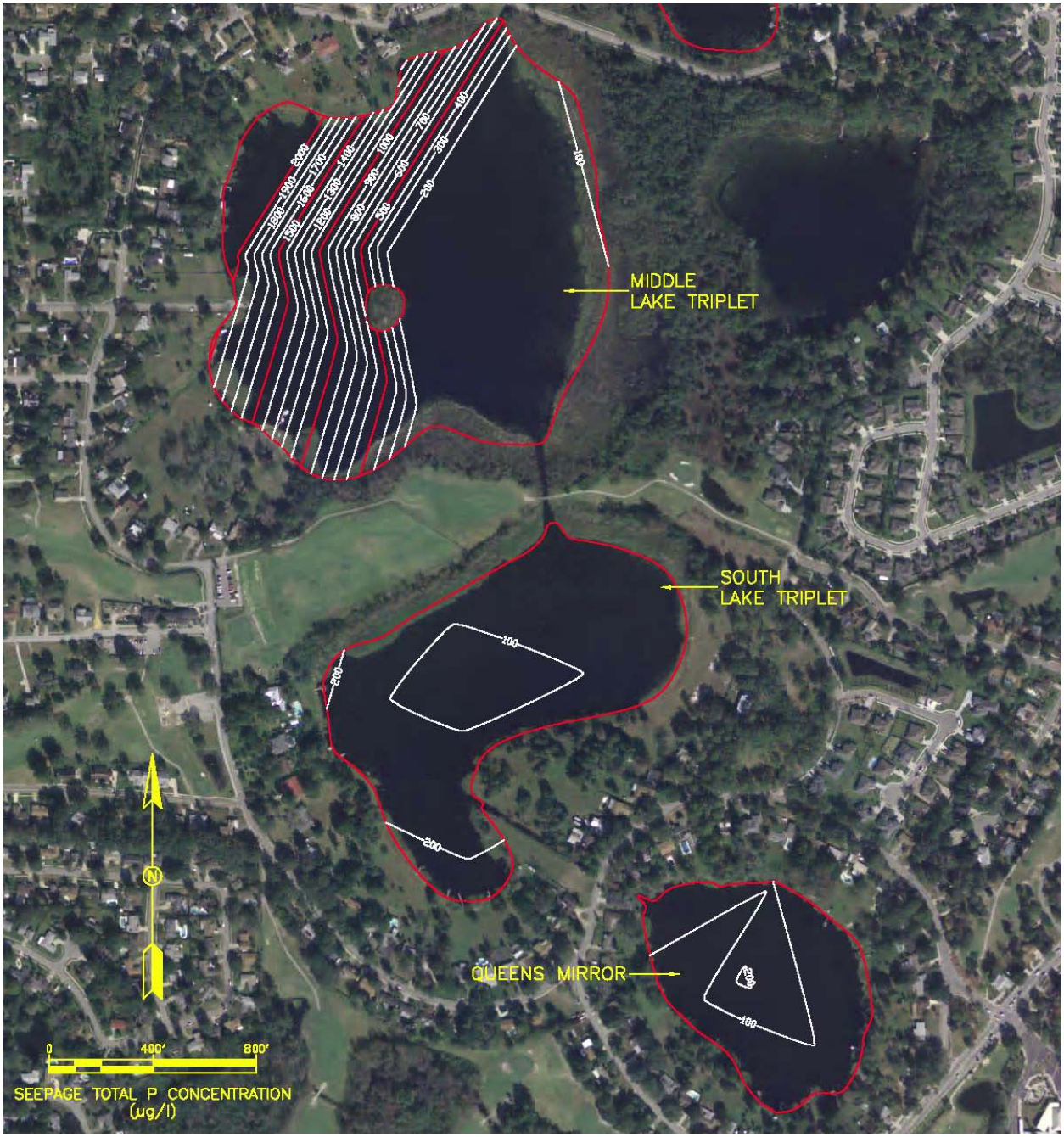



Figure 5-9. Mean Isopleths of Total Phosphorus (µg/l) in Groundwater Seepage Entering Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011.

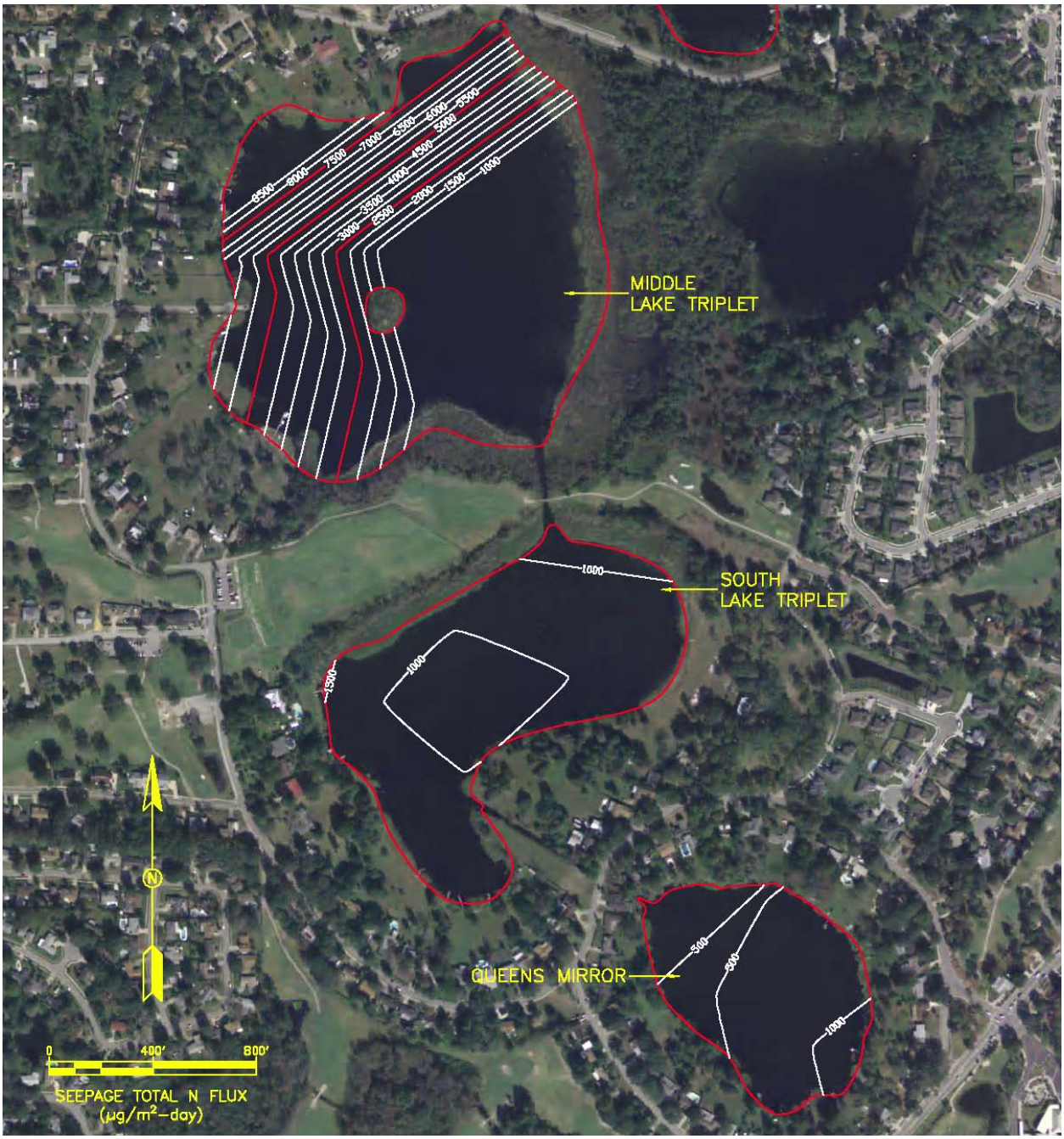



Figure 5-10. Mean Isopleths of Total Nitrogen Flux (µg/m$^2$-day) from Groundwater Seepage Entering Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011.

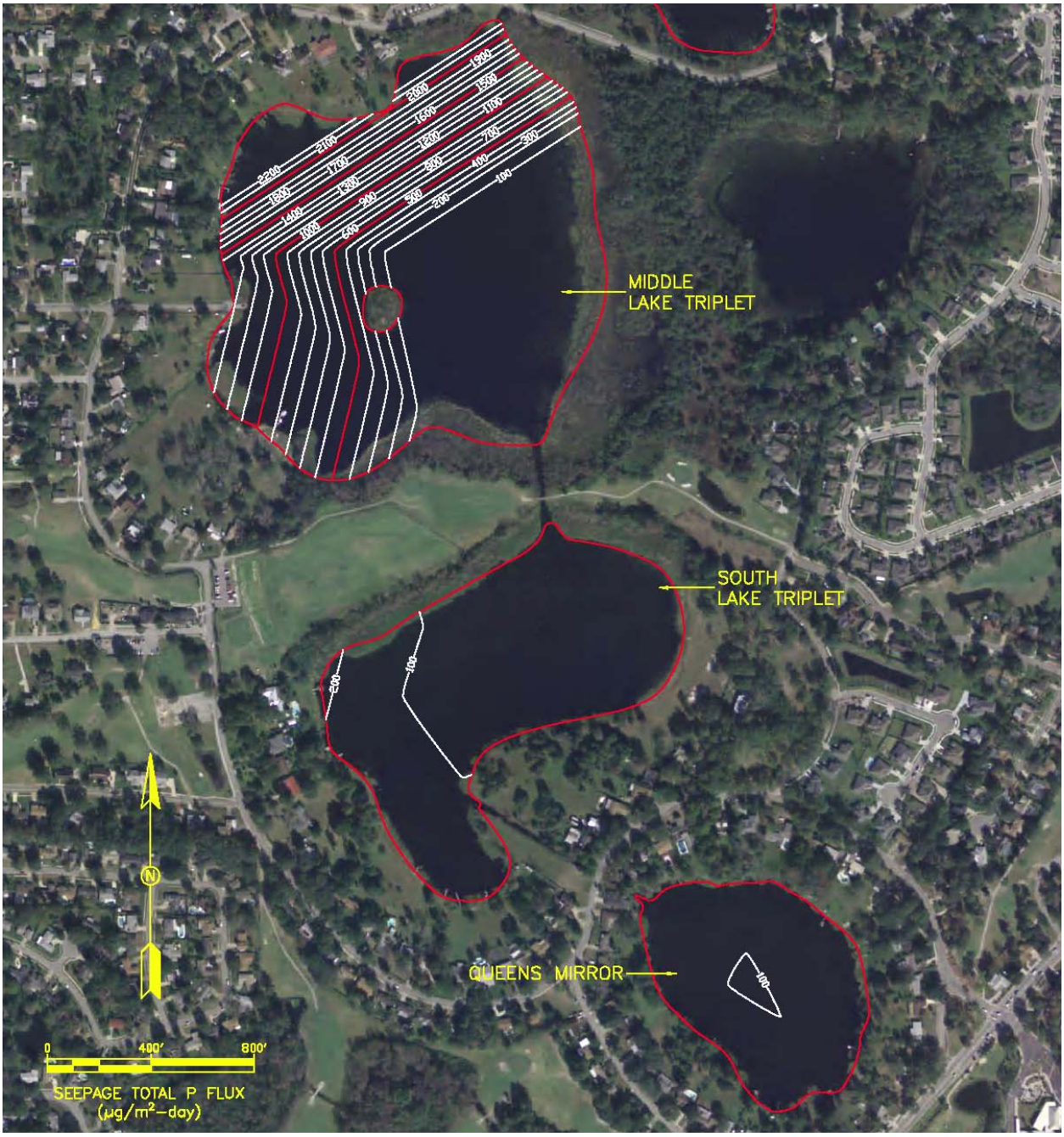



Figure 5-11. Mean Isopleths of Total Phosphorus Flux (µg/m$^2$-day) from Groundwater Seepage Entering Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from September 2010-May 2011.

The isopleths summarized in Figures 5-10 and 5-11 were graphically integrated to obtain estimates of mean daily seepage influx of total nitrogen and total phosphorus to Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet. Since the monitoring period included periods of dry and wet season conditions, the measured daily seepage influx values are assumed to reflect mean daily influx of nitrogen and phosphorus over an annual cycle. The measured daily seepage influx was converted to an annual value by multiplying the daily influx values for nitrogen and phosphorus by 365 days/year.

A summary of estimated annual mass loadings of total nitrogen and total phosphorus discharging to Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet from groundwater seepage is given in Table 5-8. Weighted mass influx values for nitrogen and phosphorus are substantially different between the three lakes, ranging from 708-3096 $\mu g/m^2$-day for total nitrogen, and 53-692 $\mu g/m^2$-day for total phosphorus. On an annual basis, seepage influx contributes approximately 13.1 kg/yr of total nitrogen to Queens Mirror Lake, 40.6 kg/yr to South Lake Triplet, and 204 kg/yr to Middle Lake Triplet. Seepage contributes approximately 1.0 kg/yr of total phosphorus to Queens Mirror Lake, 3.0 kg/yr to South Lake Triplet, and 45.6 kg/yr to Middle Lake Triplet.

**TABLE 5-8**

**ESTIMATED ANNUAL SEEPAGE INFLUX OF TOTAL NITROGEN AND TOTAL PHOSPHORUS FROM GROUNDWATER SEEPAGE TO QUEENS MIRROR LAKE, SOUTH LAKE TRIPLET, AND MIDDLE LAKE TRIPLET**

| LAKE | PARAMETER | WEIGHTED MEAN MASS INFLUX ($\mu g/m^2$-day) | MASS INFLUX | | |
|---|---|---|---|---|---|
| | | | g/day | kg/yr | kg/ac-yr |
| Queens Mirror Lake | Nitrogen | 708 | 36 | 13.1 | 1.05 |
| | Phosphorus | 53 | 2.7 | 1.0 | 0.08 |
| South Lake Triplet | Nitrogen | 1179 | 111 | 40.6 | 1.74 |
| | Phosphorus | 87 | 8.2 | 3.0 | 0.13 |
| Middle Lake Triplet | Nitrogen | 3096 | 559 | 204 | 4.58 |
| | Phosphorus | 692 | 125 | 45.6 | 1.02 |

Estimates of areal annual mass loadings from groundwater seepage are provided in the final column of Table 5-8. On an annual basis, seepage contributes approximately 1.05-1.74 kg/ac-yr of total nitrogen in Queens Mirror Lake and South Lake Triplet. However, in Middle Lake Triplet, the mass influx rate increases substantially to 4.58 kg/ac-yr for total nitrogen. A similar pattern is also apparent for total phosphorus, with approximately a 10-fold increase in phosphorus influx observed in Middle Lake Triplet compared with Queens Mirror Lake and South Lake Triplet. The areal seepage loading of total nitrogen in Middle Lake Triplet is approximately 30% less than the areal nitrogen loading measured by ERD in Bear Gully Lake, while the areal mass influx of total phosphorus in Middle Lake Triplet is approximately 364% higher than phosphorus influx measured by ERD in Bear Gully Lake.

### 5.1.5 Internal Recycling

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 Queens Mirror Lake and the Triplet Chain-of-Lakes since the lakes are 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 Queens Mirror Lake and the Triplet Chain-of-Lakes since the lakes are relatively shallow, and although a well defined hypolimnion may develop at times, circulation events are 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 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 water column, 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 Queens Mirror Lake and the Triplet Chain-of-Lakes.

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 Queens Mirror Lake and the Triplet Chain-of-Lakes under both aerobic and anoxic conditions. Large diameter lake sediment core samples were collected at multiple locations in the lakes and incubated under anoxic and aerobic conditions. Periodic measurements of orthophosphorus and total phosphorus were used to estimate sediment phosphorus release under the evaluated conditions and to provide an estimate of the significance of mass loadings of phosphorus from lake sediments as part of the overall nutrient budget for the lakes.

#### 5.1.5.1 Field and Laboratory Procedures

Sediment core samples were collected at two locations in Queens Mirror Lake and in two locations in South Lake Triplet during February 2011 using 4-inch diameter clear acrylic core tubes. 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. Locations used for collection of the sediment core tubes are indicated on Figure 5-12. Water depths at each site are also provided for reference purposes.

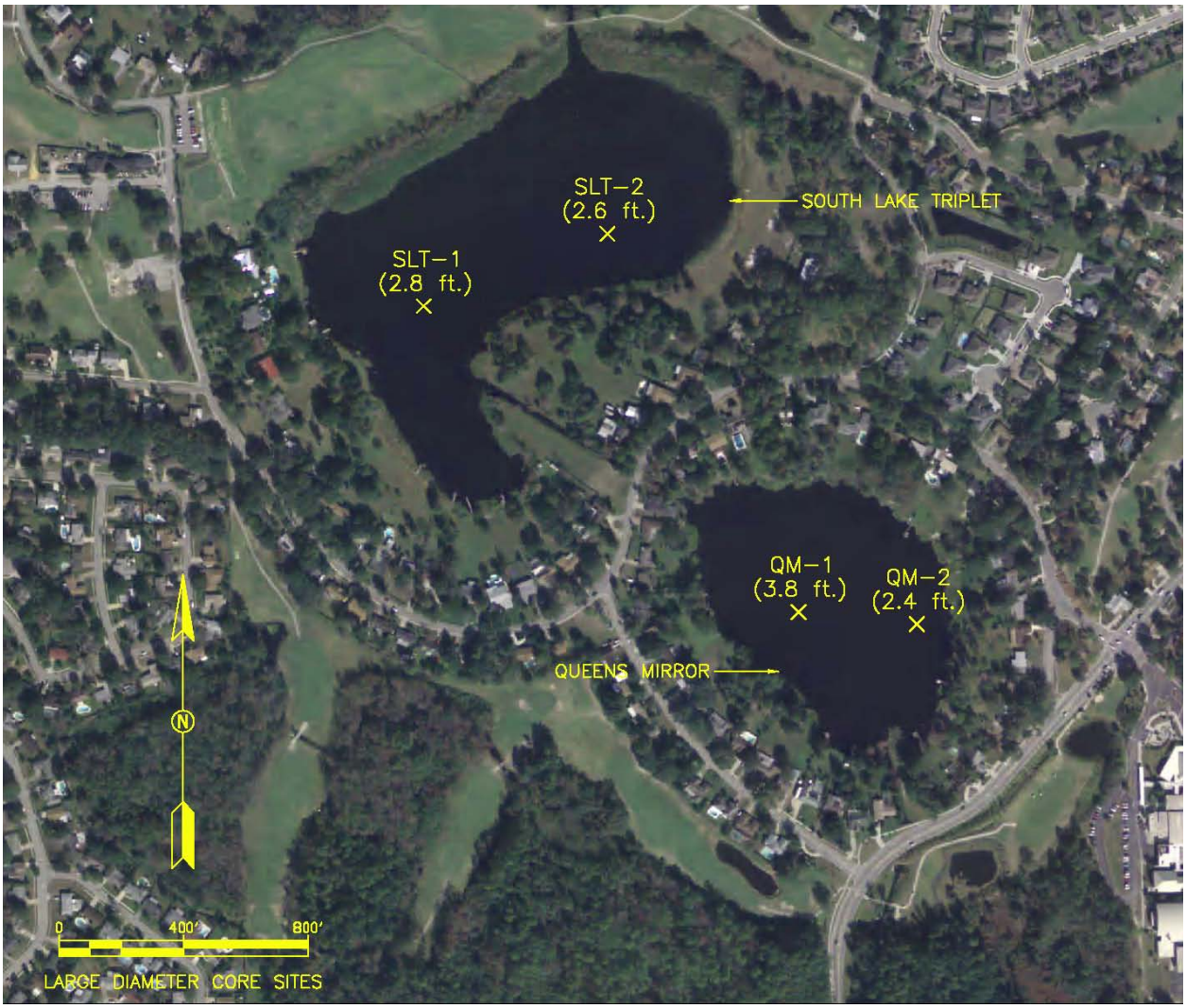



Figure 5-12. Collection Sites for the Large Diameter Sediment Cores Used in Incubation Experiments for Queens Mirror Lake and South Lake Triplet (water depth indicated in parentheses).

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, rubber caps were attached to the bottom and top of each core tube to prevent loss of sediments during transport. Each of the collected core tubes was then transported to the ERD laboratory for incubation experimentation. All samples were transported in a vertical position to avoid mixing of the sediment layers.

After return to the laboratory, each of the four collected core samples was attached to a laboratory work bench in a vertical position. The collected water volume above the sediments was carefully siphoned off until a water depth of 24 inches remained in each of the collected columns above the sediment-water interface. A 4-inch PVC cap was then placed on the top of each collected core tube. Two small diameter holes were drilled into the PVC cap, and a semi-rigid 1/4-inch 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 1/4-inch 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 5-13.

After initial set-up of the incubation apparatus, a compressed nitrogen gas cylinder was attached to the core tubes using a manifold, and nitrogen gas was gently bubbled through each of the columns to remove existing dissolved oxygen and create anoxic conditions within each tube. In general, creation of anoxic conditions, as indicated by measurements of redox potential (< 200 mv) within each of the columns, occurred after approximately 2-3 days. At the onset of anoxic conditions, sample collection was initiated. On approximately a 1-2 day interval, 20 ml of water was withdrawn from each of the columns using a 1/4-inch polyethylene tube and a plastic laboratory syringe. Each of the collected samples was immediately filtered using a 0.45 micron syringe mount membrane filter and analyzed for orthophosphorus, total phosphorus, and other significant laboratory parameters for research purposes. However, only the results of the total phosphorus analyses are utilized in this report for purposes of estimating sediment phosphorus release rates. Incubation of samples under anoxic conditions was continued for approximately 35 days.

At the conclusion of the experimentation under anoxic conditions, compressed air was introduced into each of the core tubes through the individual diffusers using a small compressor. This process quickly created aerobic conditions within each of the core tubes. This aeration process was continued in each of the core tubes for a period of approximately 35 days. During the aeration process, the 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.

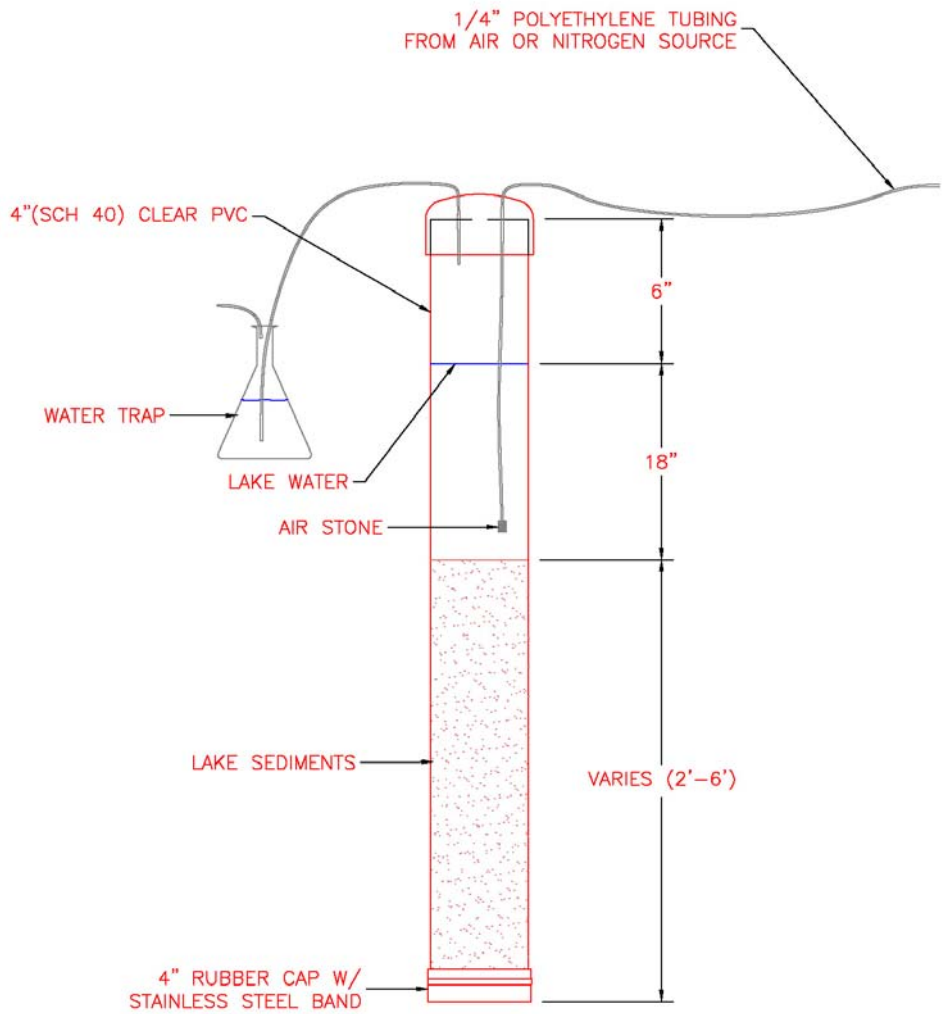



Figure 5-13. Schematic of Sediment Incubation Apparatus.

Collection of the large diameter (4-inch) sediment core samples was performed during February 2011. Experimentation under anoxic conditions was initiated on February 8, 2011 and continued until March 4, 2011. Aerobic experimentation was initiated at the end of the anoxic experiments and was continued until April 25, 2011.

#### 5.1.5.2 Results of Laboratory Testing

Each of the samples collected as part of the sediment incubation experiments was analyzed in the ERD Laboratory for $NH_3$, $NO_x$, total nitrogen, SRP, and total phosphorus. A total of 104 separate samples was collected as part of the incubation experiments conducted under aerobic conditions. A complete listing of the results of laboratory analyses conducted on sediment incubation samples under anoxic and aerobic conditions is given in Appendix E.1.

A graphical comparison of changes in total phosphorus concentrations in the large diameter core tube samples incubated under aerobic and anoxic conditions at each of the two sites in Queens Mirror Lake is given on Figure 5-14, with changes in phosphorus concentrations measured in core samples collected in South Lake Triplet illustrated on Figure 5-15. Under anoxic conditions, phosphorus concentrations increased relatively rapidly in both the Queens Mirror Lake and South Lake Triplet core samples. However, the rate and magnitude of phosphorus release appears to be greater in the Queens Mirror Lake samples than observed in South Lake Triplet. Under aerobic conditions, phosphorus concentrations increased slowly, reaching equilibrium phosphorus concentrations substantially lower than observed under anoxic conditions.

#### 5.1.5.3 Mass Release

Sediment phosphorus release under aerobic and anoxic conditions was estimated for Queens Mirror Lake and South Lake Triplet using the release rates observed in the sediment core tubes which were incubated under aerobic and anoxic conditions. Regression relationships for sediment phosphorus release in Queens Mirror Lake and South Lake Triplet under aerobic and anoxic conditions are given in Appendix E.2. The slope of each regression line represents the release rate for phosphorus in each of the sediment core samples.

A summary of measured sediment phosphorus release in large diameter core samples collected in Queens Mirror Lake and South Lake Triplet is given in Table 5-9. Release rates are provided for each of the two core samples in each lake under both anoxic and aerobic conditions. Separate release rates are provided for SRP and total phosphorus for comparison purposes. The release rates from each of the two core tubes in each lake were averaged together to provide an estimate of mean sediment phosphorus release under both aerobic and anoxic conditions. The sediment phosphorus release rates indicated on Table 5-9 were corrected for the volume of water contained in each incubation experiment and the area of sediment contained within each of the large diameter core tubes to provide estimates of phosphorus release rates in terms of $mg/m^2$-day.

**TABLE 5-9**

**MEASURED SEDIMENT PHOSPHORUS RELEASE IN LARGE DIAMETER CORE SAMPLES COLLECTED IN QUEENS MIRROR LAKE AND SOUTH LAKE TRIPLET**

| LAKE | CORE TUBE NO. | ANOXIC CONDITIONS | | AEROBIC CONDITIONS | |
|---|---|---|---|---|---|
| | | SRP Release ($mg/m^2$-day) | Total P Release ($mg/m^2$-day) | SRP Release ($mg/m^2$-day) | Total P Release ($mg/m^2$-day) |
| Queens Mirror Lake | 1 | 2.13 | 2.65 | 0.82 | 0.62 |
| | 2 | 4.45 | 4.42 | 0.39 | 0.74 |
| | **Mean** | **3.29** | **3.54** | **0.61** | **0.68** |
| South Lake Triplet | 1 | 1.59 | 1.95 | 0.36 | 0.74 |
| | 2 | 1.67 | 3.20 | 0.26 | 0.61 |
| | **Mean** | **1.63** | **2.57** | **0.31** | **0.68** |

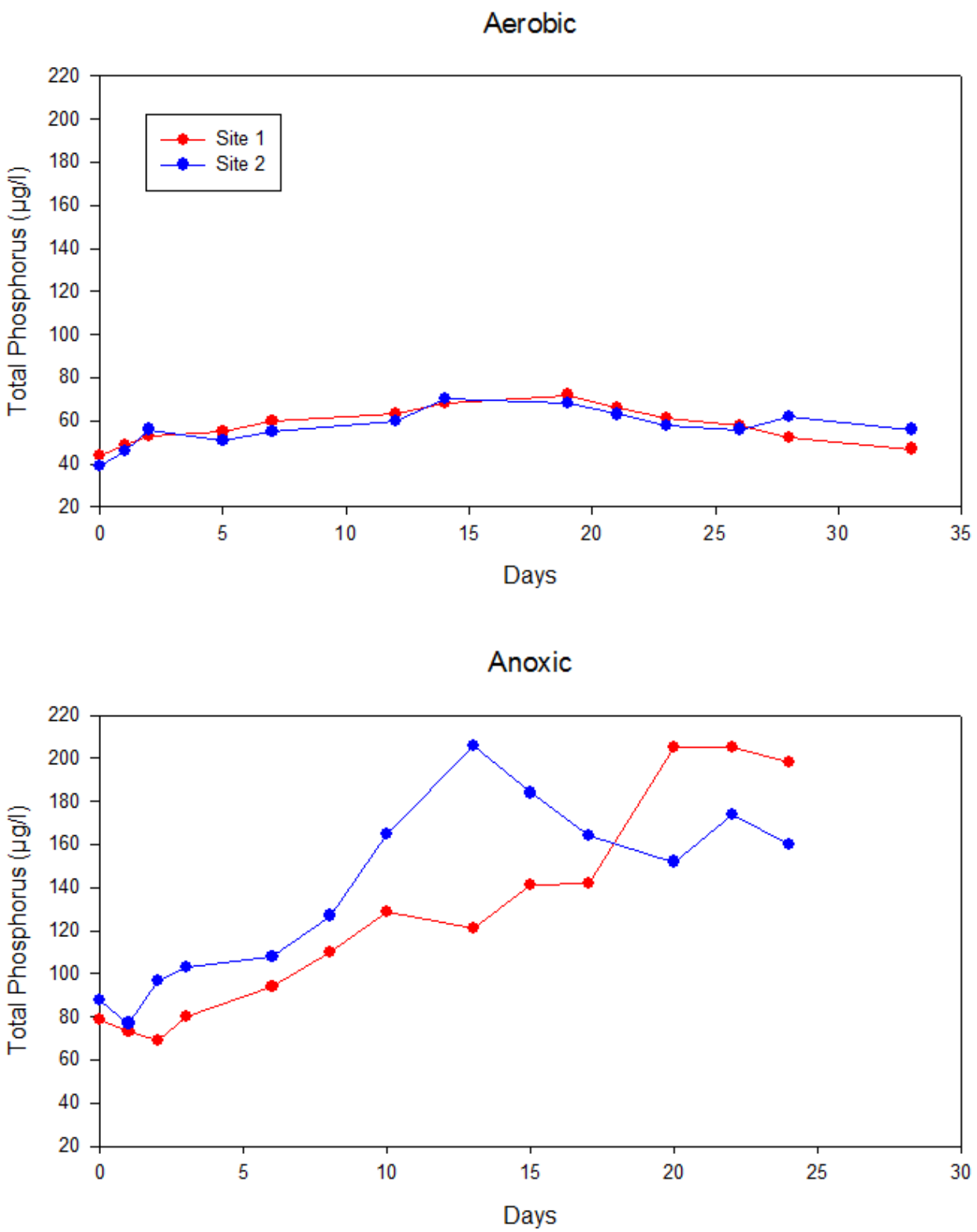



Figure 5-14. Changes in Concentrations of Total Phosphorus in Large Diameter Core Samples Collected from Queens Mirror Lake and Incubated Under Aerobic and Anoxic Conditions.

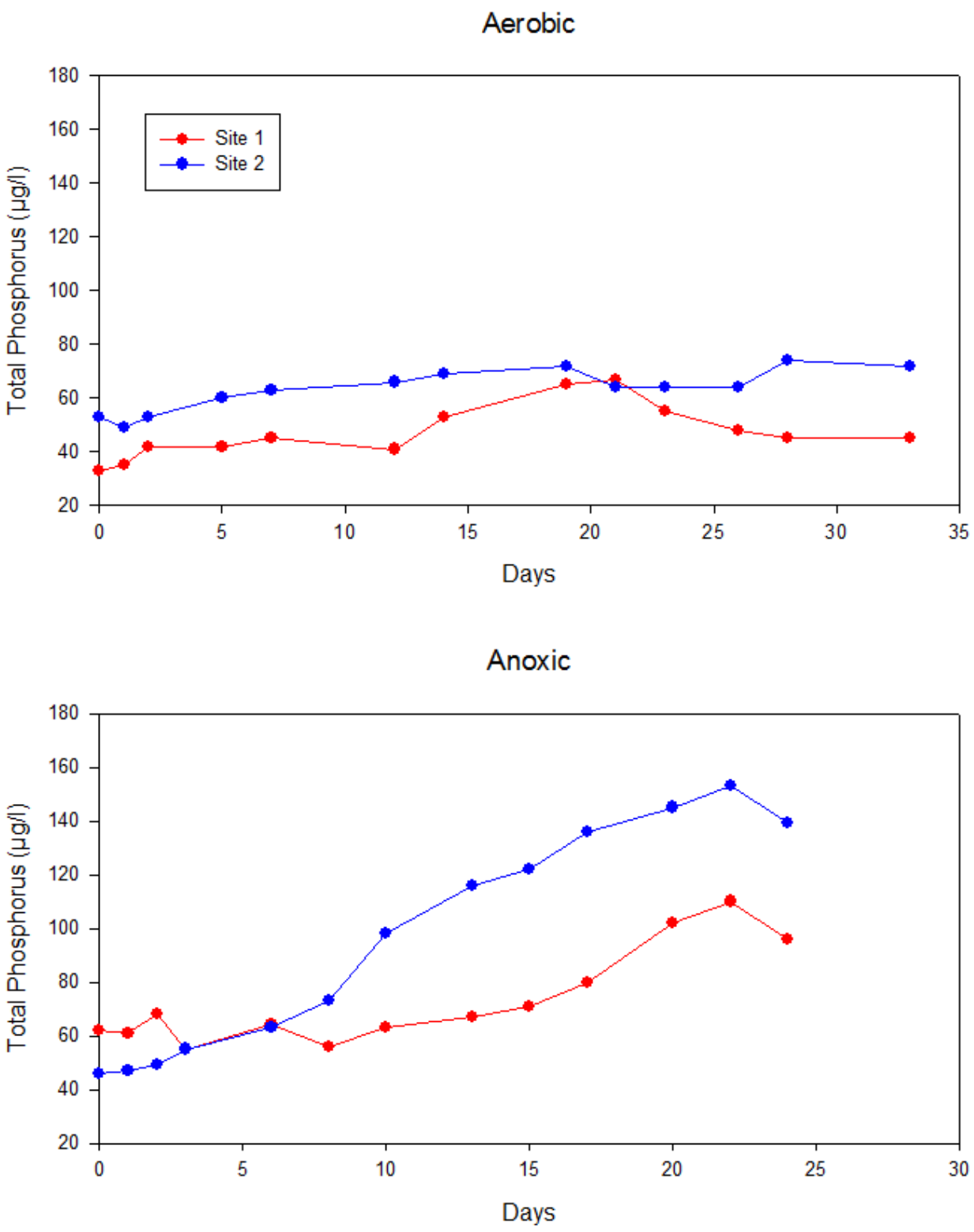



Figure 5-15. Changes in Concentrations of Total Phosphorus in Large Diameter Core Samples Collected from South Lake Triplet and Incubated Under Aerobic and Anoxic Conditions.

Under anoxic conditions, the mean total phosphorus release rate in Queens Mirror Lake was approximately 3.54 mg/m$^2$-day. The measured SRP release rate is approximately 3.29 mg/m$^2$-day, indicating that SRP comprises approximately 93% of the total phosphorus which is released. Under aerobic conditions, total phosphorus release is approximately 0.68 mg/m$^2$-day, with approximately 90% of the total phosphorus released contributed by SRP. The mean total phosphorus sediment release rate under anoxic conditions is approximately 5.2 times greater than the total phosphorus release rate under aerobic conditions.

Sediment phosphorus release rates in South Lake Triplet appear to be somewhat lower than release rates observed in Queens Mirror Lake. The mean total phosphorus sediment release rate in South Lake Triplet is 2.57 mg/m$^2$-day, with an SRP release rate of 1.63 mg/m$^2$-day. It appears that in South Lake Triplet SRP release accounts for approximately 64% of the total phosphorus released from the sediment. Sediment phosphorus release in South Lake Triplet is substantially reduced under aerobic conditions, with a release rate of 0.68 mg/m$^2$-day for total phosphorus and 0.31 mg/m$^2$-day for SRP.

Estimates of annual mass loadings for total phosphorus in Queens Mirror Lake and the Triplet Chain-of-Lakes from internal recycling are given on Table 5-10. The estimated annual mass loadings include a combination of both anoxic and aerobic release rates based upon the estimated percentage of each year during which either anoxic or aerobic conditions appear to exist at the sediment-water interface. Based upon the mean seasonal vertical field profiles for Queens Mirror Lake (illustrated on Figure 2-9), anoxic conditions appear to exist near the water-sediment interface during spring conditions, with relatively aerobic conditions (indicated by dissolved oxygen concentrations in excess of 1 mg/l) during the remaining months of the year. Therefore, for purposes of this analysis, it is assumed that anoxic conditions exist in Queens Mirror Lake near the water sediment interface during three months of the year, with aerobic conditions occurring during nine months of the year. Based upon the mean seasonal vertical field profiles for South Lake Triplet (illustrated on Figure 2-14), anoxic conditions at the water-sediment interface appear to occur during approximately six months of the year, with six months of aerobic conditions. Based upon the mean seasonal vertical field profiles for Middle Lake Triplet (illustrated on Figure 2-19) and North Lake Triplet (illustrated on Figure 2-24), each of these lakes appears to exhibit anoxic conditions during spring conditions only, with aerobic conditions during the remaining months of the year.

**TABLE 5-10**

**ESTIMATED ANNUAL MASS LOADINGS OF TOTAL PHOSPHORUS TO QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES FROM INTERNAL RECYCLING**

| LAKE | ANOXIC CONDITIONS | | | AEROBIC CONDITIONS | | | TOTAL RELEASE (kg TP/yr) |
|---|---|---|---|---|---|---|---|
| | Duration (months) | Release Rate (mg/m$^2$-day) | Mass Released (kg TP) | Duration (months) | Release Rate (mg/m$^2$-day) | Mass Released (kg TP) | |
| Queens Mirror Lake | 3 | 3.54 | 16.4 | 9 | 0.74 | 10.3 | 26.7 |
| South Lake Triplet | 6 | 1.63 | 28.1 | 6 | 0.68 | 11.7 | 39.8 |
| Middle Lake Triplet | 3 | 1.63 | 26.9 | 9 | 0.68 | 33.6 | 60.5 |
| North Lake Triplet | 3 | 1.63 | 12.9 | 9 | 0.68 | 16.2 | 29.1 |

As discussed previously, measurements of internal recycling were conducted only in Queens Mirror Lake and South Lake Triplet. However, for purposes of estimating nutrient budgets, internal recycling in Middle Lake Triplet and North Lake Triplet is assumed to be similar to internal recycling rates measured in South Lake Triplet. South Lake Triplet appears to be more similar to Middle Lake Triplet and North Lake Triplet than Queens Mirror Lake which receives a substantial annual loading from the large wetland area located south of the lake. As indicated on Table 5-10, internal recycling is estimated to contribute approximately 26.7 kg of total phosphorus per year to Queens Mirror Lake, 39.8 kg/yr to South Lake Triplet, 60.5 kg/yr to Middle Lake Triplet, and 29.1 kg/yr to North Lake Triplet. This information is used in a subsequent section to develop annual nutrient budgets for each of the lakes.

## 5.2 Nutrient Losses

Nutrient losses from Queens Mirror Lake and the Triplet Chain-of-Lakes occur primarily as a result of discharges from each lake to downstream waterbodies, with a small nutrient loss occurring as a result of estimated losses to deep recharge. Pollutant mass which is not discharged from the outfall at each lake or lost as a result of deep recharge is assumed to accumulate into the sediments of each lake. Estimates of the magnitude of these losses are given in the following sections.

### 5.2.1 Outfall Discharges

Estimated mass losses for total nitrogen and total phosphorus as a result of discharge between the interconnected waterbodies was discussed previously in Section 5.1.3 and the results of this analysis are summarized in Table 5-6.

### 5.2.2 Deep Recharge

Estimates of volumetric losses as a result of deep recharge in Queens Mirror Lake and the Triplet Chain-of-Lakes was discussed in Section 4.2.2, with a tabular summary of estimated volumetric losses for each lake given in Table 4-10. Estimates of annual mass losses resulting from deep recharge were calculated by multiplying the volumetric losses (summarized in Table 4-10) times the mean ambient concentrations of total nitrogen and total phosphorus in each of the four lakes, as discussed in Section 2. A tabular summary of estimated mass losses of total nitrogen and total phosphorus resulting from deep recharge in Queens Mirror Lake and the Triplet Chain-of-Lakes is given in Table 5-11. Mass losses were calculated by multiplying the estimated annual volumetric loss times mean ambient water quality concentrations of total nitrogen and total phosphorus in each lake. Annual mass losses of total nitrogen ranged from 2.4 kg/yr in Queens Mirror Lake to 7.5 kg/yr in Middle Lake Triplet, with relatively minimal annual mass losses of total phosphorus.

**TABLE 5-11**

**ESTIMATED ANNUAL MASS LOSSES OF TOTAL NITROGEN AND TOTAL PHOSPHORUS RESULTING FROM DEEP RECHARGE IN QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | ANNUAL VOLUME (ac-ft) | MEAN CONCENTRATION (μg/l) | | ANNUAL MASS LOSS (kg) | |
|---|---|---|---|---|---|
| | | Total Nitrogen | Total Phosphorus | Total Nitrogen | Total Phosphorus |
| Queens Mirror Lake | 2.09 | 914 | 52 | 2.4 | 0.13 |
| South Lake Triplet | 3.88 | 923 | 47 | 4.4 | 0.23 |
| Middle Lake Triplet | 7.43 | 817 | 36 | 7.5 | 0.17 |
| North Lake Triplet | 3.58 | 819 | 33 | 3.6 | 0.15 |

## 5.3 Calculated Mass Budgets

Mean annual mass budgets were developed for total nitrogen and total phosphorus in Queens Mirror Lake and the Triplet Chain-of-Lakes based upon the analyses presented in the previous section. A discussion of mass inputs and losses is given in the following sections.

