City of Naples Stormwater Quality Analysis, Pollutant Loading and Removal Efficiencies
FINAL

Prepared for:
City of Naples
Department of Streets and Stormwater

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AMEC Project No.: 6063-10-0182

January 2012

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List of acronyms and abbreviations

AMEC	AMEC Environment & Infrastructure, Inc.
BMPs	Best Management Practices
BOD	biological oxygen demand
CFU	Colony Forming Units
CN	curve number
DO	dissolved oxygen
EMCs	event mean concentrations
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
ft	feet
GIS	Geographic Information System
HSG	Hydrologic Soils Group
kg/yr	kilograms per year
mg/L	milligrams per liter
ml	milliliter
MPN	Most Probable Number
NO_x	nitrate-nitrite
O&M	operations and maintenance
SCS	Soil Conservation Service
SOPs	Standard Operating Procedures
TKN	Total Kjeldahl nitrogen
TMDL	Total Maximum Daily Load
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
µg/L	micrograms per liter
USDA	US Department of Agriculture
USEPA	US Environmental Protection Agency
WBID	Water Body Identification

1.0 Introduction

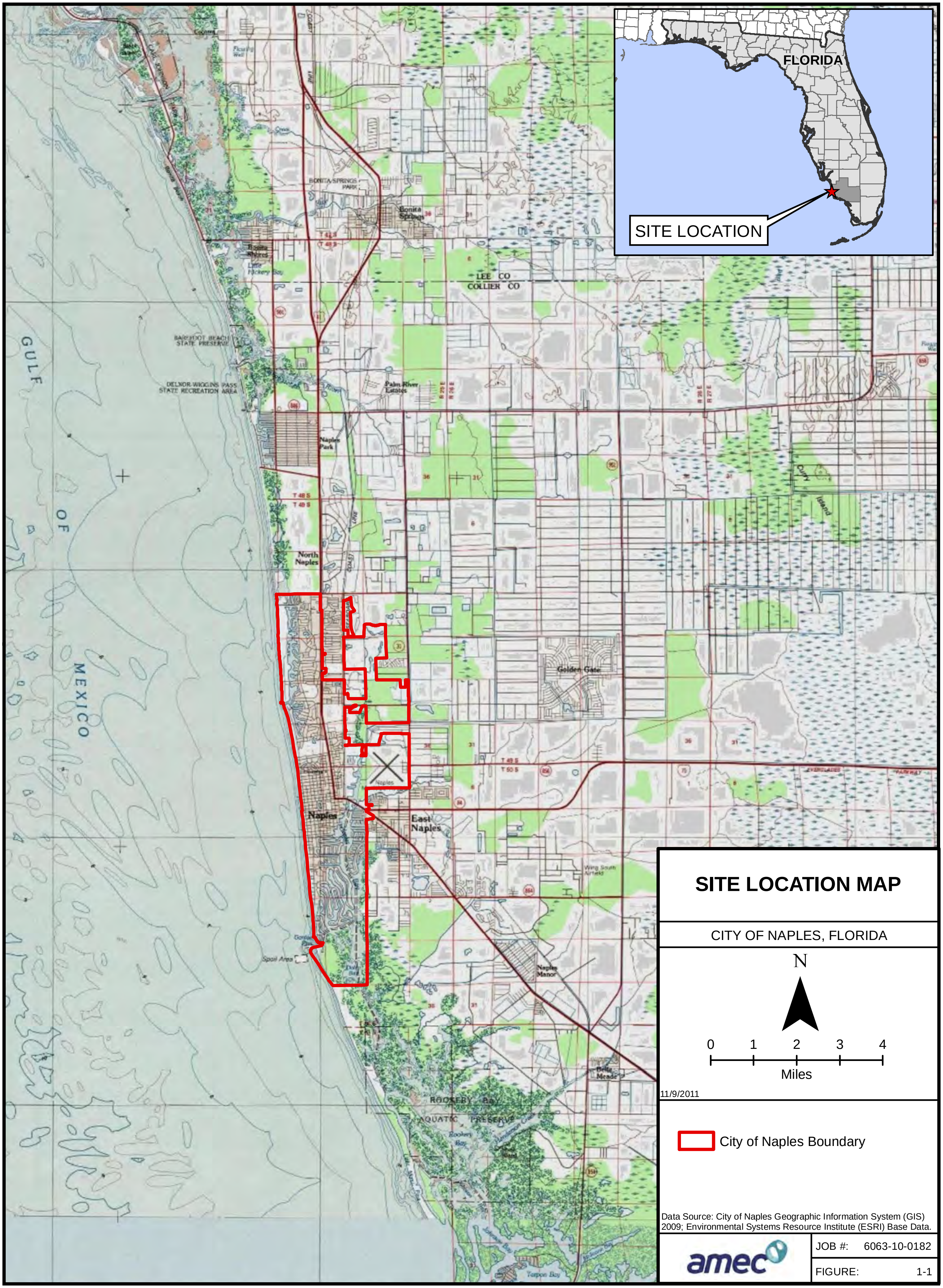
The City of Naples' (City) natural and manmade lakes serve many vital functions for the City, including flood control, stormwater treatment, aesthetic amenities and habitat for wading birds. Without appropriate maintenance, however, their ability to provide these services can deteriorate. If sediment accumulates their flood control and treatment capacities can be reduced. If overloaded with nutrients (from fertilizers, human or animal waste, and stormwater runoff) they may experience algal blooms, overgrowth of invasive aquatic plants, fish kills, or reduced water clarity. Human or animal waste could lead to public health concerns. Such water quality impairments detract from the lakes' value as amenities, and can also lead to state regulatory action adversely affecting the City.

The City has collected water quality data from lakes and/or stormwater conveyances since 2008, with increasing data collection efforts from 2008 through 2011. In 2009 the City contracted with MACTEC Engineering and Consulting, Inc. (MACTEC) now AMEC Environment & Infrastructure, Inc. (AMEC) to conduct baseline inspection and monitoring of 28 stormwater lakes within the City and develop an operations and maintenance (O&M) plan. The report and O&M plan were presented to the City in March 2010. The City has implemented their O&M Plan, resulting in a cost-effective routine inspection and maintenance program that mitigates water quality impairment and postpones or avoids much more costly corrective actions. During 2010 AMEC was contracted by the City to collect water samples from select stormwater conveyances and lakes on a quarterly basis. The City also requested AMEC to consolidate all of these data gathering efforts since 2008 to prepare a loading model that provides an initial identification of the sources of critical water pollutants observed in the lakes and receiving waters including the Gulf of Mexico, Gordon River and Naples Bay.

This report presents the results of stormwater and lakes monitoring conducted by AMEC from November 2010 through October 2011; consolidates available data from 2008 through 2011; and uses related data developed by the City or other sources to develop a model that provides a condition assessment and initial identification of the source of critical water pollutants. The data are interpreted to identify waterbodies or drainage basins that represent priority concerns for the City, primarily focusing on water quality issues that detract from amenity values of City lakes and ponds or could lead to state regulatory action adversely affecting City interests.

1.1 Project Background

The City is located in Collier County in southwest Florida. The City is bordered to the West by the Gulf of Mexico and to the East by the Gordon River and Naples Bay (Figure 1-1, Figure 1-4). The primary land use in the City is residential housing, followed by commercial land use and some recreation and industrial land use (Figure 1-2). The City is located within the Big Cypress Swamp Watershed. This watershed covers approximately 2,470 square miles of southern Florida, west of the Everglades and south of the Caloosahatchee River. Twenty four impaired waterbodies are included within this watershed.


FLORIDA
SITE LOCATION
GULF OF MEXICO
LEE CO
COLLIER CO
Bonita Springs
Naples Park
North Naples
Golden Gate
Naples
East Naples
Naples Manor
ROOKERY BAY AQUATIC PRESERVE
SITE LOCATION MAP
CITY OF NAPLES, FLORIDA
N
0 1 2 3 4
Miles
11/9/2011
City of Naples Boundary
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data.
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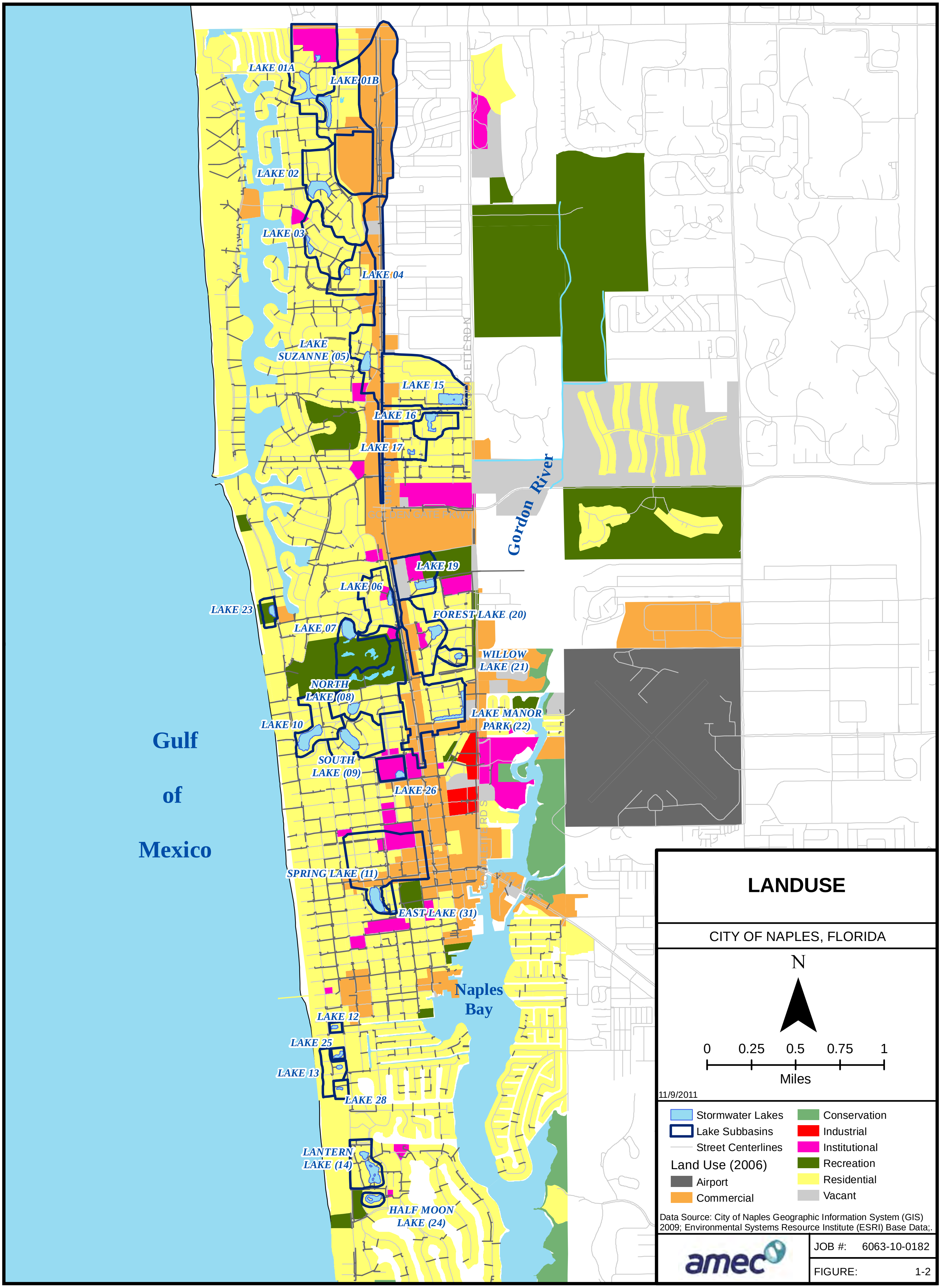
JOB #: 6063-10-0182
FIGURE: 1-1


LAKE 01A
LAKE 01B
LAKE 02
LAKE 03
LAKE 04
LAKE SUZANNE (05)
LAKE 15
LAKE 16
LAKE 17
LAKE 19
LAKE 06
LAKE 23
FOREST LAKE (20)
LAKE 07
WILLOW LAKE (21)
NORTH LAKE (08)
LAKE MANOR PARK (22)
LAKE 10
SOUTH LAKE (09)
LAKE 26
SPRING LAKE (11)
EAST LAKE (31)
LAKE 12
LAKE 25
LAKE 13
LAKE 28
LANTERN LAKE (14)
HALF MOON LAKE (24)
Gordon River
Gulf of Mexico
Naples Bay
LANDUSE
CITY OF NAPLES, FLORIDA
N
0 0.25 0.5 0.75 1
Miles
11/9/2011
Stormwater Lakes
Lake Subbasins
Street Centerlines
Land Use (2006)
Airport
Commercial
Conservation
Industrial
Institutional
Recreation
Residential
Vacant
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data;.
JOB #: 6063-10-0182
FIGURE: 1-2

Stormwater drainage for the City consists of an extensive gravity collection system including approximately 32 wet detention stormwater lakes and three (3) pumping stations. Stormwater flows through this collection system and is ultimately discharged to either the Gordon River, Naples Bay, the Moorings Bay system, or directly into the Gulf of Mexico. The 28 stormwater lakes investigated during this study drain to the following waterbodies: Lakes 1 to 5 outfall into the Moorings Bay System; Lakes 7 to 10 are connected in series and discharge into the Gulf of Mexico; Lake 11, 13, 14, 24, 25, 28, and East Lake discharge into Naples Bay; Lakes 6, 26 and 15 to 22 discharge into drainage ditches that ultimately drain into the Gordon River; and Lakes 12 and 23 do not have outlets for stormwater. Figure 1-3 shows the locations of the 28 stormwater lakes throughout the city.

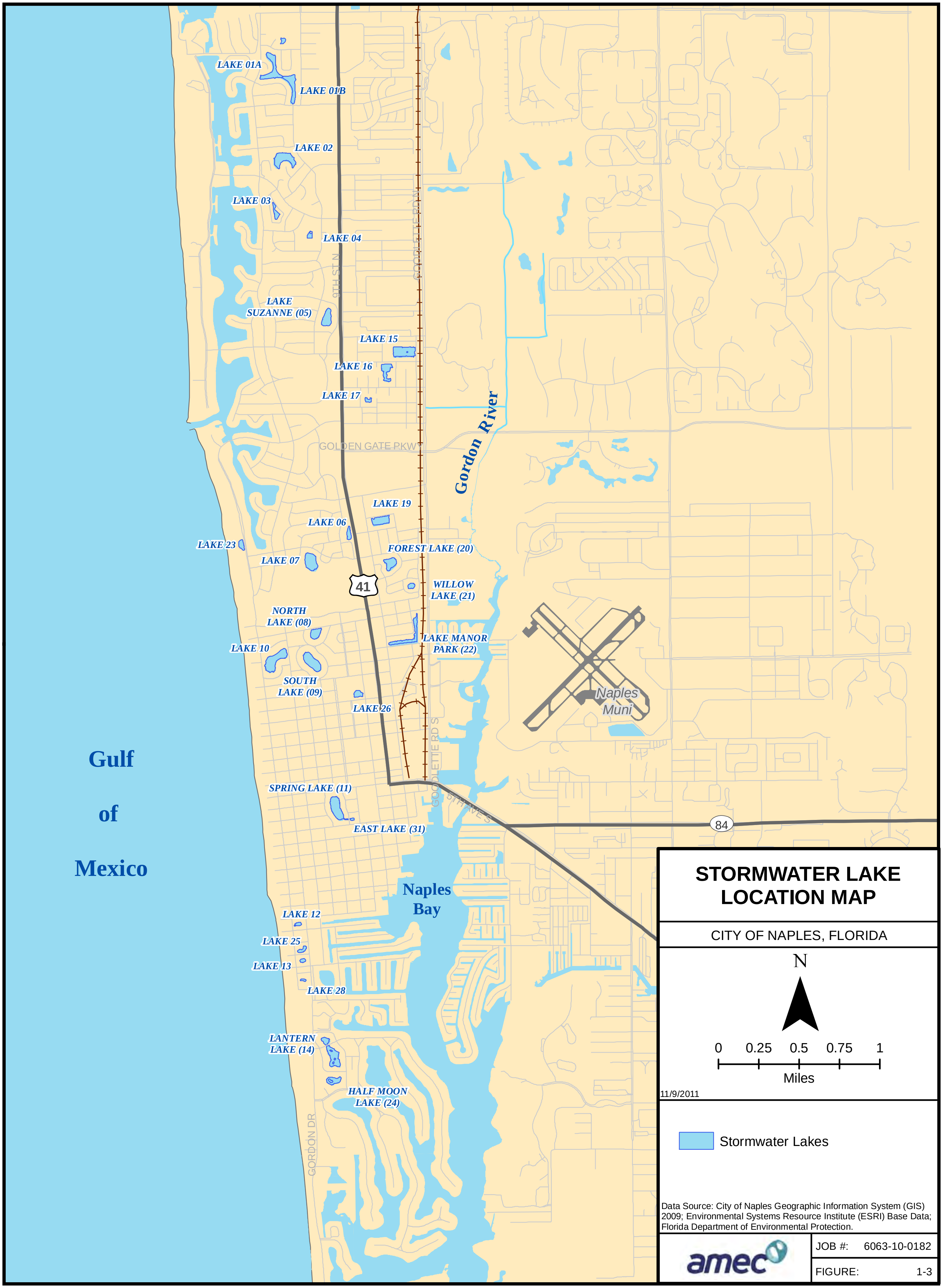

LAKE 01A
LAKE 01B
LAKE 02
LAKE 03
LAKE 04
LAKE SUZANNE (05)
LAKE 15
LAKE 16
LAKE 17
GOLDEN GATE PKWY
Gordon River
LAKE 19
LAKE 06
LAKE 23
LAKE 07
FOREST LAKE (20)
41
WILLOW LAKE (21)
NORTH LAKE (08)
LAKE MANOR PARK (22)
LAKE 10
SOUTH LAKE (09)
LAKE 26
Naples Muni
Gulf of Mexico
SPRING LAKE (11)
EAST LAKE (31)
84
Naples Bay
LAKE 12
LAKE 25
LAKE 13
LAKE 28
LANTERN LAKE (14)
HALF MOON LAKE (24)
GORDON DR
GOODLETTE RD N
GOODLETTE RD S
9TH ST N
STORMWATER LAKE LOCATION MAP
CITY OF NAPLES, FLORIDA
N
0 0.25 0.5 0.75 1
Miles
11/9/2011
Stormwater Lakes
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data; Florida Department of Environmental Protection.
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FIGURE: 1-3