### 5.3.1 Mass Inputs

A summary of estimated mean annual mass loadings of total nitrogen and total phosphorus entering Queens Mirror Lake and the Triplet Chain-of-Lakes is given in Table 5-12. Estimated mass loadings summarized in this table are based upon the discussions and analyses presented in previous sections. The largest nitrogen sources to Queens Mirror Lake are inflow from the southern canal (56%) followed by bulk precipitation (24%). However, the largest nitrogen loadings to the downstream lakes consist of inflow from upstream waterbodies, with 56% of the nitrogen loadings to South Lake Triplet contributed by inflow from Queens Mirror Lake, 44% of the nitrogen loadings to Middle Lake Triplet are contributed by inflow from South Lake Triplet, and 81% of the nitrogen loadings to North Lake Triplet contributed by inflow from Middle Lake Triplet. Seepage appears to contribute a relatively small amount of the annual nitrogen loadings, ranging from approximately 5-9%. Runoff from watershed areas also appears to be a relatively small nitrogen source, comprising 3-16% of the annual nitrogen loadings.

Phosphorus loadings to Queens Mirror Lake are contributed primarily by internal recycling (48%) and inflow from the southern canal (34%). Combined together, these two sources contribute approximately 82% of the phosphorus loading to Queens Mirror Lake. Internal recycling is also the dominant phosphorus source in the Triplet Chain-of-Lakes, contributing 51% of the phosphorus loading to South Lake Triplet, 50% of the phosphorus loading to Middle Lake Triplet, and 41% of the annual phosphorus loadings to North Lake Triplet. The second largest contributor of phosphorus loadings to the Triplet Chain-of-Lakes consists of inflow from upstream waterbodies, with 20% of the annual phosphorus loading to South Lake Triplet contributed by inflow from Queens Mirror Lake, 16% of the annual phosphorus loading to Middle Lake Triplet contributed by inflow from South Lake Triplet, and 40% of the phosphorus loading to North Lake Triplet contributed by inflow from Middle Lake Triplet. Graphical comparisons of annual nitrogen loadings to Queens Mirror Lake and the Triplet Chain-of-Lakes is given on Figure 5-16, with annual phosphorus loadings summarized on Figure 5-17.

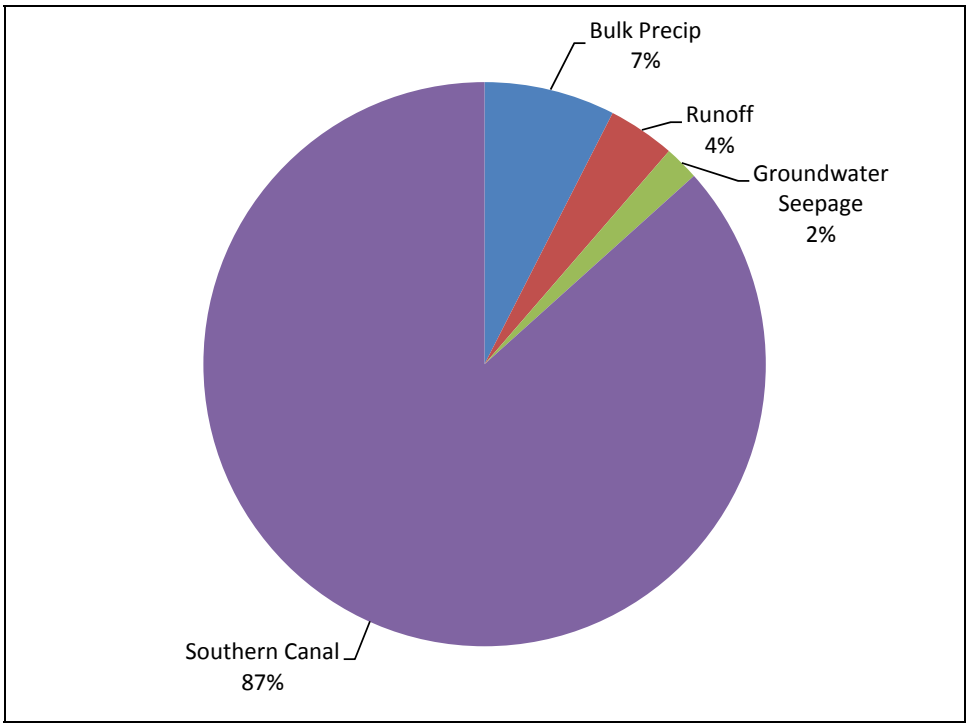
## TABLE 5-12

## ESTIMATED MEAN ANNUAL MASS LOADINGS OF TOTAL NITROGEN AND TOTAL PHOSPHORUS TO QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES

| LAKE | SOURCE | TOTAL NITROGEN | | TOTAL PHOSPHORUS | |
|---|---|---|---|---|---|
| | | kg/yr | Percent of Total | kg/yr | Percent of Total |
| Queens Mirror Lake | Bulk Precipitation | 49.6 | 7 | 3.9 | 3 |
| | Southern Canal | 571 | 87 | 90.0 | 72 |
| | Runoff | 25.4 | 4 | 4.2 | 3 |
| | Groundwater Seepage | 13.1 | 2 | 1.0 | 1 |
| | Internal Recycling | -- | -- | 26.7 | 21 |
| | **Total:** | **659** | **100** | **126** | **100** |
| South Lake Triplet | Bulk Precipitation | 92.2 | 7 | 7.3 | 6 |
| | Runoff | 73.2 | 6 | 12.3 | 10 |
| | Inflow from Queens Mirror Lake | 1084 | 84 | 61.7 | 50 |
| | Seepage | 40.6 | 3 | 3.0 | 2 |
| | Internal Recycling | -- | -- | 39.8 | 32 |
| | **Total:** | **1290** | **100** | **124** | **100** |
| Middle Lake Triplet | Bulk Precipitation | 177 | 9 | 14.0 | 7 |
| | Runoff | 178 | 10 | 29.8 | 14 |
| | Inflow from South Lake Triplet | 1208 | 65 | 61.5 | 29 |
| | Inflow from Lost Lake | 87.2 | 5 | 2.1 | 1 |
| | Seepage | 204 | 11 | 45.6 | 21 |
| | Internal Recycling | -- | -- | 60.5 | 28 |
| | **Total:** | **1854** | **100** | **213** | **100** |
| North Lake Triplet | Bulk Precipitation | 85.0 | 5 | 6.7 | 6 |
| | Runoff | 26.4 | 2 | 4.4 | 4 |
| | Inflow from Middle Lake Triplet | 1406 | 90 | 61.9 | 56 |
| | Seepage[1] | 52.7 | 3 | 8.8 | 8 |
| | Internal Recycling | -- | -- | 29.1 | 26 |
| | **Total:** | **1570** | **100** | **111** | **100** |

1. Reflects average areal loading from Queens Mirror Lake, South Lake Triplet, and Middle Lake Triplet

Queens Mirror Lake Total Nitrogen Loadings




South Lake Triplet Total Nitrogen Loadings

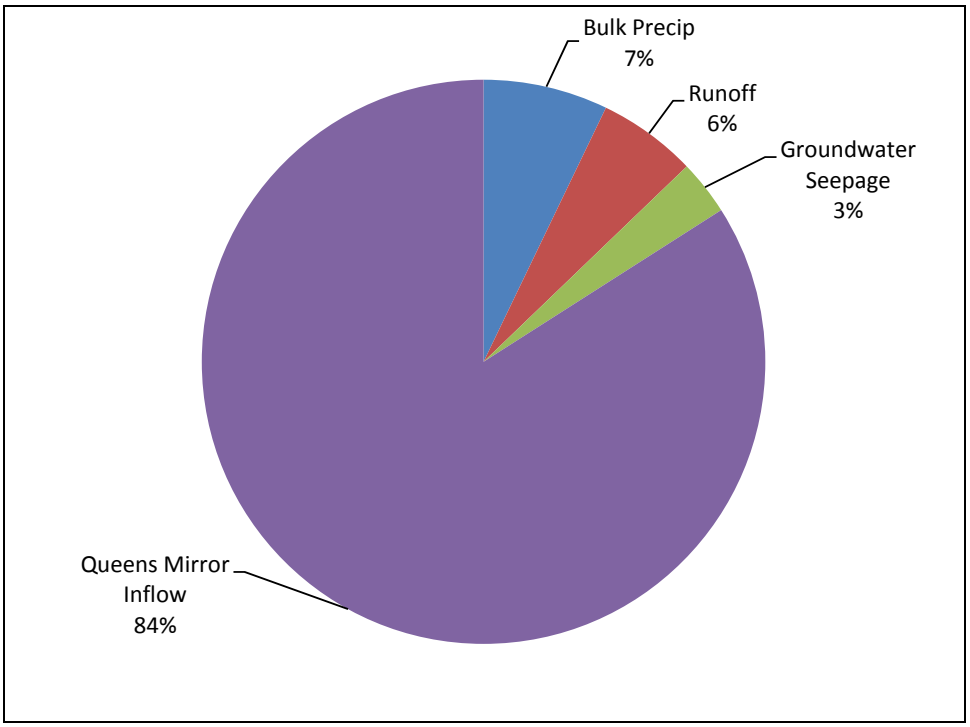
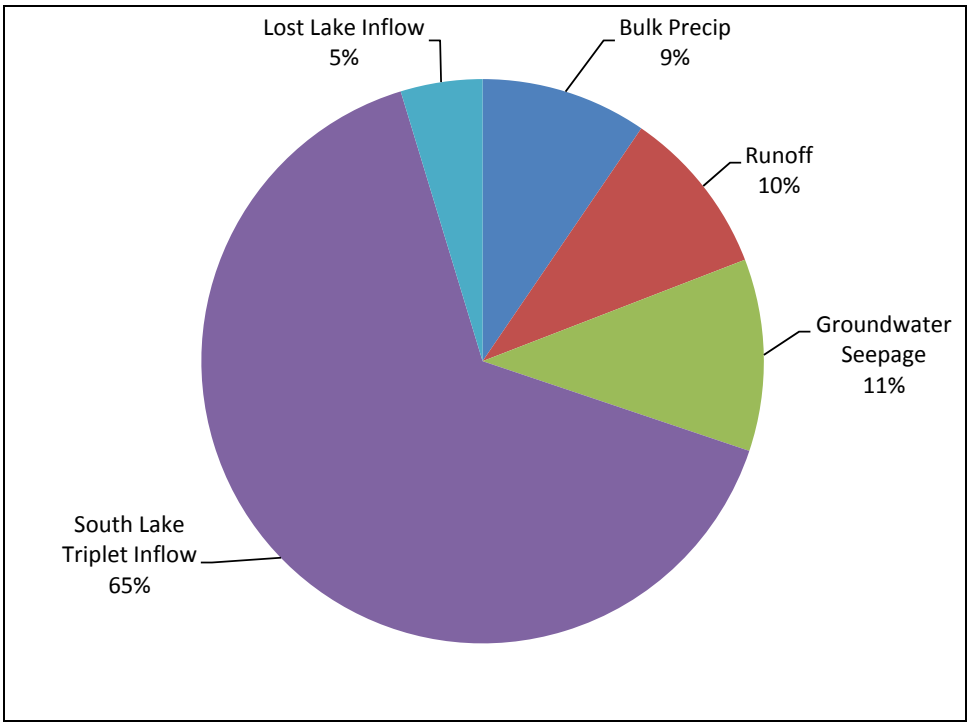



Figure 5-16. Annual Nitrogen Budgets for Queens Mirror Lake and the Triplet Chain-of-Lakes.

Middle Lake Triplet Total Nitrogen Loadings




North Lake Triplet Total Nitrogen Loadings

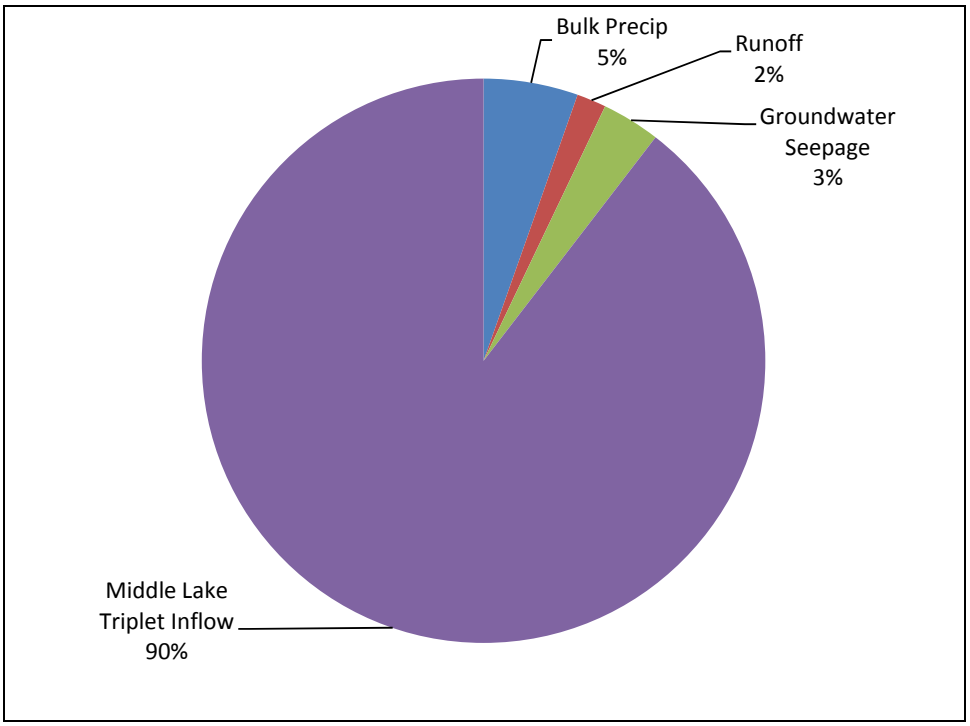
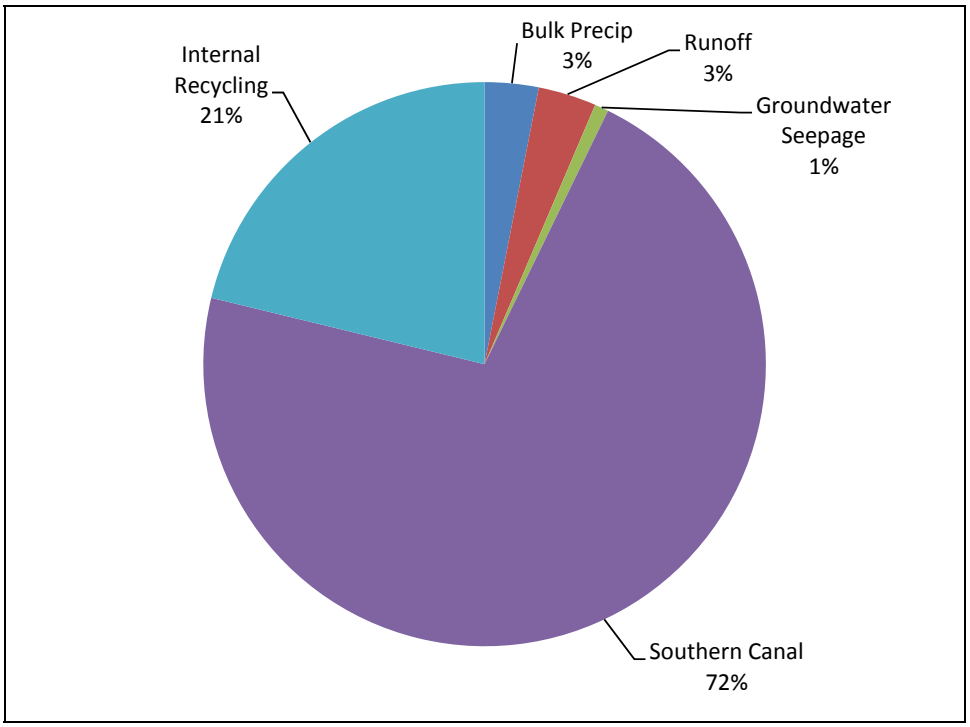



Figure 5-16. Annual Nitrogen Budgets for Queens Mirror Lake and the Triplet Chain-of-Lakes (continued).

Queens Mirror Lake Total Phosphorus Loadings




South Lake Triplet Total Phosphorus Loadings

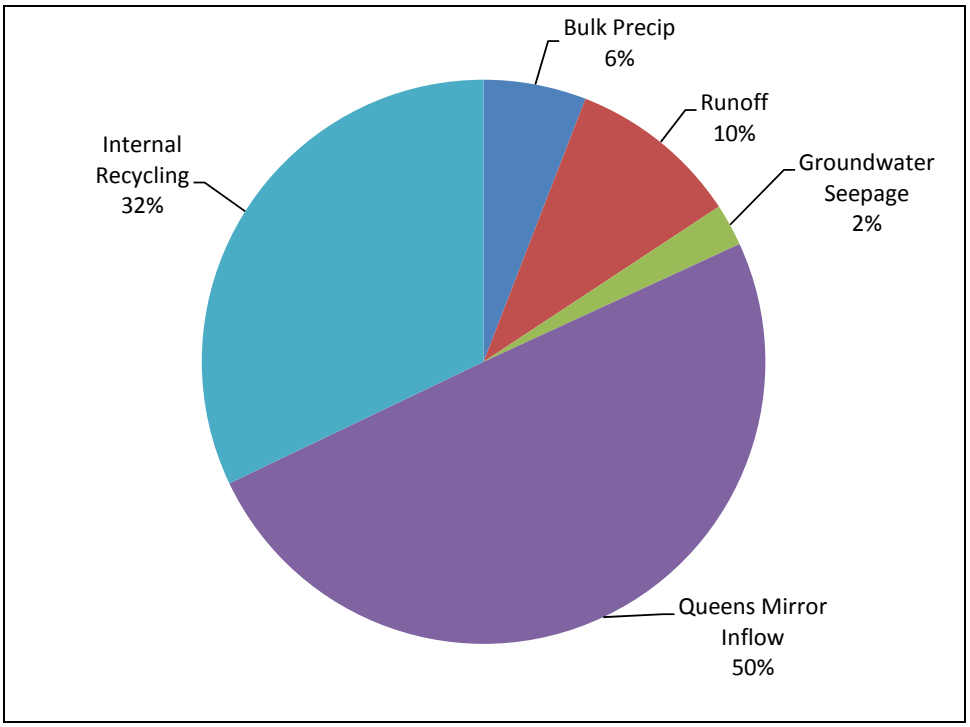
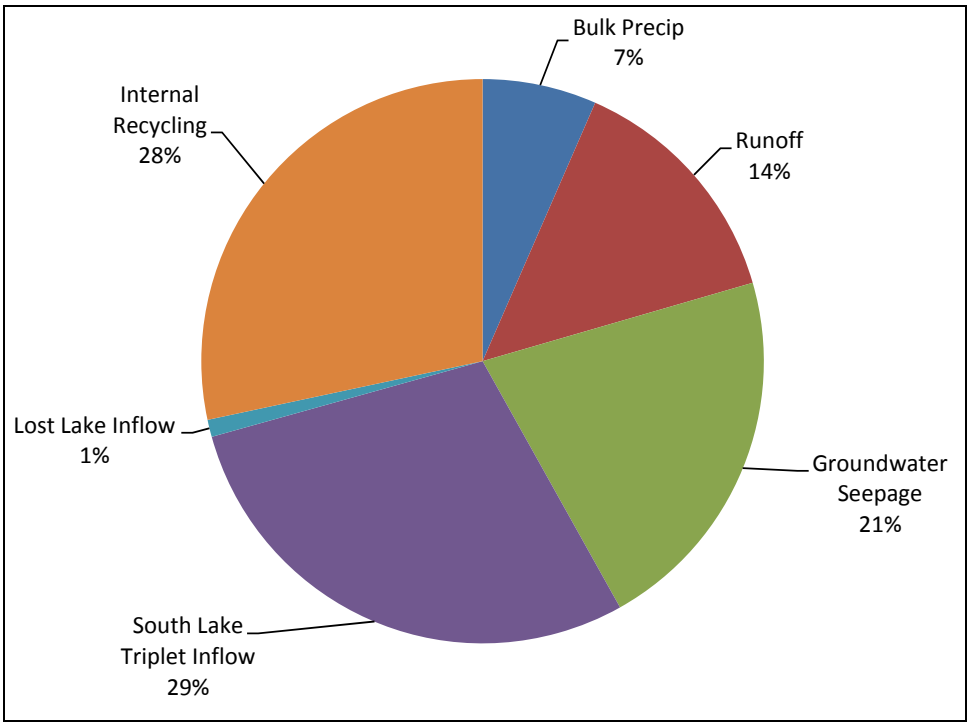



Figure 5-17. Annual Phosphorus Budgets for Queens Mirror Lake and the Triplet Chain-of-Lakes.

Middle Lake Triplet Total Phosphorus Loadings




North Lake Triplet Total Phosphorus Loadings

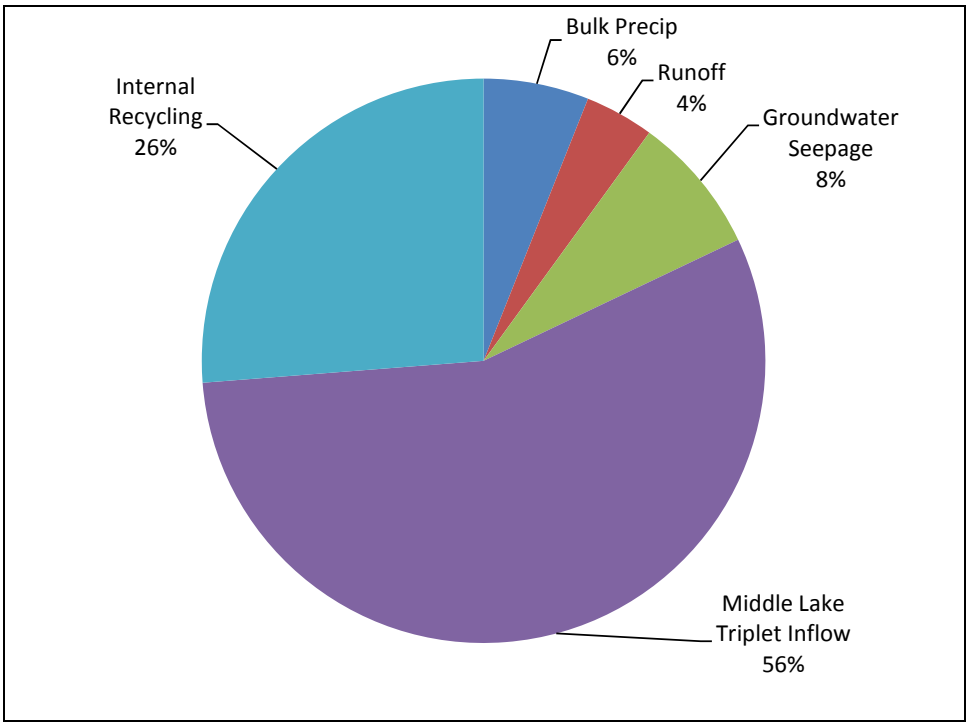



Figure 5-17. Annual Phosphorus Budgets for Queens Mirror Lake and the Triplet Chain-of-Lakes (continued).

### 5.3.2 Mass Losses

A summary of estimated mean annual mass losses of total nitrogen and total phosphorus from Queens Mirror Lake and the Triplet Chain-of-Lakes is given in Table 5-13. Approximately 30-50% of the phosphorus loadings to each of the lakes is discharged from the lake to the downstream waterbody, with approximately 50-70% of the phosphorus loadings retained within the sediments of each lake. Approximately 76-165% of the nitrogen loadings to the Triplet Chain-of-Lakes is discharged to downstream waterbodies, with 6% to -65% retained within the sediments. Queens Mirror Lake appears to be discharging a larger nitrogen loading than can be accounted for in the identified nitrogen inputs. This suggests that the deep sediment accumulations in Queens Mirror Lake may be releasing nitrogen which is discharging to downstream waterbodies. This is consistent with the significant nitrogen release which was observed in the large sediment core samples collected from Queens Mirror Lake when incubated under both aerobic and anoxic conditions.

**TABLE 5-13**

**ESTIMATED MEAN ANNUAL MASS LOSSES OF TOTAL NITROGEN AND TOTAL PHOSPHORUS FROM QUEENS MIRROR LAKE AND THE TRIPLET CHAIN-OF-LAKES**

| LAKE | SOURCE | TOTAL NITROGEN | | TOTAL PHOSPHORUS | |
|---|---|---|---|---|---|
| | | kg/yr | Percent of Total | kg/yr | Percent of Total |
| Queens Mirror Lake | Discharge to South Lake Triplet | 1084 | 165 | 61.7 | 49 |
| | Deep Recharge | 2.4 | < 1 | 0.13 | < 1 |
| | Retained in Sediments | -427 | -65 | 64.2 | 51 |
| | **Total:** | **659** | **100** | **126** | **100** |
| South Lake Triplet | Discharge to Middle Lake Triplet | 1208 | 94 | 61.5 | 50 |
| | Deep Recharge | 4.4 | < 1 | 0.23 | < 1 |
| | Retained in Sediments | 77.6 | 6 | 62.3 | 50 |
| | **Total:** | **1290** | **100** | **124** | **100** |
| Middle Lake Triplet | Discharge to North Lake Triplet | 1406 | 76 | 61.9 | 29 |
| | Deep Recharge | 7.5 | < 1 | 0.17 | < 1 |
| | Retained in Sediments | 441 | 24 | 151 | 71 |
| | **Total:** | **1854** | **100** | **213** | **100** |
| North Lake Triplet | Discharge Canal | 1455 | 93 | 58.6 | 53 |
| | Deep Recharge | 3.6 | < 1 | 0.15 | < 1 |
| | Retained in Sediments | 111 | 7 | 52.3 | 47 |
| | **Total:** | **1570** | **100** | **111** | **100** |

# SECTION 6

# EVALUATION OF WATER QUALITY IMPROVEMENT OPTIONS

A discussion of water quality maintenance and improvement options for Queens Mirror Lake and the Triplet Chain-of-Lakes is presented in this section. The evaluated water quality improvement options are designed to target sources which have been identified as significant contributors of nutrient loadings for each of the lakes and include both structural and non-structural approaches for controlling and reducing pollutant inputs. A discussion of general management philosophy and recommended water quality improvement projects is given in the following sections.

## 6.1 Management Philosophy

Based upon the evaluations summarized in previous sections, it is apparent that the most significant issue facing Queens Mirror Lake and the Triplet Chain-of-Lakes is cultural eutrophication caused by increasing levels of nutrient inputs resulting from development of the adjacent watershed areas. Development within the watershed areas has increased both the volume of stormwater runoff and mass loadings of nutrients over time. Many of the older developments within the watershed areas were constructed with no stormwater treatment of any kind. In addition, portions of the watershed area utilize septic tanks for on-site wastewater disposal, and potential evidence of nutrient enhancement in shallow groundwater was observed in seepage samples, particularly in samples collected from Middle Lake Triplet.

As discussed in Section 2.2.1, Queens Mirror Lake and the Triplet Chain-of-Lakes appear to be balanced or phosphorus-limited systems, based upon the calculated TN/TP ratios. Since nitrogen is difficult to control in stormwater, the most logical method of improving water quality within the lakes is to reduce phosphorus concentrations and create a highly phosphorus-limited ecosystem. Under this condition, the growth of algae would be regulated primarily by phosphorus concentrations, and reductions in phosphorus loadings would correspond directly with reductions in water column phosphorus concentrations and algal growth. As a result, the primary objective of the management options discussed in this section is to control and limit the introduction of phosphorus into Queens Mirror Lake and the Triplet Chain-of-Lakes.

Phosphorus inputs into Queens Mirror Lake and the Triplet Chain-of-Lakes occur from a wide variety of sources, including bulk precipitation, stormwater runoff, groundwater seepage, internal recycling, and exchange between interconnected waterbodies. Based upon the calculated nitrogen and phosphorus budgets summarized in Table 5-12, the most dominant phosphorus sources include internal recycling, exchange between interconnected waterbodies, and inflow from the large wetland system located south and west of Queens Mirror Lake. Mass

loadings of phosphorus from stormwater runoff contribute a relatively minor portion of the annual phosphorus loadings, contributing 3% of the annual phosphorus loadings to Queens Mirror Lake, 10% of the annual loadings to South Lake Triplet, 14% of the annual loadings to Middle Lake Triplet, and 4% of the annual loadings to North Lake Triplet.

Although stormwater is the dominant nutrient source in many urban lakes, it appears to be a relatively minor contribution to Queens Mirror Lake and the Triplet Chain-of-Lakes. As a result, extensive stormwater management projects do not appear warranted at this time for improvement of water quality within the lakes. Groundwater seepage also contributes a relatively small loading of total phosphorus, comprising 1-8% of the phosphorus loadings to Queens Mirror Lake, South Lake Triplet, and North Lake Triplet, while contributing 21% of the phosphorus loadings to Middle Lake Triplet. As a result, the largest reductions in phosphorus loadings can be achieved by addressing internal recycling and the inflow from the canal on the south end of Queens Mirror Lake.

The management philosophy also relies upon the fact that Queens Mirror Lake and the Triplet Chain-of-Lakes consist of a series of interconnected waterbodies which flow in a general south-to-north direction. As you progress further downstream within the Chain, inflow from interconnected waterbodies becomes more and more significant in terms of both hydraulic and pollutant loadings to downstream waterbodies. This suggests that structural pollution control systems should be constructed in upstream portions of the Chain so that the water quality benefits achieved by the pollution reduction facility will migrate downstream through the Chain-of-Lakes and improve water quality in downstream waterbodies as well.

## 6.2 Stormwater Treatment Options

The canal on the southern end of Queens Mirror Lake receives drainage from a 1283-acre drainage basin area which includes the series of interconnected lakes west of US 17-92. This basin is more than seven times larger than the next largest individual sub-basin discharging into Queens Mirror Lake or the Triplet Chain-of-Lakes. This inflow contributes 86% of the annual nitrogen loadings and 72% of the annual phosphorus loadings to Queens Mirror Lake. The nitrogen and phosphorus loadings contributed by this basin are substantially higher than any other single sub-basin area discharging into the lakes. In view of the significant nutrient loading generated by this inflow, and the fact that the inflow occurs in the upstream portions of the Chain-of-Lakes, a stormwater treatment system for this sub-basin has the potential to substantially enhance water quality characteristics in Queens Mirror Lake as well as in downstream waterbodies.

The second most significant mass inflow into the Chain-of-Lakes occurs from Middle Lake Triplet Sub-basin 1. This sub-basin, consisting of 81.99 acres of residential golf course and wetland areas, generates the second largest annual loadings of nitrogen and phosphorus, and contributes 74% of the runoff generated total phosphorus loadings to Middle Lake Triplet and 10% of the overall phosphorus loadings. A stormwater management project for this sub-basin may also be attractive, particularly if a management option can be developed at a low cost. Runoff generated phosphorus loadings from the remaining sub-basin areas are too low to warrant construction of treatment systems.

### 6.2.1 Queens Mirror Lake South Canal (Sub-basin QM-1)

Based upon the hydrologic modeling summarized in Section 4, Queens Mirror Lake Sub-basin 1, including the upstream series of interconnected lakes, contributes an annual volume of approximately 924 ac-ft/yr to Queens Mirror Lake. This volumetric inflow is by far the largest runoff inflow from any sub-basin into the Chain-of-Lakes. The large volume of water which must be treated makes it prohibitive to attempt to provide treatment using either traditional wet detention or dry retention systems. For example, a wet detention pond would typically be designed with a mean annual residence time of approximately 30 days. Based on the calculated annual inflow volume of 924 ac-ft/yr, the wet detention pond would require a permanent pool volume of approximately 77 ac-ft. At a mean water depth of 8 ft, the wet detention pond would have a surface area of approximately 10 acres, depending upon bank side slopes and configuration. Very little land is available in the vicinity of the inflow for construction of a traditional BMP.

As indicated on Table 5-3, inflow through Sub-basin QM-1 contains relatively elevated levels of SRP and dissolved organic phosphorus and also is highly colored. The high color of the water will reduce the observed removal efficiencies achieved in a traditional wet detention pond since light attenuation would occur more rapidly and limit algal production. Under these conditions, phosphorus removal within the pond would likely be approximately 30-40%, further reducing the potential effectiveness of a treatment system. Construction costs for the wet detention pond could easily exceed $2,000,000 when considering excavation costs, infrastructure revisions, and land costs.

Given the lack of available land for construction of conventional BMPs, the large annual volume of water which must be treated, and the chemical speciation of phosphorus forms in the inflow, it appears that alum treatment of the inflow may be the most effective method for rapidly reducing phosphorus concentrations entering Queens Mirror Lake. A feasibility evaluation was conducted to quantify anticipated mass removals and economic efficiency of using alum for treatment of runoff inflow from sub-basin QM-1. Alum has become a common methodology in the State of Florida for treating stormwater runoff since it can achieve rapid and cost-effective phosphorus removal in a very small footprint.

#### 6.2.1.1 Theory of Alum Treatment

The addition of alum to water results in the production of chemical precipitates which remove pollutants by two primary mechanisms. Removal of suspended solids, algae, phosphorus, heavy metals and bacteria occurs primarily by enmeshment and adsorption onto aluminum hydroxide precipitate according to the following net reaction:

$$Al^{+3} + 6H_2O \rightarrow Al(OH)_{3(s)} + 3H_3O^+$$

The aluminum hydroxide precipitate, $AlOH_3$, is a gelatinous floc which attracts and adsorbs colloidal particles onto the growing floc, thus clarifying the water. Removal of additional dissolved phosphorus occurs as a result of direct formation of $AlPO_4$ by:

$$Al^{+3} + HnPO_4^{n-3} \leftrightarrow AlPO_{4(s)} + nH^+$$

The alum precipitate formed during coagulation of stormwater can be allowed to settle in a small settling basin, which is generally 10-15% of the size of a standard wet detention basin designed to treat the same area, or discharge directly into the receiving waterbody or be collected in an in-lake floc trap. Alum precipitates are exceptionally stable in sediments and will not redissolve due to changes in redox potential or pH under conditions normally found in surface waterbodies. Over time, the freshly precipitated floc ages into even more stable complexes, eventually forming gibbsite. The solubility of dissolved aluminum in the treated water is regulated entirely by chemical equilibrium. As long as the pH of the treated water is maintained within the range of 5.5-7.5, dissolved aluminum concentrations will be minimal. In many instances, the concentration of dissolved aluminum in the treated water will be less than the concentration in the raw untreated water due to adjustment of pH into the range of minimum solubility. The floc will need to be removed periodically from the settling pond and can be dried and used as fill for various projects.

Alum treatment of stormwater runoff has now been used as a viable stormwater treatment alternative in urban areas for 25 years. Over that time, a large amount of information has been collected related to optimum system configuration, water chemistry, sediment accumulation and stability, benthic impacts, construction and operation costs, comparisons with other stormwater management techniques, and floc collection and disposal.

Once alum has been identified as an option in a stormwater retrofit project, extensive laboratory testing must be performed to verify the feasibility of alum treatment and to establish process design parameters. The feasibility of alum treatment for a particular stormwater stream is evaluated in a series of laboratory jar tests conducted on representative runoff samples collected from the project watershed area. This extensive laboratory testing is an essential part of the evaluation process necessary to determine design, maintenance and operational parameters such as the optimum coagulant dose required to achieve the desired water quality goals, chemical pumping rates and pump sizes, the need for additional chemicals to buffer receiving water pH, post-treatment water quality characteristics, floc formation and settling characteristics of the floc, required detention time of treated water to provide maximum settling, floc accumulation, annual chemical costs and storage requirements, and maintenance procedures. In addition to determining the optimum coagulant dose, jar tests can also be used to determine floc strength and stability, required mixing intensity and duration, and determine design criteria for settling basins or floc collection systems.

In a typical alum stormwater treatment system, alum is injected into the stormwater flow on a flow-proportioned basis so that the same dose of alum is added to the stormwater flow regardless of the discharge rate. A variable speed chemical metering pump is typically used as the injection pump. If a buffering agent is required to maintain desired pH levels, a separate metering system and storage tank will be necessary. The operation of each injection pump is regulated by a flow meter device attached to the incoming stormwater line to be treated. Measured flow from each stormwater flow meter is transformed into a 4-20 mA electronic signal which instructs each metering pump to inject alum according to the measured flow of runoff discharging through each individual stormsewer line. Mixing of the alum and stormwater occurs as a result of turbulence in the stormsewer line. If sufficient turbulence is not available within the stormsewer line, artificial turbulence can be generated using aeration or physical stormsewer modifications.

Mechanical components for the alum stormwater treatment system, including chemical metering pumps, stormsewer flow meters and electronic controls, are typically housed in a central facility which can be constructed as an above-ground or below-ground structure. A 5000-gallon alum storage tank is typically used for bulk alum storage. Alum feed lines and electrical conduits are run from the central facility to the point of alum addition and flow measurement. Alum injection points can be located as far as 1000 ft or more from the central pumping facility.

Over the past several decades, ERD has performed literally hundreds of laboratory jar tests to evaluate the performance efficiency of alum for treatment of stormwater and baseflow inputs. Alum has consistently provided a removal efficiency for total phosphorus of approximately 80-95% in these samples. For purposes of this analysis, a removal efficiency of approximately 80% is assumed for evaluation purposes.

#### 6.2.1.2 Conceptual System Configuration

A conceptual design was developed for an alum stormwater treatment system to provide treatment for discharges into Queens Mirror Lake from sub-basin QM-1. An overview of the conceptual design for the alum treatment system is given on Figure 6-1. The electronic controls, alum pump, and chemical storage tank would be housed inside a 700 $ft^2$ building located on an existing vacant area at the northeast corner of Winter Park Drive and the inflow canal. The building would consist of two separate rooms, one used to house the chemical storage tank and the other containing the pump and electronic controls. An underground fill structure would be located next to the existing sidewalk which would contain a connection to the chemical storage tank so that the alum tanker truck could temporarily stop along the shoulder of Winter Park Drive, connect to the fill structure, and fill the fiberglass storage tank. Alum addition would be controlled by a flow meter which would be located on the south side of Winter Park Drive at the existing weir structure. The existing concrete weir would provide an excellent location for monitoring discharge using depth measurements. The depth of water over the weir would be converted into a discharge rate, and alum would be added at a flow-proportioned rate. Alum addition would occur on the downstream side of the weir, and air would be injected to provide turbulence to assist in mixing the alum with the incoming runoff flow.

The precipitate generated by adding the alum to the runoff would form during migration through the underground stormsewer and open ditch portion of the canal. A floc screen would be constructed within Queens Mirror Lake at the end of the outfall canal which would allow water to pass through while retaining a majority of the floc material. The collected floc would settle onto the bottom of a concrete hardened sump area with a centralized drain. A connection from the drain would extend to a gravel roadway which would be constructed adjacent to the canal to provide access to the floc collection area. The collected floc would be pumped periodically from the sump area using a vactor truck, and the collected floc could be disposed of in a sanitary sewer system. The proposed system is extremely simple in concept and will require construction only for the pump/tank building and the floc collection area. Alum feed lines and flow meter conduits could be extended beneath Winter Park Drive through the existing culverts.

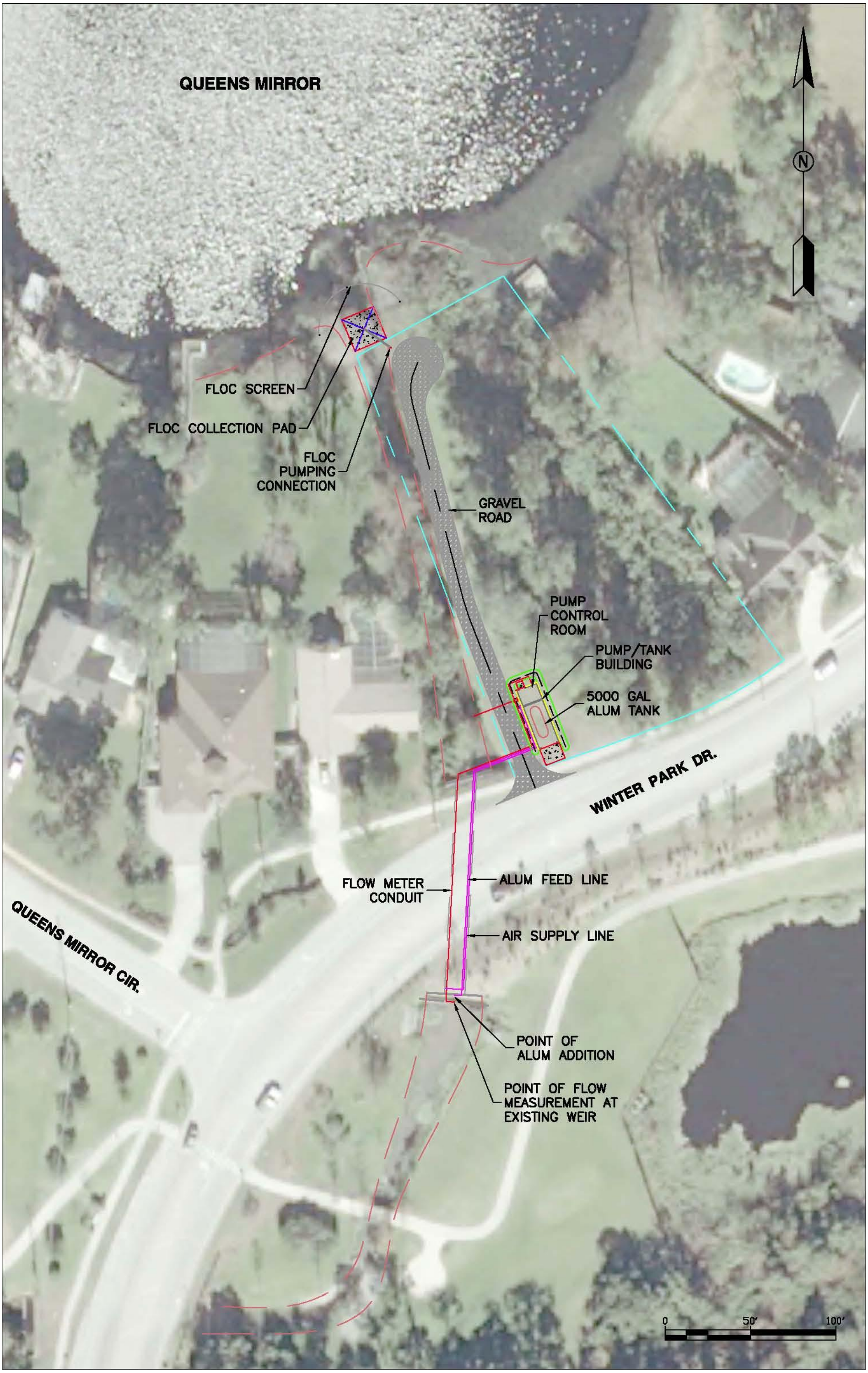



Figure 6-1. Conceptual Design for an Alum Treatment System for Sub-basin QM-1

A conceptual cost estimate for the alum treatment system for sub-basin QM-1 is given in Table 6-1. The conceptual cost estimate includes all structural components necessary to construct an alum treatment system at the proposed location. Fees are also included for mobilization along with a 10% contingency. The total estimated project cost is approximately $450,000, which does not include design, permitting, and land acquisition costs, if any.

A summary of estimated annual O&M costs for the alum treatment facility for sub-basin QM-1 is given on Table 6-2. Estimates of annual O&M costs are provided for chemicals, routine labor, maintenance/repair, floc removal/disposal, and utilities. Annual chemical costs are based upon the assumed inflow volume of 924 ac-ft/yr and an alum dose of 7.5 mg Al/liter. This dose is only an estimate and must be verified through laboratory jar testing during final design for the treatment facility. Based upon the assumed alum dose and annual inflow, the system will use approximately 38,544 gallons of alum per year. At a unit alum cost of $0.55/gallon, the annual chemical cost is expected to be approximately $21,200.

Alum treatment facilities require both weekly and monthly testing and calibration procedures. This analysis assumes a weekly manpower requirement of approximately 8 hours/week or 416 hours/year. At a labor rate of $30/hour, the annual labor costs for maintaining the system would be approximately $12,480/year. Floc removal and disposal will be required on a periodic basis. For purposes of this analysis, an annual fee of approximately $20,000 is assumed for floc removal and disposal. An additional $10,000 is included for maintenance and repair of system components. Utilities, including electricity and water, are estimated to be approximately $6,000/year. The overall total annual O&M costs for the system would be approximately $69,680.

A summary of anticipated annual floc production for alum treatment of Queens Mirror Lake sub-basin QM-1 is given in Table 6-3. In general, floc production at a treatment dose of 7.5 mg Al/liter is equivalent to approximately 0.16% of the total runoff volume treated. Therefore, the anticipated annual floc production resulting from alum treatment of Queens Mirror sub-basin QM-1 is approximately 1.48 ac-ft/yr or 64,400 $ft^3$/yr. This value is equivalent to approximately 40,142 gallons/month.

A summary of anticipated load reductions and mass removal costs for the alum treatment system for sub-basin QM-1 is given in Table 6-4. Based upon the calculations summarized in Table 5-4, sub-basin QM-1 discharges approximately 90 kg/yr of total phosphorus to Queens Mirror Lake. Phosphorus removal by the alum treatment system is conservatively estimated to be approximately 80%, resulting in an annual load removal of approximately 72 kg of total phosphorus per year. The 20-year present worth costs for the alum treatment system was calculated using the construction costs (summarized in Table 6-1) and 20 years of estimated O&M costs (summarized in Table 6-2) using an interest rate of 4% per year. The resulting estimated 20-year present worth cost is approximately $1,396,440. The calculated 20-year mass removal cost for the system is approximately $970/kg of total phosphorus removed. This is a somewhat elevated mass removal cost which is due to the relatively low inflow concentrations for total phosphorus.

# TABLE 6-1

## QUEENS MIRROR LAKE SUB-BASIN QM-1
## ALUM TREATMENT FACILITY CONCEPTUAL OPINION
## OF PROBABLE CONSTRUCTION COST

| ITEM | DESCRIPTION | QUANTITY | UNIT | UNIT COST ($) | TOTAL COST ($) |
|---|---|---|---|---|---|
| 1 | Mobilization | 1 | LS | --- | $ 50,000.00 |
| 2 | Alum Treatment and Instrumentation System Components<br>*Stormwater Flowmeter Systems<br>*Alum Pumps<br>*Alum Flowmeters<br>*Control Panels<br>*Flowmeter Data Complier Sites<br>*Sensor Cables & Wiring | 1 | LS | 120,000.00 | 120,000.00 |
| 3 | Alum Building | 1 | LS | --- | 125,000.00 |
| 4 | 5,000 Gallon Double-Walled Alum Tank | 1 | EA | 23,000.00 | 23,000.00 |
| 5 | Concrete Sidewalk & Building Driveway | 350 | SY | 40.00 | 14,000.00 |
| 6 | Crushed Concrete Entrance/Exit and Circle Driveway | 430 | SY | 25.00 | 10,750.00 |
| 7 | Alum System Piping, Valves, and Appurtenances | | LS | --- | 10,000.00 |
| 8 | Alum Building Mechanical & Electrical | 1 | LS | --- | 7,000.00 |
| 9 | 1" I.D. HDPE Double Wall Containment Pipe | 201 | LF | 25.00 | 5,025.00 |
| 10 | Air Compressor / Solenoid(s) / Connections | 1 | EA | 5,000.00 | 5,000.00 |
| 11 | Clearing and Grubbing | 1 | AC | 5,000.00 | 5,000.00 |
| 12 | pH Meter / Pump System | 1 | LS | --- | 5,000.00 |
| 13 | Silt Fence | 1,000 | LF | 5.00 | 5,000.00 |
| 14 | Sodding (includes watering) | 1,000 | SY | 5.00 | 5,000.00 |
| 15 | Alum Tank Fill Structure with Aluminum Hinged Lid | 1 | EA | 4,500.00 | 4,500.00 |
| 16 | Aerial / Audio-Visual Documentation | 1 | LS | --- | 3,000.00 |
| 17 | Safety Shower & Eyewash | 2 | EA | 1,400.00 | 2,800.00 |
| 18 | Concrete Floc Pad | 4 | SY | 400.00 | 1,600.00 |
| 19 | Water Service | 1 | LS | 1,500.00 | 1,500.00 |
| 20 | 2" HDPE Air Line | 180 | LF | 7.00 | 1,260.00 |
| 21 | 1" PVC Conduit - Instrumentation | 240 | LF | 5.00 | 1,200.00 |
| 22 | Floating Turbidity Barriers | 70 | LF | 12.00 | 840.00 |
| 23 | Alum Line Markers | 7 | EA | 100.00 | 700.00 |
| 24 | 4" PVC Building Drain Pipe with Fittings | 50 | LF | 10.00 | 500.00 |
| 25 | S.S. Cam Lock and Other Fittings in Fill Structure | 1 | LS | --- | 400.00 |
| 26 | 4" PVC Building Drain Pipe Mitered End Section at Pond | 1 | LS | --- | 350.00 |
| 27 | 2" PVC - pH Sample Water Pipe | 25 | LF | 8.00 | 200.00 |
| | | | | Sub-Total: | $ 408,625.00 |
| | | | | 10% Contingency: | $ 40,862.50 |
| | | | | **PROJECT TOTAL:** | **$ 449,487.50[1]** |

1. Does not include fees for design, permitting, and land acquisition costs, if necessary.

## TABLE 6-2

## ESTIMATED ANNUAL O&M COSTS FOR THE ALUM TREATMENT FACILITY FOR SUB-BASIN QM-1

| PARAMETER | | UNITS | VALUE |
|---|---|---|---|
| Chemical Costs | Annual Flow | ac-ft/yr | 924 |
| | Assumed Alum Dose | mg Al/liter | 7.5 |
| | Annual Alum Use | gallons | 34,544 |
| | Unit Alum Cost | $/gallon | 0.55 |
| | Annual Alum Cost | $ | 21,200 |
| Labor Costs | Weekly Inspections | hours/week<br>hours/year | 8<br>416 |
| | Labor Costs | $/hr<br>$/year | 30<br>12,480 |
| Maintenance/Repair | | $/year | 10,000 |
| Floc Removal/Disposal | | $/year | 20,000 |
| Utilities | | $/year | 6,000 |
| Total O&M Costs | | $/year | 69,680 |

## TABLE 6-3

## ANTICIPATED ANNUAL FLOC PRODUCTION FOR ALUM TREATMENT OF QUEENS MIRROR SUB-BASIN QM-1

| PARAMETER | UNITS | VALUE |
|---|---|---|
| Treated Runoff Volume | ac-ft/yr | 924 |
| Anticipated Floc Generation | % of runoff volume treated | 0.16 |
| Floc Volume | ac-ft/yr<br>$ft^3$/yr<br>gallons/month | 1.48<br>64,400<br>40,142 |

**TABLE 6-4**

**ANTICIPATED LOAD REDUCTIONS AND MASS REMOVAL COSTS FOR THE ALUM TREATMENT SYSTEM FOR SUB-BASIN QM-1**

| PARAMETER | UNITS | VALUE |
|---|---|---|
| Existing Total Phosphorus Load | kg/yr | 90 |
| Annual Total Phosphorus Removal | % | 80 |
| Annual Total Phosphorus Load Removal | kg/yr | 72 |
| Present Worth Cost (20-year, i = 4%) | $ | 1,396,440 |
| Mass Removal Costs | $/kg<br>$/lb | 970<br>440 |

### 6.2.2 Middle Lake Triplet Sub-basin MLT-1

As discussed previously, sub-basin MLT-1 consists of 81.99 acres of residential, golf course, and wetland land uses which generates the second largest annual loadings of nitrogen and phosphorus to Queens Mirror Lake and the Triplet Chain-of-Lakes. In addition, sub-basin MLT-1 may also receive runoff contributions from the Grassy Lake outfall under high water level conditions. However, since it appears that runoff inputs contribute relatively minor nutrient loadings to the lakes, a stormwater management project for this sub-basin is only attractive if it can be developed at an extremely low cost.

An extensive review of sub-basin MLT-1 was conducted by ERD to identify existing land uses and drainage pathways. This sub-basin contains a number of interconnected ponds and wetlands which ultimately discharge through an open channel into Middle Lake Triplet. An inexpensive method of improving nutrient retention within this basin would be to increase water storage and detention time to reduce the volume and concentration of runoff inflows to Middle Lake Triplet.

Based upon the field review conducted by ERD, there appears to be multiple opportunities for construction of small berms to provide additional detention time for discharges from this sub-basin. Several potential locations for berms are indicated on Figure 6-2. Shallow berms could be constructed at multiple locations along the final inflow channel, creating small pools which may provide additional treatment. Portions of the inflow canal are cut deep into the existing topography, and appear to be intercepting and discharging groundwater throughout much of the year. The additional head created by the berms would reduce the groundwater inflow and nutrient loadings to the lake.

Figure 6-2. Proposed Locations for Shallow Berms Along the Discharge Channel for Sub-basin MLT-1.

The proposed berm locations indicated on Figure 6-2 are only conceptual at this time, and specific configurations and berm height would need to be evaluated based upon a detailed hydrodynamic model of the basin area. However, it appears that there are numerous opportunities for retaining additional water within the sub-basin and reducing discharges into Middle Lake Triplet. One of the best opportunities for a shallow berm appears to be the western-most berm location indicated on Figure 6-2 which would be placed at the discharge from a hardwood and grassed wetland system. Based upon the field reconnaissance, it appears that there is substantial additional opportunity for water storage within this system. Other berms could also be constructed at downstream locations within the channel to store water and reduce groundwater inflow. Since this basin contributes a relatively small proportion of the total annual phosphorus loadings to the lake, the proposed low cost berm alternative appears appropriate for the magnitude of proposed benefits.

## 6.3 Internal Recycling

### 6.3.1 General Considerations

Sediment phosphorus inactivation is a lake restoration technique which is designed to substantially reduce internal recycling of phosphorus by combining available phosphorus in the sediments with a metal salt to form an insoluble inert precipitate, rendering the sediment phosphorus unavailable for release into the overlying water column. Although salts of aluminum calcium and iron have been used for sediment inactivation in previous projects, aluminum salts are the clear compounds of choice for this application. Inactivation of sediment phosphorus using aluminum is often a substantially less expensive option for reducing sediment phosphorus release since removal of the existing sediments is not required.

Sediment phosphorus inactivation is most often performed using aluminum sulfate, commonly called alum, which is applied at the surface in a liquid form using a boat or barge. Upon entering the water column, the alum forms an insoluble precipitate of aluminum hydroxide which attracts phosphorus, bacteria, algae, and suspended solids within the water column, settling these constituents into the bottom sediments. Upon reaching the bottom sediments, the residual aluminum binds tightly with phosphorus within the sediments, forming an inert precipitate which will not be re-released under any conceivable condition of pH or redox potential which could occur in a natural lake system. These sediment treatments have been shown to be effective from 2-20 years, depending upon the sediment accumulation rate within the lake from the remaining phosphorus sources.

Based on the nutrient budgets for Queens Mirror Lake and the Triplet Chain-of-Lakes (summarized in Table 5-12), internal recycling contributes approximately 21-32% of the phosphorus loadings to each of the lakes. An additional 1-8% is contributed by groundwater seepage. It is possible to control both internal recycling and groundwater seepage through a carefully planned alum application. Therefore, the objective of an alum sediment treatment for Queens Mirror Lake and the Triplet Chain-of-Lakes is to provide simultaneous control for both internal recycling and groundwater seepage. Together, these sources contribute approximately 22-49% of the total phosphorus loadings to the lakes. Control of these inputs has the potential to result in measurable improvements in water quality within Queens Mirror Lake and the Triplet Chain-of-Lakes.

### 6.3.2 Chemical Requirements and Costs

Sediment inactivation in Queens Mirror Lake and the Triplet Chain-of-Lakes would involve addition of liquid aluminum sulfate at the water surface. Upon entering the water, the alum would form insoluble precipitates which would settle onto the bottom while also clarifying the existing water column within the lakes. Upon entering the sediments, the alum will combine with existing phosphorus within the sediments, primarily saloid- and iron-bound associations, forming insoluble inert precipitates which will bind the phosphorus, making it unavailable for release into the overlying water column. It is generally recognized that the top 10 cm layer of the sediments is the most active in terms of release of phosphorus under anoxic conditions. Therefore, the objective of a sediment inactivation project is to provide sufficient alum to bind the saloid- and iron-bound phosphorus associations in the top 10 cm of the sediments.

Estimates of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Queens Mirror Lake and South Lake Triplet were generated by graphically integrating the total available phosphorus isopleths presented on Figure 2-37. The top 0-10 cm layer of the sediments is considered to be an active layer with respect to exchange of phosphorus between the sediments and the overlying water column. Inactivation of phosphorus within the 0-10 cm layer is typically sufficient to inactivate sediment release of phosphorus within a lake. Prior research involving sediment inactivation has indicated that an excess of aluminum is required within the sediments to cause phosphorus to preferentially bind with aluminum rather than other available competing agents. Previous sediment inactivation projects performed by ERD have been based on molar Al:P ratios of 2, 3, 5, and 10, with most recent sediment inactivation projects performed using a 10:1 ratio. An Al:P ratio of 10:1 is assumed for sediment inactivation in Queens Mirror Lake and South Lake Triplet. Estimates of available phosphorus cannot be determined for Middle Lake Triplet and North Lake Triplet since sediment monitoring was not conducted in these waterbodies.

A summary of estimated available phosphorus in the sediments of Queens Mirror Lake and South Lake Triplet is given in Table 6-5. On a mass basis, the sediments of Queens Mirror Lake contain approximately 240 kg of available phosphorus in the top 10 cm. On a molar basis, this equates to approximately 7,729 moles of available phosphorus to be inactivated as part of the sediment inactivation process. A summary of alum requirements for sediment inactivation is also provided in Table 6-5. Using an Al:P ratio of 10:1, sediment inactivation in Queens Mirror Lake would require approximately 9,412 gallons of alum, equivalent to approximately 2.1 tanker loads. The equivalent aerial aluminum dose for this application would be 41.2 g Al/m$^2$.

**TABLE 6-5**

**QUEENS MIRROR LAKE SEDIMENT INACTIVATION REQUIREMENTS**

| AVAILABLE P CONTOUR INTERVAL (µg/cm$^3$) | CONTOUR INTERVAL MID-POINT (µg/cm$^3$) | CONTOUR AREA (acres) | AVAILABLE PHOSPHORUS | | ALUM REQUIREMENTS (Al:P Ratio = 10:1) | |
|---|---|---|---|---|---|---|
| | | | kg | moles | moles Al | gal alum |
| 20-30 | 25 | 0.52 | 5 | 169 | 844 | 103 |
| 30-40 | 35 | 2.49 | 35 | 1,138 | 5,692 | 693 |
| 40-50 | 45 | 4.96 | 90 | 2,915 | 14,577 | 1,775 |
| 50-60 | 55 | 2.79 | 62 | 2,001 | 10,005 | 1,218 |
| 60-70 | 65 | 1.77 | 47 | 1,505 | 7,527 | 917 |
| **Overall Totals:** | | **12.5** | **240** | **7,729** | **77,291** | **9,412** |
| | | | | | Estimated Chemical Cost ($): | 9,412 |
| | | | | | Areal Aluminum Dose (g Al/m$^2$): | 41.2 |
| | | | | | Number of Tankers: | 2.1 |

A summary of estimated available phosphorus in the sediments of South Lake Triplet is given in Table 6-6. On a mass basis, the sediments in South Lake Triplet contain approximately 376 kg of available phosphorus in the top 10 cm. On a molar basis, this equates to approximately 12,119 moles of available phosphorus to be inactivated as part of a sediment inactivation process. A summary of alum requirements for sediment inactivation is also provided in Table 6-6. Using an Al:P ratio of 10:1, sediment inactivation in South Lake Triplet would require approximately 14,757 gallons of alum, equivalent to approximately 3.3 tanker loads. The equivalent areal aluminum dose for this application would be 34.7 g Al/m$^2$.

**TABLE 6-6**

**SOUTH LAKE TRIPLET SEDIMENT INACTIVATION REQUIREMENTS**

| AVAILABLE P CONTOUR INTERVAL (µg/cm$^3$) | CONTOUR INTERVAL MID-POINT (µg/cm$^3$) | CONTOUR AREA (acres) | AVAILABLE PHOSPHORUS | | ALUM REQUIREMENTS (Al:P Ratio = 10:1) | |
|---|---|---|---|---|---|---|
| | | | kg | moles | moles Al | gal alum |
| <10 | 5 | 0.60 | 1 | 39 | 195 | 24 |
| 10-20 | 15 | 1.35 | 8 | 265 | 1,325 | 161 |
| 20-30 | 25 | 5.33 | 54 | 1,739 | 8,695 | 1,059 |
| 30-40 | 35 | 5.66 | 80 | 2,590 | 12,948 | 1,577 |
| 40-50 | 45 | 5.55 | 101 | 3,262 | 16,310 | 1,986 |
| 50-60 | 55 | 2.13 | 47 | 1,530 | 7,648 | 931 |
| 60-70 | 65 | 0.90 | 24 | 766 | 3,832 | 467 |
| 70-80 | 75 | 0.76 | 23 | 747 | 3,737 | 455 |
| 80-90 | 85 | 0.58 | 20 | 648 | 3,242 | 395 |
| 90-100 | 95 | 0.35 | 13 | 431 | 2,156 | 263 |
| >100 | 105 | 0.07 | 3 | 102 | 508 | 62 |
| **Overall Totals:** | | **23.3** | **376** | **12,119** | **121,193** | **14,757** |
| Estimated Chemical Cost ($): | | | | | | 14,757 |
| Areal Aluminum Dose (g Al/m$^2$): | | | | | | 34.7 |
| Number of Tankers: | | | | | | 3.3 |

Previous alum surface applications performed for inactivation of sediment phosphorus release by ERD have indicated that the greatest degree of improvement in surface water characteristics and the highest degree of inactivation of sediment phosphorus release are achieved if the required alum volume is added through multiple applications of aluminum to the waterbody spaced approximately 3-6 months apart. Each subsequent application results in additional improvements in water column quality and additional aluminum floc added to the sediments for long-term inactivation of sediment phosphorus release. The use of multiple applications provides many positive benefits since it reduces the amount of alum added at a given time and enhances the effectiveness of the sediment inactivation.

Additional aluminum can also be added to the sediments to create an active absorption mechanism for additional phosphorus inputs into the water column as a result of groundwater seepage. Inputs of phosphorus from groundwater seepage into a lake can easily exceed inputs from internal recycling in only a few annual cycles. Carefully planned applications of alum can provide an abundance of aluminum which can intercept groundwater inputs of phosphorus over a period of many years. As a result, alum applications can be used to eliminate phosphorus from the combined inputs resulting from internal recycling as well as groundwater seepage.

A summary of calculations of alum requirements for control of phosphorus loading from groundwater seepage entering Queens Mirror Lake and South Lake Triplet is given in Table 6-7. Based on the field monitoring program from September 2010-May 2011, mean annual phosphorus inflow from groundwater seepage is estimated to be approximately 1.0 kg/yr in Queens Mirror Lake and 3.0 kg/yr in South Lake Triplet. This analysis assumes that control of groundwater seepage is desired for a period of 10 years. Therefore, the total mass of phosphorus from groundwater seepage which must be inactivated is approximately 10 kg in Queens Mirror Lake and 30 kg in South Lake Triplet over the 10-year period. This mass of phosphorus equates to approximately 323 moles of total phosphorus in Queens Mirror Lake and 968 moles in South Lake Triplet. Assuming an Al:P ratio of 10:1 for adequate inactivation, control of total phosphorus from seepage will require approximately 3,230 moles of aluminum in Queens Mirror Lake and 9,680 moles in South Lake Triplet, equivalent to an alum volume of 393 gallons in Queens Mirror Lake and 1,180 gallons in South Lake Triplet.

**TABLE 6-7**

**ALUM REQUIREMENTS FOR CONTROL OF PHOSPHORUS LOADING FROM GROUNDWATER SEEPAGE**

| PARAMETER | UNITS | VALUE | |
|---|---|---|---|
| | | Queens Mirror Lake | South Lake Triplet |
| Total Phosphorus Annual Mass Inflow | kg | 1.0 | 3.0 |
| Desired Length of Control | years | 10 | 10 |
| Total Phosphorus Mass to be Controlled | kg | 10 | 30 |
| Moles of Total Phosphorus to be Controlled | moles | 323 | 968 |
| Moles of Aluminum for Control[1] | moles | 3,230 | 9,680 |
| Equivalent Quantity of Alum | gallons | 393 | 1,180 |

1. Based on an Al:P ratio of 10:1

The proposed alum treatment to Queens Mirror Lake would add sufficient alum to control both internal recycling and intercept phosphorus loadings from groundwater seepage. Assuming that approximately 9,412 gallons of alum are needed for sediment inactivation and 393 gallons of alum are needed for interception of groundwater seepage, the total amount of alum to be added to Queens Mirror Lake would be 9,805 gallons. Assuming a lake volume of 67.2 ac-ft, this alum amount equates to a whole-lake water column dose of approximately 26 mg Al/liter. This dose will substantially exceed the available buffering capacity in the lake to withstand potential reductions in water column pH. As a result, the proposed treatment would need to be divided into a series of multiple small applications or a buffering compound would be needed to neutralize the pH impacts from the alum addition.

The most attractive option for Queens Mirror Lake is to use a buffering compound in addition to the alum to neutralize the anticipated undesirable pH impacts, reducing the number of required repeat applications. Due to the high water column dose of alum required for Queens Mirror Lake, a minimum of four applications is recommended to ensure a uniform coating over the lake bottom and to spread out potential impacts to the lake. Sodium aluminate, an alkaline form of alum, is commonly used in these applications as the buffering agent. Sodium aluminate provides a high level of buffering, as well as supplemental aluminum ions. If alum and sodium aluminate are used in combination, changes in pH within the lake during the application process can be easily controlled.

The specific ratio of alum and sodium aluminate required to control water column pH varies based on the characteristics of each lake and is often determined in a series of laboratory jar test experiments. However, the simultaneous addition of 1 gallon of sodium aluminate for every 4.0 gallons of alum is often sufficient to create neutral pH conditions during the application process.

A summary of estimated application costs for sediment inactivation and control of groundwater seepage in Queens Mirror Lake is given in Table 6-8. This estimate assumes a total alum volume of 9,805 gallons (9,412 gallons for sediment inactivation + 393 gallons for seepage control) will be applied, with 2,451 gallons applied during each of the four separate applications. It is assumed that the alum is purchased directly by the City at contract price. Assuming a 4:1 alum:sodium aluminate ratio, the treatment will also require 2,353 gallons of sodium aluminate, with 588 gallons applied during each of the four applications. Planning, mobilization, and set-up costs are estimated to be approximately $3,000 per application, which includes initial planning, mobilization of equipment to the site, demobilization at the completion of the application process, and clean-up. Estimates of application costs are provided based upon experience with similar previous applications by ERD. An application fee of $3,500 is assumed which includes labor costs, water quality monitoring, expenses, equipment rental, insurance, mileage, and application equipment fees. The estimated cost for sediment inactivation and control of groundwater seepage in Queens Mirror Lake is $45,152 or approximately $11,288 per application.

## TABLE 6-8

## ESTIMATED APPLICATION COSTS FOR SEDIMENT INACTIVATION AND CONTROL OF GROUNDWATER SEEPAGE IN QUEENS MIRROR LAKE (Based on 4 separate applications)

| PARAMETER | | AMOUNT REQUIRED PER APPLICATION | UNIT COST PER APPLICATION | COST PER APPLICATION ($) | TOTAL TREATMENT COST ($) |
|---|---|---|---|---|---|
| Chemicals | Alum | 2,451 gallons | $0.55/gallon[1] | 1,348 | 5,392 |
| | Sodium Aluminate | 588 gallons | $5.00/gallon | 2,940 | 11,760 |
| Labor | Planning and Mobilization | 1 per application | $3,000/application | 3,000 | 12,000 |
| | Chemical Application | 1 per application | $3,500/application[2] | 3,500 | 14,000 |
| Lab Testing | | Pre-/Post-samples | $500/application | 500 | 2,000 |
| | | | **TOTAL:** | **$ 11,288** | **$ 45,152** |

1. Assumed contract cost
2. Includes raw labor, water quality monitoring, insurance, expenses, application equipment, mileage, and rentals

The proposed alum treatment to South Lake Triplet would also add sufficient alum to control both internal recycling and intercept phosphorus loadings from groundwater seepage. Assuming that approximately 14,757 gallons of alum are needed for sediment inactivation and 1,180 gallons of alum are needed for interception of groundwater seepage, the total amount of alum to be added to South Lake Triplet would be 15,937 gallons. Assuming a lake volume of 94.8 ac-ft, this alum amount equates to a whole-lake water column dose of approximately 30 mg Al/liter. This dose will substantially exceed the available buffering capacity in the lake to withstand potential reductions in water column pH. As a result, the proposed application would need to be divided into a series of multiple small applications or a buffering compound would be needed to neutralize the pH impacts from the alum addition.

The most attractive option for South Lake Triplet is to use a buffering compound in addition to the alum to neutralize the anticipated undesirable pH impacts, reducing the number of required repeat applications. Due to the high water column dose of alum required for South Lake Triplet, a minimum of four applications is recommended to ensure a uniform coating over the lake bottom and to spread out potential impacts to the lake. Sodium aluminate, an alkaline form of alum, is commonly used in these applications as the buffering agent. Sodium aluminate provides a high level of buffering, as well as supplemental aluminum ions. If alum and sodium aluminate are used in combination, changes in pH within the lake during the application process can be easily controlled.

The specific ratio of alum and sodium aluminate required to control water column pH varies based on the characteristics of each lake and is often determined in a series of laboratory jar test experiments. However, the simultaneous addition of 1 gallon of sodium aluminate for every 4.0 gallons of alum is often sufficient to create neutral pH conditions during the application process.

A summary of estimated application costs for sediment inactivation and control of groundwater seepage in South Lake Triplet is given in Table 6-9. This estimate assumes a total alum volume of 15,937 gallons (14,757 gallons for sediment inactivation + 1,180 gallons for seepage control) will be applied during the treatment process, with 3,984 gallons applied during each of four separate applications. It is assumed that the alum is purchased directly by the City at contract price. Assuming a 4:1 alum:sodium aluminate ratio, the treatment will require approximately 3,984 gallons of sodium aluminate, with 996 gallons applied during each of the four applications. Planning, mobilization, and set-up costs are estimated to be approximately $3,000 per application, which includes initial planning, mobilization of equipment to the site, demobilization at the completion of the application process, and clean-up. Estimates of application costs are provided based upon experience with similar previous applications by ERD. An application fee of $3,500 is assumed which includes labor costs, water quality monitoring, expenses, equipment rental, insurance, mileage, and application equipment fees. The estimated cost for sediment inactivation and control of groundwater seepage in South Lake Triplet is $58,685 or approximately $14,671 per application.

**TABLE 6-9**

**ESTIMATED APPLICATION COSTS FOR SEDIMENT INACTIVATION AND CONTROL OF GROUNDWATER SEEPAGE IN SOUTH LAKE TRIPLET (Based on 4 separate applications)**

| PARAMETER | | AMOUNT REQUIRED PER APPLICATION | UNIT COST PER APPLICATION | COST PER APPLICATION ($) | TOTAL TREATMENT COST ($) |
|---|---|---|---|---|---|
| Chemicals | Alum | 3,984 gallons | $0.55/gallon[1] | 2,191 | 8,765 |
| | Sodium Aluminate | 996 gallons | $5.00/gallon | 4,980 | 19,920 |
| Labor | Planning and Mobilization | 1 per application | $3,000/application | 3,000 | 12,000 |
| | Chemical Application | 1 per application | $4,000/application[2] | 4,000 | 16,000 |
| Lab Testing | | Pre-Post-samples | $500/application | 500 | 2,000 |
| | | | **TOTAL:** | **$ 14,671** | **$ 58,685** |

1. Assumed contract cost
2. Includes raw labor, water quality monitoring, insurance, expenses, application equipment, mileage, and rentals

Estimates of phosphorus mass removal costs were also calculated for the proposed alum sediment treatments in Queens Mirror Lake and South Lake Triplet. A summary of these analyses is given in Table 6-10. Over the anticipated 10-year period of effectiveness, internal recycling and groundwater seepage will contribute approximately 277 kg of total phosphorus to Queens Mirror Lake and 428 kg to South Lake Triplet. Based on previous research performed by ERD, phosphorus inactivation is approximately 80% effective in retaining available phosphorus within sediments. Therefore, it is assumed that approximately 80% of the total phosphorus loading over the 10-year period will be attenuated by the proposed alum treatment. As a result, alum sediment inactivation will remove a total of 222 kg of total phosphorus from

Queens Mirror Lake and 342 kg of total phosphorus from South Lake Triplet over the 10-year evaluation period. The corresponding phosphorus removal costs are approximately $203/kg ($92/lb) in Queens Mirror Lake and $172/kg ($78/lb) in South Lake Triplet. These phosphorus removal costs are exceptionally attractive costs and substantially lower than phosphorus removal costs associated with traditional BMPs.

**TABLE 6-10**

**CALCULATED PHOSPHORUS REMOVAL COSTS FOR ALUM SEDIMENT INACTIVATION IN QUEENS MIRROR LAKE AND SOUTH LAKE TRIPLET**

| LAKE | TOTAL PHOSPHORUS LOAD (kg/yr) | | | TOTAL PHOSPHORUS LOAD REMOVED[2] (kg) | TREATMENT COST ($) | COST/kg TOTAL PHOSPHORUS REMOVED ($/kg) |
|---|---|---|---|---|---|---|
| | Internal Recycling[1] | Seepage[1] | Total | | | |
| Queens Mirror Lake | 267 | 10 | 277 | 222 | 45,152 | 203 |
| South Lake Triplet | 398 | 30 | 428 | 342 | 58,685 | 172 |

1. Assumes a 10-year period of analysis
2. Assumes that 80% of the internal recycling and seepage load is removed

### 6.3.3 Longevity of Treatment

After initial application, the alum precipitate will form a visible floc layer on the surface of the sediments within the lake. This floc layer will continue to consolidate for approximately 30-90 days, reaching maximum consolidation during that time. Due to the unconsolidated nature of the sediments in much of the lake, it is anticipated that a large portion of the floc will migrate into the existing sediments rather than accumulate on the surface as a distinct layer. This process is beneficial since it allows the floc to sorb soluble phosphorus during migration through the surficial sediments. Any floc remaining on the surface will provide a chemical barrier for adsorption of phosphorus which may be released from the sediments.

Based on previous experiences by ERD, as well as research by others, it appears that a properly applied chemical treatment will be successful in inactivation of the available phosphorus in the sediments of Queens Mirror Lake and South Lake Triplet as well as phosphorus inputs from groundwater seepage. However, several factors can serve to reduce the effectiveness and longevity of this treatment process. First, wind action can cause the floc to become prematurely mixed into deeper sediments, reducing the opportunity for maximum phosphorus adsorption. Significant wind re-suspension has been implicated in several alum applications in shallow lakes which exhibited reduced longevity. However, in the absence of wind re-suspension, alum inactivation in lake sediments has resulted in long-term benefits ranging from 3 to more than 20 years. Due to the relatively small size of Queens Mirror Lake and South Lake Triplet, it is not anticipated that wind-induced re-suspension will be a significant problem.

Another factor which can affect the perceived longevity and success of the application process is recycling of nutrients by macrophytes from the sediments into the water column. This recycling will bypass the inactivated sediments since phosphorus will cross the sediment-water interface using vegetation rather than through the floc layer. Although this process will not affect the inactivation of phosphorus within the sediments, it may result in increases in dissolved phosphorus concentrations which are unrelated to sediment-water column processes. However, the degree of macrophyte growth in Queens Mirror Lake and South Lake Triplet appears to be limited, confined primarily to shoreline areas, and recycling of phosphorus by macrophytes does not appear to be a significant concern.

## 6.4 Vegetated Shorelines

### 6.4.1 Existing Conditions and Issues

Shoreline areas surrounding Queens Mirror Lake and the Triplet Chain-of-Lakes exhibit a wide variety of both species and density of aquatic vegetation which range from natural vegetated shorelines, to planted shorelines, to cleared and bare shorelines. Several of the shoreline residents have removed virtually all aquatic vegetation from shoreline areas adjacent to their properties. Many areas exist where the rear lawn extends to the water's edge with no shoreline vegetation at all

A recent study conducted by ERD on the Butler Chain-of-Lakes indicated that shoreline areas which are non-vegetated are susceptible to erosion and resuspension of sediment material as a result of wave activity caused by boats or wind. Water samples collected from non-vegetated shorelines were found to have significantly higher water column concentrations of particulate phosphorus, total phosphorus, and total suspended solids. In addition to providing protection from erosion and sediment resuspension, shoreline vegetation also contributes to a diverse ecological community which is an important factor in maintaining good water quality characteristics within the water column. Shoreline vegetation provides an extremely beneficial function in lake ecosystems and should be maintained to the maximum extent possible.

Protection and regulation of shoreline development in the City of Casselberry are addressed in Part III (Unified Land Development Regulations), Chapter 3 (Performance Criteria), Article XI (Environmental Protection), Section 3-11.5 titled "Lakeshore Protection" of the City Code. This section provides guidelines for lakeshore protection during land development activities and does not appear to apply to existing residential properties. This section requires that development which occurs adjacent to lake shorelines or wetland areas shall prepare a design and management plan as part of the required site plan prior to construction. This plan shall include a plan for maintaining vegetative cover, a plan for shoreline and lakefront littoral zone management, as well as monitoring and management of the shoreline vegetation. Exemptions to the lakefront protection regulations are provided for:

1. Minor maintenance or emergency repair to existing structures;

2. Clearing of shoreline vegetation to create walking trails having no structural components and less than 4 ft in width;

3. Timber catwalks, docks, and trail bridges less than 4 ft wide, providing no filling or excavation is done;

4. Recreational fishing and temporary blinds; and

5. Constructing fences where no fill activity is required and where navigational access will not be hindered.

Although the existing City of Casselberry ordinance provides guidelines for shoreline protection and littoral zone management for new developments, the ordinance does not appear to include any specific guidelines for the amount of littoral zone which must be maintained. In addition, the lakeshore protection ordinance applies only to new development and appears to exclude the numerous lakefront properties which currently exist within the City. It appears that a revised ordinance is needed to set specific numeric guidelines for both existing and new lakefront properties within the City.

An example of an existing shoreline vegetation ordinance is the existing ordinance adopted by Seminole County. Protection and regulation of shoreline vegetation are addressed in Chapter 70 of the Seminole County Municipal Code, titled “Dredge and Filling”. This section requires that a permit be obtained prior to performing any clearing of shoreline vegetation. Information on the percentage of proposed shoreline vegetation removal, means for minimizing and controlling erosion, methods of filtering runoff, methods for reducing the nutrient concentrations in both surface runoff and lake waters, methods for stabilizing soils, and justification for the replacement vegetation must be provided and approved before a permit can be obtained. Exemptions to permit requirements are provided for:

1. Clearing of shoreline vegetation to create an access area or beach less than 25 ft in width;

2. Non-mechanical removal of undesirable aquatic or shoreline vegetation, provided that such removal does not affect the shoreline stability;

3. Mowing and maintenance activities; and

4. Property owners whose shoreline has been previously cleared and where the clearing is continuously maintained

### 6.4.2 Recommendations

Shoreline vegetation is essential for maintaining water quality characteristics, preventing shoreline erosion, and providing a diversity of habitat for aquatic organisms. The current clearing exemption outlined in Chapter 70 of the Seminole County Code of 20% or 25 ft appears to be adequate to support virtually all recreational, swimming, and boating activities which may be desired by a homeowner. It is recommended that the City of Casselberry adopt an ordinance similar to the Seminole County ordinance which would apply to both new and existing properties. It is specifically recommended that desirable vegetation be established in all non-exempt shoreline areas within Queens Mirror Lake and the Triplet Chain-of-Lakes. Although ERD fully understands the desire by some homeowners to have a vegetation-free shoreline, the water quality benefits from shoreline vegetation, combined with the negative water quality conditions observed in unvegetated shoreline areas, appear to outweigh the desire of homeowners to maintain a vegetation-free shoreline.

ERD recommends that all shoreline areas within Queens Mirror Lake and the Triplet Chain-of-Lakes, other than the exceptions referenced previously, be allowed to re-establish natural vegetation. Examples of desirable vegetated shorelines are given in Figure 6-3. Establishing vegetated shorelines will result in no cost to any impacted homeowner and may actually save money for lake front residents who keep shoreline areas in a heavily maintained state. Lake front residents may also install a planted littoral zone consisting of approved aquatic species, if desired. This allows the homeowner to have more control over the visual appearance of the shoreline area. However, both natural and planted littoral zones will provide the desired water quality and basin protection functions. Exotic and nuisance vegetation should be removed, as necessary.

Figure 6-3. Examples of Desirable Vegetated Shorelines.

## 6.5 Landscape Activities

### 6.5.1 Existing Conditions and Issues

While performing field activities for this project, ERD personnel observed instances of improper landscape and lawn maintenance activities within the Queens Mirror Lake and the Triplet Chain-of-Lakes drainage basins which included blowing lawn clippings, leaves, and other vegetation debris onto paved or roadway surfaces, as well as improper application of both granular and liquid fertilizers to impervious surfaces and roadways. An example of grass clippings blown onto the roadway is given in Figure 6-4. When grass clippings and fertilizers are introduced onto impervious surfaces, they become available for mobilization by stormwater runoff during rain events, causing them to be deposited into the nearest waterbody. Previous research conducted by ERD has indicated that soluble nutrients are released rapidly from yard wastes within a period of approximately 7-10 days after entering a receiving waterbody. These types of lawn maintenance practices are needless and irresponsible activities which have the potential to significantly increase nutrient loadings to waterbodies.

Figure 6-4. Example of Grass Clippings on Roadway Surface.

Based on a review of the City of Casselberry Municipal Code performed by ERD, there currently does not appear to be any specific prohibitions on the discharge of yard waste or fertilizers onto roadways or stormwater conveyance systems, other than general anti-littering ordinances. Section 94-10-Deposit of Refuse and Water appears to prohibit direct discharge of refuse, grass, logs, or other debris into lakes or canals but does not appear to specifically prohibit discharges onto roadways or stormwater conveyance systems. Sections 70-4 and 70-5 prohibit dumping or placing refuse, rubbish, sand, gravel, or concrete along or onto the streets of the City but does not specifically address vegetation or grass clippings.

### 6.5.2 Recommendations

Several separate issues appear to exist with respect to improper landscaping management activities. The first of these involves deliberate discharge of yard wastes, leaves, and other vegetation debris onto paved surfaces, particularly roadways and drainage systems. This is a needless and irresponsible practice since it is just as easy to blow the yard waste back onto the landscaped surfaces as it is to discharge it into the street. A strict ordinance prohibiting the discharge of yard waste onto paved surfaces would not pose a significant hardship on landscape companies.

A revised City Ordinance should be developed which prohibits direct discharge of yard waste onto impervious surfaces and requires that yard wastes be removed from impervious surfaces either by sweeping and collection or by blowing the yard waste back onto the landscaped areas. When the yard waste is returned into the landscaped areas, it will decompose and provide additional sources of nutrients to the vegetation rather than the receiving waterbody.

A second issue related to landscaping activities involves the placement of both dry and liquid fertilizers on impervious surfaces due to careless application techniques. This is also a needless practice which arises purely as a result of negligence and carelessness on the part of the applicator. Therefore, it is recommended that an ordinance also be developed which strictly prohibits this type of activity and assesses significant fines for observed violations. This ordinance should apply to both homeowners as well as landscape management professionals. An extensive educational program should also be conducted to inform both homeowners and landscape management professionals of the impacts of this activity, the new ordinance, proposed date for implementation, and penalties for violation. Landscape management companies should be required to sign an affidavit indicating acknowledgement of this ordinance before performing work within the Queens Mirror Lake and Triplet Chain-of-Lakes basins.

Sarasota and Orange Counties, among others, have recently adopted comprehensive fertilizer and landscape management ordinances which establish strict requirements for the use of fertilizers within the various counties. Although these ordinances are not binding in the City of Casselberry, the key elements of these ordinances provide excellent guidelines for application of fertilizers in lake front areas. Key elements of these ordinances include:

1. In Sarasota County, fertilizers containing nitrogen or phosphorus may not be used on lawns or plants from June 1-September 30. This restriction applies both to private residents and professional landscape companies and is designed to prevent wash-off of fertilizers during the typical Florida wet season months. In Orange County, application during this period must be conducted by a trained resident or commercial applicator.

2. Fertilizers applied to turf and landscape plants shall contain no less than 50% slow-release nitrogen. This restriction is designed to minimize leaching of nitrogen from soils.

3. Phosphorus may only be applied to landscaped areas if a soil analysis indicates that additional phosphorus fertilization is necessary. Since most soils in Florida are phosphorus-rich, this element minimizes over-fertilization with phosphorus and subsequent wash-off into receiving waters.

4. Fertilizer application is prohibited within 10 ft from the edge of any pond, stream, water course, lake, canal, or designation wetland.

5. In Orange County, fertilizers may not be applied within a 3-day cone of uncertainty for tropical storms or hurricanes.

Although it would be voluntary at this time, ERD recommends implementation of the guidelines listed above for all areas within the Queens Mirror Lake and Triplet Chain-of-Lakes watershed areas, particularly for lake front homeowners.

## 6.6 Source Reduction

Source reduction programs have the potential to provide effective reductions in stormwater concentrations, particularly for nutrients and suspended solids. Source reduction techniques, such as street sweeping and public education, have the potential to reduce loadings of pollutants entering receiving waterbodies by reducing pollutant accumulation within the watershed. If properly conducted, source reduction programs can be effective reducing pollutant loadings to lakes. The two most common source reduction techniques are street sweeping and public education which are discussed in the following sections.

### 6.6.1 Street Sweeping

Street sweeping is an effective best management practice (BMP) for reducing total suspended solids and associated pollutant wash-off from urban streets. Street sweeping is well suited to an urban environment where little land is available for installation of structural controls. Street sweeping can be extremely effective in commercial business districts, industrial sites, and intensely developed areas in close proximity to receiving waters.

Street sweeping involves the use of machines which basically "sweep" or vacuum contaminants from the street surface and deposit them in a self-contained bin or hopper. Mechanical sweepers are the most commonly used sweeping devices and consist of a series of brooms which rotate at high speeds, forcing debris from the street and gutter into a collection hopper. Water is often sprayed on the surface for dust control during the sweeping process.

Street sweeping activities are most effective on roadways where pollutants are trapped within the roadway by a curb and gutter system. Many of the roadways within the Queens Mirror Lake and Triplet Chain-of-Lakes drainage basins have existing curb and gutter systems which are suitable for street sweeping operations. Therefore, ERD recommends that frequent street sweeping be initiated in these areas, particularly during periods of leaf fall during the fall and winter seasons.

### 6.6.2 Public Education

Public education is one of the most important nonpoint source controls which can be used in a watershed. Many residents appear to be unaware of the direct link between watershed activities and the water quality in adjacent waterbodies. The more a resident understands the relationship between nonpoint source loadings and receiving water quality, the more that person may be willing to implement source controls.