1.2 Impaired Waters Determination

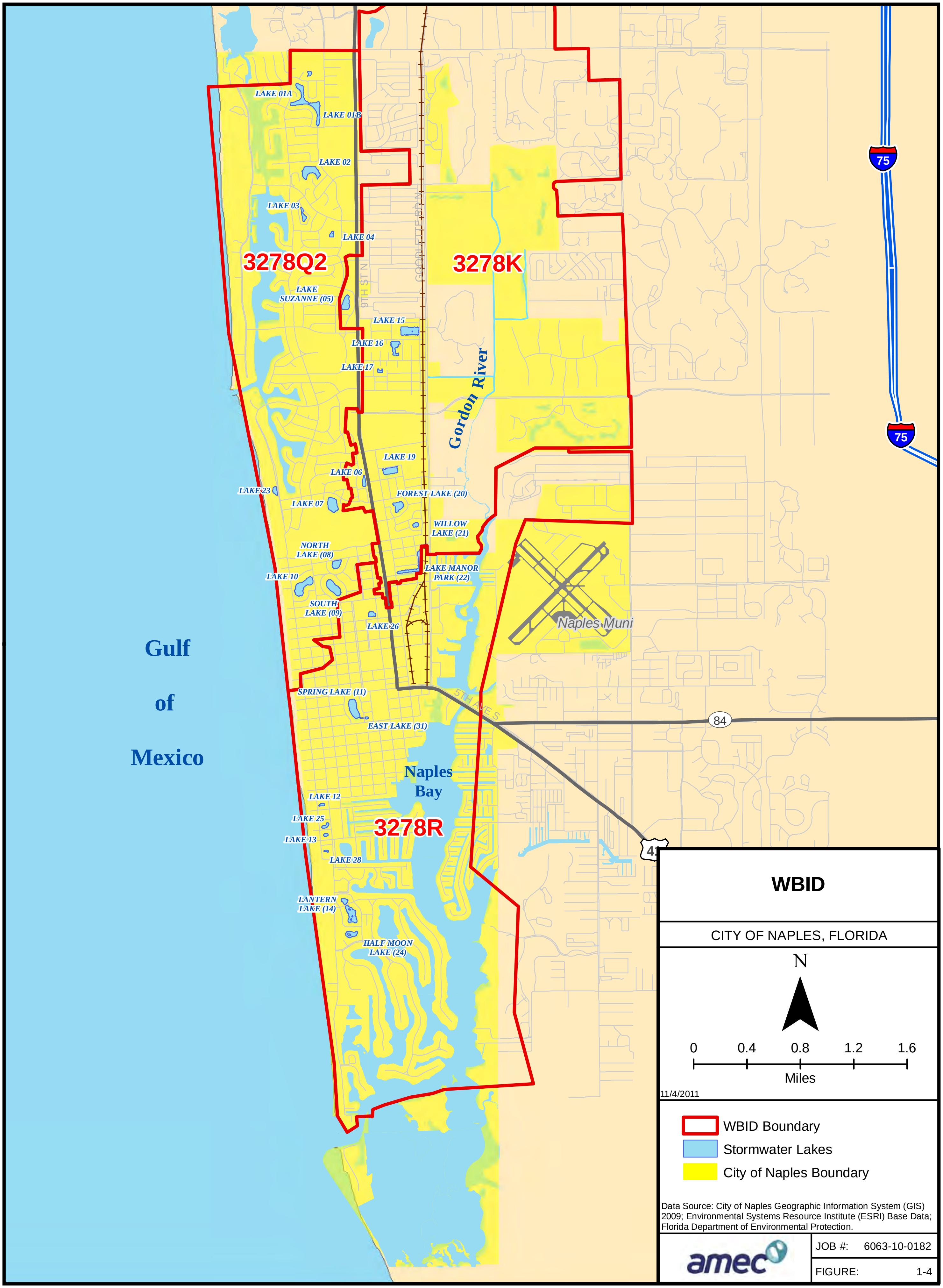
The City of Naples stormwater lakes drain into water bodies of the state that are required to meet water quality standards. The City of Naples is located within the Big Cypress Swamp Watershed which includes impaired waterbodies (Figure 1-4). The stormwater lakes investigated during this study drain into the Moorings Bay System, Gordon River, Naples Bay, and the Gulf of Mexico. Of the four (4) mentioned outfall locations, the Gordon River Extension [Water Body Identification (WBID) 3278K] and Naples Bay Coastal (WBID 3278R) are impaired according to The Everglades West Coast Group 1 Basin/ South District verified list published by the Florida Department of Environmental Protection (FDEP) in May of 2009. Naples Bay is impaired for copper, fecal coliform, dissolved oxygen (DO), and iron. Lakes 11, 12, 13, 14, 24, 25, 26, 28, and 31 discharge into Naples Bay Coastal (Figure 1-4). The Gordon River Extension is impaired for DO, and the causes are identified as excess total nitrogen (TN) and total phosphorus (TP). Lakes 5, 6, 15, 16, 17, 19, 20, 21, and 22 discharge to the Gordon River Extension.

All of the 28 lakes included in this analysis, except for Lake 7, have been sampled at least once since 2008. Some of these lakes (6, 13, 16, 17, 21, 24, 25, and 28) were sampled only once in 2009. Lake 22 has been sampled most frequently; eight (8) times since 2008.

Naples Bay is located within downtown Naples and little flushing occurs within the waterbody. Naples Bay is impaired by four (4) parameters. The concentration causing impairment for copper is ≥ 3.7 milligrams per liter (mg/L), fecal coliform is > 43 colony forming units (CFU)/100 milliliters (mL), iron is ≥ 0.3 mg/L, and DO is < 4.0 mg/L. Of these parameters, all but fecal coliform (Low Priority) were identified as Medium Priority for Total Maximum Daily Load (TMDL) Development (EWC, 2009).

FDEP developed TMDLs for the Gordon River Extension in 2008. The TMDL report evaluated biological oxygen demand (BOD), TN, and TP as potentially causative pollutants, but found there was sufficient data to determine a TMDL for TN only. FDEP determined that BOD and TP loadings also need to be returned to natural loading conditions to achieve the water quality objectives for the Gordon River Extension, although specific loading reductions for BOD and TP were not determined. The City of Naples is responsible for achieving reduction of anthropogenic TN loadings by 29% from stormwater outfalls that the City owns or controls.

The stormwater lakes of the City of Naples are not required to meet water quality concentration standards; however, they drain into water bodies of the state that are required to meet mass loading standards. These lakes provide some treatment of stormwater runoff through assimilation of pollutants thus reducing pollutant loadings to receiving water bodies. However, the stormwater lakes have been heavily loaded for decades and as pollutants concentrate in these stormwater lakes, discharge can also become a source of pollutant loading to receiving water bodies.



Gulf
of
Mexico
Naples
Bay
Gordon River
3278Q2
3278K
3278R
LAKE 01A
LAKE 01B
LAKE 02
LAKE 03
LAKE 04
LAKE SUZANNE (05)
LAKE 15
LAKE 16
LAKE 17
LAKE 19
LAKE 06
LAKE 23
LAKE 07
FOREST LAKE (20)
WILLOW LAKE (21)
NORTH LAKE (08)
LAKE 10
LAKE MANOR PARK (22)
SOUTH LAKE (09)
LAKE 26
SPRING LAKE (11)
EAST LAKE (31)
LAKE 12
LAKE 25
LAKE 13
LAKE 28
LANTERN LAKE (14)
HALF MOON LAKE (24)
Naples Muni
9TH ST N
GOODLETTE RD N
5TH AVE S
75
84
41
WBID
CITY OF NAPLES, FLORIDA
N
0
0.4
0.8
1.2
1.6
Miles
11/4/2011
WBID Boundary
Stormwater Lakes
City of Naples Boundary
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data; Florida Department of Environmental Protection.
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JOB #: 6063-10-0182
FIGURE: 1-4

1.3 Work Efforts Performed by AMEC

From September 2010 through October 2011, AMEC, under the City's direction, conducted stormwater sampling in major stormwater conveyances associated with selected City stormwater lakes. In 2009, one sample was collected from each of 27 City stormwater lakes (see Section 2.0 for summary). Based on those data and other considerations, a subset of ponds and their watersheds were investigated in greater detail during 2010-2011. Grab samples were collected from storm sewers and selected pond subbasins. In addition to grab samples, which are taken without regard to antecedent rainfall conditions, several storm event samples were collected to characterize the flow-weighted average concentrations of critical water pollutants associated with stormwater runoff. AMEC used City data, aerial photography, topographical information and our own field observations to refine drainage basin boundaries throughout the City. Using these data, AMEC developed a hydrologic and pollutant loading model for the primary pollutants total suspended solids (TSS), TN, and TP. AMEC also developed a preliminary pollutant loading model for copper and fecal coliform, however the lack of data supporting modeling of copper and fecal coliform when compared to pollutants such as TSS, TN and TP, limits the reliability of loadings of copper and fecal coliform. Estimated loading for copper and fecal coliform are included as an Appendix to this report. Finally, AMEC further interpreted these primary pollutant data and model results to focus and prioritize both future data collection and specific stormwater quality improvement projects for the City. These emphasize preservation of amenity values of the City's lakes and ponds; and reduction of loadings of specific pollutants that contribute to impaired waters of the state.

2.0 Past Work Efforts

2.1 Scope of Past Project(s)

The City first evaluated the surface water management drainage system in 1980 through 1981. The purpose of the earlier study (CH2M Hill, 1981) was to evaluate the various stormwater system components as to their adequacy and performance as water management facilities. This study also evaluated the adequacy of the system to handle large quantities of runoff during typical summer storm events and qualitatively addressed the water quality in the stormwater lakes and the impacts on receiving waterbodies. At that time, the drainage system serving the City consisted of an extensive gravity collection system, approximately 25 stormwater lakes, and three (3) stormwater pumping stations.

Water quality sampling efforts began in 2007, when the City collected preliminary water quality information on Lake 14. Water samples were analyzed for TN, total Kjeldahl nitrogen (TKN), nitrate-nitrite (NOx-N), TP, enterococci, fecal coliform, chlorophyll *a*, iron, magnesium, and ammonia. The City collected preliminary water quality information for additional select stormwater lakes in 2008. Grab water samples were collected from Lakes 8, 11, 19, 22, and 31 in February 2008 and Lakes 8, 11, 19, and 22 in September 2008. Water samples were analyzed for TN, TKN, NO_X, orthophosphate, TP, TSS, turbidity, enterococci, fecal coliform, chlorophyll *a*, arsenic and copper.

In 2009, the City authorized AMEC to conduct baseline inspection and monitoring of 28 stormwater lakes within the City and develop an O&M plan. The City was interested in acquiring baseline water quality and infrastructure data for the stormwater lakes in order to optimize O&M, develop pollutant load reductions to receiving waterbodies, and provide better stormwater lake management for aesthetic purposes. The 2009 study included a systematic survey of 28 stormwater lakes within the City of Naples. Study components, completed in each stormwater lake, included an infrastructure checklist, one water quality sample, and soft sediment thickness measurements.

The stormwater lake/infrastructure inspection included a checklist to identify and describe the condition of inflow and outflow structures, shoreline attributes (cover, emergent vegetation, erosion, riprap, etc), and occurrence of algal mats and aquatic plants. AMEC scientists performed water quality measurements at the center of each stormwater lake (unless access was limited) with a multiprobe YSI 556 sonde. Measurements included: DO, temperature, pH, salinity, and conductivity. Secchi depth (water transparency) was also measured at the center of each stormwater lake (unless access was limited). One (1) water sample was collected from each stormwater lake for laboratory analysis for common indicators of urban stormwater lake impairment including: copper, TN, NO_x, TKN, TP, TSS, and bacteria (fecal coliform and enterococci). Water chemistry samples were not collected from Lake 7 due to access issues. AMEC scientists also determined the thickness of soft sediment by driving a rod into the sediment to find the depth of first refusal. Sediment thickness was determined at a minimum of three (3) locations, with the number of observations approximately proportional to the area of the stormwater lake.

2.2 Findings of Past Project(s)

Common issues identified during the 2009 survey included bank erosion, overgrowth of aquatic vegetation (including invasive exotics and nuisance algae), and minor structural damages. In addition, the majority of lake samples revealed measurements of concern in one or more of the parameters analyzed- nutrients, copper, or bacteria. Based on the water quality and water chemistry results of the investigation, the following stormwater lakes exhibited values of primary concern.

- Lake 12 displayed the lowest DO measurement;
- Lake 14 displayed the lowest water transparency (Secchi depth);
- Lake 24 displayed the highest concentrations of TN and TP, which exceeded expected stormwater concentrations for residential land use;
- Lakes 13 and 28 revealed elevated levels of both fecal coliforms and enterococci; and

- Lake 26 revealed a concentration of copper significantly greater than the water quality standard.

Based upon the results of the soft sediment thickness measurements, thicker soft sediment was often associated with inflow structures. The following stormwater lakes revealed soft sediment thickness of 19 inches or greater: Lake 1NW, Lake 2, Lake 9, Lake 20, Lake 22, and Lake 25.

2.3 Recommendations of Past Project(s)

The 2009 investigation revealed deficiencies in many of the stormwater lakes of the City of Naples in regards to infrastructure, water quality, sedimentation, and aesthetics. These stormwater lakes are not required to comply with water quality standards; however, the lakes themselves would benefit from management adjustments to minimize them as potential sources of pollutants to receiving water bodies. In addition, poor water quality reduces the aesthetic value of the stormwater lakes.
Issues of primary importance include:

- Investigate and repair structural damage;
- Initiate public education on stormwater lake health;
- Evaluate impacts of harvesting of stormwater for irrigation and use of reclaimed water for irrigation to limit excess nutrient loading and/or drawdown;
- Perform a second round of sampling of the stormwater lakes, and prioritize lake improvements;
- Develop water and nutrient budgets to optimize reduction of pollutant loadings from stormwater lakes to impaired receiving water bodies; capture reductions to ensure crediting against TMDL load reduction requirements; and
- Evaluate all stormwater lakes of primary concern for conceptual design of retrofits.

3.0 2011 Field Data Collection

3.1 General Description

Extensive data collection efforts were a main focus of this project. Data was collected in two (2) main phases, including quarterly grab-sample monitoring at 24 locations throughout the city as well as storm event sampling at three additional locations. Sampling was conducted in order to provide a more accurate characterization of local water characteristics than could be obtained from a strictly desktop, literature based analysis. These characterization efforts have assisted in identifying areas of increased pollutant concentrations, as well as improving the accuracy of the pollutant modeling that will be discussed later in this report.

3.2 Quarterly Grab Samples

Quarterly monitoring of 24 stormwater locations throughout the City was conducted from December of 2010 to September of 2011. Samples were obtained from a variety of locations, including surface waters, pump stations, manholes, grate inlets and culverts. By selecting a variety of locations and systems around the City, water quality characteristics of typical stormwater structures and systems could be assessed, providing an indication of stormwater condition. Also, by taking samples throughout the year, seasonal variation of the various water quality parameters could be assessed, and better annual pollutant loading estimates could be performed.

Sample methods varied depending upon the type of location being sampled. Sampling was conducted in accordance with all applicable FDEP Standard Operating Procedures (SOPs). Due to the variety of locations encountered, sampling methods and equipment varied depending on the conditions at each particular site. In areas of shallow depth or high potential for sediment disturbance, a peristaltic pump was used to pump water into sample containers through a ¼ inch polyethylene tube. If there was no potential for sediment disturbance but the water surface was out of reach, a disposable polyethylene bailer was used. If there was no potential for sediment disturbance and the water surface was in reach, a plastic, laboratory grade polyethylene container was used for sample collection.

Stormwater samples were analyzed for common indicators of urban stormwater pond impairment, or of specific concern in impaired waters of the Gordon River or Naples Bay. These included copper, TN, NO_x, TK, TP, TSS and bacteria (fecal coliform and enterococci). Immediately following sample collection, sample containers were placed on ice. Water chemistry samples for copper, TN, NO_x, TKN, TP, and TSS were transported to Test America Laboratories in Tampa, FL using Federal Express. Water samples to be analyzed for fecal coliform and enterococci were transported to Sanders Laboratories in Ft. Myers, Florida by AMEC personnel within 6 hours of sample collection.

Water quality measurements were also taken for each sample location at the time of sample collection. Measurements, including DO, temperature, pH and conductivity were taken using a multiprobe YSI 556 sonde. Water quality measurements were taken following sample collection to avoid potential contamination. If there was no potential for sediment disturbance, water quality measurements were taken by directly inserting the YSI probe into the water source. If however there was potential for sediment disturbance, an in-situ flow cell was created using a laboratory grade plastic container and the peristaltic pump previously described.

3.2.1 Sample Locations

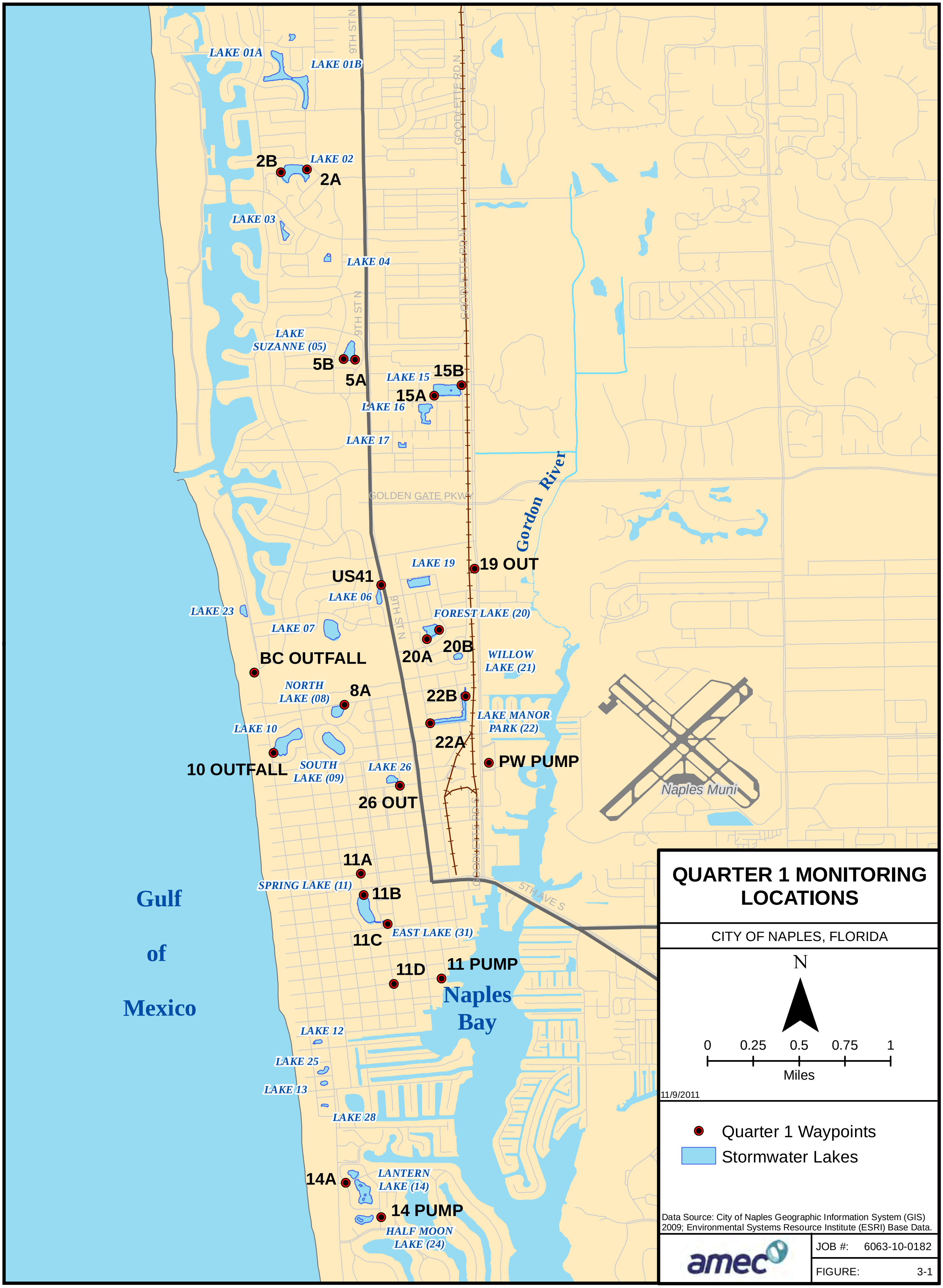
Sample locations were determined based on results of past projects (see Section 2 for discussion) as well as locations of interest to the City. Quarter 1 (Q1) locations (Figure 3-1) were determined at the project kick-off meeting, held on November 23, 2010. Of the 24 sampling locations indicated in Figure 3-1, 19 remained constant during each quarter. The remaining five (5) locations (11A, 11B, 14A, 14B, PW) were utilized as a method of source tracking: each quarter, past results were evaluated and sample locations were revised in an effort to locate the source(s) of the elevated pollutant(s) of concern. Figures illustrating the sample location revisions, along with quarterly results and discussion from each location, can be seen in Appendix A. The main pollutants of concern for the source tracking efforts were bacteria and copper.