Several national studies have indicated that it is an extremely worthwhile and cost-effective activity to periodically remind property owners of the potential for water quality degradation which can occur due to misapplication of fertilizers and pesticides. Periodic information pamphlets can be distributed by hand or enclosed with water and sewer bills which will reach virtually all residents within the watershed. These educational brochures should emphasize the fact that taxpayer funds are currently being utilized to treat nonpoint source water pollution, and the homeowners have the opportunity to reduce this tax burden by modifying their daily activities. A comprehensive public education program should concentrate, at a minimum, on the following topics:

1. Relationship between land use, stormwater runoff, and pollutants
2. Functions of stormwater treatment systems
3. How to reduce stormwater runoff volume
4. Impacts of water fowl and pets on runoff characteristics and surface water quality
5. Responsible use of fertilizer, pesticides and herbicides
6. Elimination of illicit connections to the stormwater system
7. Controlling erosion and turbidity

The public education program can be implemented in a variety of ways, including homeowner and business seminars, newsletters, performing special projects with local schools (elementary, middle and high schools), Earth Day celebrations, brochures, and special signage at stormwater treatment construction sites. Many people do not realize that stormsewers eventually drain to area lakes. Many cities and counties in Florida have implemented a signage program which places a small engraved plaque on each stormsewer inlet indicating "Do Not Dump, Drains to Lake". ERD recommends that an aggressive public education program be implemented in the Queens Mirror Lake and Triplet Chain-of-Lakes watersheds which incorporates all of the elements discussed previously.

Anticipated load reductions for implementation of public education programs are difficult to predict and depend highly upon the degree of implementation by the homeowners within the basin. The impacts of public education programs also depend, to a large extent, on the degree to which water quality within the Queens Mirror Lake and Triplet Chain-of-Lakes basins is currently being impacted by uneducated and uninformed activities by current homeowners. Several regional and national studies are currently being performed which will attempt to document the pollutant removal effectiveness of public education programs.

## SECTION 7

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# APPENDICES

# APPENDIX A

# HISTORICAL WATER QUALITY DATA FOR QUEENS MIRROR AND THE TRIPLET CHAIN-OF-LAKES

**A.1 Queens Mirror Lake**
**A.2 South Lake Triplet**
**A.3 Middle Lake Triplet**
**A.4 North Lake Triplet**

## A.1 Queens Mirror Lake

# Historical Water Quality Data for Queens Mirror Lake

| Date | pH (s.u.) | Temperature ($^oC$) | Dissolved Oxygen (mg/l) | Secchi Depth (m) | Alkalinity (mg/l) | NH3 (mg/l) | NO3/NO2 (mg/l) | TKN (mg/l) | Total N (mg/l) | Ortho-P (mg/l) | Total P (mg/l) | Turbidity (NTU) | Color (Co - Pt units) | BOD (mg/l) | Chlorophyll-a ($mg/m^3$) | Fecal Coliform (# / 100 ml) | Cadmium (µg/l) | Chromium (µg/l) | Copper (µg/l) | Iron (µg/l) | Lead (µg/l) | Mercury (µg/l) | Zinc (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/22/93 | 6.35 | 29.10 | --- | 1.20 | --- | --- | 0.050 | 0.630 | 0.680 | --- | 0.005 | 1.6 | --- | 2.5 | 30.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/22/93 | 6.79 | 29.00 | --- | 0.90 | --- | --- | 0.003 | 0.908 | 0.910 | --- | 0.050 | 2.2 | --- | 4.6 | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/6/93 | 7.50 | 19.00 | --- | 0.90 | --- | --- | --- | 0.770 | 0.770 | --- | 0.005 | 1.8 | --- | 2.8 | 37.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/17/94 | 6.32 | 18.90 | --- | 0.90 | --- | --- | 0.003 | 0.758 | 0.760 | --- | 0.050 | 1.4 | --- | 2.5 | 15.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 10/3/94 | 6.66 | 25.80 | --- | 0.46 | --- | 0.003 | --- | 0.890 | 0.910 | --- | 0.050 | 1.4 | --- | 2.5 | 83.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/23/94 | 6.40 | 16.80 | --- | 0.76 | --- | 0.070 | --- | 0.650 | 0.720 | --- | 0.005 | 1.7 | --- | 2.0 | 7.7 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/31/95 | 8.69 | 22.90 | --- | 0.31 | --- | 0.003 | --- | 2.460 | 2.460 | --- | 0.089 | 16.0 | --- | 9.6 | 100.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/23/95 | 6.90 | 28.10 | --- | 1.25 | --- | 0.003 | --- | 0.760 | 0.760 | --- | 0.054 | 2.1 | --- | 3.2 | 26.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/15/95 | 7.14 | 26.50 | --- | 0.75 | --- | 0.060 | --- | 0.680 | 0.740 | --- | 0.072 | 0.9 | --- | 2.0 | 30.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/29/95 | 7.72 | 11.00 | --- | 0.85 | --- | 0.003 | --- | 0.740 | 0.740 | --- | 0.067 | 1.9 | --- | 4.2 | 42.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/29/96 | 7.23 | 19.80 | --- | 0.75 | --- | 0.003 | --- | 1.010 | 1.010 | --- | 0.062 | 3.5 | --- | 4.4 | 43.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/19/96 | 6.47 | 26.00 | --- | 0.80 | --- | 0.003 | --- | 0.700 | 0.700 | --- | 0.063 | 1.8 | --- | 2.0 | 24.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/27/96 | 7.14 | 26.50 | --- | 0.90 | --- | 0.003 | --- | 0.670 | 0.670 | --- | 0.053 | 1.6 | --- | 2.0 | 27.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 1/7/97 | 8.04 | 19.70 | --- | 0.80 | --- | 0.003 | --- | 0.770 | 0.770 | --- | 0.042 | 2.4 | --- | 2.8 | 22.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/13/97 | 7.80 | 24.50 | --- | 0.75 | --- | 0.003 | --- | 1.060 | 1.060 | --- | 0.090 | 2.9 | --- | 4.0 | 46.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/19/97 | 7.19 | 29.40 | --- | 0.90 | --- | 0.020 | --- | 0.670 | 0.690 | --- | 0.030 | 1.5 | --- | 3.7 | 21.6 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/19/97 | 7.08 | 29.00 | --- | 0.75 | --- | 0.003 | --- | 1.050 | 1.050 | --- | 0.005 | 28.0 | --- | 3.8 | 43.8 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/10/98 | 8.54 | 30.92 | 9.0 | 0.67 | 18.6 | 0.005 | 0.019 | 1.019 | 1.038 | 0.002 | 0.058 | 8.0 | 47 | 4.8 | 25.2 | 14 | < 1 | 2.5 | 2 | 68 | < 3 | < 3 | 4 |
| 9/30/98 | 7.68 | 29.64 | 7.3 | 0.97 | 35.6 | 0.005 | 0.011 | 0.747 | 0.758 | 0.001 | 0.030 | 3.1 | 39 | 3.2 | 16.9 | 40 | < 1 | 6 | 2 | 47 | < 3 | < 3 | 2 |
| 12/14/98 | 7.66 | 22.08 | 7.5 | 0.99 | 19.0 | 0.011 | 0.003 | 1.049 | 1.053 | 0.002 | 0.057 | 4.9 | 37 | 2.8 | 31.2 | 82 | < 1 | 2.5 | 2 | 63 | < 3 | < 3 | 2 |
| 3/23/99 | 8.38 | 21.69 | 10.3 | 0.93 | 43.6 | 0.047 | 0.003 | 0.678 | 0.682 | 0.001 | 0.039 | 2.9 | 63 | 2.5 | 16.2 | 6 | < 1 | 7 | 2 | 41 | < 3 | < 3 | 2 |
| 6/16/99 | 8.26 | 30.99 | 7.3 | 0.95 | 41.4 | 0.017 | 0.003 | 0.780 | 0.784 | 0.003 | 0.079 | 4.3 | 73 | 2.2 | 16.0 | 6 | < 1 | 2.5 | 2 | 56 | < 3 | < 3 | 2 |
| 9/27/99 | 6.41 | 25.58 | 6.2 | 0.64 | 30.4 | 0.045 | 0.018 | 1.444 | 1.462 | 0.022 | 0.139 | 4.7 | 308 | 2.4 | 39.0 | 6 | < 1 | 2.5 | 4 | 256 | < 3 | < 3 | 3 |
| 12/27/99 | 7.13 | 15.27 | 9.7 | 0.59 | 46.9 | 0.007 | 0.003 | 0.935 | 0.939 | 0.003 | 0.054 | 3.3 | 156 | 4.6 | 48.1 | 20 | < 1 | 2.5 | 8 | 116 | < 3 | < 3 | 2 |
| 3/30/00 | 7.75 | 26.22 | 7.5 | 1.00 | 58.4 | 0.032 | 0.003 | 0.635 | 0.639 | 0.001 | 0.028 | 3.1 | 55 | 2.0 | 3.5 | 7 | < 1 | 2.5 | 2 | 51 | < 3 | < 3 | 6 |
| 6/28/00 | 8.59 | 30.14 | 8.9 | 0.68 | 57.4 | 0.030 | 0.007 | 0.832 | 0.839 | 0.001 | 0.051 | 3.6 | 42 | 4.4 | 44.7 | 45 | < 1 | 2.5 | 5 | 23 | < 3 | < 3 | 24 |
| 9/29/00 | 7.47 | 20.32 | 6.8 | 0.77 | 60.2 | 0.024 | 0.003 | 1.033 | 1.037 | 0.002 | 0.067 | 2.4 | 29 | 71.0 | 34.9 | 3 | < 1 | 2.5 | 2 | 42 | < 3 | < 3 | 2 |
| 12/13/00 | 7.41 | 19.82 | 8.4 | 1.32 | 53.8 | 0.005 | 0.003 | 0.676 | 0.680 | 0.001 | 0.034 | 6.7 | 27 | 40.0 | 25.9 | 15 | < 1 | 2.5 | 6 | 28 | < 3 | < 3 | 2 |
| 3/28/01 | 7.73 | 21.13 | 8.0 | 0.83 | 28.9 | 0.059 | 0.011 | 1.012 | 1.023 | 0.001 | 0.055 | 4.4 | 51 | 60.0 | 10.9 | 3 | 1 | 2.5 | 6 | 22 | < 3 | < 3 | 8 |
| 12/18/03 | 7.31 | 16.01 | 8.6 | 0.52 | 44.0 | 0.003 | 0.003 | 0.946 | 0.948 | 0.001 | 0.057 | 8.0 | 112 | 3.7 | 93.2 | 54 | < 1 | 2.5 | 3 | 216 | < 3 | --- | 2 |
| 3/17/04 | 7.57 | 23.30 | 7.8 | 0.87 | 44.2 | 0.088 | 0.003 | 0.654 | 0.658 | 0.002 | 0.036 | 5.4 | 81 | 4.1 | 28.4 | 29 | < 1 | 2.5 | 2 | 185 | < 3 | --- | 16 |
| 5/20/04 | 7.91 | 27.84 | 6.4 | 0.80 | 59.8 | 0.003 | 0.003 | 0.462 | 0.464 | 0.002 | 0.041 | 3.9 | 61 | 5.1 | 29.5 | 13 | < 1 | 2.5 | 3 | 187 | < 3 | --- | 2 |
| 9/14/04 | 6.42 | 27.06 | 0.9 | 0.63 | 44.0 | 0.043 | 0.003 | 0.509 | 0.511 | 0.048 | 0.084 | 1.3 | 228 | 2.4 | 38.3 | 15 | < 1 | 2.5 | 2 | 394 | < 3 | --- | 2 |
| 11/8/04 | 6.92 | 22.20 | 4.7 | 0.92 | 49.1 | 0.003 | 0.003 | 0.490 | 0.492 | 0.017 | 0.070 | 3.8 | 160 | 2.9 | 82.6 | 6 | < 1 | 2.5 | 13 | 438 | < 3 | --- | 3 |
| 3/9/05 | 7.16 | 17.46 | 8.9 | 0.55 | 38.0 | 0.103 | 0.003 | 2.102 | 2.104 | 0.002 | 0.034 | 9.3 | 99 | 2.6 | 35.0 | 1 | < 1 | 2.5 | 8 | 394 | < 3 | --- | 70 |
| 6/15/05 | 6.67 | 27.23 | 4.0 | 0.74 | 37.2 | 0.119 | 0.003 | 1.097 | 1.099 | 0.031 | 0.105 | 3.3 | 188 | 2.0 | 77.9 | 59 | < 1 | 2.5 | 2 | 183 | < 3 | --- | 2 |
| 9/28/05 | 6.57 | 26.75 | 4.2 | 0.67 | 47.0 | 0.273 | 0.003 | 1.621 | 1.623 | 0.005 | 0.107 | 5.7 | 102 | 2.0 | 36.4 | 832 | 1 | 2.5 | 4 | 229 | < 3 | --- | 14 |
| 12/13/05 | 7.12 | 16.04 | 8.2 | 0.63 | 47.0 | 0.033 | 0.028 | 0.766 | 0.794 | 0.001 | 0.047 | 5.1 | 94 | 4.6 | 75.7 | 42 | < 1 | 2.5 | 4 | 251 | < 3 | --- | 12 |
| 2/7/06 | 7.52 | 17.42 | 7.7 | 0.74 | 47.4 | 0.003 | 0.003 | 0.781 | 0.783 | 0.002 | 0.071 | 11.3 | 67 | 4.8 | 46.8 | 55 | < 1 | 2.5 | 2 | 342 | < 3 | --- | 34 |
| 6/7/06 | 7.37 | 28.99 | 5.2 | 0.88 | 47.0 | 0.020 | 0.003 | 0.794 | 0.796 | 0.002 | 0.056 | 8.1 | 52 | 4.3 | 41.1 | 2 | 1 | 2.5 | 2 | 129 | < 3 | --- | 89 |
| 9/11/06 | 7.01 | 26.95 | 3.1 | 0.56 | 26.8 | 0.035 | 0.006 | 0.901 | 0.907 | 0.001 | 0.059 | 5.4 | 187 | 2.2 | 48.5 | 370 | < 1 | 9 | 2 | 279 | < 3 | --- | 48 |
| 11/13/06 | 7.57 | 20.98 | 7.1 | 0.68 | 34.8 | 0.043 | 0.003 | 0.959 | 0.961 | 0.001 | 0.041 | 8.0 | 158 | 3.8 | 41.6 | 11 | < 1 | 2.5 | 3 | 237 | < 3 | --- | 5 |
| 3/1/07 | 7.21 | 20.96 | 7.2 | 0.68 | 34.6 | 0.014 | 0.005 | 0.440 | 0.445 | 0.005 | 0.015 | 8.0 | 133 | 2.0 | 24.5 | 36 | < 1 | 8 | 3 | 164 | < 3 | --- | 6 |
| 5/24/07 | 6.96 | 26.56 | 5.9 | 0.63 | 33.8 | 0.046 | 0.003 | 0.719 | 0.721 | 0.001 | 0.029 | 4.8 | 70 | 4.0 | 12.7 | 4 | 1 | 2.5 | 2 | 120 | < 3 | --- | 10 |
| 9/27/07 | 6.67 | 26.92 | 4.1 | 1.74 | 44.2 | 0.033 | 0.021 | 0.798 | 0.819 | 0.005 | 0.059 | 3.4 | 225 | 2.6 | 2.0 | 124 | 1 | 2.5 | 4 | 133 | < 3 | --- | 2 |
| 12/11/07 | 7.54 | 21.36 | 8.6 | 0.82 | 44.0 | 0.050 | 0.003 | 1.036 | 1.038 | 0.011 | 0.051 | 3.6 | 138 | 3.3 | 36.0 | 3 | 1 | 2.5 | 2 | 138 | < 3 | --- | 2 |
| 3/31/08 | 7.92 | 22.77 | 8.6 | 0.47 | 41.8 | 0.024 | 0.003 | 1.534 | 1.536 | 0.003 | 0.053 | 26.2 | 95 | 7.5 | 97.7 | 5 | 3 | 2.5 | 2 | 91.7 | < 3 | --- | 2 |
| 5/14/08 | 7.31 | 24.41 | 7.4 | 1.12 | 41.8 | 0.028 | 0.005 | 0.784 | 0.789 | 0.001 | 0.034 | 6.0 | 77 | 2.0 | 5.0 | 5 | 1 | 2.5 | 2 | 89 | < 3 | --- | 7 |
| 9/30/08 | 7.36 | 25.71 | 1.1 | 0.68 | 45.0 | 0.031 | 0.003 | 0.875 | 0.877 | 0.035 | 0.070 | 2.4 | 167 | 4.0 | 59.2 | 30 | 3 | 2.5 | 2 | 193 | < 3 | --- | 2 |
| 12/23/08 | 7.75 | 17.26 | 6.4 | 0.65 | 44.0 | 0.037 | 0.103 | 0.737 | 0.840 | 0.020 | 0.035 | 7.4 | 158 | 3.7 | 36.7 | 23 | 1 | 2.5 | 2 | 218 | < 3 | --- | 2 |
| 3/17/09 | 7.40 | 23.15 | 6.8 | 0.73 | 40.2 | 0.051 | 0.007 | 0.882 | 0.889 | 0.010 | 0.061 | 17.2 | 179 | 4.3 | 10.9 | 1 | 1 | 2.5 | 2 | 186 | < 3 | --- | 3 |
| 5/12/09 | 7.45 | 29.54 | 6.3 | 0.81 | 43.6 | 0.044 | 0.003 | 0.842 | 0.844 | 0.002 | 0.018 | 5.5 | 62 | 3.7 | 16.7 | 12 | 1 | 1 | 2 | 149 | < 3 | --- | 5 |
| 8/18/09 | 6.37 | 28.16 | 1.5 | 0.41 | 41.0 | 0.015 | 0.003 | 0.846 | 0.848 | 0.018 | 0.020 | 2.3 | 168 | 4.9 | 47.2 | 46 | 1 | 1 | 2 | 142 | < 3 | --- | 2 |
| 12/2/09 | 7.53 | 18.44 | 9.8 | 0.46 | 47.2 | 0.016 | 0.020 | 1.426 | 1.446 | 0.004 | 0.096 | 14.6 | 77 | 4.4 | 149.5 | 1 | 1 | 1 | 2 | 194 | < 3 | --- | 2 |
| 3/30/10 | 7.32 | 18.97 | 7.3 | 0.78 | 33.2 | 0.034 | 0.003 | 1.056 | 1.058 | 0.004 | 0.061 | 2.3 | 134 | 3.0 | 33.8 | 20 | 1 | 5 | 2 | 138 | < 3 | --- | 2 |
| 6/29/10 | 6.79 | 29.98 | 4.4 | 0.62 | 36.0 | 0.042 | 0.009 | 1.322 | 1.331 | 0.003 | 0.038 | 3.5 | 144 | 2.6 | 95.2 | 17 | 1 | 1 | 9 | 220 | < 3 | --- | 5 |

# Historical Water Quality Data for Queens Mirror Lake

| Date | pH (s.u.) | Temperature ($^oC$) | Dissolved Oxygen (mg/l) | Secchi Depth (m) | Alkalinity (mg/l) | NH3 (mg/l) | NO3/NO2 (mg/l) | TKN (mg/l) | Total N (mg/l) | Ortho-P (mg/l) | Total P (mg/l) | Turbidity (NTU) | Color (Co - Pt units) | BOD (mg/l) | Chlorophyll-a ($mg/m^3$) | Fecal Coliform (# / 100 ml) | Cadmium (µg/l) | Chromium (µg/l) | Copper (µg/l) | Iron (µg/l) | Lead (µg/l) | Mercury (µg/l) | Zinc (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/14/10 | 6.48 | 28.83 | 5.9 | 0.61 | 33.8 | 0.008 | 0.018 | 0.860 | 0.878 | 0.018 | 0.064 | 2.5 | 188 | 6.4 | 105.7 | 2 | 1 | 1 | 2 | 217 | < 3 | --- | 2 |
| 12/29/10 | 7.54 | 9.90 | 5.8 | 0.89 | 35.6 | 0.011 | 0.010 | 0.497 | 0.507 | 0.003 | 0.027 | 3.3 | 77 | 2.0 | 47.1 | 7 | 1 | 1 | 3 | --- | < 3 | --- | 2 |
| 3/23/11 | 8.68 | 23.49 | 10.3 | 0.36 | 34.4 | 0.049 | 0.003 | 0.559 | 0.560 | 0.001 | 0.033 | 1.3 | 96 | 5.1 | 89.6 | 6 | 1 | 1 | 5 | --- | < 3 | --- | 2 |
| **Minimum** | **6.32** | **9.90** | **0.9** | **0.31** | **18.6** | **<0.005** | **<0.005** | **0.440** | **0.445** | **<0.001** | **0.005** | **0.9** | **27** | **<2** | **2.0** | **2** | **<1** | **<5** | **<1** | **2** | **< 3** | | **2** |
| **Maximum** | **8.69** | **30.99** | **10.3** | **1.74** | **60.2** | **0.273** | **0.103** | **2.460** | **2.460** | **0.048** | **0.139** | **28.0** | **308** | **71.0** | **149** | **570** | **3** | **9** | **13** | **570** | **< 3** | | **89** |
| **Median** | **7.32** | **24.41** | **7.3** | **0.75** | **42.7** | **0.024** | **0.003** | **0.798** | **0.839** | **0.002** | **0.053** | **3.5** | **96** | **3.7** | **36.4** | **14** | **1** | **3** | **2** | **157** | **< 3** | | **2** |
| **Log-Mean** | **7.29** | **22.95** | **6.0** | **0.74** | **40.1** | **0.016** | **0.005** | **0.850** | **0.861** | **0.003** | **0.043** | **3.9** | **95** | **3.8** | **32.5** | **13** | **<1** | **2** | **3** | **130** | **< 3** | | **4** |
| **Average** | **7.32** | **23.57** | **6.7** | **0.78** | **41.3** | **0.032** | **0.009** | **0.903** | **0.914** | **0.007** | **0.052** | **5.4** | **112** | **6.2** | **42.5** | **49** | **1** | **3** | **3** | **167** | **< 3** | | **10** |

## A.2 South Lake Triplet

# Historical Water Quality Data for South Lake Triplet

| Date | pH (s.u.) | Temperature (oC) | Dissolved Oxygen (mg/l) | Secchi Depth (m) | Alkalinity (mg/l) | NH3 (mg/l) | NO3/NO2 (mg/l) | TKN (mg/l) | Total N (mg/l) | Ortho-P (mg/l) | Total P (mg/l) | Turbidity (NTU) | Color (Co - Pt units) | BOD (mg/l) | Chlorophyll-a (mg/m3) | Fecal Coliform (# / 100 ml) | Cadmium (µg/l) | Chromium (µg/l) | Copper (µg/l) | Iron (µg/l) | Lead (µg/l) | Mercury (µg/l) | Zinc (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/21/93 | 7.28 | 30.10 | --- | 1.15 | --- | --- | 0.003 | 0.728 | 0.730 | --- | 0.005 | 2.0 | --- | 2.7 | 10.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/22/93 | 7.12 | 30.60 | --- | 1.05 | --- | --- | --- | 0.720 | 0.720 | --- | 0.050 | 1.8 | --- | 3.1 | 31.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/6/93 | 7.62 | 19.40 | --- | 0.90 | --- | --- | --- | 0.760 | 0.760 | --- | 0.005 | 1.8 | --- | 2.4 | 19.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/18/94 | 6.30 | 19.60 | --- | 0.45 | --- | --- | 0.003 | 1.238 | 1.240 | --- | 0.050 | 4.9 | --- | 5.6 | 38.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 10/3/94 | 7.23 | 26.80 | --- | 0.61 | --- | 0.003 | --- | 0.880 | 0.880 | --- | 0.005 | 1.4 | --- | 4.4 | 55.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/23/94 | 6.50 | 16.60 | --- | --- | --- | 0.060 | --- | 0.730 | 0.790 | --- | 0.005 | 1.5 | --- | 2.0 | 25.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/31/95 | 7.40 | 24.00 | --- | 0.38 | --- | 0.003 | --- | 1.770 | 1.770 | --- | 0.096 | 11.0 | --- | 7.4 | 60.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/23/95 | 7.15 | 28.10 | --- | 1.00 | --- | 0.003 | --- | 0.900 | 0.900 | --- | 0.068 | 3.2 | --- | 3.3 | 24.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/15/95 | 7.29 | 28.00 | --- | 0.75 | --- | 0.003 | --- | 0.760 | 0.760 | --- | 0.075 | 1.1 | --- | 2.0 | 29.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/29/95 | 7.85 | 10.80 | --- | 0.80 | --- | 0.003 | --- | 0.680 | 0.680 | --- | 0.059 | 1.8 | --- | 4.1 | 21.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/29/96 | 7.65 | 22.50 | --- | 0.50 | --- | 0.080 | --- | 1.720 | 1.800 | --- | 0.081 | 8.6 | --- | 6.0 | 57.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/19/96 | 6.71 | 28.00 | --- | 0.80 | --- | 0.040 | --- | 0.840 | 0.880 | --- | 0.054 | 1.4 | --- | 2.2 | 20.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/27/96 | 7.22 | 27.50 | --- | 0.60 | --- | 0.003 | --- | 0.770 | 0.770 | --- | 0.057 | 2.0 | --- | 2.5 | 24.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 1/7/97 | 8.66 | 23.00 | --- | 0.60 | --- | 0.003 | --- | 1.600 | 1.600 | --- | 0.063 | 6.0 | --- | 5.2 | 48.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/13/97 | 7.76 | 24.50 | --- | 0.75 | --- | 0.003 | --- | 1.130 | 1.130 | --- | 0.100 | 3.2 | --- | 4.6 | 43.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/19/97 | 7.59 | 29.50 | --- | 0.75 | --- | 0.020 | --- | 0.720 | 0.740 | --- | 0.040 | 2.1 | --- | 3.5 | 19.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/19/97 | 7.32 | 28.00 | --- | 0.80 | --- | 0.030 | --- | 0.780 | 0.810 | --- | 0.005 | 1.8 | --- | 2.4 | 12.9 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/10/98 | 8.12 | 32.17 | 6.9 | 0.72 | 13.7 | 0.005 | 0.003 | 1.085 | 1.089 | 0.002 | 0.060 | 8.4 | 51 | 4.1 | 8.1 | 18 | 0.5 | 2.5 | 1 | 83 | < 3 | < 3 | 1 |
| 9/30/98 | 7.27 | 29.37 | 5.8 | 0.79 | 30.2 | 0.005 | 0.009 | 0.834 | 0.843 | 0.001 | 0.040 | 4.9 | 54 | 3.3 | 21.7 | 56 | 0.5 | 9 | 1 | 72 | < 3 | < 3 | 1 |
| 12/14/98 | 7.59 | 21.83 | 7.8 | 0.81 | 12.7 | 0.005 | 0.003 | 1.235 | 1.239 | 0.001 | 0.059 | 9.3 | 42 | 2.8 | 21.7 | 34 | 0.5 | 2.5 | 4 | 86 | < 3 | < 3 | 1 |
| 3/23/99 | 7.74 | 21.47 | 9.1 | 0.81 | 37.8 | 0.050 | 0.003 | 0.819 | 0.823 | 0.001 | 0.049 | 4.4 | 65 | 2.0 | 15.5 | 4 | 0.5 | 8 | 1 | 56 | < 3 | < 3 | 1 |
| 6/16/99 | 7.54 | 31.24 | 6.4 | 0.61 | 28.9 | 0.034 | 0.003 | 0.957 | 0.961 | 0.003 | 0.081 | 33.7 | 86 | 3.1 | 28.3 | 50 | 0.5 | 2.5 | 1 | 94 | < 3 | < 3 | 1 |
| 9/27/99 | 6.65 | 25.85 | 5.7 | 0.68 | 28.9 | 0.031 | 0.003 | 1.040 | 1.044 | 0.006 | 0.076 | 3.2 | 284 | 2.0 | 43.9 | 6 | 0.5 | 2.5 | 4 | 256 | < 3 | < 3 | 2 |
| 12/27/99 | 7.61 | 14.97 | 10.4 | 0.53 | 28.9 | 0.010 | 0.003 | 0.937 | 0.941 | 0.002 | 0.045 | 5.1 | 135 | 6.6 | 29.7 | 6 | 0.5 | 2.5 | 4 | 121 | < 3 | < 3 | 1 |
| 3/30/00 | 7.78 | 24.77 | 8.0 | 0.62 | 28.9 | 0.043 | 0.003 | 0.894 | 0.898 | 0.001 | 0.043 | 18.8 | 56 | 2.0 | 23.4 | 12 | 0.5 | 2.5 | 1 | 62 | < 3 | < 3 | 8 |
| 6/28/00 | 8.34 | 31.65 | 9.3 | 0.54 | 28.9 | 0.028 | 0.008 | 0.966 | 0.974 | 0.001 | 0.050 | 10.7 | 47 | 3.1 | 42.2 | 180 | 0.5 | 6 | 1 | 50 | < 3 | < 3 | 1 |
| 9/29/00 | 6.85 | 22.19 | 3.5 | 1.12 | 28.9 | 0.005 | 0.008 | 0.720 | 0.728 | 0.002 | 0.053 | 6.5 | 22 | 52.0 | 16.0 | 8 | 0.5 | 2.5 | 7 | 36 | < 3 | < 3 | 5 |
| 12/13/00 | 6.87 | 20.27 | 5.1 | --- | 28.9 | 0.017 | 0.003 | 0.763 | 0.767 | 0.001 | 0.032 | 12.7 | 21 | 46.0 | 24.8 | 58 | 0.5 | 2.5 | 6 | 33 | < 3 | < 3 | 5 |
| 3/28/01 | 7.68 | 21.33 | 8.4 | 0.52 | 28.9 | 0.037 | 0.017 | 0.696 | 0.713 | 0.001 | 0.033 | 8.4 | 31 | 33.0 | 8.5 | 17 | 0.5 | 2.5 | 6 | 32 | < 3 | < 3 | 5 |
| 12/18/03 | 7.58 | 15.93 | 8.4 | 0.80 | 43.2 | 0.042 | 0.003 | 1.734 | 1.736 | 0.001 | 0.039 | 7.6 | 84 | 3.0 | 42.1 | 14 | 0.5 | 2.5 | 2 | 112 | < 3 | --- | 1 |
| 3/17/04 | 7.31 | 22.88 | 5.9 | 0.78 | 45.3 | 0.069 | 0.003 | 0.979 | 0.982 | 0.001 | 0.034 | 5.6 | 74 | 3.2 | 23.5 | 6 | 0.5 | 2.5 | 1 | 223 | < 3 | --- | 5 |
| 5/20/04 | 7.78 | 26.45 | 5.2 | 0.71 | 51.7 | 0.003 | 0.003 | 0.944 | 0.946 | 0.002 | 0.042 | 7.8 | 64 | 3.7 | 20.0 | 22 | 0.5 | 2.5 | 1 | 115 | < 3 | --- | 1 |
| 9/14/04 | 6.62 | 28.12 | 3.0 | 0.68 | 39.6 | 0.015 | 0.003 | 0.462 | 0.464 | 0.062 | 0.110 | 3.4 | 221 | 2.0 | 22.0 | 160 | 0.5 | 2.5 | 3 | 529 | < 3 | --- | 5 |
| 11/8/04 | 6.99 | 22.17 | 5.0 | 0.63 | 46.9 | 0.003 | 0.003 | 0.434 | 0.436 | 0.011 | 0.054 | 3.0 | 163 | 2.0 | 40.0 | 81 | 0.5 | 2.5 | 3 | 314 | < 3 | --- | 1 |
| 3/9/05 | 7.36 | 17.08 | 8.9 | 0.49 | 41.0 | 0.111 | 0.003 | 1.871 | 1.873 | 0.002 | 0.041 | 13.6 | 80 | 4.7 | 55.3 | 5 | 0.5 | 2.5 | 6 | 529 | < 3 | --- | 3 |
| 6/15/05 | 7.06 | 29.24 | 6.0 | 0.58 | 36.0 | 0.082 | 0.003 | 1.274 | 1.276 | 0.010 | 0.102 | 4.2 | 151 | 2.0 | 129.0 | 39 | 0.5 | 2.5 | 1 | 176 | < 3 | --- | 23 |
| 9/28/05 | 7.03 | 28.16 | 5.5 | 0.96 | 44.0 | 0.287 | 0.003 | 1.048 | 1.050 | 0.001 | 0.060 | 3.0 | 88 | 2.0 | 19.5 | 216 | 1 | 2.5 | 3 | 133 | < 3 | --- | 24 |
| 12/13/05 | 7.36 | 16.36 | 8.3 | 0.66 | 45.4 | 0.085 | 0.029 | 0.775 | 0.804 | 0.001 | 0.049 | 6.0 | 85 | 3.4 | 52.7 | 6 | 0.5 | 2.5 | 3 | 346 | < 3 | --- | 39 |
| 2/7/06 | 7.52 | 17.19 | 8.7 | 0.85 | 45.0 | 0.003 | 0.003 | 0.710 | 0.712 | 0.001 | 0.050 | 6.9 | 61 | 3.0 | 27.3 | 4 | 0.5 | 2.5 | 1 | 278 | < 3 | --- | 41 |
| 6/7/06 | 8.54 | 30.08 | 8.3 | 0.55 | 48.2 | 0.028 | 0.003 | 1.113 | 1.115 | 0.001 | 0.113 | 17.3 | 55 | 6.5 | 56.8 | 4 | 1 | 5 | 1 | 428 | < 3 | --- | 103 |
| 9/11/06 | 7.28 | 28.93 | 4.5 | 0.68 | 33.8 | 0.022 | 0.003 | 0.683 | 0.685 | 0.001 | 0.040 | 4.6 | 107 | 2.0 | 22.8 | 330 | 0.5 | 8 | 1 | 263 | < 3 | --- | 64 |
| 11/13/06 | 7.33 | 20.89 | 6.4 | 0.70 | 38.2 | 0.042 | 0.003 | 0.965 | 0.967 | 0.002 | 0.037 | 6.7 | 106 | 2.0 | 21.6 | 18 | 0.5 | 2.5 | 4 | 153 | < 3 | --- | 13 |
| 3/1/07 | 7.50 | 20.80 | 8.6 | 0.64 | 33.4 | 0.012 | 0.005 | 0.830 | 0.835 | 0.005 | 0.037 | 7.4 | 99 | 2.0 | 25.4 | 9 | 0.5 | 5 | 1 | 123 | < 3 | --- | 7 |
| 5/24/07 | 7.05 | 25.96 | 6.1 | 0.64 | 38.6 | 0.049 | 0.003 | 0.777 | 0.779 | 0.001 | 0.027 | 4.8 | 64 | 4.2 | 6.9 | 6 | 1 | 2.5 | 1 | 122 | < 3 | --- | 8 |
| 9/27/07 | 6.98 | 28.40 | 5.6 | 0.93 | 32.8 | 0.012 | 0.003 | 0.788 | 0.790 | 0.003 | 0.015 | 4.0 | 115 | 2.5 | 10.7 | 570 | 1 | 2.5 | 1 | 105 | < 3 | --- | 6 |
| 12/11/07 | 7.03 | 21.51 | 6.7 | 0.89 | 34.0 | 0.075 | 0.003 | 0.926 | 0.928 | 0.008 | 0.027 | 2.2 | 100 | 2.0 | 7.4 | 3 | 1 | 2.5 | 1 | 161 | < 3 | --- | 1 |
| 3/31/08 | 7.46 | 22.45 | 8.2 | 0.63 | 34.6 | 0.054 | 0.003 | 1.116 | 1.118 | 0.001 | 0.038 | 18.1 | 79 | 3.9 | 38.9 | 6 | 1 | 2.5 | 1 | 83.5 | < 3 | --- | 1 |
| 5/14/08 | 7.44 | 25.85 | 6.6 | 1.03 | 36.6 | 0.032 | 0.003 | 0.943 | 0.945 | 0.001 | 0.029 | 5.6 | 69 | 2.3 | 12.3 | 5 | 1 | 2.5 | 1 | 91 | < 3 | --- | 1 |
| 9/30/08 | 7.29 | 27.13 | 4.7 | 0.73 | 44.4 | 0.041 | 0.003 | 0.654 | 0.656 | 0.026 | 0.067 | 3.4 | 142 | 2.3 | 20.3 | 78 | 3 | 2.5 | 1 | 170 | < 3 | --- | 1 |
| 12/23/08 | 8.18 | 16.71 | 8.9 | 0.65 | 46.0 | 0.040 | 0.087 | 0.641 | 0.728 | 0.005 | 0.039 | 9.7 | 119 | 2.5 | 17.8 | 33 | 1 | 2.5 | 1 | 148 | < 3 | --- | 6 |
| 3/17/09 | 7.07 | 23.90 | 4.9 | 0.62 | 40.4 | 0.052 | 0.003 | 0.607 | 0.609 | 0.007 | 0.025 | 23.5 | 117 | 2.0 | 6.1 | 2 | 1 | 2.5 | 6 | 239 | < 3 | --- | 7 |
| 5/12/09 | 7.27 | 29.92 | 6.2 | 0.82 | 39.8 | 0.061 | 0.009 | 0.891 | 0.900 | 0.002 | 0.032 | 5.1 | 61 | 2.8 | 13.9 | 4 | 1 | 1 | 1 | 244 | < 3 | --- | 150 |
| 8/18/09 | 6.79 | 29.89 | 4.7 | 0.48 | 42.0 | 0.013 | 0.003 | 0.765 | 0.767 | 0.009 | 0.036 | 2.3 | 150 | 3.3 | 45.3 | 74 | 1 | 1 | 1 | 202 | < 3 | --- | 1 |
| 12/2/09 | 7.02 | 19.96 | 9.2 | 0.54 | 41.2 | 0.003 | 0.012 | 0.690 | 0.702 | 0.001 | 0.035 | 3.2 | 81 | 2.8 | 30.0 | 20 | 1 | 1 | 1 | 126 | < 3 | --- | 1 |
| 3/30/10 | 7.04 | 19.82 | 7.7 | 0.65 | 28.6 | 0.038 | 0.010 | 0.965 | 0.975 | 0.003 | 0.027 | 1.4 | 89 | 2.0 | 5.5 | 35 | 1 | 7 | 2 | 76 | < 3 | --- | 13 |
| 6/29/10 | 6.97 | 31.28 | 4.2 | 0.62 | 39.4 | 0.048 | 0.014 | 0.975 | 0.989 | 0.004 | 0.051 | 3.8 | 92 | 2.1 | 47.8 | 17 | 1 | 1 | 2 | 347 | < 3 | --- | 7 |

# Historical Water Quality Data for South Lake Triplet

| Date | pH (s.u.) | Temperature (oC) | Dissolved Oxygen (mg/l) | Secchi Depth (m) | Alkalinity (mg/l) | NH3 (mg/l) | NO3/NO2 (mg/l) | TKN (mg/l) | Total N (mg/l) | Ortho-P (mg/l) | Total P (mg/l) | Turbidity (NTU) | Color (Co - Pt units) | BOD (mg/l) | Chlorophyll-a (mg/m3) | Fecal Coliform (# / 100 ml) | Cadmium (µg/l) | Chromium (µg/l) | Copper (µg/l) | Iron (µg/l) | Lead (µg/l) | Mercury (µg/l) | Zinc (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/14/10 | 6.69 | 30.14 | 5.4 | 0.78 | 35.6 | 0.018 | 0.015 | 0.637 | 0.652 | 0.006 | 0.044 | 2.2 | 146 | 3.5 | 18.5 | 13 | 1 | 1 | 1 | 273 | < 3 | --- | 1 |
| 12/29/10 | 7.26 | 9.30 | 9.4 | 1.12 | 34.0 | 0.006 | 0.011 | 0.410 | 0.421 | 0.001 | 0.014 | 2.3 | 71 | 2.0 | 12.4 | 5 | 1 | 1 | 3 | --- | < 3 | --- | 2 |
| 3/23/11 | 7.08 | 23.76 | 7.5 | 0.58 | 34.2 | 0.049 | 0.003 | 0.629 | 0.629 | 0.001 | 0.025 | 5.0 | 67 | 2.8 | 23.3 | 12 | 1 | 1 | 5 | --- | < 3 | --- | 1 |
| | **6.30** | **9.30** | **3.0** | **0.38** | **12.7** | **<0.005** | **<0.005** | **0.410** | **0.421** | **<0.001** | **0.005** | **1.1** | **21** | **<2** | **5.5** | **2** | **<1** | **<5** | **<1** | **2** | **< 3** | | **1** |
| **Maximum** | **8.66** | **32.17** | **10.4** | **1.15** | **51.7** | **0.287** | **0.087** | **1.871** | **1.873** | **0.062** | **0.113** | **33.7** | **284** | **52.0** | **129** | **570** | **3** | **9** | **7** | **570** | **< 3** | | **150** |
| **Median** | **7.29** | **24.50** | **6.5** | **0.68** | **36.3** | **0.028** | **0.003** | **0.834** | **0.843** | **0.002** | **0.043** | **4.8** | **83** | **2.8** | **23.4** | **16** | **1** | **3** | **1** | **130** | **< 3** | | **4** |
| **Log-Mean** | **7.32** | **23.45** | **6.5** | **0.70** | **35.0** | **0.018** | **0.004** | **0.868** | **0.878** | **0.002** | **0.038** | **4.6** | **81** | **3.4** | **23.6** | **18** | **1** | **3** | **2** | **139** | **< 3** | | **4** |
| **Average** | **7.33** | **24.14** | **6.8** | **0.72** | **36.2** | **0.035** | **0.007** | **0.914** | **0.923** | **0.005** | **0.047** | **6.4** | **93** | **5.2** | **28.7** | **53** | **1** | **3** | **2** | **177** | **< 3** | | **14** |

## A.3 Middle Lake Triplet

# Historical Water Quality Data for Middle Lake Triplet

| Date | pH (s.u.) | Temperature ($^{o}$C) | Dissolved Oxygen (mg/l) | Secchi Depth (m) | Alkalinity (mg/l) | NH3 (mg/l) | NO3/NO2 (mg/l) | TKN (mg/l) | Total N (mg/l) | Ortho-P (mg/l) | Total P (mg/l) | Turbidity (NTU) | Color (Co - Pt units) | BOD (mg/l) | Chlorophyll-a (mg/m$^3$) | Fecal Coliform (# / 100 ml) | Cadmium (µg/l) | Chromium (µg/l) | Copper (µg/l) | Iron (µg/l) | Lead (µg/l) | Mercury (µg/l) | Zinc (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/21/93 | 6.8 | 30.00 | --- | 1.20 | --- | --- | 0.003 | 0.6675 | 0.67 | --- | 0.07 | 1.6 | --- | 2.2 | 8.3 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/22/93 | 6.8 | 29.90 | --- | 1.20 | --- | --- | --- | 0.640 | 0.796 | --- | 0.005 | 1.6 | --- | 2.3 | 7.7 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/6/93 | 7.37 | 19.30 | --- | 1.20 | --- | --- | --- | 0.650 | 0.650 | --- | 0.005 | 1.1 | --- | 2.5 | 10.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/18/94 | 6.3 | 19.50 | --- | 0.90 | --- | --- | 0.003 | 0.798 | 0.800 | --- | 0.005 | 1.8 | --- | 4.4 | 7.6 | --- | --- | --- | --- | --- | --- | --- | --- |
| 10/3/94 | 7.15 | 26.80 | --- | 0.61 | --- | 0.0025 | --- | 0.810 | 0.810 | --- | 0.005 | 1.0 | --- | 2.2 | 23.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/23/94 | 6.7 | 16.50 | --- | 0.91 | --- | 0.04 | --- | 0.640 | 0.830 | --- | 0.005 | 1.0 | --- | 2 | 6.1 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/31/95 | 6.89 | 23.80 | --- | 0.76 | --- | 0.0025 | --- | 0.920 | 0.920 | --- | 0.062 | 2.8 | --- | 2 | 21.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/23/95 | 7.07 | 28.00 | --- | 1.25 | --- | 0.0025 | --- | 0.700 | 0.700 | --- | 0.057 | 2.1 | --- | 2.4 | 14.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/15/95 | 7.42 | 27.50 | --- | 0.75 | --- | 0.0025 | --- | 0.830 | 0.830 | --- | 0.060 | 1.0 | --- | 2 | 19.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/29/95 | 7.72 | 11.00 | --- | 0.90 | --- | 0.0025 | --- | 0.590 | 0.590 | --- | 0.048 | 1.4 | --- | 2.9 | 12.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/29/96 | 7.71 | 22.60 | --- | 0.50 | --- | 0.19 | --- | 1.860 | 2.050 | --- | 0.085 | 8.5 | --- | 7 | 64.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/19/96 | 6.72 | 28.00 | --- | 1.00 | --- | 0.0025 | --- | 0.760 | 0.760 | --- | 0.044 | 1.6 | --- | 2.2 | 16.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/27/96 | 7.13 | 27.00 | --- | 0.70 | --- | 0.0025 | --- | 0.790 | 0.790 | --- | 0.061 | 3.1 | --- | 2 | 19.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 1/7/97 | 7.94 | 24.00 | --- | 0.60 | --- | 0.0025 | --- | 0.930 | 0.930 | --- | 0.049 | 3.0 | --- | 2.2 | 21.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/13/97 | 7.68 | 24.00 | --- | 0.60 | --- | 0.0025 | --- | 1.070 | 1.070 | --- | 0.090 | 3.9 | --- | 3.2 | 24.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/19/97 | 7.77 | 29.00 | --- | 0.80 | --- | 0.06 | --- | 0.690 | 0.750 | --- | 0.020 | 2.5 | --- | 2.3 | 13.3 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/19/97 | 7.31 | 28.50 | --- | 0.75 | --- | 0.04 | --- | 0.900 | 0.940 | --- | 0.005 | 2.5 | --- | 2 | 11.7 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/10/98 | 8.79 | 30.31 | 10.5 | 0.67 | 12.6 | 0.005 | 0.012 | 0.961 | 0.973 | 0.001 | 0.064 | 7.2 | 44 | 5 | 19.8 | 10 | 0.5 | 3 | 2 | 65 | < 3 | < 3 | 2 |
| 9/30/98 | 7.5 | 28.73 | 6.2 | 1.02 | 37.9 | 0.005 | 0.010 | 0.811 | 0.821 | 0.001 | 0.046 | 2.8 | 79 | 3.4 | 26.2 | 6 | 0.5 | 9 | 6 | 94 | < 3 | < 3 | 2 |
| 12/14/98 | 7.61 | 21.70 | 8.2 | 0.79 | 14.9 | 0.005 | 0.003 | 1.056 | 1.060 | 0.002 | 0.044 | 3.5 | 41 | 2.4 | 22.6 | 92 | 0.5 | 3 | 7 | 78 | < 3 | < 3 | 3 |
| 3/23/99 | 7.21 | 21.92 | 7.4 | 0.93 | 37.1 | 0.083 | 0.003 | 0.773 | 0.777 | 0.001 | 0.039 | 5.7 | 67 | 2.3 | 14.1 | 16 | 0.5 | 6 | 2 | 60 | < 3 | < 3 | 2 |
| 6/16/99 | 7.61 | 31.01 | 7.1 | 0.61 | 33.7 | 0.028 | 0.003 | 0.993 | 0.997 | 0.001 | 0.073 | 9.5 | 86 | 2.9 | 29.9 | 122 | 0.5 | 7 | 2 | 159 | < 3 | < 3 | 2 |
| 9/27/99 | 6.59 | 25.79 | 5.5 | 0.79 | 33.7 | 0.031 | 0.003 | 0.938 | 0.942 | 0.004 | 0.062 | 3.5 | 230 | 2 | 27.6 | 100 | 0.5 | 3 | 2 | 191 | < 3 | < 3 | 4 |
| 12/27/99 | 7.37 | 14.77 | 9.7 | 0.79 | 33.7 | 0.017 | 0.003 | 0.980 | 0.984 | 0.003 | 0.023 | 4.2 | 140 | 3.4 | 23.7 | 6 | 0.5 | 3 | 2 | 101 | < 3 | < 3 | 2 |
| 3/30/00 | 8.09 | 27.49 | 8.5 | --- | 33.7 | 0.025 | 0.003 | 0.877 | 0.881 | 0.001 | 0.029 | 6.0 | 56 | 2.5 | 6.3 | 13 | 0.5 | 3 | 2 | 59 | < 3 | < 3 | 2 |
| 6/28/00 | 7.892 | 31.98 | 8.2 | 0.63 | 33.7 | 0.019 | 0.003 | 0.800 | 0.804 | 0.001 | 0.034 | 7.6 | 50 | 2.1 | 27.0 | 129 | 0.5 | 6 | 2 | 91 | < 3 | < 3 | 5 |
| 9/29/00 | 7.29 | 23.35 | 7.4 | 0.75 | 33.7 | 0.025 | 0.009 | 0.678 | 0.687 | 0.002 | 0.053 | 5.6 | 22 | 44 | 21.2 | 8 | 0.5 | 3 | 4 | 31 | < 3 | < 3 | 3 |
| 12/13/00 | 7.2 | 20.74 | 7.9 | --- | 33.7 | 0.005 | 0.003 | 0.778 | 0.782 | 0.001 | 0.029 | 10.7 | 21 | 39 | 16.9 | 24 | 0.5 | 3 | 8 | 39 | < 3 | < 3 | 9 |
| 3/28/01 | 7.85 | 21.49 | 8.1 | --- | 33.7 | 0.103 | 0.010 | 1.229 | 1.239 | 0.001 | 0.057 | 8.6 | 39 | 62 | 25.2 | 6 | 0.5 | 3 | 7 | 36 | < 3 | < 3 | 5 |
| 12/18/03 | 7.53 | 16.01 | 7.8 | 0.98 | 42.8 | 0.0025 | 0.019 | 0.670 | 0.689 | 0.001 | 0.028 | 4.9 | 83 | 2 | 12.9 | 32 | 0.5 | 3 | 3 | 148 | < 3 | --- | 2 |
| 3/17/04 | 7.53 | 22.83 | 6.8 | 0.84 | 43.8 | 0.095 | 0.003 | 0.678 | 0.682 | 0.001 | 0.025 | 6.4 | 69 | 2.6 | 23.1 | 7 | 0.5 | 6 | 2 | 128 | < 3 | --- | 20 |
| 5/20/04 | 7.94 | 27.87 | 6.5 | 0.83 | 47.7 | 0.0025 | 0.003 | 0.566 | 0.568 | 0.001 | 0.033 | 22.2 | 65 | 3.5 | 16.2 | 7 | 0.5 | 3 | 2 | 101 | 3 | --- | 2 |
| 9/14/04 | 6.79 | 28.22 | 3.2 | 0.67 | 37.4 | 0.1 | 0.003 | 0.666 | 0.668 | 0.042 | 0.095 | 2.7 | 204 | 2 | 14.3 | 38 | 0.5 | 3 | 3 | 314 | < 3 | --- | 5 |
| 11/8/04 | 7.05 | 22.03 | 4.5 | 0.98 | 42.8 | 0.021 | 0.003 | 0.631 | 0.633 | 0.010 | 0.045 | 2.6 | 173 | 2 | 31.1 | 14 | 0.5 | 3 | 2 | 262 | < 3 | --- | 7 |
| 3/9/05 | 7.36 | 16.99 | 9.4 | 0.52 | 40.3 | 0.102 | 0.047 | 1.283 | 1.330 | 0.014 | 0.026 | 15.6 | 79 | 2.9 | 34.3 | 7 | 0.5 | 3 | 5 | 234 | < 3 | --- | 2 |
| 6/15/05 | 7.26 | 29.62 | 6.6 | 0.93 | 38.4 | 0.054 | 0.003 | 0.720 | 0.722 | 0.001 | 0.050 | 4.7 | 104 | 2 | 54.0 | 14 | 0.5 | 3 | 2 | 151 | < 3 | --- | 7 |
| 9/28/05 | 7.09 | 27.94 | 6.1 | 0.89 | 44.2 | 0.333 | 0.003 | 0.817 | 0.819 | 0.001 | 0.041 | 2.7 | 81 | 2 | 13.8 | 216 | 0.5 | 3 | 3 | 163 | < 3 | --- | 17 |
| 12/13/05 | 7.42 | 16.33 | 8.3 | 0.72 | 42.8 | 0.042 | 0.029 | 0.653 | 0.682 | 0.001 | 0.031 | 7.5 | 91 | 3 | 37.0 | 2 | 0.5 | 3 | 4 | 241 | < 3 | --- | 25 |
| 2/7/06 | 7.6 | 17.01 | 7.8 | 0.90 | 42.6 | 0.0025 | 0.009 | 0.666 | 0.675 | 0.002 | 0.038 | 22.8 | 62 | 2.7 | 24.6 | 8 | 0.5 | 3 | 2 | 187 | 4 | --- | 20 |
| 6/7/06 | 7.52 | 28.31 | 6.3 | --- | 43.4 | 0.023 | 0.032 | 0.806 | 0.838 | 0.001 | 0.037 | 28.5 | 56 | 2.6 | 20.7 | 18 | 3 | 7 | 2 | 303 | < 3 | --- | 149 |
| 9/11/06 | 7.38 | 28.74 | 5.2 | 0.77 | 33.2 | 0.032 | 0.003 | 0.564 | 0.566 | 0.001 | 0.023 | 5.7 | 64 | 2 | 18.0 | 134 | 0.5 | 7 | 2 | 226 | < 3 | --- | 5 |
| 11/13/06 | 7.41 | 20.77 | 7.4 | 0.79 | 31.2 | 0.037 | 0.003 | 0.767 | 0.769 | 0.001 | 0.020 | 11.0 | 72 | 2 | 7.2 | 16 | 0.5 | 8 | 2 | 93 | < 3 | --- | 6 |
| 3/1/07 | 7.56 | 22.20 | 7.6 | 1.03 | 30.8 | 0.006 | 0.003 | 0.597 | 0.599 | 0.001 | 0.015 | 5.3 | 76 | 2 | 8.2 | 19 | 0.5 | 6 | 3 | 88 | < 3 | --- | 2 |
| 5/24/07 | 7.12 | 25.68 | 6.8 | 1.03 | 25.8 | 0.051 | 0.003 | 0.766 | 0.768 | 0.001 | 0.018 | 8.6 | 56 | 2 | 5.0 | 32 | 1 | 3 | 3 | 99 | < 3 | --- | 6 |
| 9/27/07 | 7.09 | 28.30 | 6.2 | 1.18 | 23.4 | 0.005 | 0.003 | 0.622 | 0.624 | 0.001 | 0.012 | 4.2 | 73 | 2.4 | 7.1 | 50 | 1 | 6 | 2 | 110 | < 3 | --- | 4 |
| 12/11/07 | 7.04 | 21.18 | 6.4 | 0.83 | 26.8 | 0.068 | 0.003 | 0.823 | 0.825 | 0.004 | 0.021 | 3.7 | 96 | 2 | 3.8 | 34 | 1 | 3 | 2 | 145 | 5 | --- | 2 |
| 3/31/08 | 7.42 | 23.40 | 8.0 | --- | 30.0 | 0.078 | 0.003 | 0.840 | 0.842 | 0.002 | 0.034 | 19.6 | 85 | 2.1 | 20.6 | 22 | 1 | 3 | 2 | 88 | < 3 | --- | 2 |
| 5/14/08 | 7.35 | 25.28 | 6.3 | --- | 28.6 | 0.032 | 0.005 | 0.953 | 0.958 | 0.001 | 0.018 | 3.9 | 70 | 2 | 35.5 | 2 | 1 | 3 | 2 | 77 | < 3 | --- | 2 |
| 9/30/08 | 7.28 | 27.22 | 5.6 | 0.85 | 39.8 | 0.039 | 0.003 | 0.453 | 0.455 | 0.010 | 0.035 | 5.0 | 114 | 2 | 12.0 | 60 | 1 | 3 | 2 | 139 | < 3 | --- | 2 |
| 12/23/08 | 8.27 | 16.74 | 8.5 | 0.93 | 40.0 | 0.032 | 0.118 | 0.539 | 0.657 | 0.001 | 0.024 | 10.4 | 114 | 2 | 5.1 | 60 | 1 | 3 | 2 | 75 | < 3 | --- | 2 |
| 3/17/09 | 7.55 | 24.30 | 7.1 | --- | 44.0 | 0.055 | 0.003 | 1.028 | 1.030 | 0.001 | 0.049 | 60.6 | 129 | 4.5 | 38.6 | 1 | 1 | 3 | 6 | 72 | < 3 | --- | 2 |
| 5/12/09 | 7.2 | 29.34 | 5.8 | 0.54 | 43.8 | 0.035 | 0.003 | 0.967 | 0.969 | 0.001 | 0.026 | 3.1 | 66 | 2.8 | 2.0 | 2 | 1 | 1 | 2 | 175 | < 3 | --- | 12 |
| 8/18/09 | 6.9 | 29.67 | 5.1 | 0.58 | 37.2 | 0.016 | 0.003 | 0.784 | 0.786 | 0.002 | 0.031 | 2.2 | 128 | 2.7 | 38.4 | 84 | 1 | 1 | 2 | 134 | < 3 | --- | 2 |
| 12/2/09 | 6.69 | 20.43 | 4.1 | 0.58 | 42.0 | 0.01 | 0.032 | 0.677 | 0.709 | 0.001 | 0.024 | 7.1 | 74 | 2 | 7.9 | 14 | 1 | 1 | 2 | 112 | < 3 | --- | 2 |
| 3/30/10 | 7.25 | 20.11 | 8.2 | 0.89 | 31.4 | 0.04 | 0.023 | 0.659 | 0.682 | 0.003 | 0.044 | 2.2 | 103 | 2 | 8.1 | 5 | 1 | 6 | 2 | 110 | < 3 | --- | 2 |
| 6/29/10 | 7.06 | 31.11 | 4.5 | 0.68 | 36.6 | 0.03 | 0.003 | 0.892 | 0.895 | 0.001 | 0.015 | 4.0 | 99 | 2 | 20.9 | 13 | 1 | 1 | 2 | 319 | < 3 | --- | 8 |
| 9/14/10 | 6.97 | 30.44 | 6.5 | 0.96 | 36.0 | 0.006 | 0.011 | 0.730 | 0.741 | 0.001 | 0.023 | 2.1 | 102 | 2.1 | 31.7 | 2 | 1 | 1 | 2 | 139 | < 3 | --- | 2 |

# Historical Water Quality Data for Middle Lake Triplet

| Date | pH | Temperature | Dissolved Oxygen | Secchi Depth | Alkalinity | NH3 | NO3/NO2 | TKN | Total N | Ortho-P | Total P | Turbidity | Color | BOD | Chlorophyll-a | Fecal Coliform | Cadmium | Chromium | Copper | Iron | Lead | Mercury | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (s.u.) | ($^{o}$C) | (mg/l) | (m) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (NTU) | (Co - Pt units) | (mg/l) | (mg/m$^3$) | (# / 100 ml) | (µg/l) | (µg/l) | (µg/l) | (µg/l) | (µg/l) | (µg/l) | (µg/l) |
| 12/29/10 | 7.32 | 9.31 | 9.3 | 1.14 | 33.0 | 0.021 | 0.025 | 0.626 | 0.651 | 0.001 | 0.013 | 1.7 | 66 | 2 | 2.0 | 1 | 1 | 1 | 3 | --- | < 3 | --- | 9 |
| 3/23/11 | 7.11 | 23.98 | 7.0 | --- | 35.4 | 0.046 | 0.003 | 0.519 | 0.523 | 0.001 | 0.012 | 2.0 | 55 | 2 | 3.7 | 1 | 1 | 1 | 8 | --- | < 3 | --- | 35 |
| **Minimum** | **6.30** | **9.31** | **3.2** | **0.50** | **12.6** | **<0.005** | **<0.005** | **0.453** | **0.455** | **<0.001** | **0.005** | **1.0** | **21** | **<2** | **2.0** | **2** | **<1** | **<5** | **<1** | **2** | **< 3** | | **2** |
| **Maximum** | **8.79** | **31.98** | **10.5** | **1.25** | **47.7** | **0.333** | **0.118** | **1.860** | **2.050** | **0.042** | **0.095** | **60.6** | **230** | **62.0** | **64** | **570** | **3** | **9** | **8** | **570** | **< 3** | | **149** |
| **Median** | **7.32** | **24.30** | **7.1** | **0.83** | **35.7** | **0.025** | **0.003** | **0.773** | **0.786** | **0.001** | **0.033** | **3.9** | **75** | **2.2** | **18.0** | **14** | **1** | **3** | **2** | **111** | **< 3** | | **3** |
| **Log-Mean** | **7.32** | **23.50** | **6.8** | **0.82** | **34.4** | **0.018** | **0.005** | **0.774** | **0.792** | **0.002** | **0.029** | **4.3** | **76** | **2.8** | **15.0** | **15** | **1** | **3** | **3** | **117** | **< 3** | | **4** |
| **Average** | **7.33** | **24.17** | **7.0** | **0.84** | **35.4** | **0.039** | **0.011** | **0.798** | **0.817** | **0.003** | **0.036** | **6.8** | **85** | **4.9** | **18.9** | **34** | **1** | **3** | **3** | **136** | **< 3** | | **10** |

## A.4 North Lake Triplet

# Historical Water Quality Data for North Lake Triplet

| Date | pH (s.u.) | Temperature ($^{o}$C) | Dissolved Oxygen (mg/l) | Secchi Depth (m) | Alkalinity (mg/l) | NH3 (mg/l) | NO3/NO2 (mg/l) | TKN (mg/l) | Total N (mg/l) | Ortho-P (mg/l) | Total P (mg/l) | Turbidity (NTU) | Color (Co - Pt units) | BOD (mg/l) | Chlorophyll-a (mg/m$^3$) | Fecal Coliform (# / 100 ml) | Cadmium (µg/l) | Chromium (µg/l) | Copper (µg/l) | Iron (µg/l) | Lead (µg/l) | Mercury (µg/l) | Zinc (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/21/93 | 6.95 | 29.50 | --- | 0.60 | --- | --- | 0.003 | 0.768 | 0.770 | --- | 0.005 | 2.2 | --- | 2.9 | 24.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/22/93 | 6.90 | 30.10 | --- | 1.20 | --- | --- | 0.003 | 0.738 | 0.740 | --- | 0.005 | 1.9 | --- | 2.2 | 21.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/6/93 | 7.49 | 19.10 | --- | 1.20 | --- | --- | --- | 0.670 | 0.690 | --- | 0.005 | 1.8 | --- | 2.0 | 14.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/18/94 | 6.12 | 20.10 | --- | 1.20 | --- | --- | 0.003 | 0.868 | 0.870 | --- | 0.005 | 1.4 | --- | 2.0 | 8.7 | --- | --- | --- | --- | --- | --- | --- | --- |
| 10/3/94 | 7.16 | 26.60 | --- | 0.61 | --- | 0.003 | --- | 0.810 | 0.810 | --- | 0.005 | 0.9 | --- | 2.0 | 18.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/23/94 | 7.08 | 16.60 | --- | 1.07 | --- | 0.090 | --- | 0.670 | 0.760 | --- | 0.005 | 1.2 | --- | 2.0 | 7.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/31/95 | 6.53 | 23.80 | --- | 0.61 | --- | 0.050 | --- | 1.300 | 1.350 | --- | 0.080 | 3.8 | --- | 5.8 | 44.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/22/95 | 7.26 | 28.50 | --- | 0.75 | --- | 0.003 | --- | 0.750 | 0.750 | --- | 0.040 | 2.6 | --- | 2.1 | 14.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/15/95 | 7.24 | 29.00 | --- | 0.90 | --- | 0.030 | --- | 0.750 | 0.780 | --- | 0.058 | 0.9 | --- | 2.0 | 19.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 12/29/95 | 7.76 | 11.00 | --- | 0.85 | --- | 0.003 | --- | 0.690 | 0.690 | --- | 0.048 | 1.7 | --- | 2.9 | 22.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/29/96 | 7.52 | 21.50 | --- | 0.50 | --- | 0.040 | --- | 1.640 | 1.680 | --- | 0.081 | 7.0 | --- | 6.7 | 69.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/19/96 | 6.68 | 28.00 | --- | 1.00 | --- | 0.003 | --- | 0.680 | 0.680 | --- | 0.048 | 1.4 | --- | 2.0 | 17.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/27/96 | 7.16 | 28.00 | --- | 1.00 | --- | 0.003 | --- | 0.720 | 0.720 | --- | 0.045 | 2.0 | --- | 2.0 | 16.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 1/7/97 | 7.93 | 22.00 | --- | 0.80 | --- | 0.003 | --- | 0.630 | 0.630 | --- | 0.035 | 1.7 | --- | 2.0 | 17.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 3/13/97 | 7.60 | 24.00 | --- | 0.80 | --- | 0.003 | --- | 0.830 | 0.830 | --- | 0.060 | 2.4 | --- | 3.2 | 17.0 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/19/97 | 7.49 | 29.00 | --- | 0.80 | --- | 0.020 | --- | 0.870 | 0.890 | --- | 0.020 | 2.6 | --- | 3.0 | 21.7 | --- | --- | --- | --- | --- | --- | --- | --- |
| 9/19/97 | 7.31 | 29.00 | --- | 1.00 | --- | 0.003 | --- | 0.720 | 0.720 | --- | 0.005 | 1.9 | --- | 2.0 | 23.7 | --- | --- | --- | --- | --- | --- | --- | --- |
| 6/10/98 | 7.71 | 30.50 | 7.1 | 1.87 | 14.0 | 0.015 | 0.026 | 0.645 | 0.671 | 0.003 | 0.024 | 1.2 | 21 | 2.0 | 3.3 | 62 | 0.5 | 2.5 | 5 | 10 | < 3 | < 3 | 1 |
| 9/30/98 | 8.15 | 29.63 | 9.5 | 0.93 | 62.4 | 0.005 | 0.009 | 0.735 | 0.744 | 0.001 | 0.032 | 4.4 | 21 | 3.1 | 23.1 | 82 | 0.5 | 8 | 2 | 21 | < 3 | < 3 | 4 |
| 12/14/98 | 7.51 | 22.21 | 7.9 | 0.94 | 15.3 | 0.005 | 0.003 | 1.013 | 1.017 | 0.001 | 0.036 | 2.2 | 32 | 2.0 | 18.0 | 14 | 0.5 | 2.5 | 2 | 60 | < 3 | < 3 | 3 |
| 3/23/99 | 7.49 | 22.05 | 9.0 | 1.26 | 35.6 | 0.135 | 0.069 | 0.701 | 0.770 | 0.003 | 0.055 | 4.6 | 57 | 2.2 | 13.5 | 4 | 0.5 | 9 | 2 | 60 | < 3 | < 3 | 1 |
| 6/16/99 | 8.50 | 30.66 | 8.0 | 0.66 | 35.2 | 0.024 | 0.003 | 1.161 | 1.165 | 0.003 | 0.079 | 8.9 | 61 | 4.9 | 48.1 | 46 | 0.5 | 6 | 2 | 66 | < 3 | < 3 | 4 |
| 9/27/99 | 6.82 | 26.09 | 5.4 | 0.84 | 23.6 | 0.070 | 0.008 | 0.898 | 0.906 | 0.002 | 0.051 | 2.9 | 180 | 2.0 | 21.4 | 4 | 0.5 | 2.5 | 2 | 139 | < 3 | < 3 | 1 |
| 12/27/99 | 6.98 | 14.70 | 7.8 | 1.06 | 39.2 | 0.097 | 0.067 | 0.958 | 1.025 | 0.002 | 0.020 | 3.5 | 153 | 2.5 | 4.2 | 6 | 1 | 2.5 | 2 | 321 | < 3 | < 3 | 1 |
| 3/30/00 | 8.41 | 27.01 | 9.1 | 0.82 | 44.4 | 0.021 | 0.005 | 1.019 | 1.024 | 0.001 | 0.043 | 4.1 | 54 | 2.1 | 12.7 | 8 | 1 | 2.5 | 2 | 55 | < 3 | < 3 | 10 |
| 6/28/00 | 8.60 | 29.96 | 9.1 | 0.69 | 40.1 | 0.042 | 0.012 | 1.184 | 1.196 | 0.001 | 0.045 | 10.6 | 42 | 3.2 | 65.3 | 24 | 0.5 | 7 | 2 | 36 | < 3 | < 3 | 2 |
| 9/29/00 | 7.46 | 22.99 | 7.2 | 0.69 | 45.0 | 0.019 | 0.016 | 0.804 | 0.820 | 0.003 | 0.085 | 5.9 | 29 | 26.0 | 34.6 | 27 | 0.5 | 2.5 | 6 | 34 | < 3 | < 3 | 3 |
| 12/13/00 | 7.75 | 21.25 | 8.6 | 0.95 | 45.7 | 0.009 | 0.007 | 0.730 | 0.737 | 0.001 | 0.024 | 8.3 | 31 | 26.0 | 19.4 | 56 | 0.5 | 2.5 | 6 | 20 | < 3 | < 3 | 4 |
| 3/28/01 | 8.23 | 20.52 | 8.9 | 0.87 | 61.5 | 0.058 | 0.003 | 0.904 | 0.908 | 0.001 | 0.055 | 7.8 | 41 | 67.0 | 16.8 | 2 | 0.5 | 2.5 | 2 | 35 | < 3 | < 3 | 6 |
| 12/18/03 | 7.62 | 16.50 | 7.9 | 1.08 | 41.4 | 0.043 | 0.037 | 1.408 | 1.445 | 0.001 | 0.032 | 4.7 | 76 | 2.7 | 25.9 | 12 | 0.5 | 2.5 | 2 | 96 | 3 | --- | 1 |
| 3/17/04 | 7.83 | 22.55 | 7.6 | 1.07 | 45.9 | 0.079 | 0.003 | 0.674 | 0.676 | 0.001 | 0.021 | 3.9 | 59 | 2.9 | 27.4 | 11 | 0.5 | 6 | 2 | 112 | < 3 | --- | 8 |
| 5/20/04 | 7.86 | 27.08 | 6.7 | 0.82 | 52.1 | 0.003 | 0.003 | 0.612 | 0.614 | 0.001 | 0.050 | 4.5 | 55 | 5.7 | 45.9 | 25 | 0.5 | 2.5 | 2 | 88 | < 3 | --- | 1 |
| 9/14/04 | 7.25 | 28.28 | 3.7 | 0.71 | 37.0 | 0.011 | 0.003 | 0.716 | 0.718 | 0.046 | 0.062 | 4.3 | 180 | 2.0 | 24.0 | 22 | 0.5 | 2.5 | 3 | 323 | < 3 | --- | 10 |
| 11/8/04 | 7.37 | 22.69 | 4.6 | 1.11 | 42.0 | 0.029 | 0.011 | 0.567 | 0.578 | 0.008 | 0.042 | 1.9 | 166 | 2.0 | 35.9 | 34 | 0.5 | 2.5 | 4 | 264 | < 3 | --- | 3 |
| 3/9/05 | 7.16 | 17.64 | 8.1 | 0.95 | 44.0 | 0.265 | 0.003 | 0.885 | 0.887 | 0.004 | 0.024 | 8.6 | 81 | 2.0 | 14.0 | 3 | 0.5 | 2.5 | 13 | 166 | < 3 | --- | 33 |
| 6/15/05 | 7.56 | 29.76 | 7.1 | 1.16 | 40.3 | 0.048 | 0.003 | 0.753 | 0.755 | 0.001 | 0.047 | 4.2 | 76 | 2.0 | 50.9 | 20 | 0.5 | 2.5 | 2 | 106 | < 3 | --- | 11 |
| 9/28/05 | 7.30 | 28.74 | 6.7 | 1.19 | 43.8 | 0.126 | 0.003 | 0.881 | 0.883 | 0.001 | 0.039 | 2.8 | 80 | 2.0 | 18.0 | 168 | 1 | 2.5 | 3 | 101 | < 3 | --- | 4 |
| 12/13/05 | 7.37 | 16.73 | 7.6 | 0.69 | 40.2 | 0.113 | 0.016 | 0.745 | 0.761 | 0.001 | 0.032 | 5.6 | 89 | 3.2 | 38.3 | 8 | 0.5 | 2.5 | 2 | 175 | < 3 | --- | 11 |
| 2/7/06 | 7.58 | 17.07 | 7.4 | 0.75 | 43.2 | 0.003 | 0.005 | 0.676 | 0.681 | 0.001 | 0.034 | 18.0 | 65 | 3.0 | 31.3 | 6 | 0.5 | 2.5 | 2 | 110 | < 3 | --- | 38 |
| 6/7/06 | 7.39 | 29.07 | 5.7 | 0.86 | 49.4 | 0.022 | 0.003 | 0.831 | 0.833 | 0.001 | 0.046 | 8.5 | 47 | 3.6 | 36.3 | 5 | 0.5 | 12 | 2 | 286 | < 3 | --- | 65 |
| 9/11/06 | 7.54 | 29.53 | 5.7 | 0.93 | 34.8 | 0.044 | 0.003 | 0.588 | 0.590 | 0.002 | 0.015 | 4.1 | 44 | 2.0 | 18.1 | 112 | 0.5 | 7 | 4 | 123 | < 3 | --- | 9 |
| 11/13/06 | 7.34 | 21.16 | 7.1 | 0.84 | 30.2 | 0.039 | 0.003 | 0.826 | 0.828 | 0.001 | 0.023 | 8.0 | 54 | 2.0 | 10.0 | 52 | 0.5 | 9 | 3 | 95 | < 3 | --- | 11 |
| 3/1/07 | 7.68 | 21.71 | 8.0 | 1.14 | 33.8 | 0.014 | 0.003 | 0.579 | 0.581 | 0.001 | 0.016 | 3.6 | 63 | 2.0 | 12.7 | 5 | 0.5 | 2.5 | 3 | 41 | < 3 | --- | 1 |
| 5/24/07 | 6.95 | 26.20 | 6.2 | 1.14 | 31.4 | 0.055 | 0.003 | 0.767 | 0.769 | 0.001 | 0.021 | 7.3 | 50 | 3.2 | 7.2 | 8 | 1 | 2.5 | 5 | 105 | < 3 | --- | 3 |
| 9/27/07 | 7.36 | 28.85 | 6.7 | 1.22 | 25.8 | 0.006 | 0.003 | 0.640 | 0.642 | 0.002 | 0.013 | 4.2 | 51 | 3.2 | 10.4 | 34 | 1 | 2.5 | 2 | 82 | 3 | --- | 4 |
| 12/11/07 | 7.40 | 21.58 | 8.2 | 0.88 | 28.0 | 0.054 | 0.006 | 0.840 | 0.846 | 0.005 | 0.018 | 2.6 | 78 | 2.0 | 10.6 | 27 | 1 | 2.5 | 3 | 141 | < 3 | --- | 1 |
| 3/31/08 | 7.58 | 23.20 | 8.3 | 0.93 | 28.2 | 0.051 | 0.003 | 0.873 | 0.875 | 0.001 | 0.025 | 4.2 | 71 | 2.2 | 17.3 | 4 | 2 | 2.5 | 2 | 79.4 | < 3 | --- | 1 |
| 5/14/08 | 7.51 | 26.52 | 7.0 | 1.35 | 30.2 | 0.022 | 0.003 | 0.963 | 0.965 | 0.001 | 0.023 | 5.5 | 62 | 3.1 | 18.0 | 1 | 1 | 2.5 | 8 | 81 | < 3 | --- | 3 |
| 9/30/08 | 7.26 | 27.34 | 6.0 | 0.85 | 39.8 | 0.034 | 0.003 | 0.717 | 0.719 | 0.004 | 0.032 | 2.5 | 109 | 2.4 | 44.7 | 20 | 1 | 2.5 | 2 | 81 | < 3 | --- | 1 |
| 12/23/08 | 8.12 | 17.50 | 7.5 | 0.73 | 41.0 | 0.027 | 0.151 | 0.637 | 0.788 | 0.002 | 0.034 | 7.4 | 106 | 2.2 | 4.1 | 47 | 1 | 2.5 | 2 | 114 | < 3 | --- | 42 |
| 3/17/09 | 8.10 | 24.15 | 8.2 | 0.82 | 44.8 | 0.177 | 0.003 | 0.772 | 0.774 | 0.003 | 0.031 | 15.0 | 111 | 2.7 | 45.8 | 2 | 1 | 2.5 | 12 | 73 | < 3 | --- | 3 |
| 5/12/09 | 7.59 | 29.74 | 7.0 | 0.83 | 48.2 | 0.028 | 0.009 | 0.776 | 0.785 | 0.002 | 0.025 | 3.6 | 52 | 3.2 | 17.6 | 2 | 1 | 1 | 3 | 234 | < 3 | --- | 69 |
| 8/18/09 | 6.84 | 29.93 | 4.4 | 0.72 | 40.8 | 0.014 | 0.003 | 0.835 | 0.837 | 0.003 | 0.018 | 2.2 | 119 | 3.5 | 42.7 | 25 | 1 | 1 | 2 | 232 | < 3 | --- | 1 |
| 12/2/09 | 7.15 | 19.49 | 7.5 | 0.87 | 38.0 | 0.082 | 0.005 | 0.698 | 0.703 | 0.001 | 0.029 | 2.0 | 36 | 2.0 | 19.2 | 13 | 1 | 1 | 2 | 63 | < 3 | --- | 1 |
| 3/30/10 | 7.20 | 19.98 | 7.7 | 0.93 | 29.2 | 0.032 | 0.011 | 0.859 | 0.870 | 0.002 | 0.020 | 1.7 | 75 | 2.0 | 9.1 | 8 | 1 | 4 | 2 | 68 | < 3 | --- | 1 |
| 6/29/10 | 7.44 | 31.28 | 6.5 | 0.84 | 35.4 | 0.040 | 0.005 | 0.798 | 0.803 | 0.001 | 0.015 | 2.7 | 76 | 2.0 | 23.2 | 3 | 1 | 1 | 2 | 138 | < 3 | --- | 4 |
| 9/14/10 | 6.99 | 30.47 | 6.3 | 1.24 | 40.0 | 0.010 | 0.012 | 0.574 | 0.586 | 0.002 | 0.012 | 1.8 | 78 | 2.1 | 17.0 | 2 | 1 | 1 | 2 | 111 | < 3 | --- | 1 |

# Historical Water Quality Data for North Lake Triplet

| Date | pH (s.u.) | Temperature ($^{o}$C) | Dissolved Oxygen (mg/l) | Secchi Depth (m) | Alkalinity (mg/l) | NH3 (mg/l) | NO3/NO2 (mg/l) | TKN (mg/l) | Total N (mg/l) | Ortho-P (mg/l) | Total P (mg/l) | Turbidity (NTU) | Color (Co - Pt units) | BOD (mg/l) | Chlorophyll-a (mg/m$^3$) | Fecal Coliform (# / 100 ml) | Cadmium (µg/l) | Chromium (µg/l) | Copper (µg/l) | Iron (µg/l) | Lead (µg/l) | Mercury (µg/l) | Zinc (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/29/10 | 6.81 | 9.50 | 2.3 | --- | 32.6 | 0.021 | 0.024 | 0.693 | 0.717 | 0.001 | 0.016 | 1.8 | 67 | 2.0 | 2.0 | 3 | 1 | 1 | 2 | --- | < 3 | --- | 12 |
| 3/23/11 | 7.10 | 23.82 | 7.3 | 1.80 | 36.8 | 0.038 | 0.003 | 0.457 | 0.457 | 0.001 | 0.012 | 1.4 | 50 | 2.0 | 8.9 | 2 | 1 | 1 | 4 | --- | < 3 | --- | 1 |
| **Minimum** | **6.12** | **9.50** | **2.3** | **0.50** | **14.0** | **<0.005** | **<0.005** | **0.457** | **0.457** | **<0.001** | **0.005** | **0.9** | **21** | **<2** | **2.0** | **2** | **<1** | **<5** | **<1** | **2** | **< 3** | | **1** |
| **Maximum** | **8.60** | **31.28** | **9.5** | **1.87** | **62.4** | **0.265** | **0.151** | **1.640** | **1.680** | **0.046** | **0.085** | **18.0** | **180** | **67.0** | **69** | **570** | **2** | **12** | **13** | **570** | **< 3** | | **69** |
| **Median** | **7.40** | **24.15** | **7.4** | **0.89** | **39.9** | **0.028** | **0.003** | **0.753** | **0.770** | **0.001** | **0.031** | **3.5** | **63** | **2.2** | **18.0** | **12** | **1** | **3** | **2** | **96** | **< 3** | | **3** |
| **Log-Mean** | **7.41** | **23.59** | **6.9** | **0.92** | **36.9** | **0.021** | **0.006** | **0.784** | **0.797** | **0.002** | **0.026** | **3.3** | **64** | **2.9** | **18.3** | **11** | **1** | **3** | **3** | **88** | **< 3** | | **4** |
| **Average** | **7.42** | **24.26** | **7.1** | **0.95** | **38.3** | **0.041** | **0.013** | **0.805** | **0.819** | **0.003** | **0.033** | **4.2** | **73** | **4.5** | **22.7** | **24** | **1** | **3** | **3** | **114** | **< 3** | | **9** |

# APPENDIX B

# HYDROLOGIC MODELING OF RUNOFF VOLUMES FOR QUEENS MIRROR LAKE, THE TRIPLET CHAIN-OF-LAKES, AND INTERCONNECTED WATERBODIES

0 **Crystal Bowl Lake**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 28.6 | 0.0 | 0.0 | 0.0 | 0.0 | 12.1 | 8.5 | 0.0 | 0.0 | 4.6 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | --- | --- | --- | --- | 80.0 | 77.0 | --- | --- | 98.0 |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | 0.0 | 0.0 | --- | --- | 100.0 |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | 0.0 | 0.0 | --- | --- | 0.0 |
| non DCIA CN | --- | --- | --- | --- | 87.9 | --- | --- | --- | --- | 80.0 | 77.0 | --- | | |
| S | --- | --- | --- | --- | 1.38 | --- | --- | --- | --- | 2.50 | 2.99 | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.46 | --- | --- | --- | --- | 0.00 | 0.00 | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.75 | --- | --- | --- | --- | 0.00 | 0.00 | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.87 | --- | --- | --- | --- | 0.00 | 0.00 | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 1.21 | --- | --- | --- | --- | 0.00 | 0.00 | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 8.15 | --- | --- | --- | --- | 0.29 | 0.05 | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 8.97 | --- | --- | --- | --- | 1.16 | 0.54 | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 7.11 | --- | --- | --- | --- | 1.32 | 0.71 | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 5.26 | --- | --- | --- | --- | 1.17 | 0.67 | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 3.45 | --- | --- | --- | --- | 0.86 | 0.50 | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 9.95 | --- | --- | --- | --- | 3.01 | 1.88 | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 46.19 | 0.00 | 0.00 | 0.00 | 0.00 | 7.80 | 4.35 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.293 | --- | --- | --- | --- | 0.117 | 0.093 | --- | | |

1 **Lake Annette 1**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | 70.6 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 77.0 | --- | --- | --- |
| Percent Impervious Area | 70.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- | --- |
| Percent Impervious DCIA | 85.7 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | 60.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- | --- |
| non DCIA CN | 77.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 77.0 | --- | | |
| S | 2.91 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 2.99 | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.12 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.19 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.21 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.25 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | 1.24 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | 1.03 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.73 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.51 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.32 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | | |
| >3.01 | 4.425 | 1.242 | 0.88 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.01 | --- | | |
| Generated Volume (ac-ft/yr) | | | 5.49 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | | |
| Weighted Basin "C" Value | | | 0.407 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.093 | --- | | |

2 **Lake Annette Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.2 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 1.1 | 0.0 | 0.7 |
| Pervious Area CN | 72.0 | --- | --- | --- | 70.3 | --- | --- | --- | 86.0 | --- | 71.7 | 74.5 | --- | 98.0 |
| Percent Impervious Area | 70.0 | --- | --- | --- | 40.0 | --- | --- | --- | 95.0 | --- | 0.0 | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | 85.7 | --- | --- | --- | 50.0 | --- | --- | --- | 94.7 | --- | --- | --- | --- | --- |
| DCIA | 60.0 | --- | --- | --- | 20.0 | --- | --- | --- | 90.0 | --- | 0.0 | 0.0 | --- | 0.0 |
| non DCIA CN | 78.5 | --- | --- | --- | 77.2 | --- | --- | --- | 92.0 | --- | 71.7 | 74.5 | | |
| S | 2.74 | --- | --- | --- | 2.96 | --- | --- | --- | 0.87 | --- | 3.96 | 3.42 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.01 | --- | --- | --- | 0.02 | --- | --- | --- | 0.00 | --- | 0.00 | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.02 | --- | --- | --- | 0.03 | --- | --- | --- | 0.00 | --- | 0.00 | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.02 | --- | --- | --- | 0.03 | --- | --- | --- | 0.00 | --- | 0.00 | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.03 | --- | --- | --- | 0.04 | --- | --- | --- | 0.00 | --- | 0.00 | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.13 | --- | --- | --- | 0.20 | --- | --- | --- | 0.02 | --- | 0.00 | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.11 | --- | --- | --- | 0.21 | --- | --- | --- | 0.02 | --- | 0.10 | 0.05 | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.08 | --- | --- | --- | 0.18 | --- | --- | --- | 0.01 | --- | 0.19 | 0.07 | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.05 | --- | --- | --- | 0.14 | --- | --- | --- | 0.01 | --- | 0.21 | 0.07 | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.03 | --- | --- | --- | 0.09 | --- | --- | --- | 0.00 | --- | 0.17 | 0.06 | | |
| >3.01 | 4.425 | 1.242 | 0.09 | --- | --- | --- | 0.30 | --- | --- | --- | 0.01 | --- | 0.72 | 0.23 | | |
| Generated Volume (ac-ft/yr) | | | 0.56 | 0.00 | 0.00 | 0.00 | 1.23 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 1.39 | 0.48 | | |
| Weighted Basin "C" Value | | | 0.410 | --- | --- | --- | 0.199 | --- | --- | --- | 0.583 | --- | 0.063 | 0.078 | | |

3 **Lake Cecile Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 | 7.6 | 0.0 | 2.3 |
| Pervious Area CN | --- | --- | --- | --- | 71.1 | --- | --- | --- | --- | --- | 75.9 | 77.0 | --- | 98.0 |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | 0.0 | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | 0.0 | 0.0 | --- | 0.0 |
| non DCIA CN | --- | --- | --- | --- | 77.8 | --- | --- | --- | --- | --- | 75.9 | 77.0 | | |
| S | --- | --- | --- | --- | 2.85 | --- | --- | --- | --- | --- | 3.18 | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.03 | --- | --- | --- | --- | --- | 0.00 | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.06 | --- | --- | --- | --- | --- | 0.00 | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.06 | --- | --- | --- | --- | --- | 0.00 | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.07 | --- | --- | --- | --- | --- | 0.00 | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.37 | --- | --- | --- | --- | --- | 0.01 | 0.05 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 0.40 | --- | --- | --- | --- | --- | 0.24 | 0.48 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.34 | --- | --- | --- | --- | --- | 0.34 | 0.63 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.27 | --- | --- | --- | --- | --- | 0.33 | 0.60 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.18 | --- | --- | --- | --- | --- | 0.25 | 0.45 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 0.58 | --- | --- | --- | --- | --- | 0.96 | 1.69 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 2.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.13 | 3.90 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.202 | --- | --- | --- | --- | --- | 0.086 | 0.093 | | |