The constant sample locations (Figure 3-1) can be classified into the following groups:

- **Pond Influent/Effluent –** These samples included locations 2, 5, 8/10, 15, 20, and 22 and consisted of surface water samples at the influent and effluent end of stormwater lakes. Locations 8A and 10-Outfall represent influent and effluent samples from the stormwater lake 8 through 10 system, which is a system of three (3) ponds in series.
- **Final Discharge –** These samples included locations 2B, 5B, 10-Outfall, 11-Pump, 15B, 19-Out, 20B, 22B, 26-Out and BC-Outfall and consisted of surface water samples taken from locations that represent the final stormwater concentration prior to discharge into the final receiving waterbody. These locations allowed for characterization of stormwater inputs into Gordon River, Naples Bay, the Moorings Bay system, and the Gulf of Mexico.
- **Stormwater Conveyance –** These samples included locations 11C, 11D and US41 and consisted of samples taken from concrete conveyances.

The source tracking sample locations provide general conveyance information useful in characterizing baseflow information and identifying areas of potentially elevated pollutant loadings, and include the following:

- **Spring Lake Basin** – Sample locations 11A and 11B were located upstream of Spring Lake and were moved every quarter in response to elevated copper or fecal coliform concentrations indicated from the previous quarter's sampling. Quarterly sample locations are indicated in Figure A-1.
- **Lantern Lane Basin –** Sample locations 14A and 14B were located upstream of the Lantern Lane Pump Station and were moved every quarter in response to elevated copper or fecal coliform concentrations indicated from the previous quarter's sampling. Quarterly sample locations are indicated in Figure A-2. As previously stated, the Lantern Lane Pump Station (14-Pump) was sampled as one of the two Q1 Lantern Lane Basin samples.
- **Public Works Basin** – Sample location PW was located upstream of the Public Works Pump Station and was moved every quarter in response to elevated copper or fecal coliform concentrations indicated from the previous quarter's sampling. Quarterly sample locations are indicated in Figure A-3. As previously stated, the Public Works Pump Station (PW-Pump) was sampled as the Q1 Public Works Basin sample.


LAKE 01A
LAKE 01B
9TH ST N
GOODLETTE RD N
LAKE 02
2B
2A
LAKE 03
LAKE 04
LAKE SUZANNE (05)
5B
5A
LAKE 15
15B
15A
LAKE 16
LAKE 17
GOLDEN GATE PKWY
Gordon River
LAKE 19
19 OUT
US41
LAKE 06
LAKE 23
FOREST LAKE (20)
LAKE 07
BC OUTFALL
20A
20B
WILLOW LAKE (21)
NORTH LAKE (08)
8A
22B
LAKE MANOR PARK (22)
LAKE 10
22A
10 OUTFALL
SOUTH LAKE (09)
LAKE 26
PW PUMP
26 OUT
Naples Muni
11A
SPRING LAKE (11)
11B
5TH AVE S
Gulf of Mexico
11C
EAST LAKE (31)
11D
11 PUMP
Naples Bay
LAKE 12
LAKE 25
LAKE 13
LAKE 28
14A
LANTERN LAKE (14)
14 PUMP
HALF MOON LAKE (24)
QUARTER 1 MONITORING LOCATIONS
CITY OF NAPLES, FLORIDA
N
0
0.25
0.5
0.75
1
Miles
11/9/2011
Quarter 1 Waypoints
Stormwater Lakes
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data.
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JOB #: 6063-10-0182
FIGURE: 3-1

3.2.2 Results

Quarterly sampling results were divided according to the nature of the sample location. The first group of results that are presented in Section 3.2.2.1 were results in which an influent-end and effluent-end samples were taken from the same stormwater lake. The second group of results that are presented in Section 3.2.2.2 were results in which a sample was taken that represents the water quality just prior to discharge into a major receiving waterbody. When available, regulatory criteria for specific parameters were displayed on each figure. It should be noted that these regulatory criteria however apply to downstream, regulated waterbodies and not necessarily to the stormwater lakes themselves. For TN and TP, the regulatory criteria displayed represent the estuarine numeric nutrient criteria recently promulgated in Chapter 62-302.532 Florida Administrative Code (F.A.C.) for Naples Bay. For fecal coliform and copper, the regulatory criteria displayed represent the numeric criteria given in Chapter 62-302.530.

3.2.2.1 Pond Influent/Effluent Sample

Stormwater lakes in which influent-end and effluent-end samples were taken include Lakes 2, 5, 15, 8/10, 20 and 22. Except for sample locations associated with Lakes 11 and 14, sample location identifications consisted of the number of the lake being sampled and a suffix: suffixes included “A” for upstream, “B” for downstream, “Out” for downstream with no corresponding upstream sample taken, and “Outfall” for beach outfall. Sample locations 8A and 10-Out were treated as one system, as Lake 8 flows into Lake 9, which then flows into Lake 10. The results for the six (6) main water quality parameters analyzed for, which include TSS, TN, TP, copper, fecal coliform and enterococci, are presented in Figures 3-2 through 3-7. Influent and effluent samples are grouped together on each figure, for a direct comparison of each and to visually assess the functioning condition of that stormwater lake. It is desirable that pollutant levels would be reduced during the period that water resides within the lake, leading to a reduction at the effluent-end compared with the influent-end. Although this was the initial intent of choosing these 12 sample locations, the results are not necessarily indicative of the true pollutant removal capacity of each lake, as grab samples were taken without regard to storm events, and in some cases there was little to no flow observed at many of the influent locations and even some outflow locations. Outflow was consistently observed at stormwater lakes 2 and 5 during all quarters, while stormwater lakes 10 and 22 had intermittently observed outflow and stormwater lakes 15 and 20 were never observed flowing. Observed inflows at all six (6) systems were intermittent at best.

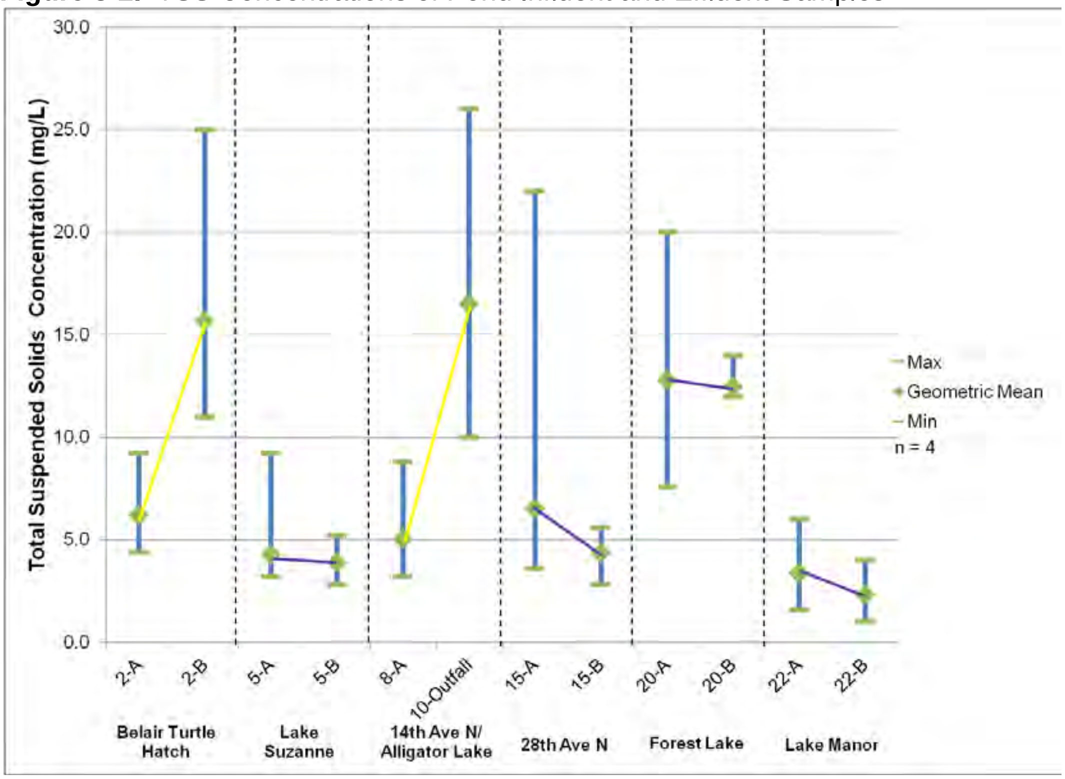
3.2.2.1.1 TSS, TN, TP

Figures 3-2 through 3-4 show TSS, TN and TP results of the 12 comparison samples. Results displayed for each sample location include minimum, maximum, and geometric mean. Figure 3-2 shows that all lake systems showed a TSS concentration reduction from influent to effluent end except for Lakes 2 and 8/10. These two (2) systems indicated potential export of TSS, as the minimum measured value of each effluent-end sample was greater than the maximum measured value of each influent-end sample.

For TN (Figure 3-3), Lakes 5 and 20 were the two (2) systems that showed concentration increases from influent-end sample to effluent-end sample. Results from Lake 5 may however be affected by the lack of inflow during sample collection events as well as the presence of three (3) submerged aeration units within the stormwater lake. There was also consistently observed flow through the control structure each time location 5B was sampled, which indicates that results from sample locations 5A and 5B may represent a near background TN concentration for that specific, well mixed stormwater lake. Results from Lake 20 also indicate potential TN export, however it should be noted that the water level in Lake 20 was consistently low, at approximately 1 to 2 feet (ft) below the invert of the outflow pipe during each sample collection event. Inflow to Lake 20 was also only observed during the Q4 sampling event. For these reasons, TN concentrations at sample locations 20A and 20B may also be indicative of a lake-wide background concentration, as little to no flow-through conditions were observed.

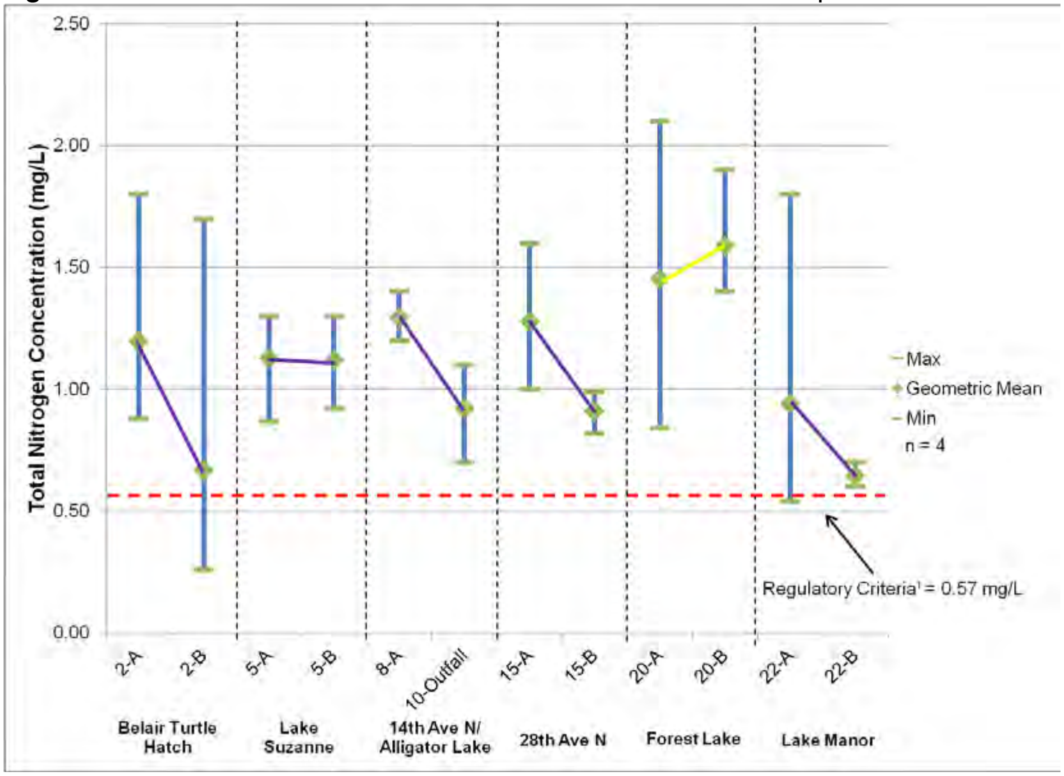
Figure 3-4 shows quarterly TP concentrations and ranges from the six (6) systems, and indicates that all systems provide some level of TP removal. The three (3) systems with the highest TP concentrations, which are Lakes 5, 8 and 20, were the most visibly eutrophic during sample collection events. This observation indicates phosphorus limits primary production and suggests that phosphorus controls would reduce eutrophication of downstream waterbodies. Based on this data-set, it appears that the systems analyzed are providing some level of phosphorus removal, but the more heavily loaded systems (i.e. 5, 8/10 and 20) may be reaching saturation.

Figure 3-2. TSS Concentrations of Pond Influent and Effluent Samples



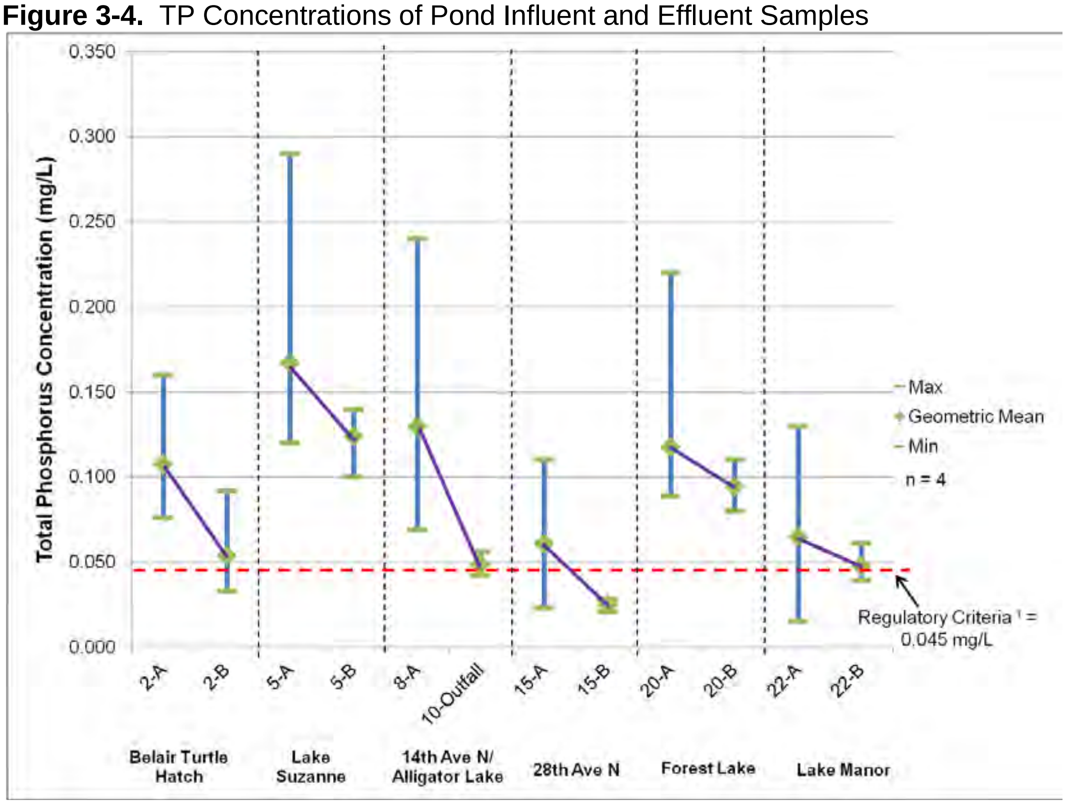
Created By: SEM Checked By: SCA

Figure 3-3. TN Concentrations of Pond Influent and Effluent Samples



Created By: SEM Checked By: SCA
[1]Ch. 62-302.532 F.A.C. applicable to the receiving waters, but not to City of Naples lakes

Figure 3-4. TP Concentrations of Pond Influent and Effluent Samples



Created By: SEM Checked By: SCA
[1]Ch. 62-302.532 F.A.C. applicable to the receiving waters, but not City of Naples lakes

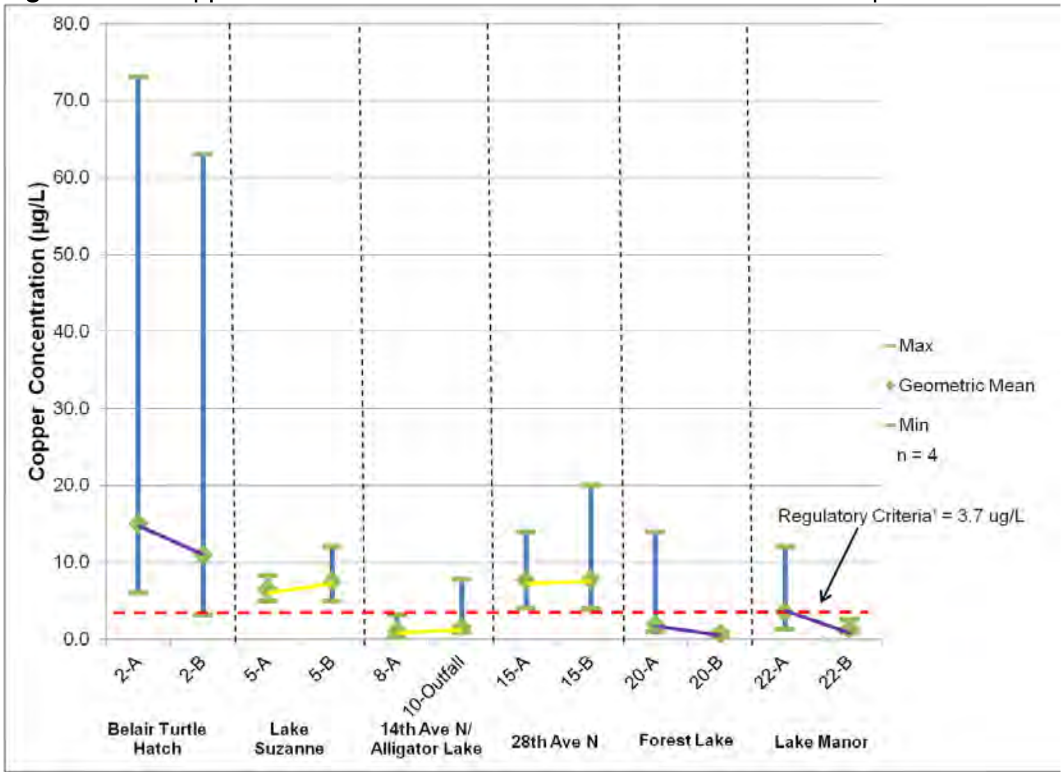
3.2.2.1.2 Copper, Fecal Coliform Bacteria, Enterococci Bacteria

Figures 3-5 through 3-7 show copper, fecal coliform and enterococci results for the 12 comparison sample locations. Results displayed for each sample location include minimum, maximum, and geometric mean. For copper (Figure 3-5) and fecal coliform (Figure 3-6) figures, the state regulatory criteria for Class II waters are displayed as red dashed lines. The regulatory limit for copper is 3.7 micrograms per liter (µg/L) while the regulatory criteria for fecal coliform states that not more than 10% of the samples can exceed 43 CFU/100mL.

Figure 3-5 shows that the general trend in all lake systems for copper is downward, however removal rates for the most part are not large. Lakes 2, 5, and 15 consistently measured influent and effluent-end concentrations above the regulatory limit of 3.7 µg/L discussed in Section 1, which may indicate increased loading of the heavy metal or legacy sources within the stormwater lake sediments, caused by years of copper-based nuisance/exotic management. Lake 2 also showed highly elevated copper levels, particularly during the Q2 sampling event (2A = 73 µg/L, 2B = 63 µg/L), that warrant further evaluation and potential source tracking efforts. A potential explanation may be the large portion of US41 that drains to Lake 2 (see Figure 4-1), as automotive components such as tires and brake pads can be a significant source of heavy metal deposition on major roadways (WWE & GC, 2011). Historic and current copper-based algaecide treatment may also explain some of the elevated concentrations, however little information is available to explain if and at what frequency algaecides are currently applied.

Bacteria results, including fecal coliform and enterococci, are shown in Figures 3-6 and 3-7, respectively. The Lake 8/10 system shows the greatest removal rate for fecal coliform, however results may have been influenced by the reduced persistence of the fecal coliform indicator organism in higher salinity environments and the periodic tidal influence on sample location 10-Outfall. This idea is further substantiated by the increase in enterococci between 8A and 10-Outfall, as enterococci is more persistent in saline environments. Lake 5 generally had the lowest bacteria counts while Lake 22 generally had the highest bacteria counts, with a mean fecal coliform count for sample location 22A of 2894 CFU/100mL. This elevated mean concentration may be the result of a number of anthropogenic or natural environmental inputs. The Lake 22 drainage basin that flows to the influent culvert sampled by location 22A is composed of a significant amount of impervious surface as well as an extensive network of underground conveyances. Several studies have shown stormwater conveyances may provide suitable environments for the survival and persistence of non-enteric fecal coliform bacteria (Marino & Gannon, 1991; Skinner *et al*., 2010). This, along with the consistently observed duck feces on the headwall near sample location 22A may explain the high bacteria counts.

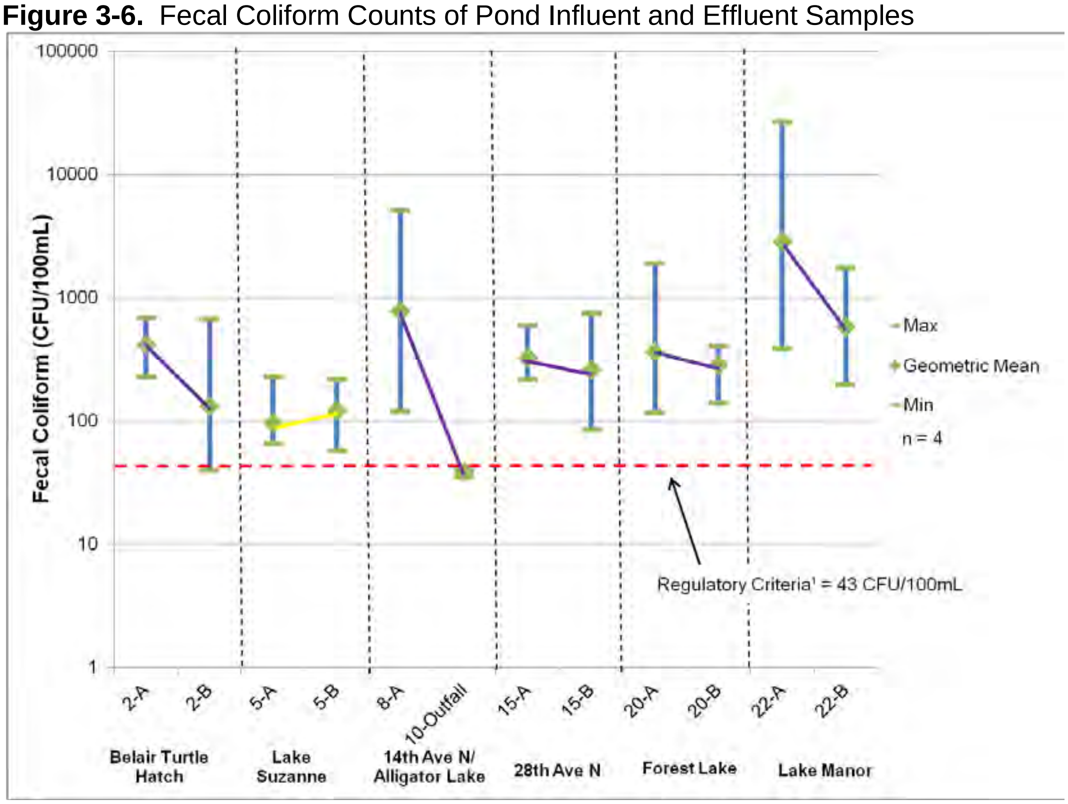
Figure 3-5. Copper Concentrations of Pond Influent and Effluent Samples



Created By: SEM Checked By: SCA

[1]Ch. 62-302.530 F.A.C. applicable to the receiving waters but not to City of Naples lakes

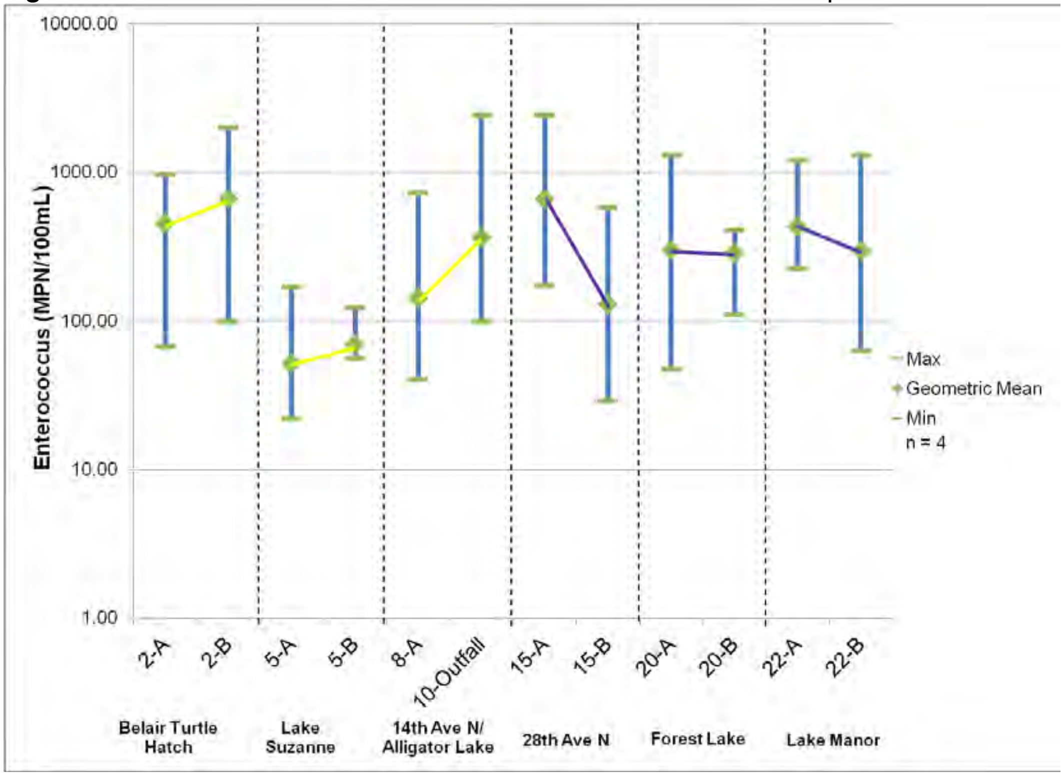
Figure 3-6. Fecal Coliform Counts of Pond Influent and Effluent Samples



Created By: SEM Checked By: SCA

[1]Ch. 62-302.530 F.A.C. applicable to the receiving waters but not City of Naples lakes

Figure 3-7. Enterococci Counts of Pond Influent and Effluent Samples



Created By: SEM Checked By: SCA

3.2.2.2 Discharge Characterization Samples

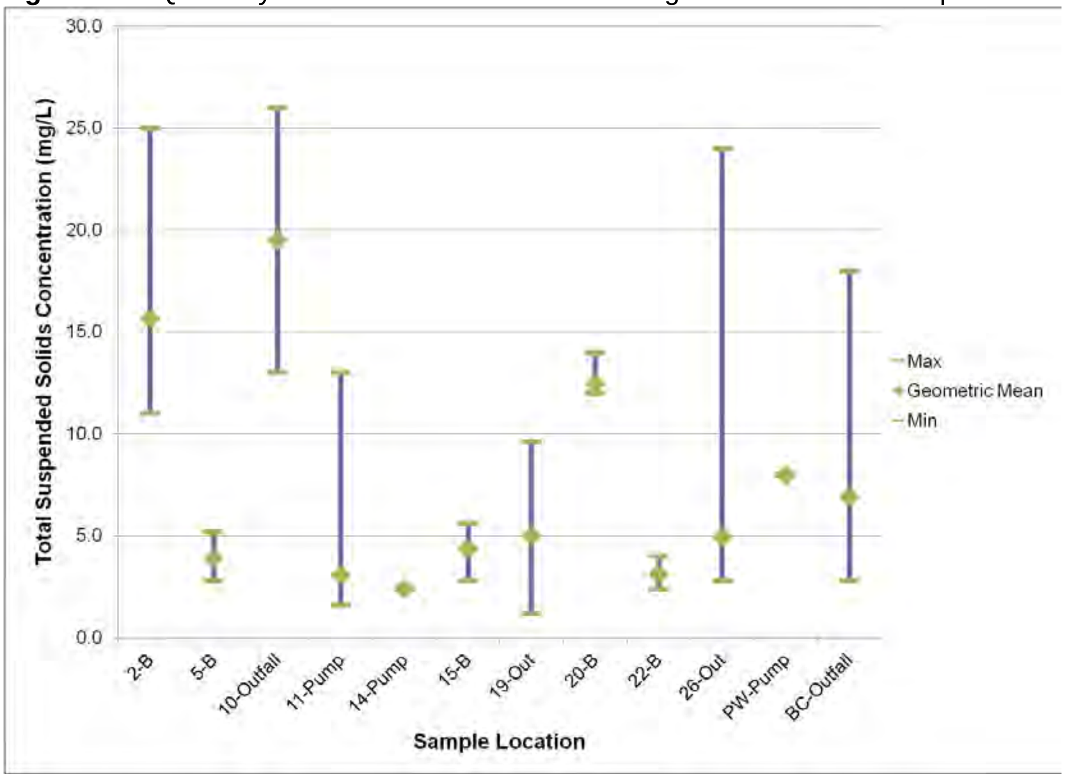
Sample locations that represent water quality just prior to discharge into a major receiving waterbody were 2B, 5B, 10-Outfall, 11-Pump, 14-Pump, 15B, 19-Out, 20B, 22B, 26-Out, PW-Pump and BC-Outfall. Results for the six (6) main water quality parameters analyzed (TSS, TN, TP, Copper, fecal coliform and enterococci) are presented in Figures 3-8 through 3-13. Although highly variable, these results are good indications of the pollutant concentrations being delivered to the major receiving waterbodies, including the Moorings Bay system, Gordon River, Naples Bay and the Gulf of Mexico. These results are used in conjunction with all other discharge characterization data to assess stormwater lake performance and develop estimates for total annual pollutant loads discharged to the aforementioned major receiving waterbodies.

3.2.2.2.1 TSS, TN, TP

Figures 3-8 through 3-10 show TSS, TN and TP results of the 12 locations that represent water quality just prior to discharge into a major receiving waterbody. Results displayed for each sample location include minimum, maximum, and geometric mean. Locations 14-Pump and PW-Pump have sample sizes of 1 (n=1), while all other locations have sample sizes of 4 (n=4). Figure 3-8 shows high variability in TSS discharge concentrations. Sample locations 2B and 10-Outfall had the highest mean concentrations, at 16 and 20 mg/L, respectively, while sample locations 5B, 15B and 22B had consistently low concentrations, indicating that the respective stormwater lakes provided adequate TSS retention.

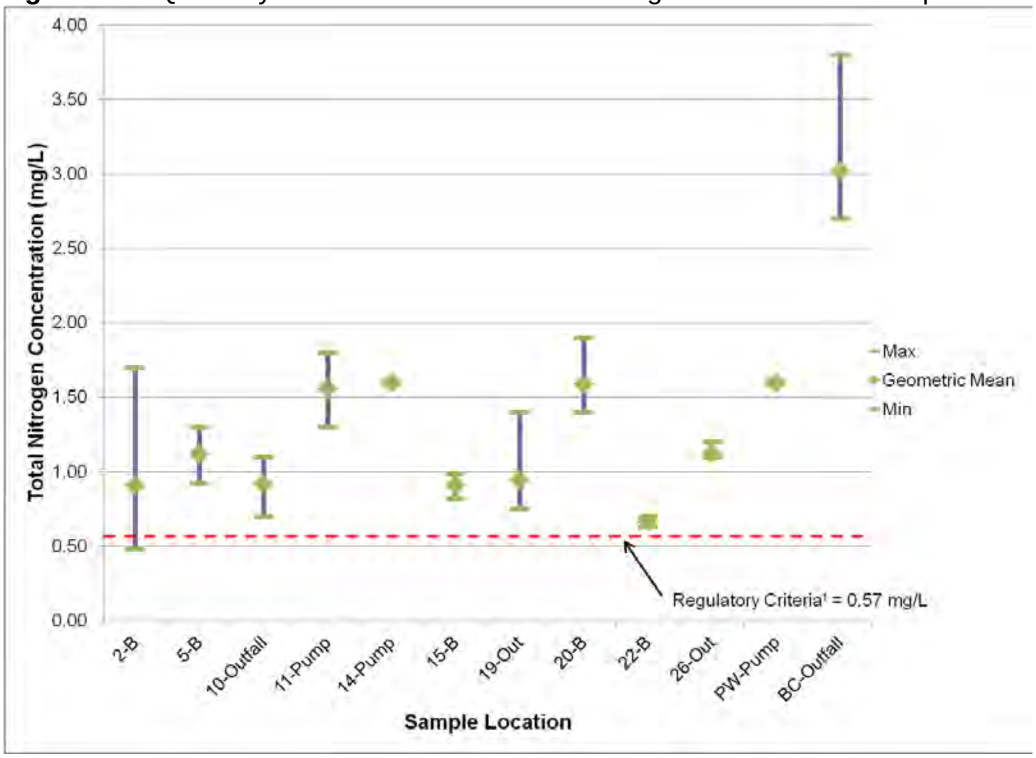
Figure 3-9 and 3-10 show TN and TP concentrations, respectively of the 12 discharge sample locations. BC-Outfall had the highest mean TN concentration and the second highest mean TP concentration, at mean of 3.0 mg/L TN and 0.25 mg/L TP. Based on conveyance data (see Figure 4-2), BC-Outfall receives flow directly from two of the wet detention ponds located on the Naples Beach Golf Club course. These elevated nutrient concentrations may be indicative of over-fertilization of the golf course. Three pump stations report mean TN and TP concentrations greater than the concentrations measured directly from stormwater lakes. This indicates that the stormwater lakes are removing nutrients.

Figure 3-8. Quarterly TSS Concentrations of Discharge Characteristic Samples



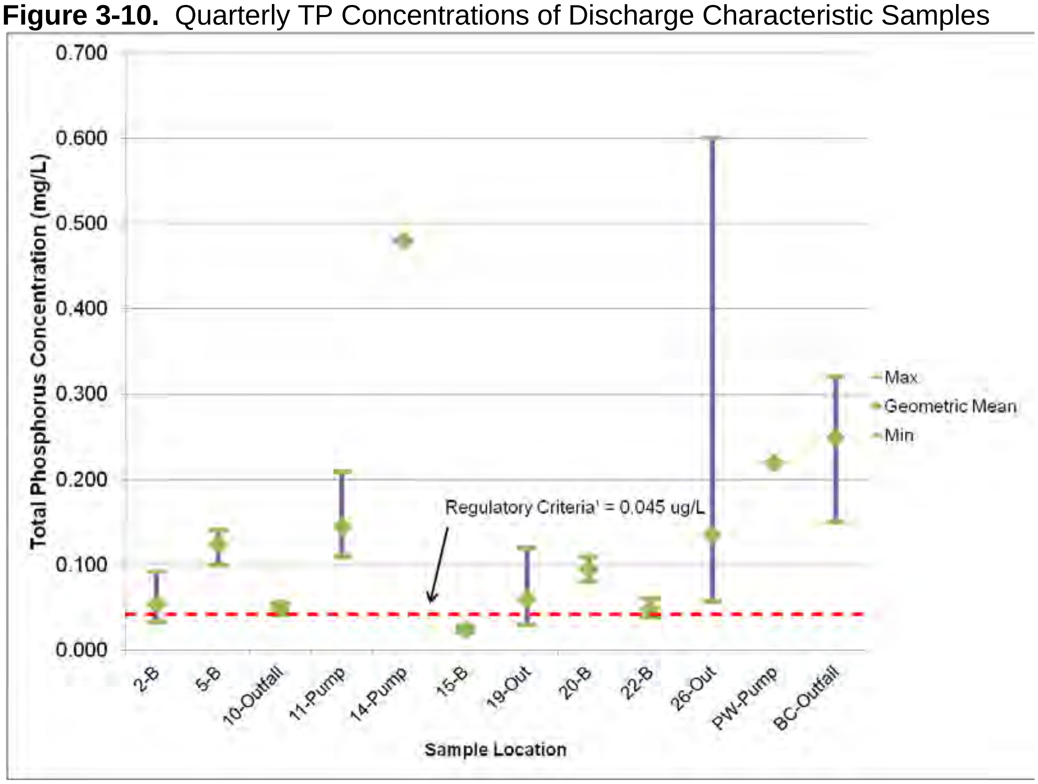
Created By: SEM Checked By: SCA
n = 1 for 14-Pump and PW-Pump, n = 4 for all other sample locations

Figure 3-9. Quarterly TN Concentrations of Discharge Characteristic Samples



Created By: SEM Checked By: SCA
n = 1 for 14-Pump and PW-Pump, n = 4 for all other sample locations
[1]Ch. 62-302.532 F.A.C. applicable to the receiving waters but not to City of Naples lakes

Figure 3-10. Quarterly TP Concentrations of Discharge Characteristic Samples



Created By: SEM Checked By: SCA
n = 1 for 14-Pump and PW-Pump, n = 4 for all other sample locations
[1]Ch. 62-302.532 F.A.C. applicable to the receiving waters but not to City of Naples lakes

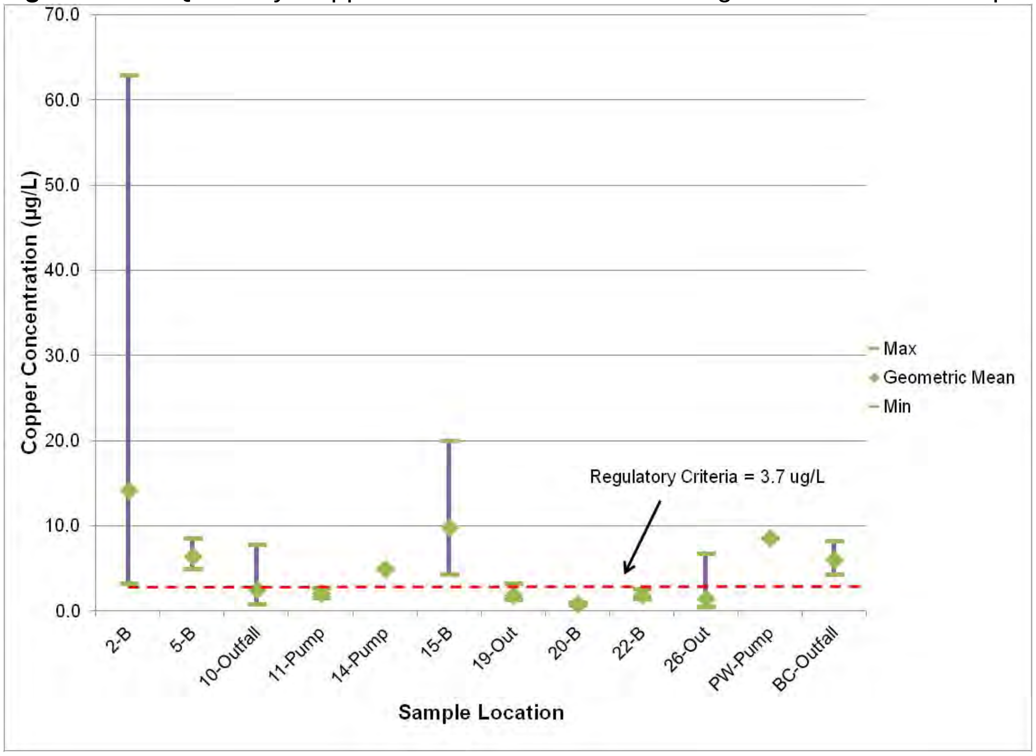
3.2.2.2.2 Copper, Fecal Coliform Bacteria, Enterococci

Figures 3-11 through 3-13 show copper, fecal coliform and enterococci results for the 12 discharge characterization sample locations. Results displayed for each sample location include minimum, maximum, and geometric mean. Locations 14-Pump and PW-Pump have sample sizes of 1 (n=1), while all other locations have sample sizes of 4 (n=4).