4 **Lake Emily Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 1.7 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 3.7 | 2.0 | 0.0 | 15.2 |
| Pervious Area CN | 66.5 | --- | --- | --- | 55.5 | --- | --- | --- | --- | 78.2 | 57.2 | 77.0 | --- | 98.0 |
| Percent Impervious Area | 25.0 | --- | --- | --- | 40.0 | --- | --- | --- | --- | 0.0 | 0.0 | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | 20.0 | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | 5.0 | --- | --- | --- | 20.0 | --- | --- | --- | --- | 0.0 | 0.0 | 0.0 | --- | 0.0 |
| | | | | | | | | | | | | | | |
| non DCIA CN | 73.1 | --- | --- | --- | 66.1 | --- | --- | --- | --- | 78.2 | 57.2 | 77.0 | | |
| S | 3.67 | --- | --- | --- | 5.12 | --- | --- | --- | --- | 2.78 | 7.48 | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.01 | --- | --- | --- | 0.02 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.01 | --- | --- | --- | 0.03 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.01 | --- | --- | --- | 0.04 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.01 | --- | --- | --- | 0.04 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.07 | --- | --- | --- | 0.21 | --- | --- | --- | --- | 0.05 | 0.00 | 0.01 | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.11 | --- | --- | --- | 0.17 | --- | --- | --- | --- | 0.30 | 0.00 | 0.13 | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.13 | --- | --- | --- | 0.13 | --- | --- | --- | --- | 0.37 | 0.01 | 0.17 | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.12 | --- | --- | --- | 0.10 | --- | --- | --- | --- | 0.34 | 0.03 | 0.16 | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.09 | --- | --- | --- | 0.07 | --- | --- | --- | --- | 0.26 | 0.04 | 0.12 | | |
| >3.01 | 4.425 | 1.242 | 0.34 | --- | --- | --- | 0.25 | --- | --- | --- | --- | 0.93 | 0.31 | 0.46 | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.89 | 0.00 | 0.00 | 0.00 | 1.07 | 0.00 | 0.00 | 0.00 | 0.00 | 2.26 | 0.40 | 1.05 | | |
| Weighted Basin "C" Value | | | 0.098 | --- | --- | --- | 0.156 | --- | --- | --- | --- | 0.102 | 0.020 | 0.093 | | |

5 **Lake Marie**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.3 | 0.0 | 0.0 | 0.0 | 2.9 | 0.0 | 0.0 | 0.0 | 0.0 | 14.5 | 3.2 | 2.0 | 0.0 | 5.0 |
| Pervious Area CN | 51.4 | --- | --- | --- | 55.8 | --- | --- | --- | --- | 60.5 | 30.9 | 59.2 | --- | 98.0 |
| Percent Impervious Area | 25.0 | --- | --- | --- | 40.0 | --- | --- | --- | --- | 0.0 | 0.0 | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | 20.0 | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | 5.0 | --- | --- | --- | 20.0 | --- | --- | --- | --- | 0.0 | 0.0 | 0.0 | --- | 0.0 |
| | | | | | | | | | | | | | | |
| non DCIA CN | 61.2 | --- | --- | --- | 66.3 | --- | --- | --- | --- | 60.5 | 30.9 | 59.2 | | |
| S | 6.33 | --- | --- | --- | 5.07 | --- | --- | --- | --- | 6.54 | 22.32 | 6.88 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.00 | --- | --- | --- | 0.05 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.00 | --- | --- | --- | 0.08 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.00 | --- | --- | --- | 0.08 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.00 | --- | --- | --- | 0.10 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.01 | --- | --- | --- | 0.48 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.01 | --- | --- | --- | 0.39 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.01 | --- | --- | --- | 0.31 | --- | --- | --- | --- | 0.10 | 0.00 | 0.01 | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.01 | --- | --- | --- | 0.24 | --- | --- | --- | --- | 0.23 | 0.00 | 0.03 | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.01 | --- | --- | --- | 0.17 | --- | --- | --- | --- | 0.24 | 0.00 | 0.03 | | |
| >3.01 | 4.425 | 1.242 | 0.03 | --- | --- | --- | 0.58 | --- | --- | --- | --- | 1.51 | 0.00 | 0.19 | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.08 | 0.00 | 0.00 | 0.00 | 2.48 | 0.00 | 0.00 | 0.00 | 0.00 | 2.08 | 0.00 | 0.25 | | |
| Weighted Basin "C" Value | | | 0.057 | --- | --- | --- | 0.156 | --- | --- | --- | --- | 0.026 | 0.000 | 0.023 | | |

6 **Lake Marie 1**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 8.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 77.3 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 82.5 | --- | --- | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 2.12 | --- | --- | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.14 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.23 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.25 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.30 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.78 | --- | --- | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 2.02 | --- | --- | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.67 | --- | --- | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.28 | --- | --- | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.86 | --- | --- | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.63 | --- | --- | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 11.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.236 | --- | --- | --- | --- | --- | --- | --- | | |

7 **Lake Marie 2**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 2.8 | 0.0 | 0.0 | 0.0 | 22.0 | 0.0 | 0.0 | 6.9 | 0.3 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | 53.8 | --- | --- | --- | 71.8 | --- | --- | 69.9 | 68.5 | 39.0 | --- | --- | --- | --- |
| Percent Impervious Area | 40.0 | --- | --- | --- | 40.0 | --- | --- | 5.0 | 95.0 | 0.0 | --- | --- | --- | --- |
| Percent Impervious DCIA | 50.0 | --- | --- | --- | 50.0 | --- | --- | --- | 94.7 | --- | --- | --- | --- | --- |
| DCIA | 20.0 | --- | --- | --- | 20.0 | --- | --- | 0.0 | 90.0 | 0.0 | --- | --- | --- | --- |
| non DCIA CN | 64.8 | --- | --- | --- | 78.3 | --- | --- | 71.3 | 83.3 | 39.0 | --- | --- | | |
| S | 5.43 | --- | --- | --- | 2.76 | --- | --- | 4.03 | 2.01 | 15.64 | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.04 | --- | --- | --- | 0.35 | --- | --- | 0.00 | 0.02 | 0.00 | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.07 | --- | --- | --- | 0.58 | --- | --- | 0.00 | 0.04 | 0.00 | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.08 | --- | --- | --- | 0.63 | --- | --- | 0.00 | 0.04 | 0.00 | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.10 | --- | --- | --- | 0.76 | --- | --- | 0.00 | 0.05 | 0.00 | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.47 | --- | --- | --- | 3.92 | --- | --- | 0.00 | 0.25 | 0.00 | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.37 | --- | --- | --- | 4.26 | --- | --- | 0.16 | 0.20 | 0.00 | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.28 | --- | --- | --- | 3.59 | --- | --- | 0.32 | 0.14 | 0.00 | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.22 | --- | --- | --- | 2.81 | --- | --- | 0.35 | 0.09 | 0.00 | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.15 | --- | --- | --- | 1.92 | --- | --- | 0.28 | 0.06 | 0.00 | --- | --- | | |
| >3.01 | 4.425 | 1.242 | 0.54 | --- | --- | --- | 6.08 | --- | --- | 1.21 | 0.14 | 0.01 | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 2.32 | 0.00 | 0.00 | 0.00 | 24.89 | 0.00 | 0.00 | 2.32 | 1.04 | 0.01 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | 0.153 | --- | --- | --- | 0.205 | --- | --- | 0.061 | 0.568 | 0.002 | --- | --- | | |

8 **Lake Yvonne 1a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 18.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | --- | --- | --- | --- | --- | --- | 77.0 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 87.9 | --- | --- | --- | --- | --- | --- | 77.0 | | |
| S | --- | --- | --- | --- | 1.38 | --- | --- | --- | --- | --- | --- | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.30 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.49 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.57 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.79 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 5.33 | --- | --- | --- | --- | --- | --- | 0.01 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 5.86 | --- | --- | --- | --- | --- | --- | 0.06 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 4.64 | --- | --- | --- | --- | --- | --- | 0.07 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 3.44 | --- | --- | --- | --- | --- | --- | 0.07 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 2.25 | --- | --- | --- | --- | --- | --- | 0.05 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 6.50 | --- | --- | --- | --- | --- | --- | 0.19 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 30.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.44 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.293 | --- | --- | --- | --- | --- | --- | 0.093 | | |

9 **Lake Yvonne 1b**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 74.4 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | --- | --- | 80.9 | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | 5.0 | --- | --- | --- | --- | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | 0.0 | --- | --- | --- | --- | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | 87.9 | --- | --- | 81.8 | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 1.38 | --- | --- | 2.23 | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 1.20 | --- | --- | 0.00 | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 1.95 | --- | --- | 0.00 | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 2.27 | --- | --- | 0.00 | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 3.15 | --- | --- | 0.00 | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 21.20 | --- | --- | 0.02 | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 23.32 | --- | --- | 0.07 | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 18.47 | --- | --- | 0.07 | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 13.68 | --- | --- | 0.06 | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 8.97 | --- | --- | 0.04 | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 25.85 | --- | --- | 0.15 | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 120.06 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.293 | --- | --- | 0.133 | --- | --- | --- | --- | | |

10 **Lake Yvonne Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 10.7 | 0.0 | 0.0 | 0.0 | 0.0 | 5.1 | 0.9 | 10.4 | 0.0 | 3.7 |
| Pervious Area CN | --- | --- | --- | --- | 70.6 | --- | --- | --- | --- | 54.9 | 70.3 | 68.0 | --- | 98.0 |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | 0.0 | 0.0 | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | 0.0 | 0.0 | 0.0 | --- | 0.0 |
| | | | | | | | | | | | | | | |
| non DCIA CN | --- | --- | --- | --- | 77.4 | --- | --- | --- | --- | 54.9 | 70.3 | 68.0 | | |
| S | --- | --- | --- | --- | 2.91 | --- | --- | --- | --- | 8.22 | 4.23 | 4.70 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.17 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.28 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.31 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.37 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.87 | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.99 | --- | --- | --- | --- | 0.00 | 0.02 | 0.10 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.68 | --- | --- | --- | --- | 0.00 | 0.04 | 0.32 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.32 | --- | --- | --- | --- | 0.03 | 0.04 | 0.39 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.91 | --- | --- | --- | --- | 0.04 | 0.04 | 0.34 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.89 | --- | --- | --- | --- | 0.37 | 0.16 | 1.60 | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 11.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.44 | 0.30 | 2.75 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.200 | --- | --- | --- | --- | 0.016 | 0.057 | 0.048 | | |

11 **Lost Lake 1a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.8 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 70.4 | --- | --- | --- | --- | --- | --- | 76.2 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| | | | | | | | | | | | | | | |
| non DCIA CN | --- | --- | --- | --- | 77.3 | --- | --- | --- | --- | --- | --- | 76.2 | | |
| S | --- | --- | --- | --- | 2.94 | --- | --- | --- | --- | --- | --- | 3.11 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.01 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.01 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.01 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.02 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.09 | --- | --- | --- | --- | --- | --- | 0.01 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 0.10 | --- | --- | --- | --- | --- | --- | 0.22 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.08 | --- | --- | --- | --- | --- | --- | 0.30 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.06 | --- | --- | --- | --- | --- | --- | 0.28 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.04 | --- | --- | --- | --- | --- | --- | 0.22 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 0.14 | --- | --- | --- | --- | --- | --- | 0.82 | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.85 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.199 | --- | --- | --- | --- | --- | --- | 0.088 | | |

12 **Lost Lake 1b1**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 49.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.9 | 3.2 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 72.6 | --- | --- | --- | --- | --- | --- | 77.0 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | 78.9 | --- | --- | --- | --- | --- | --- | 77.0 | | |
| S | --- | --- | --- | --- | 2.67 | --- | --- | --- | --- | --- | --- | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.79 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 1.29 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 1.41 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 1.69 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 8.93 | --- | --- | --- | --- | --- | --- | 0.02 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 9.79 | --- | --- | --- | --- | --- | --- | 0.19 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 8.24 | --- | --- | --- | --- | --- | --- | 0.24 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 6.43 | --- | --- | --- | --- | --- | --- | 0.23 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 4.38 | --- | --- | --- | --- | --- | --- | 0.17 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 13.83 | --- | --- | --- | --- | --- | --- | 0.65 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 56.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.51 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.209 | --- | --- | --- | --- | --- | --- | 0.093 | | |

13 **Lost Lake 1b2**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 10.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 1.5 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 70.4 | --- | --- | --- | --- | --- | --- | 77.0 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | 77.3 | --- | --- | --- | --- | --- | --- | 77.0 | | |
| S | --- | --- | --- | --- | 2.93 | --- | --- | --- | --- | --- | --- | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.17 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.28 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.31 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.37 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.87 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.99 | --- | --- | --- | --- | --- | --- | 0.02 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.68 | --- | --- | --- | --- | --- | --- | 0.02 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.32 | --- | --- | --- | --- | --- | --- | 0.02 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.91 | --- | --- | --- | --- | --- | --- | 0.01 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.90 | --- | --- | --- | --- | --- | --- | 0.05 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 11.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.199 | --- | --- | --- | --- | --- | --- | 0.093 | | |

14 **Lost Lake 1b3**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 1.5 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 11.3 | 0.0 | 0.5 | 0.0 | 2.9 | 0.0 |
| Pervious Area CN | 63.1 | --- | --- | --- | 75.9 | --- | --- | --- | 83.7 | 39.0 | 64.5 | --- | --- | --- |
| Percent Impervious Area | 36.7 | --- | --- | --- | 40.0 | --- | --- | --- | 95.0 | 0.0 | 0.0 | --- | 100.0 | --- |
| Percent Impervious DCIA | 54.3 | --- | --- | --- | 50.0 | --- | --- | --- | 94.7 | --- | --- | --- | 100.0 | --- |
| DCIA | 20.0 | --- | --- | --- | 20.0 | --- | --- | --- | 90.0 | 0.0 | 0.0 | --- | 100.0 | --- |
| non DCIA CN | 70.4 | --- | --- | --- | 81.4 | --- | --- | --- | 90.9 | 39.0 | 64.5 | --- | | |
| S | 4.20 | --- | --- | --- | 2.28 | --- | --- | --- | 1.01 | 15.64 | 5.50 | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.02 | --- | --- | --- | 0.08 | --- | --- | --- | 0.82 | 0.00 | 0.00 | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.04 | --- | --- | --- | 0.13 | --- | --- | --- | 1.34 | 0.00 | 0.00 | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.04 | --- | --- | --- | 0.14 | --- | --- | --- | 1.47 | 0.00 | 0.00 | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.05 | --- | --- | --- | 0.17 | --- | --- | --- | 1.78 | 0.00 | 0.00 | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.25 | --- | --- | --- | 0.98 | --- | --- | --- | 8.86 | 0.00 | 0.00 | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.22 | --- | --- | --- | 1.11 | --- | --- | --- | 7.07 | 0.00 | 0.00 | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.18 | --- | --- | --- | 0.93 | --- | --- | --- | 4.76 | 0.00 | 0.01 | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.14 | --- | --- | --- | 0.71 | --- | --- | --- | 3.19 | 0.00 | 0.01 | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.10 | --- | --- | --- | 0.48 | --- | --- | --- | 1.96 | 0.00 | 0.01 | --- | | |
| >3.01 | 4.425 | 1.242 | 0.34 | --- | --- | --- | 1.49 | --- | --- | --- | 4.97 | 0.00 | 0.06 | --- | | |
| Generated Volume (ac-ft/yr) | | | 1.40 | 0.00 | 0.00 | 0.00 | 6.23 | 0.00 | 0.00 | 0.00 | 36.21 | 0.00 | 0.09 | 0.00 | | |
| Weighted Basin "C" Value | | | 0.169 | --- | --- | --- | 0.227 | --- | --- | --- | 0.580 | 0.002 | 0.036 | --- | | |

15 **Lost Lake 1b4**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 14.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.1 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 65.6 | --- | --- | --- | --- | 51.0 | --- | 72.6 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | 0.0 | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | 0.0 | --- | 0.0 | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 73.7 | --- | --- | --- | --- | 51.0 | --- | 72.6 | | |
| S | --- | --- | --- | --- | 3.57 | --- | --- | --- | --- | 9.59 | --- | 3.77 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.23 | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.38 | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.41 | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.49 | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 2.41 | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 2.32 | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.95 | --- | --- | --- | --- | 0.00 | --- | 0.01 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.54 | --- | --- | --- | --- | 0.00 | --- | 0.01 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 1.07 | --- | --- | --- | --- | 0.00 | --- | 0.01 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 3.53 | --- | --- | --- | --- | 0.03 | --- | 0.02 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 14.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.05 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.181 | --- | --- | --- | --- | 0.011 | --- | 0.068 | | |

16 **Lost Lake 2a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | 0.9 | 0.0 | 0.0 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 70.3 | --- | 62.9 | --- | --- | 61.0 | 77.0 | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 5.0 | --- | --- | 0.0 | 0.0 | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 0.0 | --- | --- | 0.0 | 0.0 | --- | --- | --- |
| | | | | | | | | | | | | | | |
| non DCIA CN | --- | --- | --- | --- | 77.2 | --- | 64.6 | --- | --- | 61.0 | 77.0 | --- | | |
| S | --- | --- | --- | --- | 2.96 | --- | 5.48 | --- | --- | 6.39 | 2.99 | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.04 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.07 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.07 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.09 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.43 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 0.46 | --- | 0.00 | --- | --- | 0.00 | 0.01 | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.39 | --- | 0.02 | --- | --- | 0.00 | 0.02 | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.30 | --- | 0.02 | --- | --- | 0.01 | 0.01 | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.21 | --- | 0.02 | --- | --- | 0.01 | 0.01 | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 0.67 | --- | 0.12 | --- | --- | 0.04 | 0.04 | --- | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 2.72 | 0.00 | 0.19 | 0.00 | 0.00 | 0.05 | 0.09 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.199 | --- | 0.036 | --- | --- | 0.027 | 0.093 | --- | | |

17 **Lost Lake 2b**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 15.8 | 0.0 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 75.4 | --- | 64.0 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 5.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 0.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| | | | | | | | | | | | | | | |
| non DCIA CN | --- | --- | --- | --- | 81.0 | --- | 65.7 | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 2.34 | --- | 5.21 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.25 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.41 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.45 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.54 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 3.07 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 3.45 | --- | 0.02 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 2.88 | --- | 0.10 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 2.23 | --- | 0.14 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 1.51 | --- | 0.13 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 4.66 | --- | 0.65 | --- | --- | --- | --- | --- | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 19.47 | 0.00 | 1.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.224 | --- | 0.040 | --- | --- | --- | --- | --- | | |

18 **Lost Lake 2c**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 | 0.0 | 8.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | --- | 80.9 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 5.0 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 0.0 | --- | --- | --- | --- | --- | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 87.9 | --- | 81.8 | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 1.38 | --- | 2.23 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.16 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.26 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.30 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.41 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 2.77 | --- | 0.34 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 3.05 | --- | 1.01 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 2.41 | --- | 1.08 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.79 | --- | 0.93 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 1.17 | --- | 0.66 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 3.38 | --- | 2.26 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 15.69 | 0.00 | 6.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.293 | --- | 0.133 | --- | --- | --- | --- | --- | | |

19 **Lost Lake Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 11.4 | 0.0 | 1.9 | 0.0 | 0.0 | 1.8 | 0.0 | 17.0 | 0.0 | 12.8 |
| Pervious Area CN | --- | --- | --- | --- | 67.5 | --- | 62.5 | --- | --- | 61.0 | --- | 76.9 | --- | 98.0 |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 5.0 | --- | --- | 0.0 | --- | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 0.0 | --- | --- | 0.0 | --- | 0.0 | --- | 0.0 |
| non DCIA CN | --- | --- | --- | --- | 75.1 | --- | 64.3 | --- | --- | 61.0 | --- | 76.9 | | |
| S | --- | --- | --- | --- | 3.31 | --- | 5.56 | --- | --- | 6.39 | --- | 3.01 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.18 | --- | 0.00 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.30 | --- | 0.00 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.33 | --- | 0.00 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.39 | --- | 0.00 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.93 | --- | 0.00 | --- | --- | 0.00 | --- | 0.10 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.94 | --- | 0.00 | --- | --- | 0.00 | --- | 1.06 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.63 | --- | 0.03 | --- | --- | 0.01 | --- | 1.40 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.29 | --- | 0.05 | --- | --- | 0.03 | --- | 1.33 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.89 | --- | 0.05 | --- | --- | 0.03 | --- | 1.00 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.91 | --- | 0.25 | --- | --- | 0.19 | --- | 3.76 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 11.79 | 0.00 | 0.38 | 0.00 | 0.00 | 0.27 | 0.00 | 8.65 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.188 | --- | 0.035 | --- | --- | 0.027 | --- | 0.093 | | |

20 **Middle Lake Triplet 1a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 13.9 | 0.0 | 2.5 | 0.0 | 0.0 | 0.9 | 0.0 | 0.1 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 75.4 | --- | 60.8 | --- | --- | 74.0 | --- | 45.1 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 14.6 | --- | --- | 0.0 | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | 65.8 | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 9.6 | --- | --- | 0.0 | --- | 0.0 | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 81.1 | --- | 62.9 | --- | --- | 74.0 | --- | 45.1 | | |
| S | --- | --- | --- | --- | 2.34 | --- | 5.91 | --- | --- | 3.51 | --- | 12.16 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.22 | --- | 0.02 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.36 | --- | 0.03 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.40 | --- | 0.03 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.48 | --- | 0.04 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 2.70 | --- | 0.20 | --- | --- | 0.00 | --- | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 3.04 | --- | 0.16 | --- | --- | 0.04 | --- | 0.00 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 2.54 | --- | 0.13 | --- | --- | 0.06 | --- | 0.00 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.96 | --- | 0.12 | --- | --- | 0.06 | --- | 0.00 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 1.33 | --- | 0.09 | --- | --- | 0.05 | --- | 0.00 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 4.10 | --- | 0.37 | --- | --- | 0.19 | --- | 0.00 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 17.14 | 0.00 | 1.19 | 0.00 | 0.00 | 0.39 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.224 | --- | 0.088 | --- | --- | 0.075 | --- | 0.005 | | |

21 **Middle Lake Triplet 1b**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 0.1 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 68.0 | --- | 75.3 | --- | --- | --- | --- | 75.0 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 15.0 | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | 66.7 | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 10.0 | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | 75.5 | --- | 76.6 | --- | --- | --- | --- | 75.0 | | |
| S | --- | --- | --- | --- | 3.25 | --- | 3.06 | --- | --- | --- | --- | 3.34 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.04 | --- | 0.01 | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.07 | --- | 0.02 | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.07 | --- | 0.02 | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.09 | --- | 0.03 | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.43 | --- | 0.13 | --- | --- | --- | --- | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 0.44 | --- | 0.18 | --- | --- | --- | --- | 0.08 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.37 | --- | 0.17 | --- | --- | --- | --- | 0.12 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.29 | --- | 0.15 | --- | --- | --- | --- | 0.12 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.20 | --- | 0.10 | --- | --- | --- | --- | 0.09 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 0.66 | --- | 0.36 | --- | --- | --- | --- | 0.36 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 2.66 | 0.00 | 1.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.78 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.190 | --- | 0.143 | --- | --- | --- | --- | 0.081 | | |

22 **Middle Lake Triplet 1c**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.8 | 0.0 | 0.0 | 0.0 | 23.1 | 0.0 | 6.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | 86.0 | --- | --- | --- | 84.5 | --- | 80.9 | --- | --- | 80.0 | 77.0 | --- | --- | --- |
| Percent Impervious Area | 90.0 | --- | --- | --- | 40.0 | --- | 5.0 | --- | --- | 0.0 | 0.0 | --- | --- | --- |
| Percent Impervious DCIA | 94.4 | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | 85.0 | --- | --- | --- | 20.0 | --- | 0.0 | --- | --- | 0.0 | 0.0 | --- | --- | --- |
| non DCIA CN | 90.0 | --- | --- | --- | 87.9 | --- | 81.8 | --- | --- | 80.0 | 77.0 | --- | | |
| S | 1.11 | --- | --- | --- | 1.38 | --- | 2.23 | --- | --- | 2.50 | 2.99 | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.05 | --- | --- | --- | 0.37 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.09 | --- | --- | --- | 0.61 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.10 | --- | --- | --- | 0.70 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.12 | --- | --- | --- | 0.98 | --- | 0.00 | --- | --- | 0.00 | 0.00 | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.60 | --- | --- | --- | 6.57 | --- | 0.24 | --- | --- | 0.00 | 0.00 | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.48 | --- | --- | --- | 7.23 | --- | 0.71 | --- | --- | 0.02 | 0.01 | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.33 | --- | --- | --- | 5.72 | --- | 0.75 | --- | --- | 0.02 | 0.02 | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.22 | --- | --- | --- | 4.24 | --- | 0.65 | --- | --- | 0.02 | 0.02 | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.14 | --- | --- | --- | 2.78 | --- | 0.46 | --- | --- | 0.01 | 0.01 | --- | | |
| >3.01 | 4.425 | 1.242 | 0.35 | --- | --- | --- | 8.01 | --- | 1.58 | --- | --- | 0.05 | 0.05 | --- | | |
| Generated Volume (ac-ft/yr) | | | 2.47 | 0.00 | 0.00 | 0.00 | 37.21 | 0.00 | 4.38 | 0.00 | 0.00 | 0.12 | 0.11 | 0.00 | | |
| Weighted Basin "C" Value | | | 0.560 | --- | --- | --- | 0.293 | --- | 0.133 | --- | --- | 0.117 | 0.093 | --- | | |

23 **Middle Lake Triplet 1d**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 4.8 | 0.5 | 7.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | 84.5 | 80.9 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | 70.0 | 5.0 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | 85.7 | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | 60.0 | 0.0 | --- | --- | --- | --- | --- | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 87.9 | 87.9 | 81.8 | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 1.38 | 1.38 | 2.23 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.08 | 0.03 | 0.00 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.13 | 0.04 | 0.00 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.15 | 0.05 | 0.00 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.20 | 0.06 | 0.00 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.38 | 0.30 | 0.31 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.51 | 0.26 | 0.93 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.20 | 0.18 | 0.99 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.89 | 0.13 | 0.86 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.58 | 0.08 | 0.61 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 1.68 | 0.21 | 2.08 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 7.80 | 1.34 | 5.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.293 | 0.454 | 0.133 | --- | --- | --- | --- | --- | | |

24 **Middle Lake Triplet 1e**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 2.9 | 0.0 | 0.0 | 0.0 | 2.7 | 4.2 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | 0.8 | 2.1 | 0.0 |
| Pervious Area CN | 86.0 | --- | --- | --- | 84.5 | 84.5 | --- | --- | --- | 80.0 | --- | 77.0 | --- | --- |
| Percent Impervious Area | 90.0 | --- | --- | --- | 40.0 | 70.0 | --- | --- | --- | 0.0 | --- | 0.0 | 100.0 | --- |
| Percent Impervious DCIA | 94.4 | --- | --- | --- | 50.0 | 85.7 | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | 85.0 | --- | --- | --- | 20.0 | 60.0 | --- | --- | --- | 0.0 | --- | 0.0 | 100.0 | --- |
| non DCIA CN | 90.0 | --- | --- | --- | 87.9 | 87.9 | --- | --- | --- | 80.0 | --- | 77.0 | | |
| S | 1.11 | --- | --- | --- | 1.38 | 1.38 | --- | --- | --- | 2.50 | --- | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.20 | --- | --- | --- | 0.04 | 0.21 | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.32 | --- | --- | --- | 0.07 | 0.33 | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.36 | --- | --- | --- | 0.08 | 0.37 | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.43 | --- | --- | --- | 0.11 | 0.45 | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 2.16 | --- | --- | --- | 0.76 | 2.39 | --- | --- | --- | 0.06 | --- | 0.01 | | |
| 1.01-1.50 | 1.225 | 7.032 | 1.74 | --- | --- | --- | 0.83 | 2.06 | --- | --- | --- | 0.24 | --- | 0.05 | | |
| 1.51-2.00 | 1.725 | 3.242 | 1.18 | --- | --- | --- | 0.66 | 1.46 | --- | --- | --- | 0.27 | --- | 0.07 | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.79 | --- | --- | --- | 0.49 | 1.01 | --- | --- | --- | 0.24 | --- | 0.06 | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.49 | --- | --- | --- | 0.32 | 0.63 | --- | --- | --- | 0.17 | --- | 0.05 | | |
| >3.01 | 4.425 | 1.242 | 1.25 | --- | --- | --- | 0.92 | 1.69 | --- | --- | --- | 0.61 | --- | 0.18 | | |
| Generated Volume (ac-ft/yr) | | | 8.91 | 0.00 | 0.00 | 0.00 | 4.28 | 10.60 | 0.00 | 0.00 | 0.00 | 1.59 | 0.00 | 0.42 | | |
| Weighted Basin "C" Value | | | 0.560 | --- | --- | --- | 0.293 | 0.454 | --- | --- | --- | 0.117 | --- | 0.093 | | |

25 **Middle Lake Triplet 2a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 6.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | --- | --- | --- | --- | --- | --- | 77.0 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 87.8 | --- | --- | --- | --- | --- | --- | 77.0 | | |
| S | --- | --- | --- | --- | 1.38 | --- | --- | --- | --- | --- | --- | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.10 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.17 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.19 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.27 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.80 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.98 | --- | --- | --- | --- | --- | --- | 0.01 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.57 | --- | --- | --- | --- | --- | --- | 0.01 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.16 | --- | --- | --- | --- | --- | --- | 0.01 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.76 | --- | --- | --- | --- | --- | --- | 0.01 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.20 | --- | --- | --- | --- | --- | --- | 0.03 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 10.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.292 | --- | --- | --- | --- | --- | --- | 0.093 | | |

26 **Middle Lake Triplet 2b**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.3 | 14.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | 83.6 | 84.5 | --- | --- | --- | --- | --- | --- | 77.0 | --- | --- |
| Percent Impervious Area | --- | --- | --- | 20.0 | 40.0 | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | 0.0 | 20.0 | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| | | | | | | | | | | | | | | |
| non DCIA CN | --- | --- | --- | 86.5 | 87.9 | --- | --- | --- | --- | --- | --- | 77.0 | | |
| S | --- | --- | --- | 1.56 | 1.38 | --- | --- | --- | --- | --- | --- | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | 0.00 | 0.23 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | 0.00 | 0.38 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | 0.00 | 0.44 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | 0.00 | 0.61 | --- | --- | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | 0.03 | 4.10 | --- | --- | --- | --- | --- | --- | 0.02 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | 0.06 | 4.51 | --- | --- | --- | --- | --- | --- | 0.23 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | 0.05 | 3.57 | --- | --- | --- | --- | --- | --- | 0.30 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | 0.04 | 2.65 | --- | --- | --- | --- | --- | --- | 0.29 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | 0.03 | 1.73 | --- | --- | --- | --- | --- | --- | 0.22 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | 0.09 | 5.00 | --- | --- | --- | --- | --- | --- | 0.81 | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.30 | 23.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.87 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | 0.191 | 0.293 | --- | --- | --- | --- | --- | --- | 0.093 | | |

27 **Middle Lake Triplet Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.3 | 0.0 | 0.0 | 0.0 | 17.9 | 0.0 | 2.2 | 0.0 | 0.0 | 10.4 | 0.0 | 21.2 | 0.0 | 39.3 |
| Pervious Area CN | 73.6 | --- | --- | --- | 79.7 | --- | 73.8 | --- | --- | 74.7 | --- | 76.4 | --- | 98.0 |
| Percent Impervious Area | 50.0 | --- | --- | --- | 40.0 | --- | 14.3 | --- | --- | 0.0 | --- | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | 60.0 | --- | --- | --- | 50.0 | --- | 65.0 | --- | --- | --- | --- | --- | --- | --- |
| DCIA | 30.0 | --- | --- | --- | 20.0 | --- | 9.3 | --- | --- | 0.0 | --- | 0.0 | --- | 0.0 |
| | | | | | | | | | | | | | | |
| non DCIA CN | 80.6 | --- | --- | --- | 84.3 | --- | 75.1 | --- | --- | 74.7 | --- | 76.4 | | |
| S | 2.41 | --- | --- | --- | 1.87 | --- | 3.31 | --- | --- | 3.39 | --- | 3.09 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.01 | --- | --- | --- | 0.29 | --- | 0.02 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.01 | --- | --- | --- | 0.47 | --- | 0.03 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.01 | --- | --- | --- | 0.51 | --- | 0.03 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.01 | --- | --- | --- | 0.64 | --- | 0.03 | --- | --- | 0.00 | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.07 | --- | --- | --- | 4.04 | --- | 0.17 | --- | --- | 0.01 | --- | 0.09 | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.07 | --- | --- | --- | 4.59 | --- | 0.23 | --- | --- | 0.46 | --- | 1.24 | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.05 | --- | --- | --- | 3.76 | --- | 0.22 | --- | --- | 0.69 | --- | 1.67 | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.04 | --- | --- | --- | 2.85 | --- | 0.19 | --- | --- | 0.69 | --- | 1.60 | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.03 | --- | --- | --- | 1.90 | --- | 0.14 | --- | --- | 0.54 | --- | 1.22 | | |
| >3.01 | 4.425 | 1.242 | 0.08 | --- | --- | --- | 5.70 | --- | 0.49 | --- | --- | 2.11 | --- | 4.61 | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.37 | 0.00 | 0.00 | 0.00 | 24.75 | 0.00 | 1.55 | 0.00 | 0.00 | 4.50 | 0.00 | 10.44 | | |
| Weighted Basin "C" Value | | | 0.270 | --- | --- | --- | 0.252 | --- | 0.131 | --- | --- | 0.079 | --- | 0.089 | | |

28 **North Lake Triplet 1a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 72.0 | 73.3 | --- | --- | --- | --- | --- | 74.3 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | 60.0 | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | 66.7 | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | 40.0 | --- | --- | --- | --- | --- | 0.0 | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 78.5 | 81.6 | --- | --- | --- | --- | --- | 74.3 | | |
| S | --- | --- | --- | --- | 2.74 | 2.26 | --- | --- | --- | --- | --- | 3.46 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.06 | 0.00 | --- | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.11 | 0.00 | --- | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.12 | 0.01 | --- | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.14 | 0.01 | --- | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.72 | 0.03 | --- | --- | --- | --- | --- | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 0.78 | 0.03 | --- | --- | --- | --- | --- | 0.01 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.66 | 0.02 | --- | --- | --- | --- | --- | 0.02 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.52 | 0.02 | --- | --- | --- | --- | --- | 0.02 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.35 | 0.01 | --- | --- | --- | --- | --- | 0.02 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 1.12 | 0.03 | --- | --- | --- | --- | --- | 0.07 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 4.58 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.206 | 0.324 | --- | --- | --- | --- | --- | 0.077 | | |

29 **North Lake Triplet 1b**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 2.9 | 10.2 | 0.0 | 0.0 | 0.1 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 54.5 | 60.6 | --- | --- | 78.3 | 39.0 | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | 60.0 | --- | --- | 95.0 | 0.0 | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | 66.7 | --- | --- | 94.7 | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | 40.0 | --- | --- | 90.0 | 0.0 | --- | --- | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 65.4 | 73.1 | --- | --- | 88.1 | 39.0 | --- | --- | | |
| S | --- | --- | --- | --- | 5.30 | 3.69 | --- | --- | 1.34 | 15.64 | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.05 | 0.33 | --- | --- | 0.01 | 0.00 | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.08 | 0.54 | --- | --- | 0.02 | 0.00 | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.08 | 0.59 | --- | --- | 0.02 | 0.00 | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.10 | 0.70 | --- | --- | 0.02 | 0.00 | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.48 | 3.44 | --- | --- | 0.11 | 0.00 | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 0.39 | 2.90 | --- | --- | 0.09 | 0.00 | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.30 | 2.14 | --- | --- | 0.06 | 0.00 | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.23 | 1.55 | --- | --- | 0.04 | 0.00 | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.16 | 1.02 | --- | --- | 0.02 | 0.00 | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 0.57 | 3.00 | --- | --- | 0.06 | 0.00 | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 2.44 | 16.20 | 0.00 | 0.00 | 0.45 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.154 | 0.288 | --- | --- | 0.575 | 0.002 | --- | --- | | |

30 **North Lake Triplet 1c**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 1.6 | 0.0 | 0.0 | 0.0 | 4.1 | 0.6 | 0.0 | 0.0 | 0.0 | 1.9 | 5.6 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | 64.3 | --- | --- | --- | 53.8 | 58.7 | --- | --- | 89.0 | 39.0 | 30.0 | --- | --- | --- |
| Percent Impervious Area | 40.0 | --- | --- | --- | 40.0 | 60.0 | --- | --- | 95.0 | 0.0 | 0.0 | --- | --- | --- |
| Percent Impervious DCIA | 25.0 | --- | --- | --- | 50.0 | 66.7 | --- | --- | 94.7 | --- | --- | --- | --- | --- |
| DCIA | 10.0 | --- | --- | --- | 20.0 | 40.0 | --- | --- | 90.0 | 0.0 | 0.0 | --- | --- | --- |
| non DCIA CN | 75.6 | --- | --- | --- | 64.8 | 71.8 | --- | --- | 93.5 | 39.0 | 30.0 | --- | | |
| S | 3.23 | --- | --- | --- | 5.43 | 3.93 | --- | --- | 0.70 | 15.64 | 23.33 | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.01 | --- | --- | --- | 0.07 | 0.02 | --- | --- | 0.00 | 0.00 | 0.00 | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.02 | --- | --- | --- | 0.11 | 0.03 | --- | --- | 0.00 | 0.00 | 0.00 | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.02 | --- | --- | --- | 0.12 | 0.04 | --- | --- | 0.00 | 0.00 | 0.00 | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.03 | --- | --- | --- | 0.14 | 0.04 | --- | --- | 0.01 | 0.00 | 0.00 | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.14 | --- | --- | --- | 0.68 | 0.21 | --- | --- | 0.03 | 0.00 | 0.00 | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.18 | --- | --- | --- | 0.54 | 0.17 | --- | --- | 0.02 | 0.00 | 0.00 | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.17 | --- | --- | --- | 0.41 | 0.13 | --- | --- | 0.02 | 0.00 | 0.00 | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.15 | --- | --- | --- | 0.32 | 0.09 | --- | --- | 0.01 | 0.00 | 0.00 | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.11 | --- | --- | --- | 0.23 | 0.06 | --- | --- | 0.01 | 0.00 | 0.00 | --- | | |
| >3.01 | 4.425 | 1.242 | 0.37 | --- | --- | --- | 0.79 | 0.18 | --- | --- | 0.02 | 0.02 | 0.00 | --- | | |
| Generated Volume (ac-ft/yr) | | | 1.21 | 0.00 | 0.00 | 0.00 | 3.41 | 0.98 | 0.00 | 0.00 | 0.12 | 0.02 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | 0.137 | --- | --- | --- | 0.153 | 0.284 | --- | --- | 0.587 | 0.002 | 0.000 | --- | | |

31 **North Lake Triplet Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 2.5 | 0.0 | 0.0 | 0.0 | 8.8 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.4 | 0.0 | 22.2 |
| Pervious Area CN | 74.0 | --- | --- | --- | 74.3 | 76.2 | --- | --- | --- | --- | --- | 76.8 | --- | 98.0 |
| Percent Impervious Area | 50.0 | --- | --- | --- | 40.0 | 40.0 | --- | --- | --- | --- | --- | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | 60.0 | --- | --- | --- | 3.2 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | 30.0 | --- | --- | --- | 1.3 | 0.0 | --- | --- | --- | --- | --- | 0.0 | --- | 0.0 |
| non DCIA CN | 80.9 | --- | --- | --- | 83.6 | 84.9 | --- | --- | --- | --- | --- | 76.8 | | |
| S | 2.36 | --- | --- | --- | 1.96 | 1.78 | --- | --- | --- | --- | --- | 3.02 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.06 | --- | --- | --- | 0.01 | 0.00 | --- | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.10 | --- | --- | --- | 0.02 | 0.00 | --- | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.11 | --- | --- | --- | 0.02 | 0.00 | --- | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 0.13 | --- | --- | --- | 0.03 | 0.00 | --- | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 0.69 | --- | --- | --- | 0.65 | 0.08 | --- | --- | --- | --- | --- | 0.03 | | |
| 1.01-1.50 | 1.225 | 7.032 | 0.68 | --- | --- | --- | 1.35 | 0.16 | --- | --- | --- | --- | --- | 0.34 | | |
| 1.51-2.00 | 1.725 | 3.242 | 0.53 | --- | --- | --- | 1.32 | 0.15 | --- | --- | --- | --- | --- | 0.44 | | |
| 2.01-2.50 | 2.228 | 1.645 | 0.40 | --- | --- | --- | 1.10 | 0.12 | --- | --- | --- | --- | --- | 0.42 | | |
| 2.51-3.00 | 2.702 | 0.823 | 0.26 | --- | --- | --- | 0.77 | 0.08 | --- | --- | --- | --- | --- | 0.32 | | |
| >3.01 | 4.425 | 1.242 | 0.78 | --- | --- | --- | 2.50 | 0.27 | --- | --- | --- | --- | --- | 1.19 | | |
| Generated Volume (ac-ft/yr) | | | 3.74 | 0.00 | 0.00 | 0.00 | 7.75 | 0.86 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.74 | | |
| Weighted Basin "C" Value | | | 0.272 | --- | --- | --- | 0.159 | 0.169 | --- | --- | --- | --- | --- | 0.092 | | |

32 **Queens Mirror 1a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 6.2 | 0.0 | 1.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.1 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 82.9 | --- | 65.4 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 39.7 | --- | 5.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 19.9 | --- | 0.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | 86.6 | --- | 67.0 | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 1.54 | --- | 4.92 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.10 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.16 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.18 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.24 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.62 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.81 | --- | 0.01 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.45 | --- | 0.04 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.09 | --- | 0.06 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.72 | --- | 0.05 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.09 | --- | 0.25 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 9.46 | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.277 | --- | 0.044 | --- | --- | --- | --- | --- | | |

33 **Queens Mirror 1b**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.3 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | --- | --- | 71.1 | --- | --- | --- | --- | 70.0 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | --- | --- | 5.0 | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | --- | --- | 0.0 | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | --- | --- | 72.4 | --- | --- | --- | --- | 70.0 | | |
| S | --- | --- | --- | --- | --- | --- | 3.80 | --- | --- | --- | --- | 4.29 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | --- | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | --- | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | --- | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | --- | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | --- | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | --- | --- | 0.05 | --- | --- | --- | --- | 0.01 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | --- | --- | 0.08 | --- | --- | --- | --- | 0.03 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | --- | --- | 0.09 | --- | --- | --- | --- | 0.03 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | --- | --- | 0.07 | --- | --- | --- | --- | 0.03 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | --- | --- | 0.30 | --- | --- | --- | --- | 0.11 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | --- | --- | 0.067 | --- | --- | --- | --- | 0.056 | | |

34 **Queens Mirror 1c-1**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 |
| Pervious Area CN | --- | --- | 65.9 | --- | --- | --- | 62.9 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | 35.0 | --- | --- | --- | 5.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | 71.4 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | 25.0 | --- | --- | --- | 0.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| non DCIA CN | --- | --- | 70.2 | --- | --- | --- | 64.6 | --- | --- | --- | --- | --- | | |
| S | --- | --- | 4.24 | --- | --- | --- | 5.48 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | 0.00 | --- | --- | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | 0.00 | --- | --- | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | 0.00 | --- | --- | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | 0.00 | --- | --- | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | 0.02 | --- | --- | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | 0.02 | --- | --- | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | 0.01 | --- | --- | --- | 0.03 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | 0.01 | --- | --- | --- | 0.04 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | 0.01 | --- | --- | --- | 0.04 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | 0.02 | --- | --- | --- | 0.20 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | 0.196 | --- | --- | --- | 0.036 | --- | --- | --- | --- | --- | | |