Copper results in Figure 3-11 are generally near or below the 3.7 μg/L regulatory limit discussed in Section 1, with notable exceptions including sample locations 2B, 5B, 15B, PW-Pump and BC-Outfall. As previously discussed, Lake 2 is served by a watershed with heavy automotive traffic, which may be a source of high copper concentrations. The same can be said of the Public Works Pump Station (PW-Pump), which has a drainage basin with significant impervious surface coverage. Copper-based algaecide treatment may also explain some of the elevated concentrations, however little information is available to explain if and at what frequency algaecides are currently applied.

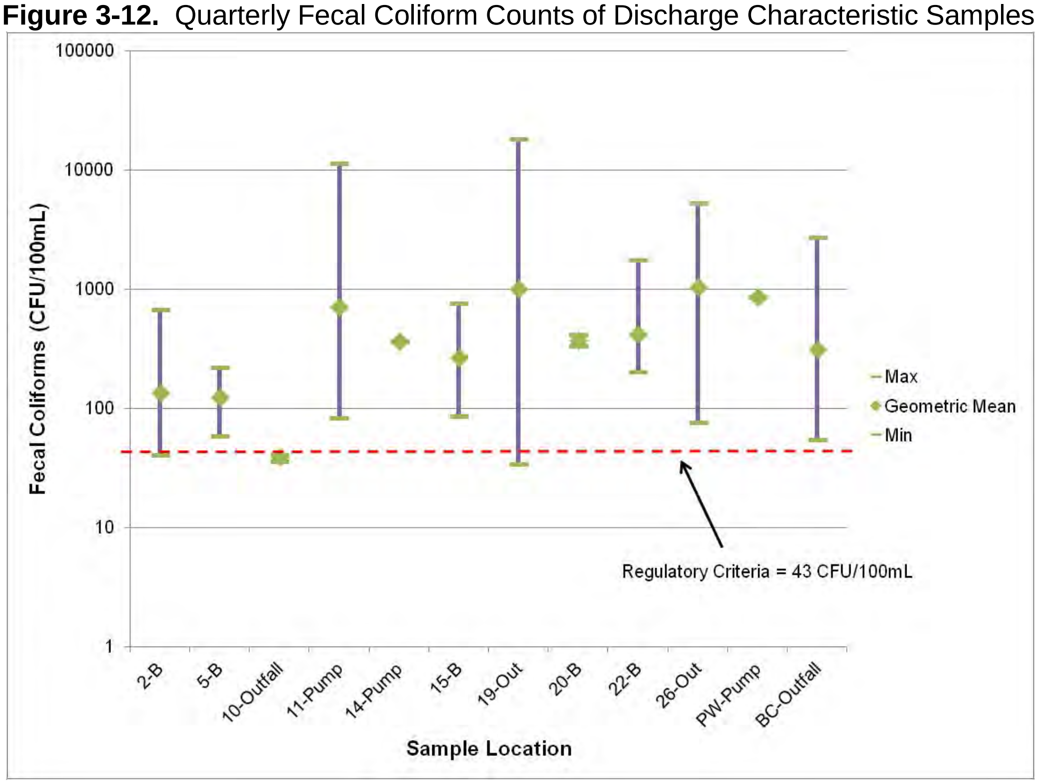
Figures 3-12 and 3-13 show the variability in fecal coliform and enterococci bacteria at each of the 12 sample locations. Causes of this variability include seasonality, as concentrations measured during the Q3 and Q4 (July and September) sample events were much greater than those measured during Q1 and Q2 (December and March) sample events. A potential explanation for this observed seasonality is the difference in moisture conditions. Many studies have documented a correlation between runoff magnitude and bacteria counts, as precipitation provides a source of moisture necessary for bacterial survival and growth and bacteria is often associated with the suspended sediments washed off during heavy rain events (Skinner *et* al., 2010; George *et al.,* 2004; Schoonover *et al*., 2006; Anzil & Servais, 2004). Because the majority of rainfall in the City occurs between the months of June and September (Figure 5-1), there is a positive correlation in the City between bacteria counts and total rainfall.

Figure 3-11. Quarterly Copper Concentrations of Discharge Characteristic Samples



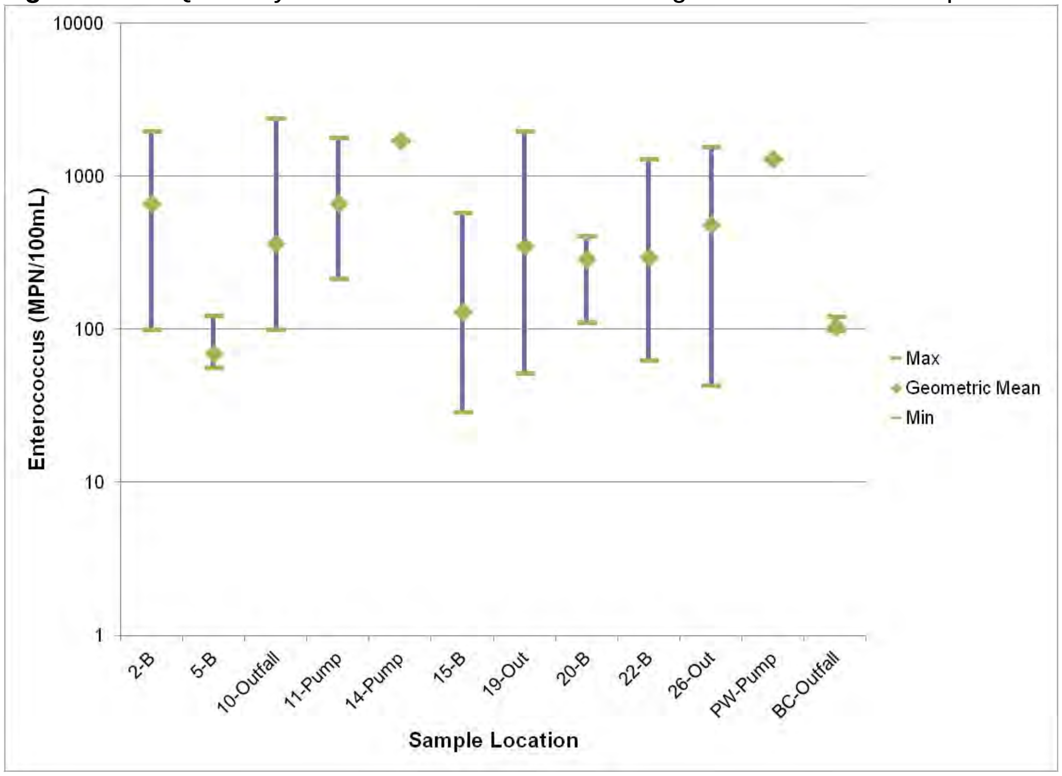
Created By: SEM Checked By: SCA
n = 1 for 14-Pump and PW-Pump, n = 4 for all other sample locations
[1]Ch. 62-302.530 F.A.C. applicable to the receiving waters but not to City of Naples lakes

Figure 3-12. Quarterly Fecal Coliform Counts of Discharge Characteristic Samples



Created By: SEM Checked By: SCA
n = 1 for 14-Pump and PW-Pump, n = 4 for all other sample locations
[1]Ch. 62-302.530 F.A.C. applicable to the receiving waters but not to City of Naples lakes

Figure 3-13. Quarterly Enterococci Counts of Discharge Characteristic Samples



Created By: SEM Checked By: SCA
n = 1 for 14-Pump and PW-Pump, n = 4 for all other sample locations

3.3 Automated Stormwater Sampling

As a second component of the field data collection efforts, three (3) locations were chosen for direct characterization of stormwater runoff during significant rainfall events. Sample locations were determined by City and AMEC staff in order to provide characterization of representative sites across the City. Locations are given in Figure 3-14, and include the Public Works Pump Station, Lantern Lane Pump Station, and the Influent Conveyance to Spring Lake.

Sampling was conducted in order to provide a flow weighted composite sample of a qualifying storm event. Flow weighted composite samples provide a full characterization of runoff produced during an entire storm event, and can be used to increase the accuracy of total pollutant mass loading estimates. Equipment utilized at each location included an ISCO® 3700 Automated Sampler, ISCO® 4120 Data Logger, and ISCO® 674 Rain Gauge. A submerged probe level logger was installed at the Spring Lake Location in order to collect flow data, while pump station data were collected from the City for use in pump station flow weighting calculations. Samplers were programmed to collect one discrete sample per hour for 24 hours if a storm of 0.25 inches or greater was detected. Once the single storm event sampling program had completed, hydrographs for each location were developed and discrete samples were composited based on the proportion of total flow calculated at the time of discrete sample collection. Water quality results of the stormwater sampling are given in Table 3-1, while additional discussion is given in Section 6.1.2.1.

Table 3-1. Automated Stormwater Collection Results

Parameter	TKN as N	Nitrate + Nitrite as N	Nitrogen, Total	Phosphorus, Total	Total Suspended Solids	Copper, Total	Fecal Coliform	Enterococcus
Units	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(MF)	(MPN)
Location								
C3 Spring Lake	1.2	.19I	1.4	0.078	5.6	11	10600	199000
C2 Lantern Lane	0.90	.19I	1.10	0.4	27	12	18800	101000
C4 Public Works	1.20	.39I	1.60	0.25	80	32	16800	173000

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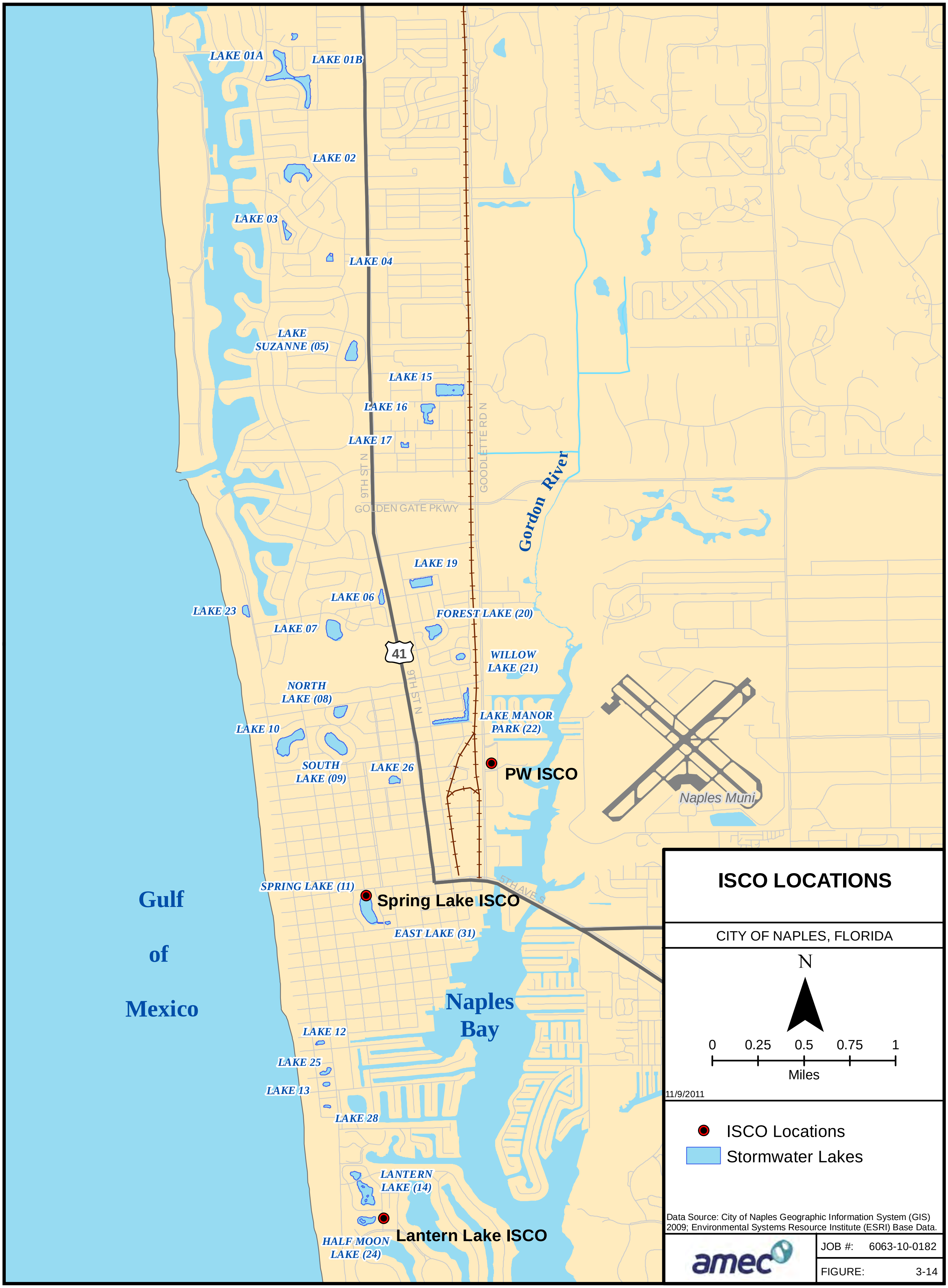
I- Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit

TN calculated as sum of TKN and NOx.



LAKE 01A
LAKE 01B
LAKE 02
LAKE 03
LAKE 04
LAKE SUZANNE (05)
LAKE 15
LAKE 16
LAKE 17
9TH ST N
GOODLETTE RD N
GOLDEN GATE PKWY
Gordon River
LAKE 19
LAKE 06
LAKE 23
FOREST LAKE (20)
LAKE 07
41
WILLOW LAKE (21)
NORTH LAKE (08)
9TH ST N
LAKE MANOR PARK (22)
LAKE 10
PW ISCO
SOUTH LAKE (09)
LAKE 26
Naples Muni
SPRING LAKE (11)
Spring Lake ISCO
5TH AVE S
Gulf of Mexico
EAST LAKE (31)
Naples Bay
LAKE 12
LAKE 25
LAKE 13
LAKE 28
LANTERN LAKE (14)
HALF MOON LAKE (24)
Lantern Lake ISCO
ISCO LOCATIONS
CITY OF NAPLES, FLORIDA
N
0
0.25
0.5
0.75
1
Miles
11/9/2011
ISCO Locations
Stormwater Lakes
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data.
amec
JOB #: 6063-10-0182
FIGURE: 3-14

4.0 Drainage Basin Characteristics

4.1 Basin Delineations

As part of this project, AMEC was tasked with developing drainage basin delineations for each stormwater lake within the City utilizing existing delineations, land contours, existing stormwater drainage conveyance systems, and field observations. Electronic 1 ft contour maps of the City were obtained from the City of Naples Streets and Stormwater Department, in addition to available stormwater infrastructure information in Geographic Information System (GIS) and AutoCAD format. Using existing basin delineations as a guide, AMEC either confirmed or revised basin boundaries based on all the information previously described. In many cases, basin revisions were significant, based on the detailed topography and stormwater conveyance information. Figures 4-1 through 4-3 show the final stormwater lake basin delineations, with the study area divided into three components (north, middle, south) for better visualization.

4.2 Land Use

Land use information for the City was obtained from the City of Naples GIS (Naples, 2009). Within the City stormwater lake contributing basin areas, the landuse consisted of 12 categories represented in Table 4-1 in order of descending acreages. The predominant land use within the contributing basins is low density residential, accounting for approximately 44% of the total land area.