35 **Queens Mirror 1c-2**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 29.9 | 0.0 | 11.9 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | 81.0 | --- | 84.5 | --- | 80.9 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | 35.0 | --- | 40.0 | --- | 5.0 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | 71.4 | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | 25.0 | --- | 20.0 | --- | 0.0 | --- | --- | --- | --- | --- | --- | --- |
| non DCIA CN | --- | --- | 83.3 | --- | 87.9 | --- | 81.8 | --- | --- | --- | --- | --- | | |
| S | --- | --- | 2.01 | --- | 1.38 | --- | 2.23 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | 0.60 | --- | 0.19 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | 0.98 | --- | 0.31 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | 1.07 | --- | 0.36 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | 1.30 | --- | 0.51 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | 7.60 | --- | 3.40 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | 8.08 | --- | 3.74 | --- | 0.01 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | 6.47 | --- | 2.96 | --- | 0.01 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | 4.86 | --- | 2.19 | --- | 0.01 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | 3.22 | --- | 1.44 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | 9.58 | --- | 4.14 | --- | 0.02 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 43.76 | 0.00 | 19.24 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | 0.266 | --- | 0.293 | --- | 0.133 | --- | --- | --- | --- | --- | | |

36 **Queens Mirror 1d**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | --- | 76.0 | --- | --- | --- | --- | 70.0 | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 5.0 | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 0.0 | --- | --- | --- | --- | 0.0 | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | 87.9 | --- | 77.1 | --- | --- | --- | --- | 70.0 | | |
| S | --- | --- | --- | --- | 1.38 | --- | 2.97 | --- | --- | --- | --- | 4.29 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.01 | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.02 | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.03 | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.04 | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.24 | --- | 0.01 | --- | --- | --- | --- | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 0.27 | --- | 0.11 | --- | --- | --- | --- | 0.00 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.21 | --- | 0.15 | --- | --- | --- | --- | 0.00 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.16 | --- | 0.14 | --- | --- | --- | --- | 0.00 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.10 | --- | 0.11 | --- | --- | --- | --- | 0.00 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 0.30 | --- | 0.39 | --- | --- | --- | --- | 0.01 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 1.37 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.293 | --- | 0.094 | --- | --- | --- | --- | 0.056 | | |

37 **Queens Mirror 1e-1**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.1 | 0.0 | 71.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 28.4 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | 65.9 | --- | 84.0 | --- | 66.1 | --- | --- | --- | --- | 76.9 | --- | --- |
| Percent Impervious Area | --- | --- | 35.0 | --- | 40.0 | --- | 5.0 | --- | --- | --- | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | --- | --- | 71.4 | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | 25.0 | --- | 20.0 | --- | 0.0 | --- | --- | --- | --- | 0.0 | --- | --- |
| non DCIA CN | --- | --- | 70.2 | --- | 87.5 | --- | 67.7 | --- | --- | --- | --- | 76.9 | | |
| S | --- | --- | 4.24 | --- | 1.43 | --- | 4.78 | --- | --- | --- | --- | 3.00 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | 0.00 | --- | 1.15 | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | 0.00 | --- | 1.87 | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | 0.00 | --- | 2.14 | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | 0.00 | --- | 2.95 | --- | 0.00 | --- | --- | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | 0.02 | --- | 19.76 | --- | 0.00 | --- | --- | --- | --- | 0.17 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | 0.02 | --- | 21.84 | --- | 0.00 | --- | --- | --- | --- | 1.80 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | 0.01 | --- | 17.37 | --- | 0.00 | --- | --- | --- | --- | 2.35 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | 0.01 | --- | 12.90 | --- | 0.00 | --- | --- | --- | --- | 2.23 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | 0.01 | --- | 8.47 | --- | 0.00 | --- | --- | --- | --- | 1.69 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | 0.02 | --- | 24.53 | --- | 0.02 | --- | --- | --- | --- | 6.30 | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.10 | 0.00 | 112.97 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 14.54 | | |
| Weighted Basin "C" Value | | | --- | --- | 0.196 | --- | 0.288 | --- | 0.047 | --- | --- | --- | --- | 0.093 | | |

38 **Queens Mirror 1e-2**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 7.3 | 0.6 | 0.0 | 0.0 | 82.8 | 0.0 | 9.3 | 0.0 | 1.2 | 0.0 | 0.0 | 48.4 | 0.0 | 0.0 |
| Pervious Area CN | 86.0 | 85.4 | --- | --- | 84.2 | --- | 73.3 | --- | 89.0 | --- | --- | 76.5 | --- | --- |
| Percent Impervious Area | 90.0 | 30.0 | --- | --- | 40.0 | --- | 5.0 | --- | 95.0 | --- | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | 94.4 | --- | --- | --- | 49.2 | --- | --- | --- | 94.7 | --- | --- | --- | --- | --- |
| DCIA | 85.0 | 0.0 | --- | --- | 19.7 | --- | 0.0 | --- | 90.0 | --- | --- | 0.0 | --- | --- |
| non DCIA CN | 90.0 | 89.2 | --- | --- | 87.7 | --- | 74.5 | --- | 93.5 | --- | --- | 76.5 | | |
| S | 1.11 | 1.21 | --- | --- | 1.41 | --- | 3.42 | --- | 0.70 | --- | --- | 3.06 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.50 | 0.00 | --- | --- | 1.31 | --- | 0.00 | --- | 0.09 | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.81 | 0.00 | --- | --- | 2.14 | --- | 0.00 | --- | 0.15 | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.89 | 0.00 | --- | --- | 2.47 | --- | 0.00 | --- | 0.16 | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 1.08 | 0.01 | --- | --- | 3.42 | --- | 0.00 | --- | 0.20 | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 5.42 | 0.10 | --- | --- | 23.06 | --- | 0.00 | --- | 0.98 | --- | --- | 0.22 | | |
| 1.01-1.50 | 1.225 | 7.032 | 4.37 | 0.15 | --- | --- | 25.52 | --- | 0.40 | --- | 0.78 | --- | --- | 2.89 | | |
| 1.51-2.00 | 1.725 | 3.242 | 2.96 | 0.13 | --- | --- | 20.28 | --- | 0.61 | --- | 0.52 | --- | --- | 3.87 | | |
| 2.01-2.50 | 2.228 | 1.645 | 1.99 | 0.10 | --- | --- | 15.05 | --- | 0.61 | --- | 0.35 | --- | --- | 3.70 | | |
| 2.51-3.00 | 2.702 | 0.823 | 1.23 | 0.06 | --- | --- | 9.88 | --- | 0.48 | --- | 0.21 | --- | --- | 2.81 | | |
| >3.01 | 4.425 | 1.242 | 3.14 | 0.19 | --- | --- | 28.58 | --- | 1.88 | --- | 0.54 | --- | --- | 10.58 | | |
| Generated Volume (ac-ft/yr) | | | 22.39 | 0.75 | 0.00 | 0.00 | 131.71 | 0.00 | 3.99 | 0.00 | 3.97 | 0.00 | 0.00 | 24.06 | | |
| Weighted Basin "C" Value | | | 0.560 | 0.236 | --- | --- | 0.289 | --- | 0.078 | --- | 0.587 | --- | --- | 0.090 | | |

39 **Queens Mirror 1e-3**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 7.2 | 0.0 | 0.0 | 0.0 | 80.6 | 0.0 | 3.3 | 0.0 | 2.0 | 0.0 | 0.0 | 9.8 | 0.0 | 0.0 |
| Pervious Area CN | 86.0 | --- | --- | --- | 84.2 | --- | 73.5 | --- | 89.0 | --- | --- | 76.5 | --- | --- |
| Percent Impervious Area | 90.0 | --- | --- | --- | 40.0 | --- | 5.0 | --- | 95.0 | --- | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | 94.4 | --- | --- | --- | 49.8 | --- | --- | --- | 94.7 | --- | --- | --- | --- | --- |
| DCIA | 85.0 | --- | --- | --- | 19.9 | --- | 0.0 | --- | 90.0 | --- | --- | 0.0 | --- | --- |
| non DCIA CN | 90.0 | --- | --- | --- | 87.7 | --- | 74.7 | --- | 93.5 | --- | --- | 76.5 | | |
| S | 1.11 | --- | --- | --- | 1.40 | --- | 3.38 | --- | 0.70 | --- | --- | 3.07 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.49 | --- | --- | --- | 1.29 | --- | 0.00 | --- | 0.15 | --- | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 0.81 | --- | --- | --- | 2.11 | --- | 0.00 | --- | 0.24 | --- | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 0.89 | --- | --- | --- | 2.43 | --- | 0.00 | --- | 0.27 | --- | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 1.08 | --- | --- | --- | 3.36 | --- | 0.00 | --- | 0.32 | --- | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 5.39 | --- | --- | --- | 22.60 | --- | 0.00 | --- | 1.61 | --- | --- | 0.04 | | |
| 1.01-1.50 | 1.225 | 7.032 | 4.35 | --- | --- | --- | 24.95 | --- | 0.15 | --- | 1.29 | --- | --- | 0.59 | | |
| 1.51-2.00 | 1.725 | 3.242 | 2.95 | --- | --- | --- | 19.80 | --- | 0.22 | --- | 0.86 | --- | --- | 0.78 | | |
| 2.01-2.50 | 2.228 | 1.645 | 1.98 | --- | --- | --- | 14.69 | --- | 0.22 | --- | 0.58 | --- | --- | 0.75 | | |
| 2.51-3.00 | 2.702 | 0.823 | 1.22 | --- | --- | --- | 9.64 | --- | 0.17 | --- | 0.35 | --- | --- | 0.57 | | |
| >3.01 | 4.425 | 1.242 | 3.12 | --- | --- | --- | 27.86 | --- | 0.67 | --- | 0.90 | --- | --- | 2.15 | | |
| Generated Volume (ac-ft/yr) | | | 22.26 | 0.00 | 0.00 | 0.00 | 128.73 | 0.00 | 1.42 | 0.00 | 6.57 | 0.00 | 0.00 | 4.88 | | |
| Weighted Basin "C" Value | | | 0.560 | --- | --- | --- | 0.290 | --- | 0.079 | --- | 0.587 | --- | --- | 0.090 | | |

40 **Queens Mirror 1e-4**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 7.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.2 | --- | --- | --- | --- | --- | --- | --- | 98.0 | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | 77.1 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | --- | --- | 77.1 | --- |
| non DCIA CN | --- | --- | --- | --- | 87.6 | --- | --- | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 1.41 | --- | --- | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.12 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.19 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.22 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.30 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 2.02 | --- | --- | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 2.23 | --- | --- | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.77 | --- | --- | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.31 | --- | --- | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.86 | --- | --- | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.49 | --- | --- | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 11.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.290 | --- | --- | --- | --- | --- | --- | --- | | |

41 **Queens Mirror 1e-5a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 48.7 | 0.0 | 0.0 | 0.0 | 3.4 | 22.3 | 0.0 | 0.0 | 10.2 | 3.2 | 3.5 | 7.9 | 0.0 | 0.0 |
| Pervious Area CN | 76.3 | --- | --- | --- | 76.0 | 69.6 | --- | --- | 86.6 | 64.5 | 46.3 | 77.0 | --- | --- |
| Percent Impervious Area | 90.0 | --- | --- | --- | 40.0 | 70.0 | --- | --- | 95.0 | 0.0 | 0.0 | 0.0 | --- | --- |
| Percent Impervious DCIA | 94.4 | --- | --- | --- | 50.0 | 75.9 | --- | --- | 94.7 | --- | --- | --- | --- | --- |
| DCIA | 85.0 | --- | --- | --- | 20.0 | 53.1 | --- | --- | 90.0 | 0.0 | 0.0 | 0.0 | --- | --- |
| non DCIA CN | 83.5 | --- | --- | --- | 81.5 | 79.8 | --- | --- | 92.3 | 64.5 | 46.3 | 77.0 | | |
| S | 1.97 | --- | --- | --- | 2.27 | 2.53 | --- | --- | 0.84 | 5.51 | 11.59 | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 3.33 | --- | --- | --- | 0.06 | 0.95 | --- | --- | 0.74 | 0.00 | 0.00 | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 5.43 | --- | --- | --- | 0.09 | 1.55 | --- | --- | 1.21 | 0.00 | 0.00 | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 5.93 | --- | --- | --- | 0.10 | 1.69 | --- | --- | 1.34 | 0.00 | 0.00 | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 7.11 | --- | --- | --- | 0.12 | 2.03 | --- | --- | 1.62 | 0.00 | 0.00 | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 35.28 | --- | --- | --- | 0.68 | 10.18 | --- | --- | 8.05 | 0.00 | 0.00 | 0.05 | | |
| 1.01-1.50 | 1.225 | 7.032 | 28.34 | --- | --- | --- | 0.76 | 8.77 | --- | --- | 6.43 | 0.01 | 0.00 | 0.50 | | |
| 1.51-2.00 | 1.725 | 3.242 | 19.22 | --- | --- | --- | 0.64 | 6.30 | --- | --- | 4.32 | 0.05 | 0.00 | 0.66 | | |
| 2.01-2.50 | 2.228 | 1.645 | 12.95 | --- | --- | --- | 0.49 | 4.44 | --- | --- | 2.89 | 0.08 | 0.00 | 0.62 | | |
| 2.51-3.00 | 2.702 | 0.823 | 8.00 | --- | --- | --- | 0.33 | 2.84 | --- | --- | 1.78 | 0.08 | 0.00 | 0.47 | | |
| >3.01 | 4.425 | 1.242 | 20.56 | --- | --- | --- | 1.02 | 7.86 | --- | --- | 4.50 | 0.41 | 0.12 | 1.75 | | |
| Generated Volume (ac-ft/yr) | | | 146.15 | 0.00 | 0.00 | 0.00 | 4.28 | 46.61 | 0.00 | 0.00 | 32.88 | 0.63 | 0.12 | 4.06 | | |
| Weighted Basin "C" Value | | | 0.545 | --- | --- | --- | 0.227 | 0.380 | --- | --- | 0.583 | 0.036 | 0.006 | 0.093 | | |

42 **Queens Mirror 1e-5b**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 4.8 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | --- | 80.9 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 5.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 0.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | 87.9 | --- | 81.8 | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 1.38 | --- | 2.23 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.08 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.13 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.15 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.20 | --- | 0.00 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.36 | --- | 0.01 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.49 | --- | 0.03 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.18 | --- | 0.03 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.88 | --- | 0.02 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.57 | --- | 0.02 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 1.66 | --- | 0.06 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 7.69 | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.293 | --- | 0.133 | --- | --- | --- | --- | --- | | |

43 **Queens Mirror 1e-6**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 9.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 1.6 | 0.1 | 1.5 | 0.0 |
| Pervious Area CN | 85.8 | --- | --- | --- | --- | --- | --- | --- | --- | 67.6 | 77.0 | 77.0 | --- | --- |
| Percent Impervious Area | 90.0 | --- | --- | --- | --- | --- | --- | --- | --- | 0.0 | 0.0 | 0.0 | 100.0 | --- |
| Percent Impervious DCIA | 94.4 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | 85.0 | --- | --- | --- | --- | --- | --- | --- | --- | 0.0 | 0.0 | 0.0 | 100.0 | --- |
| non DCIA CN | 89.9 | --- | --- | --- | --- | --- | --- | --- | --- | 67.6 | 77.0 | 77.0 | | |
| S | 1.13 | --- | --- | --- | --- | --- | --- | --- | --- | 4.79 | 2.99 | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 0.63 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 1.02 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 1.13 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 1.36 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 6.83 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | 0.01 | 0.00 | | |
| 1.01-1.50 | 1.225 | 7.032 | 5.51 | --- | --- | --- | --- | --- | --- | --- | --- | 0.02 | 0.10 | 0.01 | | |
| 1.51-2.00 | 1.725 | 3.242 | 3.74 | --- | --- | --- | --- | --- | --- | --- | --- | 0.07 | 0.13 | 0.01 | | |
| 2.01-2.50 | 2.228 | 1.645 | 2.51 | --- | --- | --- | --- | --- | --- | --- | --- | 0.09 | 0.13 | 0.01 | | |
| 2.51-3.00 | 2.702 | 0.823 | 1.55 | --- | --- | --- | --- | --- | --- | --- | --- | 0.08 | 0.10 | 0.01 | | |
| >3.01 | 4.425 | 1.242 | 3.96 | --- | --- | --- | --- | --- | --- | --- | --- | 0.39 | 0.36 | 0.02 | | |
| Generated Volume (ac-ft/yr) | | | 28.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.66 | 0.83 | 0.06 | | |
| Weighted Basin "C" Value | | | 0.560 | --- | --- | --- | --- | --- | --- | --- | --- | 0.046 | 0.093 | 0.093 | | |

44 **Queens Mirror 1e-7**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 18.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 5.2 | 0.0 | 0.0 |
| Pervious Area CN | 83.8 | --- | --- | --- | --- | --- | --- | --- | --- | 61.0 | --- | 77.0 | --- | --- |
| Percent Impervious Area | 90.0 | --- | --- | --- | --- | --- | --- | --- | --- | 0.0 | --- | 0.0 | --- | --- |
| Percent Impervious DCIA | 94.4 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | 85.0 | --- | --- | --- | --- | --- | --- | --- | --- | 0.0 | --- | 0.0 | --- | --- |
| non DCIA CN | 88.5 | --- | --- | --- | --- | --- | --- | --- | --- | 61.0 | --- | 77.0 | | |
| S | 1.29 | --- | --- | --- | --- | --- | --- | --- | --- | 6.39 | --- | 2.99 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | 1.27 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | 2.07 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | 2.27 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | 2.74 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | 13.71 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.03 | | |
| 1.01-1.50 | 1.225 | 7.032 | 11.06 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.33 | | |
| 1.51-2.00 | 1.725 | 3.242 | 7.50 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.43 | | |
| 2.01-2.50 | 2.228 | 1.645 | 5.05 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.41 | | |
| 2.51-3.00 | 2.702 | 0.823 | 3.11 | --- | --- | --- | --- | --- | --- | --- | --- | 0.00 | --- | 0.31 | | |
| >3.01 | 4.425 | 1.242 | 7.97 | --- | --- | --- | --- | --- | --- | --- | --- | 0.01 | --- | 1.15 | | |
| Generated Volume (ac-ft/yr) | | | 56.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 2.65 | | |
| Weighted Basin "C" Value | | | 0.556 | --- | --- | --- | --- | --- | --- | --- | --- | 0.027 | --- | 0.093 | | |

45 **Queens Mirror 2**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 5.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 84.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 87.9 | --- | --- | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 1.38 | --- | --- | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.08 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.14 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.16 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.22 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.47 | --- | --- | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.61 | --- | --- | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.28 | --- | --- | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.95 | --- | --- | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.62 | --- | --- | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 1.79 | --- | --- | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 8.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.293 | --- | --- | --- | --- | --- | --- | --- | | |

46 **Queens Mirror Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 22.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 12.5 |
| Pervious Area CN | --- | --- | --- | --- | 81.2 | --- | 80.9 | --- | --- | --- | 77.0 | --- | --- | 98.0 |
| Percent Impervious Area | --- | --- | --- | --- | 26.8 | --- | 5.0 | --- | --- | --- | 0.0 | --- | --- | 100.0 |
| Percent Impervious DCIA | --- | --- | --- | --- | 35.2 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 9.4 | --- | 0.0 | --- | --- | --- | 0.0 | --- | --- | 0.0 |
| non DCIA CN | --- | --- | --- | --- | 84.4 | --- | 81.8 | --- | --- | --- | 77.0 | --- | | |
| S | --- | --- | --- | --- | 1.85 | --- | 2.23 | --- | --- | --- | 2.99 | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.17 | --- | 0.00 | --- | --- | --- | 0.00 | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.27 | --- | 0.00 | --- | --- | --- | 0.00 | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.30 | --- | 0.00 | --- | --- | --- | 0.00 | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.39 | --- | 0.00 | --- | --- | --- | 0.00 | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 3.23 | --- | 0.00 | --- | --- | --- | 0.00 | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 4.53 | --- | 0.01 | --- | --- | --- | 0.03 | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 3.99 | --- | 0.01 | --- | --- | --- | 0.04 | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 3.15 | --- | 0.01 | --- | --- | --- | 0.04 | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 2.14 | --- | 0.01 | --- | --- | --- | 0.03 | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 6.66 | --- | 0.02 | --- | --- | --- | 0.11 | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 24.83 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.26 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.205 | --- | 0.133 | --- | --- | --- | 0.093 | --- | | |

47 **South Lake Triplet 1**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 6.4 | 0.0 | 0.2 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 86.3 | --- | 80.9 | --- | --- | 67.7 | --- | --- | --- | 98.0 |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 5.0 | --- | --- | 0.0 | --- | --- | --- | 100.0 |
| Percent Impervious DCIA | --- | --- | --- | --- | 18.8 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 7.5 | --- | 0.0 | --- | --- | 0.0 | --- | --- | --- | 0.0 |
| non DCIA CN | --- | --- | --- | --- | 90.4 | --- | 81.8 | --- | --- | 67.7 | --- | --- | | |
| S | --- | --- | --- | --- | 1.06 | --- | 2.23 | --- | --- | 4.77 | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.04 | --- | 0.00 | --- | --- | 0.00 | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.07 | --- | 0.00 | --- | --- | 0.00 | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.12 | --- | 0.00 | --- | --- | 0.00 | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.21 | --- | 0.00 | --- | --- | 0.00 | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.71 | --- | 0.01 | --- | --- | 0.00 | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 2.02 | --- | 0.03 | --- | --- | 0.01 | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.62 | --- | 0.03 | --- | --- | 0.02 | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.20 | --- | 0.03 | --- | --- | 0.03 | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.79 | --- | 0.02 | --- | --- | 0.03 | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.26 | --- | 0.06 | --- | --- | 0.13 | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 10.04 | 0.00 | 0.17 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.287 | --- | 0.133 | --- | --- | 0.047 | --- | --- | | |

48 **South Lake Triplet 2**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 87.2 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 0.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 91.5 | --- | --- | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 0.93 | --- | --- | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.00 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.01 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.05 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.11 | --- | --- | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.99 | --- | --- | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.20 | --- | --- | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.97 | --- | --- | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.72 | --- | --- | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.47 | --- | --- | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 1.34 | --- | --- | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 5.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.285 | --- | --- | --- | --- | --- | --- | --- | | |

49 **South Lake Triplet 3a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 8.0 | 0.1 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 77.4 | 84.5 | 61.9 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | 70.0 | 10.9 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 48.5 | 85.7 | 54.1 | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 19.4 | 60.0 | 5.9 | --- | --- | --- | --- | --- | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 82.7 | 87.9 | 63.8 | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 2.10 | 1.38 | 5.67 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.13 | 0.00 | 0.01 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.20 | 0.01 | 0.01 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.22 | 0.01 | 0.01 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.27 | 0.01 | 0.02 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.63 | 0.04 | 0.08 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.87 | 0.04 | 0.06 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.56 | 0.03 | 0.06 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 1.20 | 0.02 | 0.06 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.80 | 0.01 | 0.05 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 2.46 | 0.03 | 0.22 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 10.34 | 0.20 | 0.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.234 | 0.454 | 0.068 | --- | --- | --- | --- | --- | | |

50 **South Lake Triplet 3b**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 6.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.8 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 53.8 | --- | 50.6 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 15.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | 66.7 | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 10.0 | --- | --- | --- | --- | --- | 100.0 | --- |
| non DCIA CN | --- | --- | --- | --- | 64.8 | --- | 53.2 | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 5.43 | --- | 8.78 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.01 | --- | 0.05 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.02 | --- | 0.08 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.02 | --- | 0.09 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.02 | --- | 0.11 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 0.11 | --- | 0.54 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 0.09 | --- | 0.42 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 0.07 | --- | 0.28 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.05 | --- | 0.21 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.04 | --- | 0.15 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 0.13 | --- | 0.66 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 | 0.00 | 2.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.153 | --- | 0.074 | --- | --- | --- | --- | --- | | |

51 **South Lake Triplet 4a**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 9.0 | 0.0 | 5.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 58.2 | --- | 60.0 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 15.0 | --- | --- | --- | --- | --- | --- | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 50.0 | --- | 66.7 | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 20.0 | --- | 10.0 | --- | --- | --- | --- | --- | --- | --- |
| non DCIA CN | --- | --- | --- | --- | 68.2 | --- | 62.1 | --- | --- | --- | --- | --- | | |
| S | --- | --- | --- | --- | 4.67 | --- | 6.11 | --- | --- | --- | --- | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.14 | --- | 0.04 | --- | --- | --- | --- | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.24 | --- | 0.07 | --- | --- | --- | --- | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.26 | --- | 0.08 | --- | --- | --- | --- | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.31 | --- | 0.09 | --- | --- | --- | --- | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.51 | --- | 0.45 | --- | --- | --- | --- | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.26 | --- | 0.36 | --- | --- | --- | --- | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.01 | --- | 0.29 | --- | --- | --- | --- | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.80 | --- | 0.25 | --- | --- | --- | --- | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.56 | --- | 0.19 | --- | --- | --- | --- | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 1.92 | --- | 0.79 | --- | --- | --- | --- | --- | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 8.00 | 0.00 | 2.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.162 | --- | 0.088 | --- | --- | --- | --- | --- | | |

52 **South Lake Triplet 5**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 8.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 0.3 | 0.0 |
| Pervious Area CN | --- | --- | --- | --- | 64.1 | --- | --- | --- | --- | --- | 73.9 | --- | --- | --- |
| Percent Impervious Area | --- | --- | --- | --- | 36.1 | --- | --- | --- | --- | --- | 0.0 | --- | 100.0 | --- |
| Percent Impervious DCIA | --- | --- | --- | --- | 48.9 | --- | --- | --- | --- | --- | --- | --- | 100.0 | --- |
| DCIA | --- | --- | --- | --- | 17.7 | --- | --- | --- | --- | --- | 0.0 | --- | 100.0 | --- |
| | | | | | | | | | | | | | | |
| non DCIA CN | --- | --- | --- | --- | 71.7 | --- | --- | --- | --- | --- | 73.9 | --- | | |
| S | --- | --- | --- | --- | 3.94 | --- | --- | --- | --- | --- | 3.52 | --- | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.12 | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.20 | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.22 | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.26 | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 1.28 | --- | --- | --- | --- | --- | 0.00 | --- | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 1.19 | --- | --- | --- | --- | --- | 0.16 | --- | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 1.01 | --- | --- | --- | --- | --- | 0.25 | --- | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 0.82 | --- | --- | --- | --- | --- | 0.25 | --- | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 0.58 | --- | --- | --- | --- | --- | 0.20 | --- | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 1.96 | --- | --- | --- | --- | --- | 0.80 | --- | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 7.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.66 | 0.00 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.161 | --- | --- | --- | --- | --- | 0.075 | --- | | |

53 **South Lake Triplet Direct**

| Parameter | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 0.0 | 0.0 | 0.0 | 0.0 | 12.3 | 0.0 | 8.6 | 0.0 | 0.0 | 14.7 | 1.9 | 5.9 | 0.0 | 22.6 |
| Pervious Area CN | --- | --- | --- | --- | 86.6 | --- | 74.6 | --- | --- | 67.3 | 77.0 | 76.2 | --- | 98.0 |
| Percent Impervious Area | --- | --- | --- | --- | 40.0 | --- | 14.3 | --- | --- | 0.0 | 0.0 | 0.0 | --- | 100.0 |
| Percent Impervious DCIA | --- | --- | --- | --- | 1.4 | --- | 65.0 | --- | --- | --- | --- | --- | --- | --- |
| DCIA | --- | --- | --- | --- | 0.6 | --- | 9.3 | --- | --- | 0.0 | 0.0 | 0.0 | --- | 0.0 |
| | | | | | | | | | | | | | | |
| non DCIA CN | --- | --- | --- | --- | 91.1 | --- | 75.9 | --- | --- | 67.3 | 77.0 | 76.2 | | |
| S | --- | --- | --- | --- | 0.97 | --- | 3.18 | --- | --- | 4.86 | 2.99 | 3.12 | | |

**Annual Runoff Volume Calculation for Basin**

| Rainfall Event Range (in) | Rainfall Interval Point (in) | Number of Annual Events in Range | Annual Runoff Volume for Each Land Use and Soil Group (ac-ft/yr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Commercial | Industrial | Institutional | Low Density Residential | Medium Density Residential | High Density Residential | Golf Course | Recreational | Transportation | Open | Woods | Wetlands | Ponds | Lakes |
| 0.11-0.20 | 0.152 | 18.516 | --- | --- | --- | --- | 0.01 | --- | 0.06 | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.21-0.30 | 0.252 | 10.371 | --- | --- | --- | --- | 0.04 | --- | 0.10 | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.31-0.40 | 0.353 | 6.790 | --- | --- | --- | --- | 0.16 | --- | 0.11 | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.41-0.50 | 0.456 | 5.790 | --- | --- | --- | --- | 0.34 | --- | 0.14 | --- | --- | 0.00 | 0.00 | 0.00 | | |
| 0.51-1.00 | 0.716 | 16.387 | --- | --- | --- | --- | 3.10 | --- | 0.69 | --- | --- | 0.00 | 0.01 | 0.02 | | |
| 1.01-1.50 | 1.225 | 7.032 | --- | --- | --- | --- | 3.84 | --- | 0.95 | --- | --- | 0.11 | 0.12 | 0.34 | | |
| 1.51-2.00 | 1.725 | 3.242 | --- | --- | --- | --- | 3.12 | --- | 0.93 | --- | --- | 0.40 | 0.16 | 0.46 | | |
| 2.01-2.50 | 2.228 | 1.645 | --- | --- | --- | --- | 2.32 | --- | 0.80 | --- | --- | 0.52 | 0.15 | 0.44 | | |
| 2.51-3.00 | 2.702 | 0.823 | --- | --- | --- | --- | 1.53 | --- | 0.58 | --- | --- | 0.46 | 0.11 | 0.33 | | |
| >3.01 | 4.425 | 1.242 | --- | --- | --- | --- | 4.38 | --- | 2.02 | --- | --- | 2.19 | 0.43 | 1.27 | | |
| | | | | | | | | | | | | | | | | |
| Generated Volume (ac-ft/yr) | | | 0.00 | 0.00 | 0.00 | 0.00 | 18.83 | 0.00 | 6.38 | 0.00 | 0.00 | 3.67 | 0.98 | 2.86 | | |
| Weighted Basin "C" Value | | | --- | --- | --- | --- | 0.278 | --- | 0.135 | --- | --- | 0.045 | 0.093 | 0.088 | | |

# APPENDIX C

# CHARACTERISTICS OF GROUNDWATER SEEPAGE ENTERING QUEENS MIRROR LAKE, SOUTH LAKE TRIPLET, AND MIDDLE LAKE TRIPLET FROM SEPTEMBER 2010-MAY 2011

## C.1 Field Measurements of Seepage Volume
## C.2 Chemical Characteristics of Seepage Samples

## C.1 Field Measurements of Seepage Volume

## Seepage Meter Field Measurements

Location: Middle Lake Triplet  Site: 1

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 10:20 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 8:35 | 16.5 | 8/30/10 | 10:20 | 38.9 | 1.57 | Measured volume, no sample collected |
| 10/25/10 | 10:00 | 5.5 | 10/8/10 | 8:35 | 17.1 | 1.19 | Sample collected, bag in good condition |
| 2/2/11 | 12:20 | 12.5 | 10/25/10 | 10:00 | 100.1 | 0.46 | Sample collected, bag in good condition |
| 3/14/11 | 12:19 | 5.75 | 2/2/11 | 12:20 | 40.0 | 0.53 | Sample collected, bag in good condition |
| 5/13/11 | 10:05 | 6.25 | 3/14/11 | 12:19 | 59.9 | 0.39 | Sample collected, bag in good condition |
| | | | | **Mean Seepage Rate:** | | **0.67** | |

## Seepage Meter Field Measurements

Location: Middle Lake Triplet  Site: 2

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 10:28 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 8:40 | 11.25 | 8/30/10 | 10:28 | 38.9 | 1.07 | Measured volume, no sample collected |
| 10/25/10 | 10:04 | 8.25 | 10/8/10 | 8:40 | 17.1 | 1.79 | Sample collected, bag in good condition |
| 2/2/11 | 12:25 | ----- | 10/25/10 | 10:04 | 100.1 | ----- | No sample collected, meter missing, meter replaced |
| 3/14/11 | 12:23 | ----- | 2/2/11 | 12:25 | 40.0 | ----- | No sample collected, meter missing, meter replaced |
| 5/13/11 | 10:00 | ----- | 3/14/11 | 12:23 | 59.9 | ----- | No sample collected, meter missing |
| | | | | **Mean Seepage Rate:** | | **1.29** | |

## Seepage Meter Field Measurements

Location: Middle Lake Triplet  Site: 3

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 10:41 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 8:45 | 7.25 | 8/30/10 | 10:41 | 38.9 | 0.69 | Measured volume, no sample collected |
| 10/25/10 | 10:08 | 8.75 | 10/8/10 | 8:45 | 17.1 | 1.90 | Sample collected, bag in good condition |
| 2/2/11 | 12:31 | 6.25 | 10/25/10 | 10:08 | 100.1 | 0.23 | Sample collected, bag in good condition |
| 3/14/11 | 12:27 | 6.75 | 2/2/11 | 12:31 | 40.0 | 0.63 | Sample collected, bag in good condition |
| 5/13/11 | 10:07 | ----- | 3/14/11 | 12:27 | 59.9 | ----- | No sample collected, bag damaged |
| | | | | **Mean Seepage Rate:** | | **0.55** | |

## Seepage Meter Field Measurements

Location: Middle Lake Triplet  Site: 4

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 10:49 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 9:55 | ----- | 8/30/10 | 10:49 | 39.0 | ----- | No sample collected, meter missing, meter replaced |
| 10/25/10 | 9:50 | ----- | 10/8/10 | 9:55 | 17.0 | ----- | No sample collected, meter missing, meter replaced |
| 2/2/11 | 12:28 | 10.75 | 10/25/10 | 9:50 | 100.1 | 0.40 | Sample collected, bag in good condition |
| 3/14/11 | 12:24 | 11.25 | 2/2/11 | 12:28 | 40.0 | 1.04 | Sample collected, bag in good condition |
| 5/13/11 | 10:12 | 5.75 | 3/14/11 | 12:24 | 59.9 | 0.36 | Sample collected, bag in good condition |
| | | | | | **Mean Seepage Rate:** | **0.51** | |

## Seepage Meter Field Measurements

Location: South Lake Triplet  Site: 1

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 11:18 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 8:50 | 5.5 | 8/30/10 | 11:18 | 38.9 | 0.52 | Measured volume, no sample collected |
| 10/25/10 | 10:15 | 11.5 | 10/8/10 | 8:50 | 17.1 | 2.50 | Sample collected, bag in good condition |
| 2/2/11 | 12:36 | 13.75 | 10/25/10 | 10:15 | 100.1 | 0.51 | Sample collected, bag in good condition |
| 3/14/11 | 12:35 | 17.5 | 2/2/11 | 12:36 | 40.0 | 1.62 | Sample collected, bag in good condition |
| 5/13/11 | 10:35 | 0.625 | 3/14/11 | 12:35 | 59.9 | 0.04 | Sample collected, bag in good condition |
| | | | | | **Mean Seepage Rate:** | **0.71** | |

## Seepage Meter Field Measurements

Location: South Lake Triplet  Site: 2

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 11:30 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 8:55 | 10.5 | 8/30/10 | 11:30 | 38.9 | 1.00 | Measured volume, no sample collected |
| 10/25/10 | 10:20 | 3.25 | 10/8/10 | 8:55 | 17.1 | 0.71 | Sample collected, bag in good condition |
| 2/2/11 | 12:42 | 15.5 | 10/25/10 | 10:20 | 100.1 | 0.57 | Sample collected, bag in good condition |
| 3/14/11 | 12:39 | 5.25 | 2/2/11 | 12:42 | 40.0 | 0.49 | Sample collected, bag in good condition |
| 5/13/11 | 10:45 | ----- | 3/14/11 | 12:39 | 59.9 | ----- | No sample collected, meter flipped over |
| | | | | | **Mean Seepage Rate:** | **0.65** | |

## Seepage Meter Field Measurements

Location: South Lake Triplet  Site: 3

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 11:43 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 9:08 | 4.75 | 8/30/10 | 11:43 | 38.9 | 0.45 | Measured volume, no sample collected |
| 10/25/10 | 10:35 | 6.75 | 10/8/10 | 9:08 | 17.1 | 1.47 | Sample collected, bag in good condition |
| 2/2/11 | 12:57 | 16.25 | 10/25/10 | 10:35 | 100.1 | 0.60 | Sample collected, pinhole, bag replaced |
| 3/14/11 | 13:00 | 12.75 | 2/2/11 | 12:57 | 40.0 | 1.18 | Sample collected, bag in good condition |
| 5/13/11 | 10:50 | 12.5 | 3/14/11 | 13:00 | 59.9 | 0.77 | Sample collected, bag in good condition |
| | | | | | **Mean Seepage Rate:** | **0.77** | |

## Seepage Meter Field Measurements

Location: South Lake Triplet  Site: 4

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 11:58 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 9:05 | 13.5 | 8/30/10 | 11:58 | 38.9 | 1.29 | Measured volume, no sample collected |
| 10/25/10 | 10:28 | 14.25 | 10/8/10 | 9:05 | 17.1 | 3.09 | Sample collected, bag in good condition |
| 2/2/11 | 12:53 | 18.75 | 10/25/10 | 10:28 | 100.1 | 0.69 | Sample collected, pinhole, bag replaced |
| 3/14/11 | 12:53 | 33.75 | 2/2/11 | 12:53 | 40.0 | 3.13 | Sample collected, bag in good condition |
| 5/13/11 | 10:55 | 13.25 | 3/14/11 | 12:53 | 59.9 | 0.82 | Sample collected, bag in good condition |
| | | | | | **Mean Seepage Rate:** | **1.35** | |

## Seepage Meter Field Measurements

Location: South Lake Triplet  Site: 5

Date Installed: 8/30/10  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 | | | |
| 8/30/10 | 12:07 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 9:00 | 9.5 | 8/30/10 | 12:07 | 38.9 | 0.91 | Measured volume, no sample collected |
| 10/25/10 | 10:25 | 8.75 | 10/8/10 | 9:00 | 17.1 | 1.90 | Sample collected, bag in good condition |
| 2/2/11 | 12:49 | 7.75 | 10/25/10 | 10:25 | 100.1 | 0.29 | Sample collected, bag in good condition |
| 3/14/11 | 12:45 | 10.75 | 2/2/11 | 12:49 | 40.0 | 1.00 | Sample collected, bag in good condition |
| 5/13/11 | 11:05 | 8.5 | 3/14/11 | 12:45 | 59.9 | 0.53 | Sample collected, bag in good condition |
| | | | | | **Mean Seepage Rate:** | **0.65** | |

## Seepage Meter Field Measurements

Location: Queens Mirror Site: 1

Date Installed: 8/30/10 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 | | | |
| 8/30/10 | 12:42 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 9:20 | 3.75 | 8/30/10 | 12:42 | 38.9 | 0.36 | Measured volume, no sample collected |
| 10/25/10 | 10:50 | 8.5 | 10/8/10 | 9:20 | 17.1 | 1.85 | Sample collected, bag in good condition |
| 2/2/11 | 13:12 | 10.25 | 10/25/10 | 10:50 | 100.1 | 0.38 | Sample collected, bag in good condition |
| 3/14/11 | 13:15 | 3.5 | 2/2/11 | 13:12 | 40.0 | 0.32 | Sample collected, bag in good condition |
| 5/13/11 | 11:45 | 9.25 | 3/14/11 | 13:15 | 59.9 | 0.57 | Sample collected, bag in good condition |
| | | | | **Mean Seepage Rate:** | | **0.51** | |

## Seepage Meter Field Measurements

Location: Queens Mirror Site: 2

Date Installed: 8/30/10 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 | | | |
| 8/30/10 | 12:56 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 9:25 | 32.5 | 8/30/10 | 12:56 | 38.9 | 3.10 | Measured volume, no sample collected |
| 10/25/10 | 11:00 | 7.75 | 10/8/10 | 9:25 | 17.1 | 1.68 | Sample collected, bag in good condition |
| 2/2/11 | 13:17 | 18.75 | 10/25/10 | 11:00 | 100.1 | 0.69 | Sample collected, bag in good condition |
| 3/14/11 | 13:19 | 16.25 | 2/2/11 | 13:17 | 40.0 | 1.50 | Sample collected, bag in good condition |
| 5/13/11 | 12:05 | 12.75 | 3/14/11 | 13:19 | 59.9 | 0.79 | Sample collected, bag in good condition |
| | | | | **Mean Seepage Rate:** | | **1.27** | |

## Seepage Meter Field Measurements

Location: Queens Mirror Site: 3

Date Installed: 8/30/10 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 | | | |
| 8/30/10 | 13:08 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 9:30 | 8.25 | 8/30/10 | 13:08 | 38.8 | 0.79 | Measured volume, no sample collected |
| 10/25/10 | 11:09 | 10.5 | 10/8/10 | 9:30 | 17.1 | 2.28 | Sample collected, bag in good condition |
| 2/2/11 | 13:25 | 8.25 | 10/25/10 | 11:09 | 100.1 | 0.31 | Sample collected, bag in good condition |
| 3/14/11 | 13:24 | 3.5 | 2/2/11 | 13:25 | 40.0 | 0.32 | Sample collected, bag in good condition |
| 5/13/11 | 12:00 | 8.5 | 3/14/11 | 13:24 | 59.9 | 0.53 | Sample collected, bag in good condition |
| | | | | **Mean Seepage Rate:** | | **0.56** | |

## Seepage Meter Field Measurements

Location: Queens Mirror

Site: 4

Date Installed: 8/30/10

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 | | | |
| 8/30/10 | 13:20 | ----- | ----- | ----- | ----- | ----- | Meter installed and bag attached |
| 10/8/10 | 9:35 | 13.75 | 8/30/10 | 13:20 | 38.8 | 1.31 | Measured volume, no sample collected |
| 10/25/10 | 11:04 | 5.25 | 10/8/10 | 9:35 | 17.1 | 1.14 | Sample collected, bag in good condition |
| 2/2/11 | 13:30 | 9.5 | 10/25/10 | 11:04 | 100.1 | 0.35 | Sample collected, bag in good condition |
| 3/14/11 | 13:30 | 3.75 | 2/2/11 | 13:30 | 40.0 | 0.35 | Sample collected, bag in good condition |
| 5/13/11 | 11:52 | 5.75 | 3/14/11 | 13:30 | 59.9 | 0.36 | Sample collected, bag in good condition |
| | | | | **Mean Seepage Rate:** | | **0.55** | |

## C.2 Chemical Characteristics of Seepage Samples

## Characteristics of Shallow Groundwater Seepage Samples Collected from September 2010 - May 2011

| Lake | Sample Location | Date Collected | pH (s.u.) | Alkalinity (mg/l) | Cond. (µmho/cm) | $NH_3$-N (µg/l) | $NO_X$-N (µg/l) | Organic N (µg/l) | Total N (µg/l) | SRP (µg/l) | Organic P (µg/l) | Total P (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Middle Triplet | Site 1 | 10/25/10 | 7.44 | 281 | 681 | 7,063 | 9,509 | 491 | 17,063 | 3,245 | 1,323 | 4,568 |
| Middle Triplet | Site 1 | 2/2/11 | 7.22 | 233 | 672 | 7,550 | 10,662 | 906 | 19,118 | 616 | 4,065 | 4,681 |
| Middle Triplet | Site 1 | 3/14/11 | 7.41 | 140 | 506 | 295 | 6,238 | 3,803 | 10,336 | 531 | 1,621 | 2,152 |
| Middle Triplet | Site 1 | 6/13/11 | 6.99 | 54.6 | 243 | 27 | 1,700 | 560 | 2,287 | 324 | 80 | 404 |
| | **Log-Normal Mean:** | | **7.26** | **150** | **487** | **807** | **5,726** | **987** | **9,371** | **766** | **914** | **2,076** |
| Middle Triplet | Site 2 | 10/25/10 | 6.49 | 29.8 | 211 | 312 | 6131 | 420 | 6863 | 1535 | 192 | 1727 |
| | **Log-Normal Mean:** | | **6.49** | **29.8** | **211** | **312** | **6131** | **420** | **6863** | **1535** | **192** | **1727** |
| Middle Triplet | Site 3 | 10/25/10 | 6.55 | 32.6 | 169 | 100 | 214 | 718 | 1032 | 46 | 23 | 69 |
| Middle Triplet | Site 3 | 2/2/11 | 6.81 | 42.8 | 169 | 88 | 466 | 986 | 1540 | 101 | 66 | 167 |
| Middle Triplet | Site 3 | 3/14/11 | 6.89 | 51.2 | 202 | 157 | 592 | 457 | 1206 | 82 | 47 | 129 |
| | **Log-Normal Mean:** | | **6.75** | **41.5** | **179** | **111** | **389** | **686** | **1242** | **72** | **41** | **114** |
| Middle Triplet | Site 4 | 2/2/11 | 6.96 | 43.4 | 175 | 582 | 447 | 1391 | 2420 | 104 | 148 | 252 |
| Middle Triplet | Site 4 | 3/14/11 | 6.92 | 40.2 | 190 | 71 | 589 | 612 | 1272 | 172 | 45 | 217 |
| Middle Triplet | Site 4 | 6/13/11 | 7.19 | 38.2 | 204 | 105 | 494 | 1716 | 2315 | 126 | 310 | 436 |
| | **Log-Normal Mean:** | | **7.02** | **40.5** | **189** | **163** | **507** | **1135** | **1924** | **131** | **127** | **288** |
| Queens Mirror | Site 1 | 10/25/10 | 6.61 | 49.2 | 281 | 519 | 3030 | 50 | 3599 | 83 | 7 | 90 |
| Queens Mirror | Site 1 | 2/2/11 | 6.62 | 36.4 | 166 | 191 | 331 | 574 | 1096 | 131 | 72 | 203 |
| Queens Mirror | Site 1 | 3/14/11 | 6.60 | 55.8 | 222 | 479 | 23 | 90 | 592 | 21 | 53 | 74 |
| Queens Mirror | Site 1 | 6/13/11 | 6.74 | 36.4 | 179 | 32 | 266 | 16 | 314 | 44 | 39 | 83 |
| | **Log-Normal Mean:** | | **6.64** | **43.7** | **207** | **197** | **280** | **80** | **925** | **56** | **32** | **103** |
| Queens Mirror | Site 2 | 10/25/10 | 5.86 | 16.4 | 138 | 66 | 1624 | 45 | 1735 | 16 | 11 | 27 |
| Queens Mirror | Site 2 | 2/2/11 | 6.31 | 24.0 | 150 | 33 | 158 | 569 | 760 | 15 | 33 | 48 |
| Queens Mirror | Site 2 | 3/14/11 | 6.43 | 30.4 | 182 | 50 | 177 | 250 | 477 | 36 | 11 | 47 |
| Queens Mirror | Site 2 | 6/13/11 | 6.71 | 41.4 | 201 | 14 | 635 | 318 | 967 | 179 | 30 | 209 |
| | **Log-Normal Mean:** | | **6.32** | **26.5** | **166** | **35** | **412** | **212** | **883** | **35** | **19** | **60** |
| Queens Mirror | Site 3 | 10/25/10 | 6.70 | 36.6 | 163 | 54 | 73 | 585 | 712 | 35 | 5 | 40 |
| Queens Mirror | Site 3 | 2/2/11 | 6.56 | 31.8 | 165 | 61 | 95 | 619 | 775 | 32 | 46 | 78 |
| Queens Mirror | Site 3 | 3/14/11 | 6.65 | 41.4 | 177 | 156 | 95 | 60 | 311 | 19 | 6 | 25 |
| Queens Mirror | Site 3 | 6/13/11 | 6.69 | 32.6 | 172 | 33 | 49 | 416 | 498 | 31 | 17 | 48 |
| | **Log-Normal Mean:** | | **6.65** | **35.4** | **169** | **64** | **75** | **308** | **541** | **28** | **12** | **44** |

## Characteristics of Shallow Groundwater Seepage Samples Collected from September 2010 - May 2011

| Lake | Sample Location | Date Collected | pH (s.u.) | Alkalinity (mg/l) | Cond. (µmho/cm) | $NH_3$-N (µg/l) | $NO_X$-N (µg/l) | Organic N (µg/l) | Total N (µg/l) | SRP (µg/l) | Organic P (µg/l) | Total P (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Queens Mirror | Site 4 | 10/25/10 | 6.89 | 48.6 | 182 | 554 | 199 | 505 | 1258 | 175 | 10 | 185 |
| Queens Mirror | Site 4 | 2/2/11 | 6.60 | 37.8 | 183 | 32 | 597 | 465 | 1094 | 142 | 19 | 161 |
| Queens Mirror | Site 4 | 3/14/11 | 6.98 | 46.4 | 212 | 309 | 262 | 136 | 707 | 220 | 39 | 259 |
| Queens Mirror | Site 4 | 6/13/11 | 6.79 | 65.8 | 215 | 495 | 600 | 1060 | 2155 | 196 | 83 | 279 |
| | **Log-Normal Mean:** | | **6.81** | **48.7** | **197** | **228** | **370** | **429** | **1,203** | **181** | **28** | **215** |
| South Triplet | Site 1 | 10/25/10 | 6.50 | 42.8 | 193 | 879 | 3295 | 221 | 4395 | 232 | 24 | 256 |
| South Triplet | Site 1 | 2/2/11 | 6.44 | 26.4 | 164 | 138 | 220 | 747 | 1105 | 41 | 24 | 65 |
| South Triplet | Site 1 | 3/14/11 | 6.66 | 37.0 | 184 | 213 | 781 | 149 | 1143 | 77 | 24 | 101 |
| South Triplet | Site 1 | 6/13/11 | 6.87 | 33.0 | 182 | 159 | 66 | 952 | 1177 | 70 | 21 | 91 |
| | **Log-Normal Mean:** | | **6.62** | **34** | **180** | **253** | **440** | **391** | **1,599** | **85** | **23** | **111** |
| South Triplet | Site 2 | 10/25/10 | 6.77 | 51.4 | 220 | 455 | 4289 | 56 | 4800 | 159 | 28 | 187 |
| South Triplet | Site 2 | 2/2/11 | 6.63 | 35.0 | 166 | 67 | 613 | 826 | 1506 | 88 | 42 | 130 |
| South Triplet | Site 2 | 3/14/11 | 6.82 | 38.8 | 191 | 28 | 604 | 270 | 902 | 58 | 8 | 66 |
| | **Log-Normal Mean:** | | **6.74** | **41.2** | **191** | **95** | **1167** | **232** | **1868** | **93** | **21** | **117** |
| South Triplet | Site 3 | 10/25/10 | 6.61 | 35.8 | 181 | 80 | 2196 | 306 | 2582 | 279 | 4 | 283 |
| South Triplet | Site 3 | 2/2/11 | 6.50 | 34.6 | 174 | 84 | 787 | 1117 | 1988 | 136 | 71 | 207 |
| South Triplet | Site 3 | 6/13/11 | 6.72 | 34.0 | 179 | 136 | 523 | 684 | 1343 | 178 | 19 | 197 |
| | **Log-Normal Mean:** | | **6.61** | **34.8** | **178** | **97** | **967** | **616** | **1903** | **189** | **18** | **226** |
| South Triplet | Site 4 | 10/25/10 | 6.70 | 36.0 | 162 | 246 | 168 | 676 | 1090 | 135 | 17 | 152 |
| South Triplet | Site 4 | 2/2/11 | 6.76 | 37.8 | 191 | 136 | 389 | 434 | 959 | 152 | 33 | 185 |
| South Triplet | Site 4 | 3/14/11 | 6.45 | 34.0 | 179 | 17 | 458 | 57 | 532 | 21 | 25 | 46 |
| South Triplet | Site 4 | 6/13/11 | 6.61 | 36.2 | 187 | 77 | 174 | 835 | 1086 | 104 | 92 | 196 |
| | **Log-Normal Mean:** | | **6.63** | **36** | **179** | **81** | **269** | **344** | **882** | **82** | **34** | **126** |
| South Triplet | Site 5 | 10/25/10 | 6.87 | 36.6 | 155 | 93 | 320 | 585 | 998 | 50 | 36 | 86 |
| South Triplet | Site 5 | 2/2/11 | 6.63 | 33.6 | 165 | 36 | 404 | 526 | 966 | 41 | 31 | 72 |
| South Triplet | Site 5 | 3/14/11 | 6.59 | 34.6 | 186 | 398 | 126 | 1211 | 1735 | 53 | 24 | 77 |
| South Triplet | Site 5 | 6/13/11 | 6.59 | 34.2 | 175 | 35 | 55 | 653 | 743 | 22 | 18 | 40 |
| | **Log-Normal Mean:** | | **6.67** | **35** | **170** | **83** | **173** | **702** | **1,056** | **39** | **26** | **66** |

# APPENDIX D

# CHARACTERISTICS OF RUNOFF INFLOW SAMPLES COLLECTED AT THE WINTER PARK DRIVE AND SOUTH TRIPLET LAKE DRIVE MONITORING SITES

# Characteristics of Inflow Samples to Queens Mirror and Middle Lake Triplet from September 2010 - May 2011

| Sample Location | Date Collected | pH (s.u.) | Alkalinity (mg/l) | Cond. (µmho/cm) | $NH_3$-N (µg/l) | $NO_X$-N (µg/l) | Diss. Org. N (µg/l) | Particulate 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thomas Dr. | 9/8/10 | 6.76 | 52.8 | 308 | 116 | 72 | 597 | 6 | 791 | 70 | 17 | 21 | 108 | 1.8 | 84 | 3.2 |
| Thomas Dr. | 9/16/10 | 6.70 | 52.2 | 229 | 176 | 64 | 51 | 289 | 580 | 163 | 30 | 16 | 209 | 2.5 | 93 | 8.4 |
| Thomas Dr. | 9/23/10 | 6.71 | 47.4 | 299 | 737 | 80 | 116 | 140 | 1073 | 95 | 87 | 1 | 183 | 1.2 | 82 | 2.0 |
| Thomas Dr. | 10/6/10 | 6.23 | 46.0 | 288 | 68 | 67 | 919 | 117 | 1171 | 48 | 11 | 3 | 62 | 0.4 | 67 | 1.5 |
| Thomas Dr. | 11/4/10 | 6.30 | 34.0 | 289 | 85 | 19 | 144 | 95 | 343 | 88 | 9 | 12 | 109 | 1.6 | 73 | 4.0 |
| **Minimum Value:** | | **6.23** | **34.0** | **229** | **68** | **19** | **51** | **6** | **343** | **48** | **9** | **1** | **62** | **0.4** | **67** | **1.5** |
| **Maximum Value:** | | **6.76** | **52.8** | **308** | **737** | **80** | **919** | **289** | **1171** | **163** | **87** | **21** | **209** | **2.5** | **93** | **8.4** |
| **Log-Normal Mean Value:** | | **6.54** | **45.9** | **281** | **154** | **54** | **216** | **77** | **723** | **86** | **21** | **7** | **123** | **1.3** | **79** | **3.2** |
| Winter Park Dr | 9/8/10 | 6.79 | 44.6 | 169 | 59 | 15 | 389 | 233 | 696 | 52 | 61 | 20 | 133 | 1.5 | 162 | 1.4 |
| Winter Park Dr | 9/16/10 | 6.54 | 40.6 | 149 | 58 | 35 | 184 | 89 | 366 | 46 | 97 | 4 | 147 | 0.9 | 161 | 1.6 |
| Winter Park Dr | 9/23/10 | 7.15 | 48.8 | 168 | 21 | 27 | 157 | 99 | 304 | 52 | 87 | 6 | 145 | 1.0 | 128 | 1.8 |
| Winter Park Dr | 10/6/10 | 6.25 | 41.8 | 159 | 50 | 62 | 338 | 631 | 1081 | 36 | 50 | 1 | 87 | 0.8 | 120 | 1.3 |
| Winter Park Dr | 10/21/10 | 6.76 | 47.8 | 178 | 76 | 44 | 254 | 27 | 401 | 52 | 20 | 11 | 83 | 1.8 | 80 | 2.7 |
| Winter Park Dr. | 11/4/10 | 6.56 | 43.0 | 151 | 82 | 9 | 248 | 146 | 485 | 22 | 17 | 6 | 45 | 2.0 | 103 | 3.5 |
| Winter Park Dr. | 11/11/10 | 6.54 | 46.0 | 167 | 116 | 46 | 110 | 510 | 782 | 13 | 13 | 8 | 34 | 2.2 | 143 | 1.4 |
| Winter Park Dr. | 12/20/10 | 6.49 | 47.2 | 181 | 85 | 36 | 112 | 32 | 265 | 61 | 7 | 10 | 78 | 1.9 | 152 | 2.0 |
| Winter Park Dr. | 1/7/11 | 6.23 | 54.6 | 164 | 132 | 27 | 310 | 63 | 532 | 36 | 9 | 7 | 52 | 2.5 | 172 | 2.2 |
| Winter Park Dr. | 1/12/11 | 6.49 | 43.6 | 172 | 113 | 14 | 283 | 136 | 546 | 24 | 17 | 5 | 46 | 1.6 | 121 | 1.7 |
| Winter Park Dr. | 1/19/11 | 6.59 | 30.0 | 145 | 71 | 6 | 388 | 57 | 522 | 39 | 35 | 14 | 88 | 2.9 | 180 | 1.3 |
| Winter Park Dr. | 2/3/11 | 6.44 | 34.6 | 173 | 88 | 33 | 340 | 26 | 487 | 100 | 11 | 12 | 123 | 3.2 | 205 | 3.3 |
| **Minimum Value:** | | **6.23** | **30.0** | **145** | **21** | **6** | **110** | **26** | **265** | **13** | **7** | **1** | **34** | **0.8** | **80** | **1.3** |
| **Maximum Value:** | | **7.15** | **54.6** | **181** | **132** | **62** | **389** | **631** | **1081** | **100** | **97** | **20** | **147** | **3.2** | **205** | **3.5** |
| **Log-Normal Mean Value:** | | **6.56** | **43.1** | **164** | **72** | **24** | **239** | **100** | **501** | **39** | **25** | **7** | **79** | **1.7** | **140** | **1.9** |

# APPENDIX E

# SEDIMENT INCUBATION EXPERIMENTS

**E.1 Results of Laboratory Analyses on Sediment Incubation Samples Under Aerobic and Anoxic Conditions**

**E.2 Regression Relationships for Estimation of Sediment Phosphorus Release Rates in the Incubation Experiments**

## E.1 Results of Laboratory Analyses on Sediment Incubation Samples Under Aerobic and Anoxic Conditions

# Results of Laboratory Analyses on Sediment Core Samples Incubated Under Aerobic and Anoxic Conditions

| Lake | Sample Location | Incubation Condition | Date Collected | Time (Days) | $NH_3$-N (µg/l) | $NO_X$-N (µg/l) | Diss. Org. N (µg/l) | Total N (µg/l) | SRP (µg/l) | Diss. Org. P (µg/l) | Total P (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/8/11 | 0 | 183 | 23 | 54 | 260 | 5 | 74 | 79 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/9/11 | 1 | 200 | 19 | 31 | 250 | 12 | 61 | 73 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/10/11 | 2 | 254 | 13 | 15 | 282 | 20 | 49 | 69 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/11/11 | 3 | 344 | 15 | 42 | 401 | 50 | 30 | 80 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/14/11 | 6 | 329 | 10 | 76 | 415 | 54 | 40 | 94 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/16/11 | 8 | 376 | 14 | 54 | 444 | 62 | 48 | 110 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/18/11 | 10 | 301 | 42 | 96 | 439 | 71 | 58 | 129 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/21/11 | 13 | 90 | 450 | 72 | 612 | 81 | 40 | 121 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/23/11 | 15 | 85 | 582 | 144 | 811 | 100 | 41 | 141 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/25/11 | 17 | 76 | 746 | 253 | 1075 | 109 | 33 | 142 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 2/28/11 | 20 | 60 | 726 | 327 | 1113 | 112 | 93 | 205 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 3/2/11 | 22 | 41 | 643 | 493 | 1177 | 113 | 92 | 205 |
| Queen's Mirror | Core Tube Site 1 | Anoxic | 3/4/11 | 24 | 40 | 687 | 506 | 1233 | 118 | 80 | 198 |
| | | | | | | | | | | | |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 3/23/11 | 0 | 17 | 297 | 468 | 782 | 7 | 43 | 44 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 3/24/11 | 1 | 21 | 387 | 481 | 889 | 8 | 47 | 49 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 3/25/11 | 2 | 27 | 458 | 267 | 752 | 10 | 43 | 53 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 3/28/11 | 5 | 15 | 579 | 250 | 844 | 16 | 39 | 55 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 3/30/11 | 7 | 82 | 669 | 320 | 1071 | 19 | 31 | 60 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 4/4/11 | 12 | 67 | 621 | 323 | 1011 | 20 | 33 | 63 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 4/6/11 | 14 | 72 | 660 | 360 | 1092 | 18 | 40 | 68 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 4/11/11 | 19 | 69 | 687 | 386 | 1142 | 18 | 54 | 72 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 4/13/11 | 21 | 72 | 671 | 464 | 1207 | 19 | 47 | 66 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 4/15/11 | 23 | 67 | 684 | 428 | 1179 | 19 | 42 | 61 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 4/18/11 | 26 | 77 | 666 | 558 | 1301 | 17 | 41 | 58 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 4/20/11 | 28 | 73 | 598 | 570 | 1241 | 17 | 35 | 52 |
| Queen's Mirror | Core Tube Site 1 | Aerobic | 4/25/11 | 33 | 66 | 513 | 553 | 1132 | 16 | 31 | 47 |

# Results of Laboratory Analyses on Sediment Core Samples Incubated Under Aerobic and Anoxic Conditions

| Lake | Sample Location | Incubation Condition | Date Collected | Time (Days) | $NH_3$-N (µg/l) | $NO_X$-N (µg/l) | Diss. Org. N (µg/l) | Total N (µg/l) | SRP (µg/l) | Diss. Org. P (µg/l) | Total P (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/8/11 | 0 | 73 | 10 | 218 | 301 | 9 | 79 | 88 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/9/11 | 1 | 41 | 7 | 309 | 357 | 11 | 66 | 77 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/10/11 | 2 | 44 | 9 | 312 | 365 | 22 | 75 | 97 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/11/11 | 3 | 44 | 7 | 365 | 416 | 41 | 62 | 103 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/14/11 | 6 | 55 | 6 | 383 | 444 | 55 | 53 | 108 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/16/11 | 8 | 56 | 20 | 496 | 572 | 75 | 52 | 127 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/18/11 | 10 | 59 | 83 | 572 | 714 | 100 | 65 | 165 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/21/11 | 13 | 84 | 486 | 531 | 1101 | 138 | 68 | 206 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/23/11 | 15 | 77 | 647 | 499 | 1223 | 121 | 63 | 184 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/25/11 | 17 | 76 | 684 | 456 | 1216 | 111 | 53 | 164 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 2/28/11 | 20 | 66 | 634 | 487 | 1187 | 96 | 56 | 152 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 3/2/11 | 22 | 36 | 534 | 499 | 1069 | 88 | 86 | 174 |
| Queen's Mirror | Core Tube Site 2 | Anoxic | 3/4/11 | 24 | 35 | 473 | 532 | 1040 | 82 | 78 | 160 |
| | | | | | | | | | | | |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 3/23/11 | 0 | 11 | 224 | 370 | 605 | 7 | 32 | 39 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 3/24/11 | 1 | 12 | 353 | 269 | 634 | 7 | 39 | 46 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 3/25/11 | 2 | 12 | 372 | 251 | 635 | 8 | 48 | 56 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 3/28/11 | 5 | 12 | 457 | 225 | 694 | 11 | 40 | 51 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 3/30/11 | 7 | 69 | 520 | 107 | 696 | 13 | 42 | 55 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 4/4/11 | 12 | 65 | 446 | 103 | 614 | 15 | 45 | 60 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 4/6/11 | 14 | 72 | 513 | 100 | 685 | 16 | 54 | 70 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 4/11/11 | 19 | 91 | 513 | 492 | 1096 | 17 | 51 | 68 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 4/13/11 | 21 | 69 | 560 | 420 | 1049 | 19 | 44 | 63 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 4/15/11 | 23 | 98 | 552 | 458 | 1108 | 23 | 35 | 58 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 4/18/11 | 26 | 89 | 657 | 446 | 1192 | 28 | 28 | 56 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 4/20/11 | 28 | 72 | 543 | 519 | 1134 | 35 | 27 | 62 |
| Queen's Mirror | Core Tube Site 2 | Aerobic | 4/25/11 | 33 | 72 | 473 | 340 | 885 | 37 | 19 | 56 |

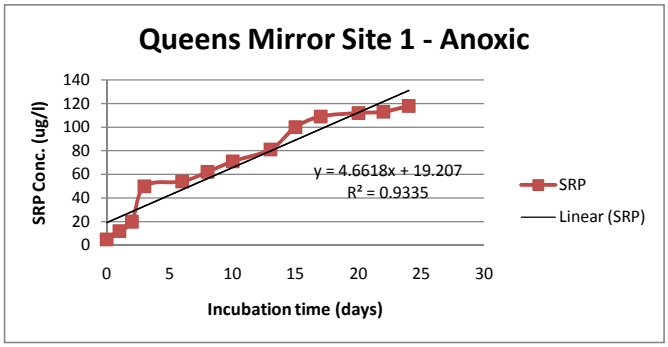
# Results of Laboratory Analyses on Sediment Core Samples Incubated Under Aerobic and Anoxic Conditions

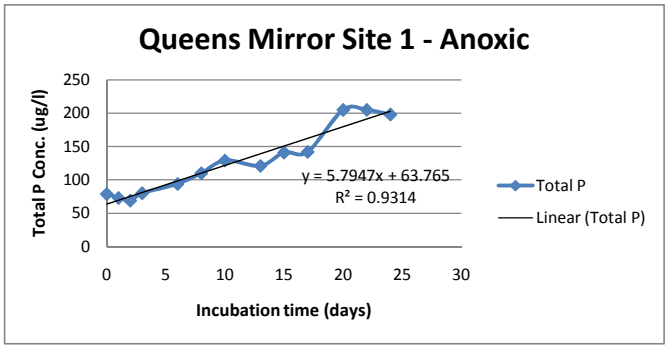
| Lake | Sample Location | Incubation Condition | Date Collected | Time (Days) | $NH_3$-N (µg/l) | $NO_X$-N (µg/l) | Diss. Org. N (µg/l) | Total N (µg/l) | SRP (µg/l) | Diss. Org. P (µg/l) | Total P (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| South Triplet | Core Tube Site 1 | Anoxic | 2/8/11 | 0 | 72 | 26 | 184 | 282 | 9 | 53 | 62 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/9/11 | 1 | 129 | 21 | 162 | 312 | 11 | 50 | 61 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/10/11 | 2 | 129 | 21 | 142 | 292 | 13 | 55 | 68 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/11/11 | 3 | 180 | 20 | 173 | 373 | 16 | 39 | 55 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/14/11 | 6 | 210 | 13 | 197 | 420 | 17 | 47 | 64 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/16/11 | 8 | 42 | 15 | 342 | 399 | 19 | 37 | 56 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/18/11 | 10 | 34 | 46 | 361 | 441 | 20 | 43 | 63 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/21/11 | 13 | 38 | 313 | 140 | 491 | 23 | 64 | 67 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/23/11 | 15 | 46 | 353 | 133 | 532 | 29 | 42 | 71 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/25/11 | 17 | 45 | 391 | 145 | 581 | 30 | 50 | 80 |
| South Triplet | Core Tube Site 1 | Anoxic | 2/28/11 | 20 | 40 | 437 | 142 | 619 | 32 | 70 | 102 |
| South Triplet | Core Tube Site 1 | Anoxic | 3/2/11 | 22 | 43 | 384 | 589 | 1016 | 35 | 75 | 110 |
| South Triplet | Core Tube Site 1 | Anoxic | 3/4/11 | 24 | 39 | 390 | 531 | 960 | 31 | 65 | 96 |
| | | | | | | | | | | | |
| South Triplet | Core Tube Site 1 | Aerobic | 3/23/11 | 0 | 20 | 75 | 428 | 523 | 7 | 30 | 33 |
| South Triplet | Core Tube Site 1 | Aerobic | 3/24/11 | 1 | 10 | 90 | 455 | 555 | 8 | 42 | 35 |
| South Triplet | Core Tube Site 1 | Aerobic | 3/25/11 | 2 | 27 | 116 | 230 | 373 | 9 | 43 | 42 |
| South Triplet | Core Tube Site 1 | Aerobic | 3/28/11 | 5 | 44 | 137 | 232 | 413 | 11 | 21 | 42 |
| South Triplet | Core Tube Site 1 | Aerobic | 3/30/11 | 7 | 68 | 135 | 214 | 417 | 12 | 33 | 45 |
| South Triplet | Core Tube Site 1 | Aerobic | 4/4/11 | 12 | 67 | 136 | 231 | 434 | 11 | 30 | 41 |
| South Triplet | Core Tube Site 1 | Aerobic | 4/6/11 | 14 | 71 | 136 | 271 | 478 | 12 | 46 | 53 |
| South Triplet | Core Tube Site 1 | Aerobic | 4/11/11 | 19 | 66 | 138 | 381 | 585 | 12 | 37 | 65 |
| South Triplet | Core Tube Site 1 | Aerobic | 4/13/11 | 21 | 69 | 174 | 853 | 1096 | 12 | 75 | 67 |
| South Triplet | Core Tube Site 1 | Aerobic | 4/15/11 | 23 | 71 | 133 | 457 | 661 | 8 | 47 | 55 |
| South Triplet | Core Tube Site 1 | Aerobic | 4/18/11 | 26 | 81 | 153 | 458 | 692 | 10 | 38 | 48 |
| South Triplet | Core Tube Site 1 | Aerobic | 4/20/11 | 28 | 90 | 150 | 647 | 887 | 8 | 37 | 45 |
| South Triplet | Core Tube Site 1 | Aerobic | 4/25/11 | 33 | 68 | 132 | 357 | 557 | 10 | 35 | 45 |

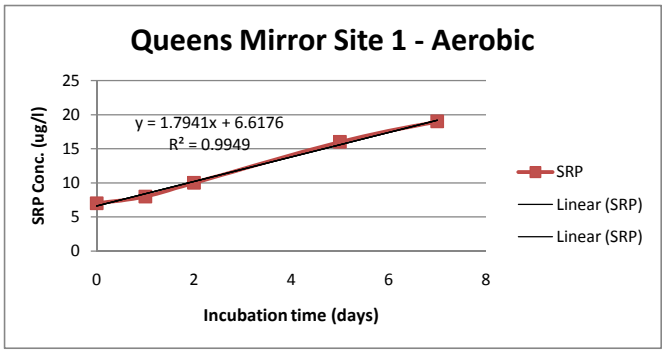
# Results of Laboratory Analyses on Sediment Core Samples Incubated Under Aerobic and Anoxic Conditions

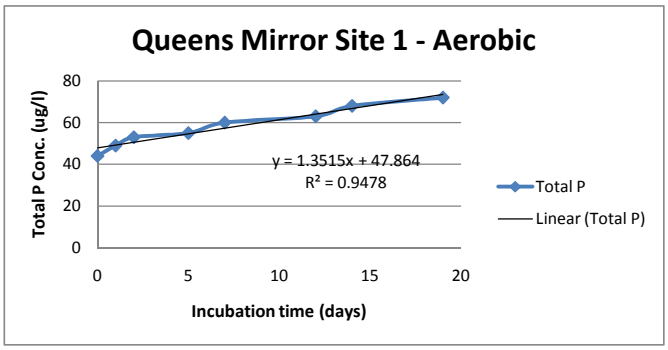
| Lake | Sample Location | Incubation Condition | Date Collected | Time (Days) | $NH_3$-N (µg/l) | $NO_X$-N (µg/l) | Diss. Org. N (µg/l) | Total N (µg/l) | SRP (µg/l) | Diss. Org. P (µg/l) | Total P (µg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| South Triplet | Core Tube Site 2 | Anoxic | 2/8/11 | 0 | 41 | 8 | 144 | 193 | 2 | 44 | 46 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/9/11 | 1 | 68 | 9 | 187 | 264 | 2 | 45 | 47 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/10/11 | 2 | 65 | 8 | 212 | 285 | 6 | 43 | 49 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/11/11 | 3 | 83 | 7 | 216 | 306 | 11 | 44 | 55 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/14/11 | 6 | 175 | 4 | 211 | 390 | 17 | 46 | 63 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/16/11 | 8 | 254 | 4 | 230 | 488 | 23 | 50 | 73 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/18/11 | 10 | 374 | 3 | 235 | 612 | 28 | 70 | 98 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/21/11 | 13 | 342 | 16 | 284 | 642 | 44 | 82 | 116 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/23/11 | 15 | 375 | 16 | 228 | 619 | 52 | 40 | 122 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/25/11 | 17 | 122 | 104 | 270 | 496 | 66 | 50 | 136 |
| South Triplet | Core Tube Site 2 | Anoxic | 2/28/11 | 20 | 53 | 523 | 305 | 881 | 69 | 76 | 145 |
| South Triplet | Core Tube Site 2 | Anoxic | 3/2/11 | 22 | 74 | 544 | 310 | 928 | 62 | 91 | 153 |
| South Triplet | Core Tube Site 2 | Anoxic | 3/4/11 | 24 | 73 | 534 | 286 | 893 | 61 | 78 | 139 |
| | | | | | | | | | | | |
| South Triplet | Core Tube Site 2 | Aerobic | 3/23/11 | 0 | 7 | 109 | 273 | 389 | 6 | 47 | 53 |
| South Triplet | Core Tube Site 2 | Aerobic | 3/24/11 | 1 | 14 | 101 | 264 | 379 | 6 | 33 | 49 |
| South Triplet | Core Tube Site 2 | Aerobic | 3/25/11 | 2 | 6 | 130 | 250 | 386 | 11 | 42 | 53 |
| South Triplet | Core Tube Site 2 | Aerobic | 3/28/11 | 5 | 12 | 165 | 184 | 361 | 16 | 44 | 60 |
| South Triplet | Core Tube Site 2 | Aerobic | 3/30/11 | 7 | 65 | 206 | 107 | 378 | 15 | 38 | 63 |
| South Triplet | Core Tube Site 2 | Aerobic | 4/4/11 | 12 | 59 | 184 | 141 | 384 | 14 | 48 | 66 |
| South Triplet | Core Tube Site 2 | Aerobic | 4/6/11 | 14 | 75 | 193 | 127 | 395 | 13 | 48 | 69 |
| South Triplet | Core Tube Site 2 | Aerobic | 4/11/11 | 19 | 76 | 210 | 444 | 730 | 16 | 56 | 72 |
| South Triplet | Core Tube Site 2 | Aerobic | 4/13/11 | 21 | 84 | 184 | 441 | 709 | 19 | 45 | 64 |
| South Triplet | Core Tube Site 2 | Aerobic | 4/15/11 | 23 | 82 | 192 | 442 | 716 | 20 | 44 | 64 |
| South Triplet | Core Tube Site 2 | Aerobic | 4/18/11 | 26 | 70 | 212 | 481 | 763 | 22 | 42 | 64 |
| South Triplet | Core Tube Site 2 | Aerobic | 4/20/11 | 28 | 82 | 228 | 502 | 812 | 24 | 50 | 74 |
| South Triplet | Core Tube Site 2 | Aerobic | 4/25/11 | 33 | 69 | 195 | 409 | 673 | 26 | 46 | 72 |

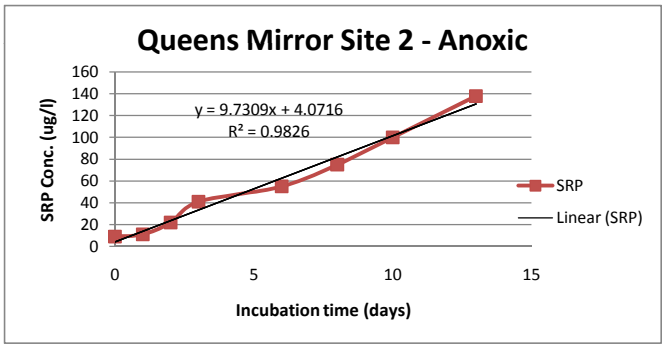
## E.2 Regression Relationships for Estimation of Sediment Phosphorus Release Rates in the Incubation Experiments

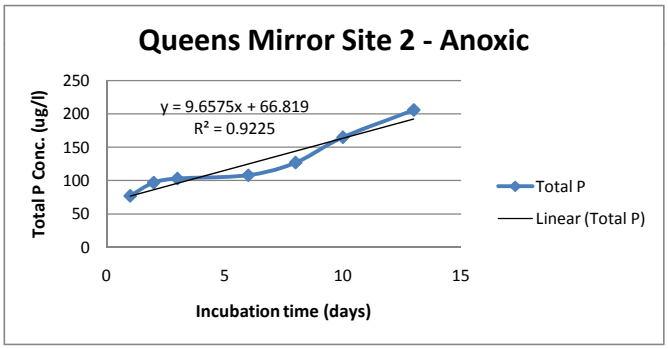

Queens Mirror Site 1 - Anoxic
SRP Conc. (ug/l)
Incubation time (days)
y = 4.6618x + 19.207
R² = 0.9335
SRP
Linear (SRP)

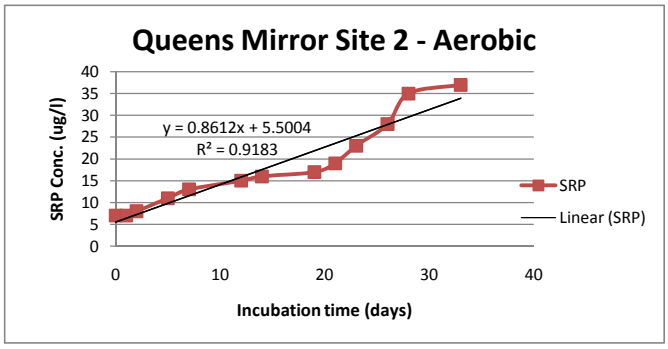

Queens Mirror Site 1 - Anoxic
Total P Conc. (ug/l)
Incubation time (days)
y = 5.7947x + 63.765
R² = 0.9314
Total P
Linear (Total P)

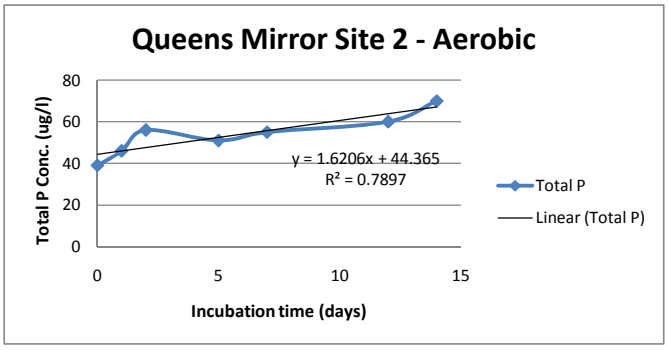

Queens Mirror Site 1 - Aerobic
SRP Conc. (ug/l)
Incubation time (days)
y = 1.7941x + 6.6176
R² = 0.9949
SRP
Linear (SRP)
Linear (SRP)

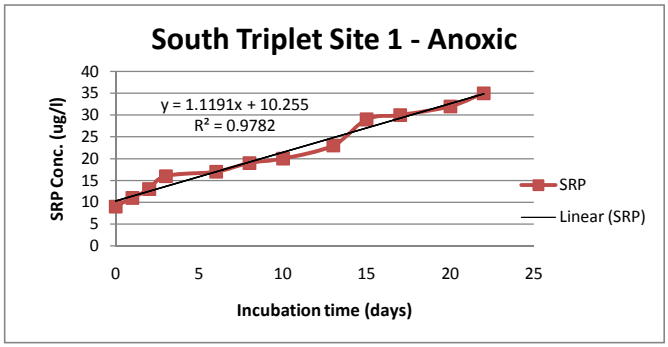

Queens Mirror Site 1 - Aerobic
Total P Conc. (ug/l)
Incubation time (days)
y = 1.3515x + 47.864
R² = 0.9478
Total P
Linear (Total P)

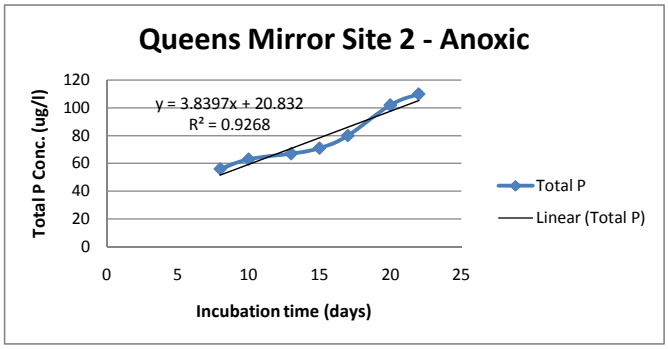

Queens Mirror Site 2 - Anoxic
SRP Conc. (ug/l)
Incubation time (days)
y = 9.7309x + 4.0716
R² = 0.9826
SRP
Linear (SRP)

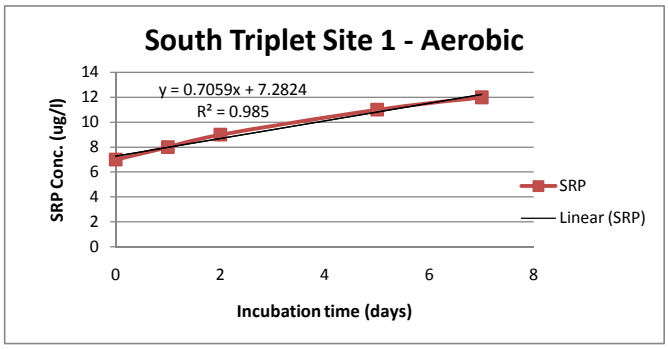

Queens Mirror Site 2 - Anoxic
Total P Conc. (ug/l)
Incubation time (days)
y = 9.6575x + 66.819
R² = 0.9225
Total P
Linear (Total P)

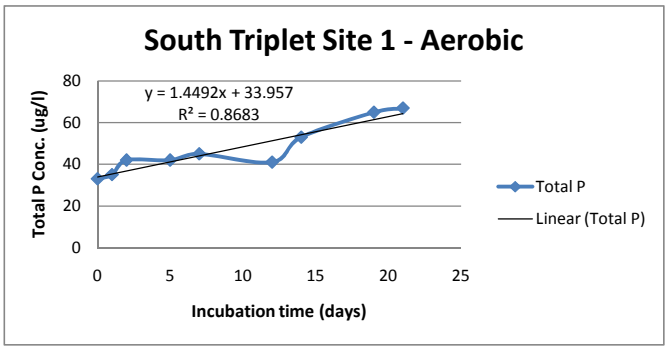

Queens Mirror Site 2 - Aerobic
SRP Conc. (ug/l)
Incubation time (days)
y = 0.8612x + 5.5004
R² = 0.9183
SRP
Linear (SRP)

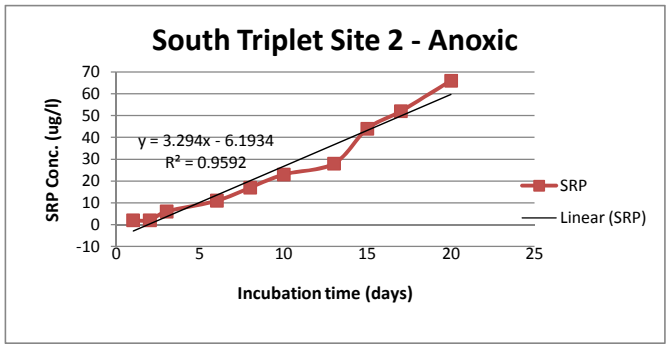

Queens Mirror Site 2 - Aerobic
Total P Conc. (ug/l)
Incubation time (days)
y = 1.6206x + 44.365
R² = 0.7897
Total P
Linear (Total P)

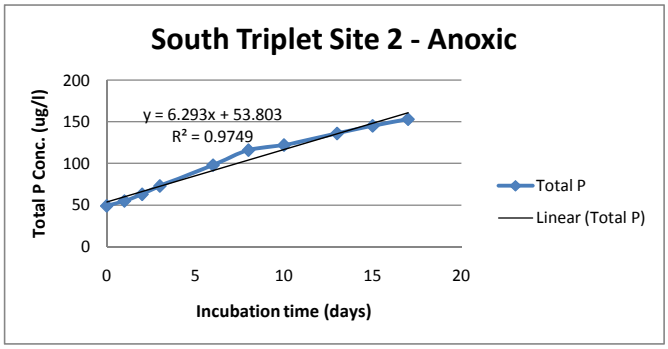

South Triplet Site 1 - Anoxic
y = 1.1191x + 10.255
R² = 0.9782
SRP Conc. (ug/l)
Incubation time (days)
SRP
Linear (SRP)

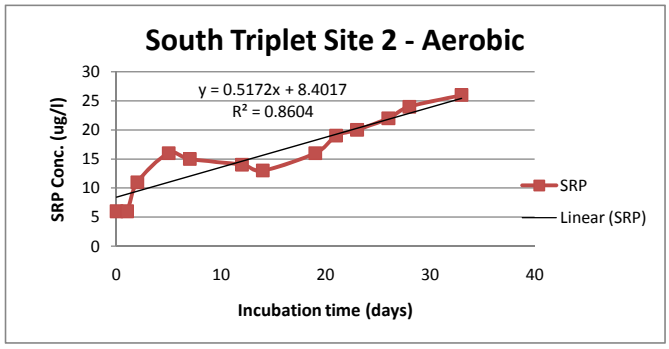

Queens Mirror Site 2 - Anoxic
y = 3.8397x + 20.832
R² = 0.9268
Total P Conc. (ug/l)
Incubation time (days)
Total P
Linear (Total P)

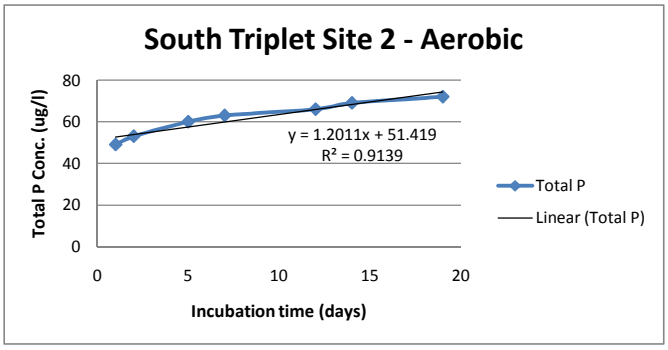

South Triplet Site 1 - Aerobic
y = 0.7059x + 7.2824
R² = 0.985
SRP Conc. (ug/l)
Incubation time (days)
SRP
Linear (SRP)


South Triplet Site 1 - Aerobic
y = 1.4492x + 33.957
R² = 0.8683
Total P Conc. (ug/l)
Incubation time (days)
Total P
Linear (Total P)


South Triplet Site 2 - Anoxic
y = 3.294x - 6.1934
R² = 0.9592
SRP Conc. (ug/l)
Incubation time (days)
SRP
Linear (SRP)


South Triplet Site 2 - Anoxic
y = 6.293x + 53.803
R² = 0.9749
Total P Conc. (ug/l)
Incubation time (days)
Total P
Linear (Total P)


South Triplet Site 2 - Aerobic
y = 0.5172x + 8.4017
R² = 0.8604
SRP Conc. (ug/l)
Incubation time (days)
SRP
Linear (SRP)


South Triplet Site 2 - Aerobic
y = 1.2011x + 51.419
R² = 0.9139
Total P Conc. (ug/l)
Incubation time (days)
Total P
Linear (Total P)