Table 4-1. Land Use in the Study Area for the Stormwater lake Contributing Basins

LU Description	Area (acres)	% of Total
Residential Low Density	518	44%
Commercial Highway	209	18%
Recreation Public, Semi-Public, Private	116	10%
Residential Medium Density	111	10%
Institutional Public, Semi-Public	64	5%
Water	63	5%
Commercial General	41	3%
Commercial Limited	26	2%
Vacant	16	1%
Residential High Density	3	0%
Total	**1167**	**100%**

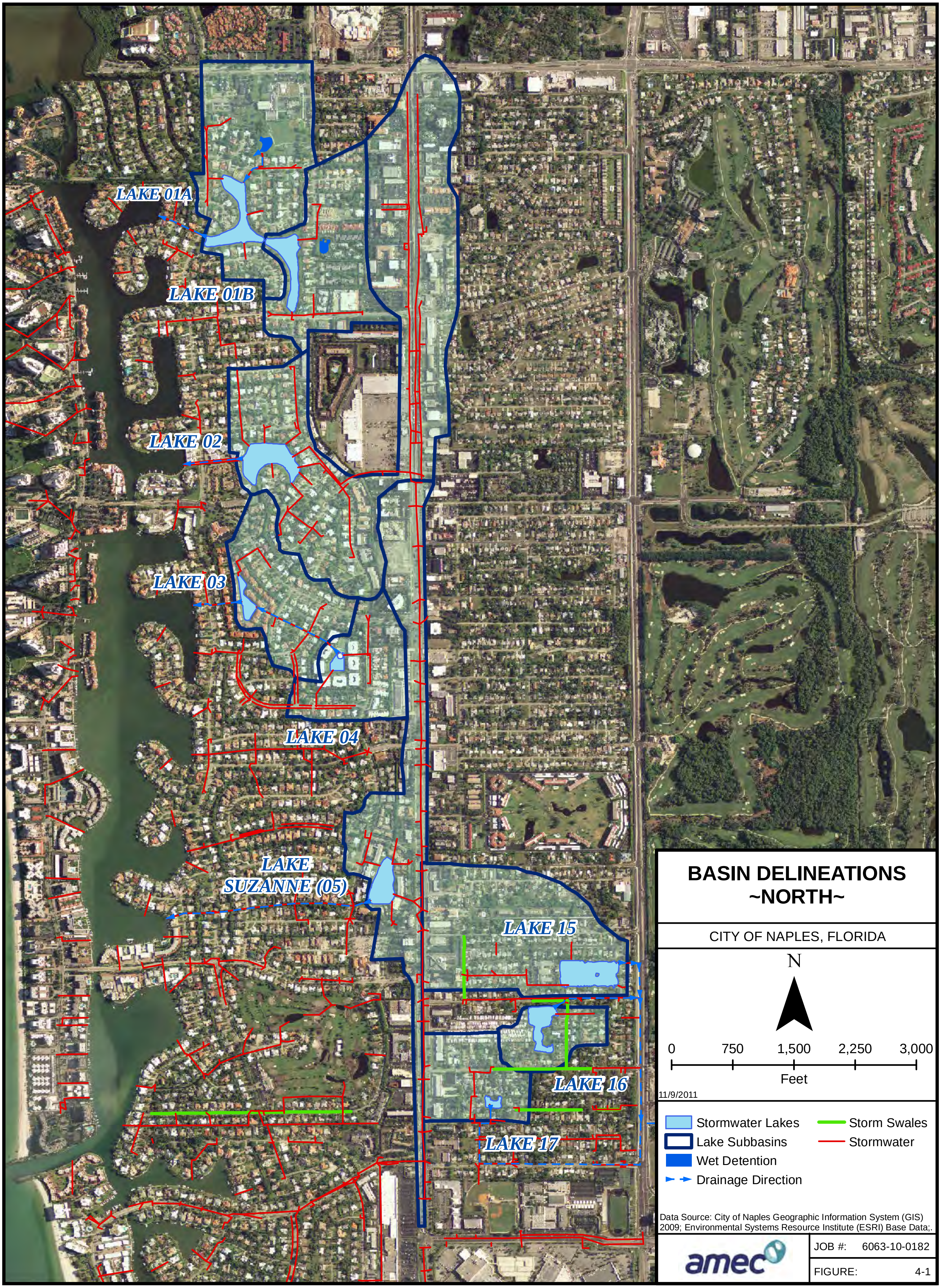
Prepared by: SCA Checked by: TGD

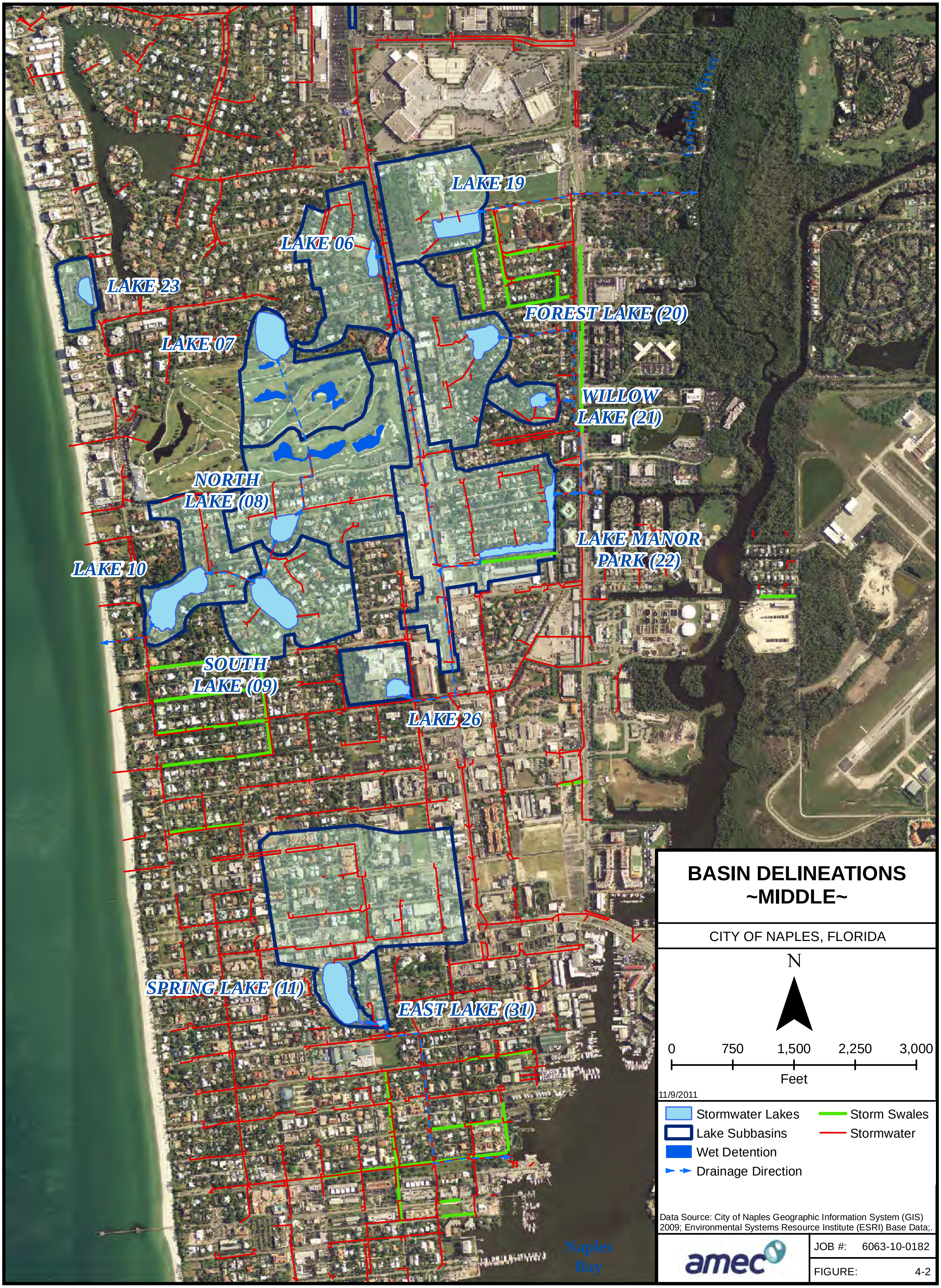
4.3 Soil Characteristics

Information on soil types within the City was obtained from the Natural Resources Conservation Service Soil Survey Geographic database for Collier County, FL, dated 2010 (NRCS, 2010). 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 five (5) groups for evaluation and modeling purposes. The chief consideration in each of the soil group types is inherent capacity of bare soil to permit infiltration. A summary of the characteristics of each hydrologic soil group is presented below.

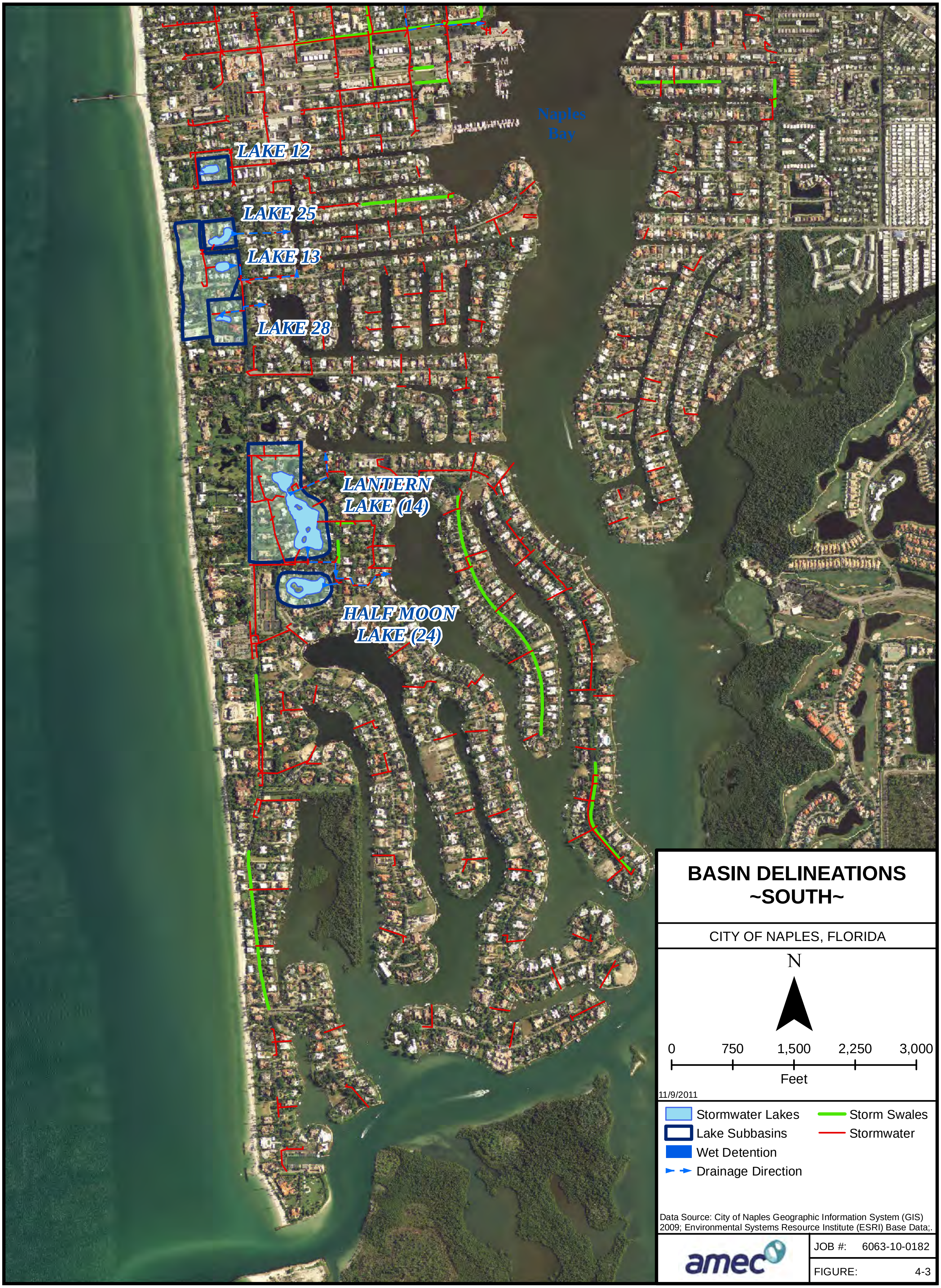
Group A: Soils having low runoff potential and high infiltration rates even when thoroughly saturated. They consist primarily of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

Group B: Soils having moderate infiltration rates when thoroughly saturated and consist primarily of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.


LAKE 01A
LAKE 01B
LAKE 02
LAKE 03
LAKE 04
LAKE SUZANNE (05)
LAKE 15
LAKE 16
LAKE 17
BASIN DELINEATIONS
~NORTH~
CITY OF NAPLES, FLORIDA
N
0
750
1,500
2,250
3,000
Feet
11/9/2011
Stormwater Lakes
Lake Subbasins
Wet Detention
Drainage Direction
Storm Swales
Stormwater
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data;.
amec
JOB #: 6063-10-0182
FIGURE: 4-1



Gordon River
LAKE 19
LAKE 06
LAKE 23
FOREST LAKE (20)
LAKE 07
WILLOW LAKE (21)
NORTH LAKE (08)
LAKE MANOR PARK (22)
LAKE 10
SOUTH LAKE (09)
LAKE 26
SPRING LAKE (11)
EAST LAKE (31)
Naples Bay
BASIN DELINEATIONS
~MIDDLE~
CITY OF NAPLES, FLORIDA
N
0
750
1,500
2,250
3,000
Feet
11/9/2011
Stormwater Lakes
Lake Subbasins
Wet Detention
Drainage Direction
Storm Swales
Stormwater
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data;.
amec
JOB #: 6063-10-0182
FIGURE: 4-2


Naples Bay
LAKE 12
LAKE 25
LAKE 13
LAKE 28
LANTERN LAKE (14)
HALF MOON LAKE (24)
BASIN DELINEATIONS ~SOUTH~
CITY OF NAPLES, FLORIDA
N
0
750
1,500
2,250
3,000
Feet
11/9/2011
Stormwater Lakes
Lake Subbasins
Wet Detention
Drainage Direction
Storm Swales
Stormwater
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data;.
JOB #: 6063-10-0182
FIGURE: 4-3

Group C: Soils having low infiltration rates when thoroughly saturated and consist primarily of soils with a layer that impedes downward movement of water and soils with moderately fine-to-fine texture. These soils have a low rate of water transmission.

Group D: Soils having high runoff potential. These soils have low infiltration rates when thoroughly saturated and consist primarily of clay soils with high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

Dual Hydrologic Soil Groups (Group X/D): Soils located in areas where the water table is within 60 centimeters of the surface: In their saturated state, these soils still have a hydraulic conductivity that may be favorable for water transmission. If these soils can be adequately drained, they are assigned a dual hydrologic soil group (A/D, B/D, and C/D). The first letter applies to the drained condition and the second to the undrained condition.

Group W: Soils are categorized as wetland or hydric soils.

Due to the highly developed nature of the City and the contributing drainage basins in particular, only 9% of the soils within contributing drainage basins were classified by HSG. Of this 9%, all soils were classified as HSG Type A soils. The lack of HSG classification is due to the fact that the hydrologic characteristics of soils often change considerably when significantly disturbed as a result of urban development. Table 4-2 provides a tabular summary, in descending order, of the soils within contributing drainage basins. In the soil description column of the table, the soil descriptor "Urban" denotes a disturbance that has altered the natural hydrologic properties of the soil. As will be discussed in Section 5 of this report, surface runoff calculations are highly dependent upon soil types, with Type A soils providing the least amount of surface runoff for any given land cover.

Table 4-2. Hydrologic Soil Groups in the Study Area for Stormwater lake Contributing Basins

Soil Description	HSG	Area (acres)	% of Total
Urban land	NA	948	81%
Udorthents, shaped	A	99	9%
Water	NA	69	6%
Urban land-Immokalee-Oldsmar, limestone substratum, complex	NA	33	3%
Satellite fine sand	A	10	1%
Urban land-Aquents complex, organic substratum	NA	7	1%
Canaveral-Beaches complex	A	0	0%
Total		**1167**	**100%**

Data Source: NRCS Soil Survey Geographic Database for Collier County, FL, 2010
Prepared by: SCA Checked by: TGD

Although the City is located on historically sandy, well drained soils, it is highly urbanized and developed, and surface runoff calculations that assume a HSG Type A soil would significantly underestimate the amount of surface runoff contributed to each stormwater lake. Based on extensive experience in urban stormwater design as well as common engineering practice in highly developed areas, AMEC assumed a uniform HSG of Type C throughout the contributing drainage areas. In support of this assumption, AMEC also performed a runoff calibration to better characterize the hydrologic soil characteristics within the City. Flow data from the Public Works Pump Station, obtained as part of the Stormwater Sampling task (see Section 3.3 for further discussion), were used in conjunction with daily runoff calculations of the contributing drainage basin (see Section 5.0 for further methodology discussion). By analyzing daily runoff calculations as a function of HSG, a better understanding of drainage basin characteristics within the City could be obtained. Table 4-3 shows the results of this calibration.

Table 4-3. HSG Runoff Calibration for Public Works Pump Station

HSG Type	24-hr Rainfall Total (in)	Observed Runoff (acre-ft)	Calculated Runoff (acre-ft)
A	1.34	17.5	1.5
B	1.34	17.5	6.2
C	1.34	17.5	11.3

Data Source: AMEC, 2011
Prepared by:SCA Checked by: TGD

By comparing the surface runoff results of different HSG model scenarios, it can be seen that Type C soils provide a more accurate representation of actual runoff volumes. Although absolute calibration is beyond the scope of this project due to the lack of available, event specific flow data, the results of this single analysis can be used as an approximation of general runoff characteristics throughout the study area, as the City is fairly homogenous in its degree of urbanization and development.

5.0 Hydrologic Loading Analysis

A hydrologic loading analysis was developed for each stormwater lake for the period from January 2003 through December 2010. The hydrologic loading analysis includes inputs from direct precipitation, stormwater runoff, and upstream waterbodies (where applicable). Hydrologic losses were not directly calculated, as a detailed hydrologic budget for each stormwater lake was beyond the scope of this project, and because the final nutrient loading analysis would have benefited little from a detailed quantification of hydrologic losses (see Section 5.2 for additional information on hydrologic losses). The hydrologic loadings were used as input for development of a nutrient budget and water quality analysis of each stormwater lake. A discussion of the hydrologic loading methodologies utilized is provided in the following sections.

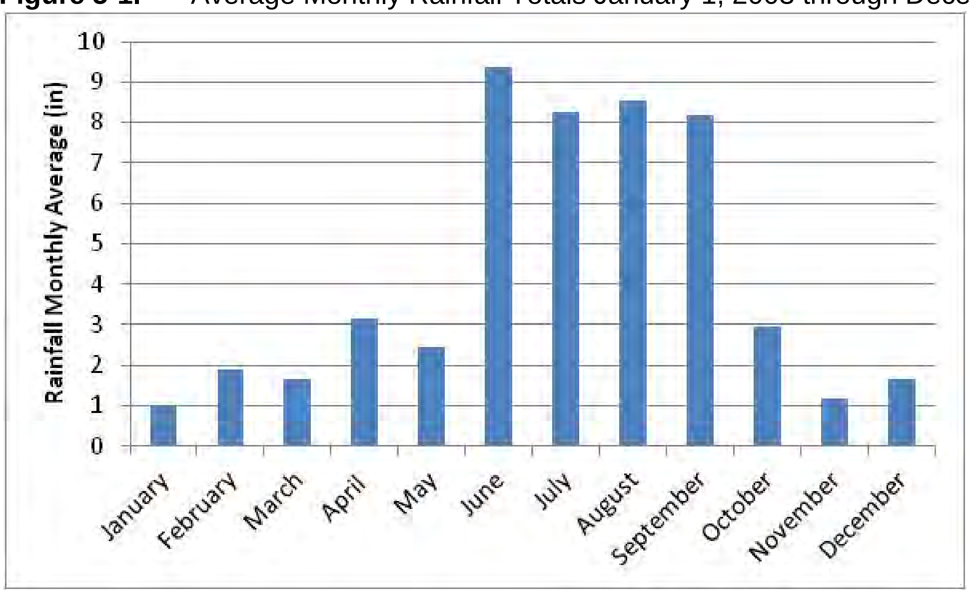
5.1 Hydrologic Inputs

5.1.1 Precipitation

Daily precipitation data from January 2003 through December 2010 were collected from the South Florida Water Management District NAPCON_R weather station (SFWMD, 2011), located in Collier County. This weather station was chosen due to its proximity to the study area and the completeness of its data set for the most recent 8 years. The 8 year period of daily rainfall totals reflect weather variations from drought, normal, and significant storm event rainfall periods.

A total of 932 days with rain were recorded during this eight-year period, with a cumulative rainfall of 403 inches. Figure 5-1 is a graphical representation of the average monthly rainfall associated with this timeframe, while Figure 5-2 is a graphical representation of the average annual rainfall associated with this timeframe. The wet season is primarily during June through September, when monthly precipitation totals were observed to be double those of October through May. Over the 8 year period of record, the average annual rainfall was 50.4 inches, ranging from 27.0 inches in 2007 to 63.1 inches in 2003.

Figure 5-1. Average Monthly Rainfall Totals January 1, 2003 through December 31, 2010



Source: SFWMD (2011).
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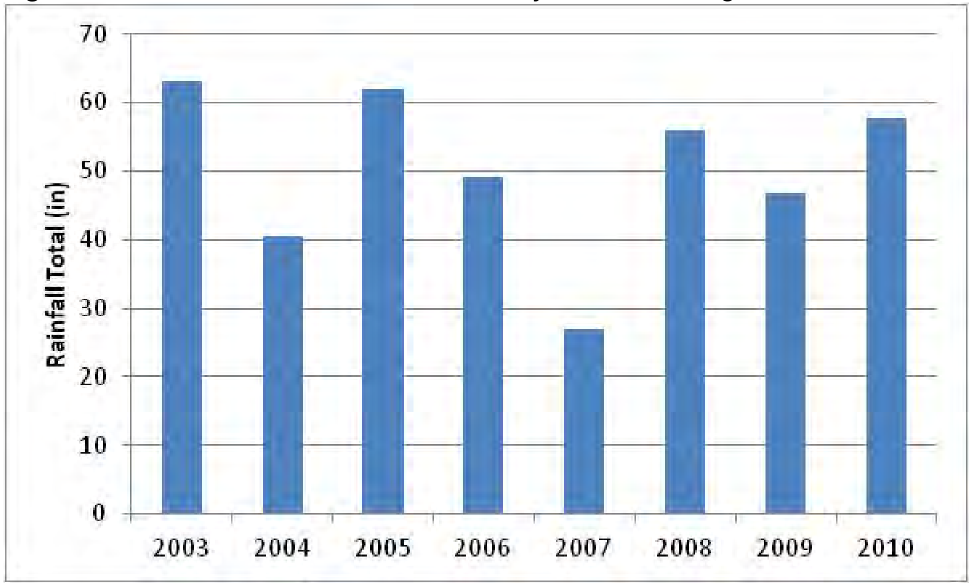
Figure 5-2. Annual Rainfall Totals January 1, 2003 through December 31, 2010



Source: SFWMD (2011).
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Daily rainfall data was used to calculate direct precipitation contributions to each stormwater lake, as well as surface runoff contributions, which will be discussed in the next section.

5.1.2 Surface Runoff

Surface runoff is a significant component of the overall hydrologic loading for each stormwater lake. Each stormwater lake drainage basin was analyzed for daily runoff volume based on daily rainfall and local runoff characteristics. Local runoff characteristics are based on sub-basin area and the runoff curve number (CN), which is a function of land use and hydrologic soil group. The methodology is described in more detail below.

5.1.2.1 Runoff Curve Number Calculation

Information on hydrologic characteristics of the drainage basin areas were developed for use in modeling inputs of surface runoff to the stormwater lakes. In order to accurately estimate runoff occurring within each of the basins, basin specific hydrologic characteristics were calculated using GIS, land use and hydrologic soils data, as well as the digitized drainage basins for each stormwater lake. Land use information was provided by the City of Naples GIS Department (Naples, 2009). Soils data was provided by the NRCS Soil Survey Geographic Database for Collier County, FL (NRCS, 2010). Using the hydrologic characteristics collected from the soils data layer, as well as the land use classification, CNs were assigned using the Curve Number Lookup Table (Appendix C). An area weighted CN was calculated for each drainage basin, using the following equation:

$$CN=\frac{\sum_{i=1}^{n} CN_i A_i}{\sum_{i=1}^{n} A_i}$$

5.1.2.2 Spreadsheet Loading Model

Determination of surface water runoff during an individual rain event requires a known amount of precipitation falling on the project area as well as the drainage basin runoff CN. Drainage basin CNs were defined according to the methodology described in Section 5.2.1.2.1. Land uses within the basins consisted of residential, commercial, institutional, recreation, vacant, commercial and highway. Hydrologic soil groups for the project area were assumed to be Type C (see Section 4.3 for further discussion).

Weighted CNs calculated for each drainage basin were used in the spreadsheet runoff model to estimate the amount of runoff produced by the drainage basin. Daily runoff volumes were calculated using the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) Runoff Curve Number Method (USDA, 1986), which takes into account initial abstractions due to ponding and infiltration for the various land use/hydrologic soil group combinations. Model runs for the drainage basins were prepared using all 8 years of data, with the final annual runoff estimate calculated as the yearly average over the 8 year period.

The procedure described above allows for the determination of total runoff volumes generated from a given area. However, existing stormwater management systems (hereafter referred to as Best Management Practices, or BMPs) within the contributing drainage basins provide for a certain degree of runoff volume attenuation. Runoff volume attenuations were taken into account by first identifying all existing BMPs and classifying them appropriately. Because the stormwater lakes in the City serve as the primary BMPs for each drainage basin, there were few additional existing BMPs identified. The ones that were identified were classified as swales and wet detention systems. Swales were identified using a digitized layer provided by the City GIS department (Naples, 2009). Wet detention systems included any detention facility that had a persistent permanent pool volume and were identified using recent aerial images. The only wet detention facilities identified consisted of two (2) systems in the Lake 1 system drainage basin and several systems in the Lake 7 and 8 drainage basins. Attenuation coefficients for each BMP type are given in Table 5-1. Following BMP identification, contributing drainage basin areas were identified using both aerial photography and topographical information. Attenuation coefficients were applied to the daily runoff volumes generated from each contributing area. These final runoff volumes were assumed to be the hydrologic contributions to the downstream stormwater lake.

Table 5-1. BMP Attenuation Coefficients

BMP Type	Attenuation Coefficient	Source
Wet Detention	0.2	(ERD, 2007)
Swale	0.8	(FDEP, 2010)

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5.2 Hydrologic Losses

For this analysis, hydrologic losses from the 28 stormwater lakes were not directly calculated due to the lack of pond-specific data. Typical hydrologic losses from stormwater lakes include evaporation and infiltration, which along with surface overflow are the balancing components to inputs that include direct precipitation, surface runoff and shallow groundwater seepage. Based on discussions with City staff, field observations, and the occurrence of a generally shallow groundwater table across the City, it was assumed for this analysis that shallow groundwater seepage is a significant component of the hydrologic budget of each stormwater lake, and generally balances out any losses due to infiltration or evaporation. In the case of the 7 stormwater lakes that receive discharge from upstream stormwater lakes, this allows for the direct calculation of upstream hydrologic and nutrient contributions.

6.0 Pollutant Loading Analysis

A pollutant loading analysis was performed for each of the 27 stormwater lakes throughout the City. The pollutant loading analyses are built upon the hydrologic components described in the previous section, and include pollutant inputs from direct precipitation, stormwater runoff, and upstream waterbodies (where applicable). Pollutant load calculations were performed for TSS, TN and TP. A discussion of identified pollutant loads for the stormwater lakes is provided in the following sections.

6.1 Nutrient Inputs

6.1.1 Precipitation

Atmospheric deposition of nutrients was calculated using the previously developed rainfall data, as well as average concentrations of total nitrogen and total phosphorus measured in south Florida rainfall. Although rainfall can be a significant source of TN and TP, it is generally a negligible source of TSS therefore the concentration of this constituent in rainfall was assumed to be zero.

Concentrations of total nitrogen and total phosphorus in precipitation were based upon data from a summary report of south Florida water hydrologic characteristics. Haag *et al*. (1996) compiled seven (7) south Florida data sources that measured nutrient concentrations in precipitation over a 3 year period from 1990 to 1992. Because data sites were scattered over a wide range of land uses, and because atmospheric deposition is often dependent upon sources hundreds of miles away, an average concentration of all seven sites was used for TN and TP concentration input. The average TN concentration used for precipitation input to each stormwater lake was 1.09 mg/L, while the average TP concentration used was 0.045 mg/L. Total precipitation loadings to each stormwater lake are given in Table 6-1.

Table 6-1. Total Precipitation Loadings to each Stormwater Lake

Pond #	Direct Precipitation acre-ft/yr	TN kg/yr	TP kg/yr
1NW	21.1	28.4	1.2
1SE	16.5	22.2	0.9
2	20.2	27.2	1.1
3	4.9	6.6	0.3
4	2.6	3.4	0.1
5	12.4	16.7	0.7
6	4.3	5.8	0.2
7	27.3	36.7	1.5
8	23.3	31.4	1.3
9	19.1	25.7	1.1
10	24.1	32.4	1.3
11	20.4	27.5	1.1
12	1.8	2.5	0.1
13	1.7	2.3	0.1
14	21.1	28.3	1.2
15	20.5	27.7	1.1
16	10.9	14.7	0.6
17	2.1	2.9	0.1
19	12.5	16.8	0.7
20	10.3	13.8	0.6
21	3.1	4.2	0.2
22	13.8	18.5	0.8
23	4.2	5.7	0.2
24	7.2	9.6	0.4
25	3.0	4.0	0.2
26	4.8	6.4	0.3
28	1.0	1.4	0.1
31	0.8	1.1	0.0

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6.1.2 Surface Runoff

Surface runoff volumes used in developing the pollutant loadings for each stormwater lake were obtained from the hydrologic loadings previously described. Inputs from surface runoff, including both volume of water and corresponding nutrient concentrations, were estimated from the hydrologic model and nutrient loading model.

6.1.2.1 Event Mean Concentrations

In order to calculate total mass loadings for any pollutant, a total volume and pollutant concentration must be defined. Total volumes were calculated using the hydrologic loading methodology described in Section 5.0, while surface runoff pollutant concentrations, also known as event mean concentrations (EMCs), were defined using literature-based sources.

For typical pollutants such as TSS, TN and TP, there are a number of Florida studies that have been compiled that link average observed EMCs to common land uses found across the state (Harper & Baker, 2007). These literature-based values were used for TSS, TN and TP, and as will be shown, provide reasonable agreement with directly measured EMCs found in the City.

As a first step in defining total mass loadings to each stormwater lake, EMCs for specific landuses were applied to the volumes of surface runoff coming from those land uses. Literature-based EMC values used for loading calculations are given in Table 6-2. Values were obtained from the 2007 document "Evaluation of Current Stormwater Design Criteria within the State of Florida," which lists summaries of experimentally obtained EMC values for major landuses encountered in Florida. When the landuse source utilized for this evaluation was more specifically defined than those given in Harper and Baker (2007), the most similar landuse was used for EMC values.

Table 6-2. Literature Based EMC Values for Pollutant Load Calculations

Land Use	FLUCCS	TSS mg/L	TN mg/L	TP mg/L
Residential Low Density	1100	23.0	1.61	0.19
Residential Medium Density	1200	37.5	2.07	0.33
Residential High Density	1300	77.8	2.32	0.52
Commercial General	1400	63.6	1.79	0.26
Commercial Limited	1450	57.5	1.18	0.18
Industrial	1500	60.0	1.20	0.26
Institutional Public, Semi-Public	1700	57.5	2.40	0.18
Recreation Public, Semi-Public, Private	1800	23.0	1.61	0.19
Vacant	1900	8.4	1.15	0.06
Water	5100	0.0	1.09	0.05
Commercial Highway	8100	37.3	1.64	0.22

Source: (Harper & Baker, 2007)
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Following definition of literature-based EMCs, observed EMCs were incorporated into the loading analysis. Observed EMCs were obtained through automated stormwater sampling at three (3) locations throughout the City that included land uses representative of those encountered in each of the stormwater lake drainage basins (see Section 3.3 for further discussion on automated stormwater sampling). Table 6-3 shows a comparison of observed and predicted EMCs for each pollutant at each of the three monitoring locations. Predicted concentrations represent composite EMCs for each specific drainage basin that are a function of the land uses within that basin. Predicted concentrations were calculated by dividing the total mass loading by the total volumetric loading.

For TSS, TN and TP, observed concentrations were used as validation that literature-based EMCs provide a reasonable assessment of concentrations found throughout the City. Because there is inherent variability in measured EMCs dependent upon changing factors such as storm intensity, storm duration and antecedent moisture conditions, and observed EMCs were based on a single event, it was decided to use literature-based EMCs for the final loading analysis. The percent variation between observed and calculated EMCs given in Table 6-3 provides reasonable justification for using literature-based EMCs, as the percent difference for TSS, TN and TP is 7%, -10%, and 30%, respectively.

As additional justification that literature-based EMCs represent observed values throughout the City, analysis of the variation in literature-based values was completed. As an example, studies cited for single family residential landuses (which represents 44% of the landuse analyzed in this report) in Harper & Baker (2007) were analyzed. Results of the cursory analysis indicate that mean values of the 17 cited studies for TSS, TN and TP were 37.5 mg/L, 2.07 mg/L, and 0.327 mg/L, with standard deviations of 21.8 mg/L, 1.02 mg/L, and 0.126 mg/L, respectively. In all cases, standard deviations were approximately 50% of the mean value, indicating wide variability in these measurements. Also, average observed EMCs given in Table 6-3 are well within the standard deviation ranges previously described.

Table 6-3. Pollutant Specific Calibration Coefficients

Observed and Calculated EMCs				
Location	**Data Type**	**TSS**	**TN**	**TP**
		mg/L	**mg/L**	**mg/L**
Spring Lake (11)	Observed	5.6	1.40	0.08
	Calculated	46.1	1.74	0.23
LL	Observed	27.0	1.10	0.40
	Calculated	9.9	1.07	0.10
PW	Observed	80.0	1.60	0.25
	Calculated	48.9	1.76	0.23
Average	Observed	37.5	1.37	0.24
	Calculated	35.0	1.52	0.19
% Variation		**7%**	**-10%**	**30%**

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6.1.3 Upstream Waterbodies

Hydrologic and pollutant contributions from upstream waterbodies were assessed for the seven (7) ponds that receive direct drainage from upstream ponds. Due to the lack of available hydrologic data for each individual stormwater lake (see Section 5.2 for further discussion), it was assumed that volumetric inflow equaled volumetric outflow for each pond. In order to calculate total pollutant contributions from upstream waterbodies, a pond-specific removal rate was applied to the total pollutant loading of each upstream waterbody. This methodology is described in further detail in Section 6.4.

6.2 Surface Runoff Loading Estimates

Hydrologic and pollutant contributions from upstream waterbodies were assessed for the seven (7) ponds that receive direct drainage from upstream ponds. Due to the lack of available hydrologic data for each individual stormwater lake (see Section 5.2 for further discussion), it was assumed that volumetric inflow equaled volumetric outflow for each pond. In order to calculate total pollutant contributions from upstream waterbodies, a pond-specific removal rate was applied to the total pollutant loading of each upstream waterbody. This methodology is described in further detail in Section 6.4.

A pollutant loading model was developed for each of the 27 stormwater lakes in this analysis based on regional land use and soils information. Previously discussed EMCs for TSS, TN and TP was combined with modeled runoff to develop annual nutrient loadings for each stormwater lake. The results of the loading models were used to identify areas of elevated loadings and to assess the current condition and performance of each stormwater lake.

A spreadsheet Watershed Management Model was used to estimate pollution loading for the primary pollutants to each stormwater lake. The model uses literature-based stormwater event mean concentration for TSS, TN and TP, along with daily precipitation and runoff volumes calculated via methods described in Section 5, to estimate annual pollutant loads to each stormwater lake.

The primary constituent loading estimates analyzed in the model include TN, TP, and TSS. Stormwater conveyance systems, existing BMPs, and measured rainfall for the area were included in the model, and loadings were calculated taking into account existing BMPs. Existing BMPs within each drainage basin were determined through analysis of aerial photographs and existing GIS layers provided by the City. There was no existing information available regarding the drainage area impacted by existing stormwater BMPs within each drainage basin. The contributing portion of each drainage basin treated by existing BMPs was estimated through analysis of aerial photography and topographical maps.

Pollutant load reductions from existing BMPs were quantified in the model using two (2) types of reduction coefficients that directly correspond to the nutrient removal mechanisms at work in each BMP. Table 6-4 lists the reduction coefficients, which include volumetric and concentration coefficients, or removal percentages.

Table 6-4. BMP Removal Rates

BMP Type	Volume	TSS	TN	TP	Source
Wet Detention	0.20	0.80	0.25	0.65	(ERD, 2007), (Harper & Baker, 2007)
Swale	0.80	0.00	0.00	0.00	(FDEP, 2010)

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Wet detention basins identified within the watershed were assumed to function according to current design criteria, which impart different removal mechanisms on the water and nutrient loads that they treat. Surface runoff that is directed to a wet detention facility is partially attenuated (20%) via volumetric removal mechanisms such as slow infiltration and evaporation (or evapotranspiration if vegetation is present), however additional concentration reductions are realized due to ongoing physical, biological and chemical removal mechanisms present in the permanent pool volume. The nutrient removal rates given in Table 6-4 represent the cumulative effects of these various removal mechanisms.

Swales identified within the watershed were assumed to function according to current design criteria, which require that they percolate 80% of the volume generated from a 3-year, 1-hour storm event. The primary nutrient removal mechanism in swales – volume control through rapid infiltration – is similar to that of dry detention systems, which is why concentration reduction rates assigned to the remaining average of 20% of water that flows out of a swale are 0% for each constituent. Because swales in the basin were numerous and of varying lengths and dimensions, a typical cross-section was assumed and treatment capacity was related to the total length of each individual swale using the following equations (FDEP, 2010):

$$Q=\frac{1}{2}C\,I\,A$$

$$L=\frac{43{,}200Q}{\left\{B+2\left[\frac{1.068\,n\,Q\,\left(1+Z^2\right)^{\frac{1}{3}}}{S^{\frac{1}{2}}\,Z^{\frac{2}{3}}\,2\left[\left(1+Z^2\right)^{\frac{1}{2}}-Z\right]}\right]^{\frac{3}{8}}\left(1+Z^2\right)^{\frac{1}{2}}\right\}i}$$

where

C = Runoff coefficient
I = Rainfall intensity of the 3-yr, 1-hr storm event (in/hr)
A = Portion of drainage basin contributing runoff (acre)
L = Length of swale (ft)
B = Bottom width (ft)
Q = Average flow rate to be percolated from first equation (cfs)
n = Manning's roughness coefficient
Z = Side slope (horizontal distance for a one foot vertical change)
S = Longitudinal slope
i = Infiltration rate (in/hr)

Q was uniquely defined for each sub-portion of the drainage basin treated by a swale. The lookup table for the runoff coefficients is located in Appendix E. Once swales within the basin were identified via aerial photography and/or field verification, they were assigned a total length. Swale length and locations were cross-referenced in GIS with the areas of the sub-basin that contributed surface runoff to them, and assigned an efficiency based on the ratio of the actual length of swale that existed to the total length of swale required to treat that portion of the sub-basin, calculated using the above equations. The maximum allotted efficiency to any swale was 100%. This efficiency was then multiplied by the volumetric attenuation coefficient given in Table 5-2 to produce the resultant hydrologic and nutrient load ultimately delivered to the downstream stormwater lake.

Total nutrient loads attributable to each of the 28 stormwater lakes analyzed (with existing BMPs) were estimated from the modeled data to be 45,325 kilograms per year (kg/yr) of TSS, 2870 kg/yr of TN, and 307 kg/yr of TP. Existing BMPs throughout the study area (not including the 28 stormwater lakes) removed 2.5% of TSS, 2.1% of TN, and 2.2% of TP. Figures 6-1, 6-2 and 6-3 show total annual TSS, TN and TP mass loadings, respectively, for each of the stormwater lakes. Total mass loadings are comprised of precipitation inputs, surface runoff, and input from upstream waterbodies where applicable.

Based on modeling results, the stormwater lakes that receive the three (3) highest mass loadings of TSS, TN and TP are Ponds 2, 11 and 22. Stormwater lake 2 receives the greatest annual mass loading, with nutrient loadings of 7580 kg/yr TSS, 388 kg/yr TN, and 51 kg/yr of TP.

Figure 6-1. Total Suspended Solids Loading to Stormwater Lakes with existing BMPs

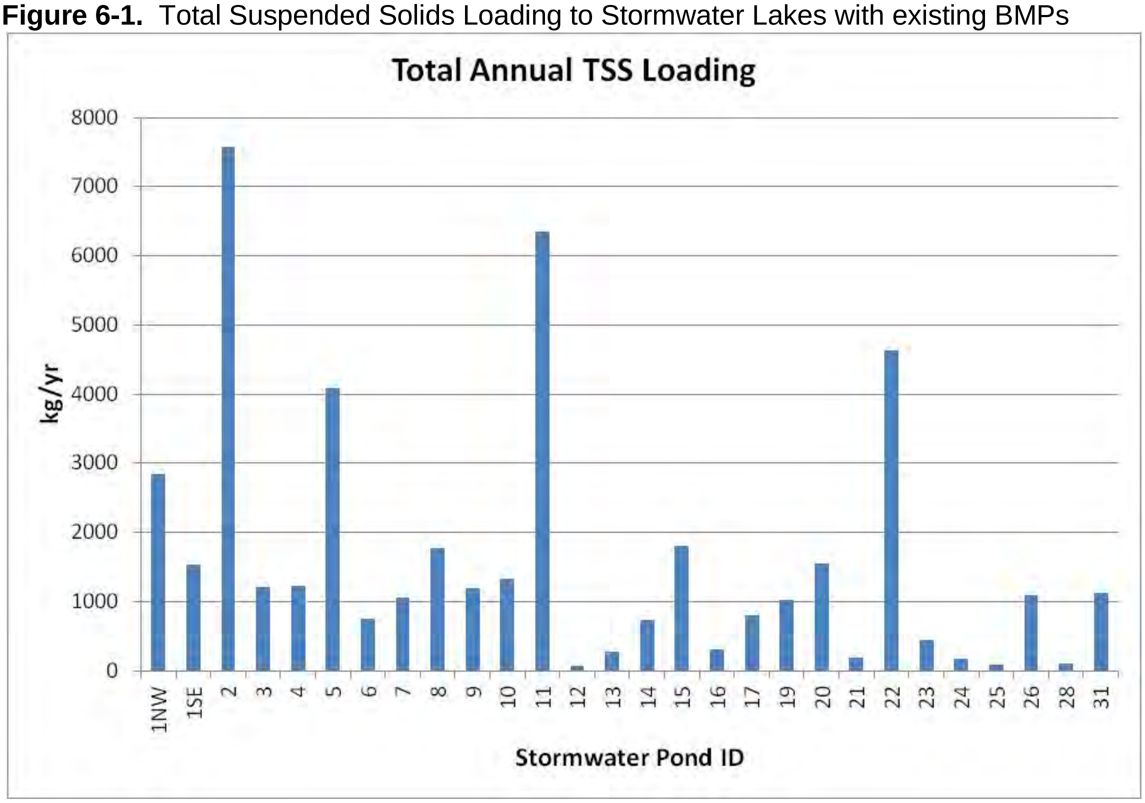

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Figure 6-2. Total Nitrogen Loading to Stormwater Lakes with existing BMPs

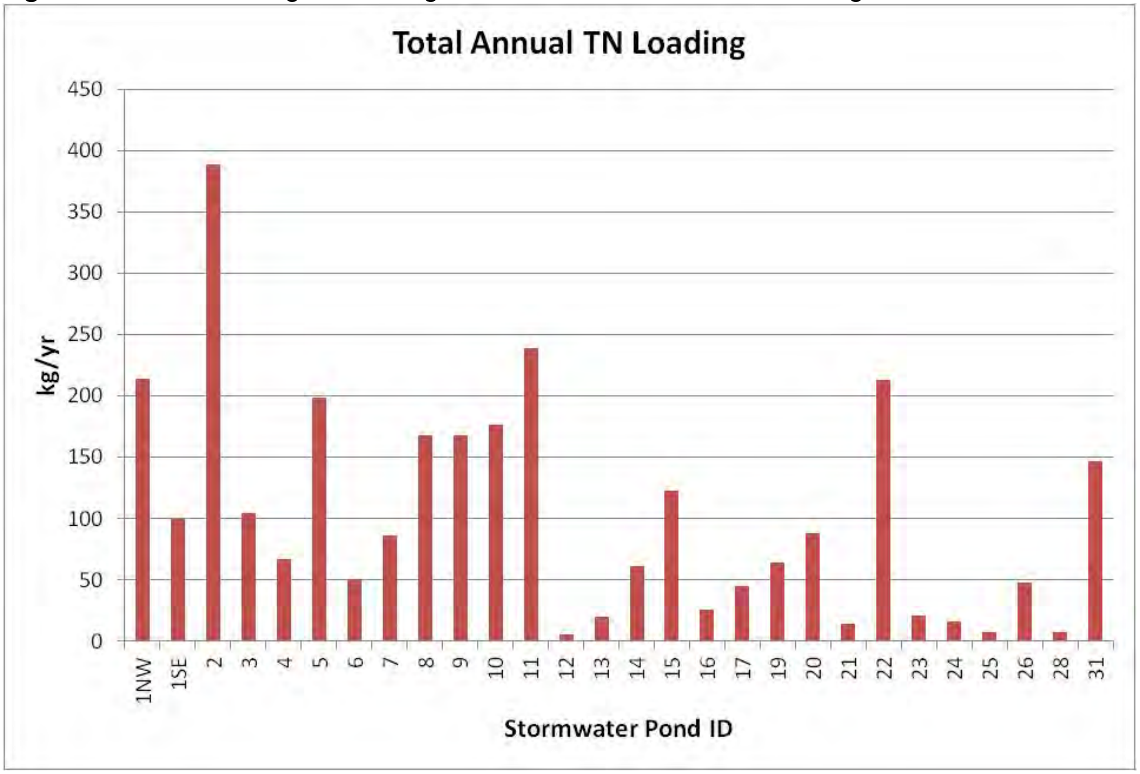

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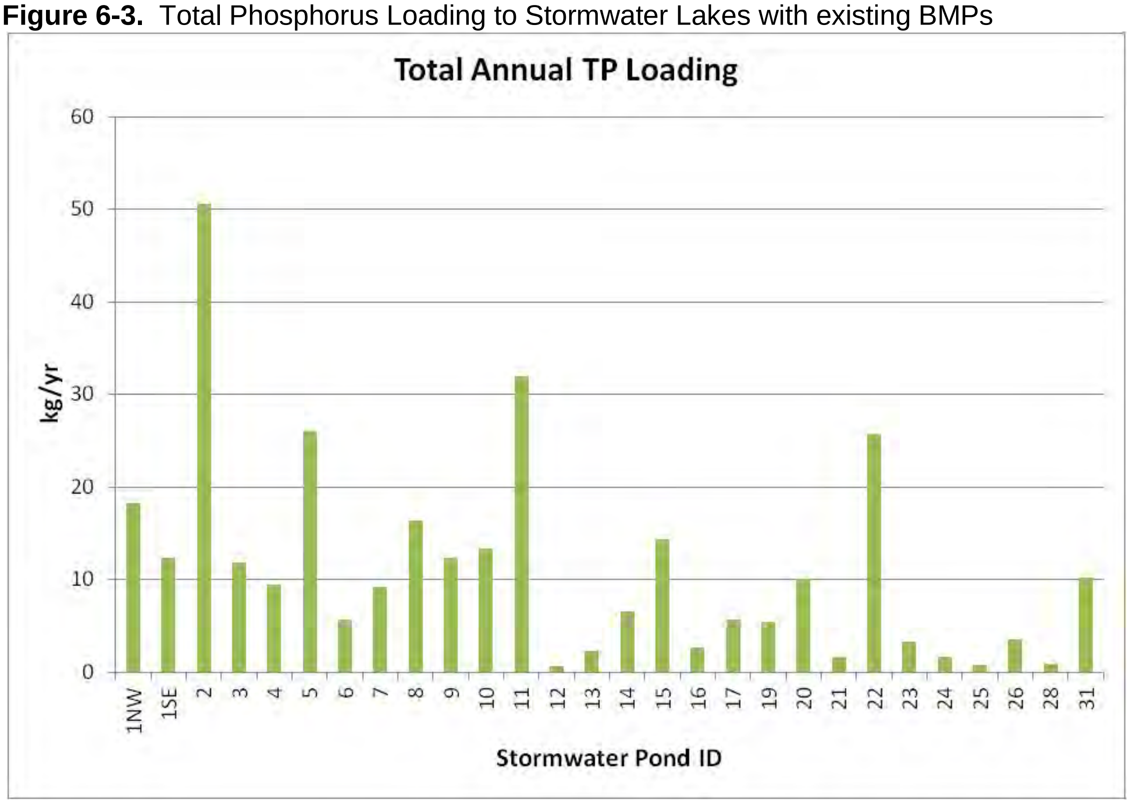
Figure 6-3. Total Phosphorus Loading to Stormwater Lakes with existing BMPs



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The three (3) aforementioned sub-basins contributed the largest nutrient loads via surface runoff primarily due to the size and fully developed nature of their drainage basins.

Table 6-5. Total Mass Loadings and % Reduction from Existing BMPs

Total	Pond Size (acre)	kg/yr			% Reduction from BMP		
		TSS	TN	TP	TSS	TN	TP
1NW	5.03	2844	214	17	15%	6%	7%
1SE	3.93	1535	100	12	8%	4%	7%
2	4.82	7580	388	51	0%	0%	0%
3	1.16	1202	104	11	0%	0%	0%
4	0.61	1219	67	9	0%	0%	0%
5	2.97	4078	199	26	0%	0%	0%
6	1.03	756	51	6	0%	0%	0%
7	6.51	1051	86	9	0%	0%	0%
8	5.57	1776	168	16	0%	0%	0%
9	4.56	1195	168	11	1%	1%	1%
10	5.74	1323	176	12	0%	0%	0%
11	4.87	6347	239	32	0%	0%	0%
12	0.44	68	6	1	0%	0%	0%
13	0.40	280	20	2	0%	0%	0%
14	5.02	735	62	7	0%	0%	0%
15	4.90	1798	123	14	7%	7%	7%
16	2.60	304	26	3	36%	31%	34%
17	0.51	802	45	6	7%	9%	8%
19	2.97	1022	65	5	0%	0%	0%
20	2.45	1543	88	10	0%	0%	0%
21	0.74	193	15	2	0%	0%	0%
22	3.29	4633	213	25	3%	5%	5%
23	1.01	448	21	3	0%	0%	0%
24	1.71	171	16	2	0%	0%	0%
25	0.72	86	8	1	0%	0%	0%
26	1.14	1095	48	4	0%	0%	0%
28	0.24	107	8	1	0%	0%	0%
31	0.20	1132	147	9	0%	0%	0%

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7.0 Condition Assessment

7.1 Goals and Methodologies

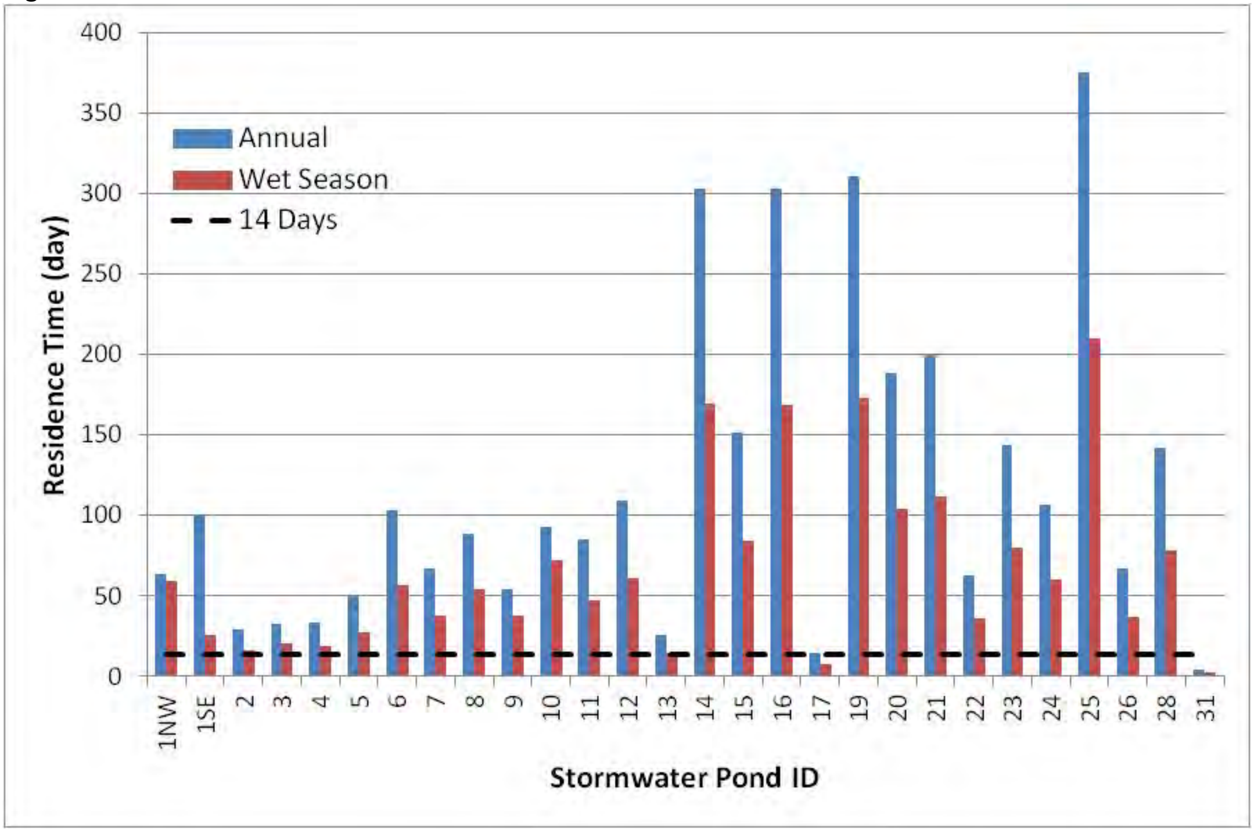
In order to provide a condition assessment of the 28 stormwater lakes included in this analysis, several indices were generated that allow for the ranking of each pond according to modeled loadings, predicted performance, observed performance and observed conditions. By analyzing several components that are direct measures of hydrologic, chemical and biological condition, a comprehensive ranking can be generated that will allow for the efficient allocation of City resources used for condition enhancement and corrective actions. Due to the natural variability of these systems, as well as limited data availability, it is the intention of this analysis to provide a comprehensive assessment based on a variety of data inputs, in order to provide a more statistically robust condition ranking. No one index should be used as a final determination of impairment; rather, all available data should be taken into account. Following is a description of the indices, which are based on all available data, the hydrologic loading analyses, and the pollutant loading analyses previously described.

7.2 Residence Time

Although the initial design and intention of the 28 stormwater lakes throughout the City is not clearly defined, they provide important stormwater services, including flood control and pollutant attenuation of the significant surface runoff that is generated from the mostly developed surrounding areas. While not designed according to current design criteria, these stormwater lakes are hydrologically similar to wet detention ponds, which have been extensively studied and function in very predictable ways when basic hydrologic parameters such as morphometry and residence time are known. In general, residence time alone provides a good baseline indication of a pond's potential capacity for pollutant removal. Figure 7-1 shows the annual and wet season residence times of each stormwater lake. Annual residence time will be used in upcoming analysis that relates removal efficiencies to residence time, while wet season residence time is used as an initial indication of potentially overloaded systems, as the wet season is when these systems receive the majority of the surface runoff-generated pollutant loadings.

Various regulatory agencies throughout the state recommend that newly constructed wet detention systems have an average wet season residence time of 14 days or greater to provide for healthy nutrient removal capabilities. Based on Figure 7-1, all but Lakes 17 and 31 have wet season residence times greater than 14 days. It should be noted however that Lake 31 is directly connected to Lake 11, and as such Lake 31 may be viewed as a direct extension of Lake 11.

Figure 7-1. Annual and Wet Season Residence Time of Each Stormwater lake



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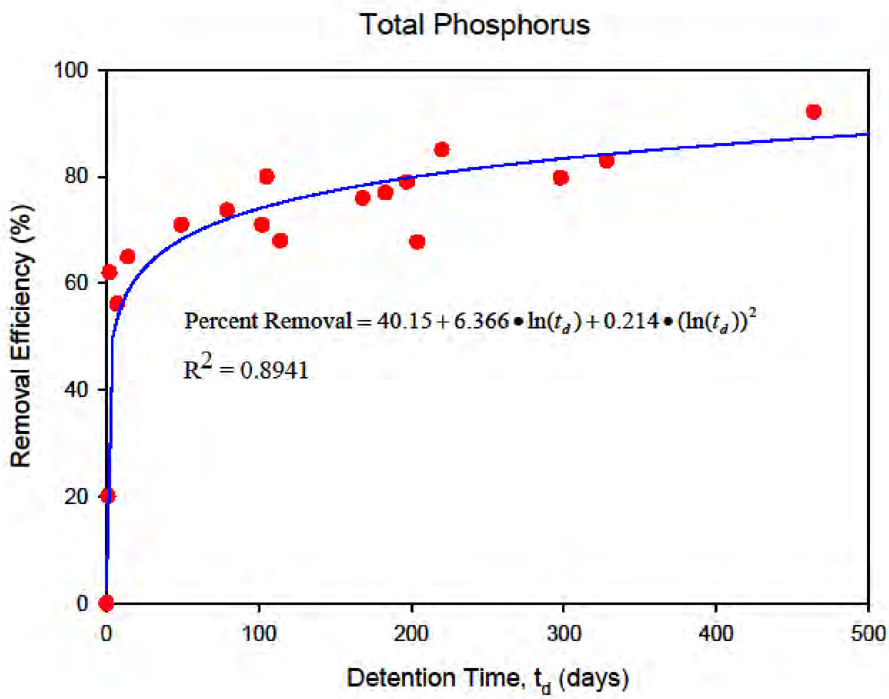
Although Lakes 17 and 31 are the only lakes that have wet season residence times less than 14 days, several other lakes have wet season residence times approaching this threshold, including Lake 2 (16 days), 3 (20 days), 4 (19 days) and 13 (14 days). While not a direct indication of impairment, reduced residence times can be used as one measure of potentially reduced pollutant removal capacity. In contrast, the relatively lengthy residence times experienced in most of the stormwater lakes is a good indication that the majority of these systems either provide or have the potential to provide significant pollutant removal efficiencies.

7.3 Predicted and Observed Removal Rates

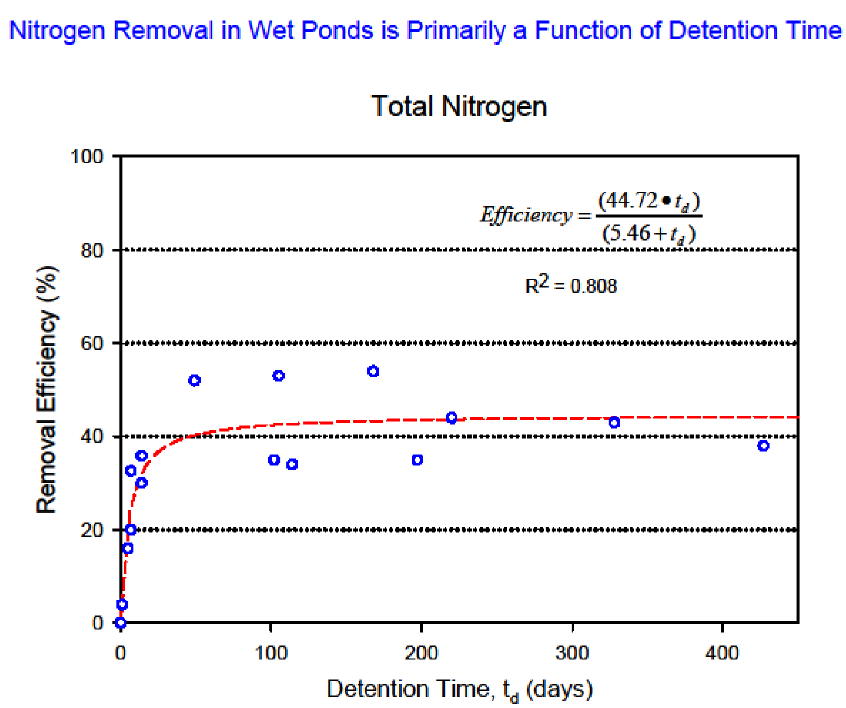
Wet detention ponds reduce pollutant concentrations in surface runoff through a variety of mechanisms, including physical processes such as particle sedimentation, biological processes such as algal and vegetative uptake, and chemical processes such as precipitation and adsorption. These processes work in concert, and are generally well correlated with annual residence time of the waterbody. For nutrients such as TP and TN, the relationship between removal efficiency and residence time have been well studied and a fairly predictable correlation exists between the variables. For this analysis, theoretical mass removal efficiencies for TP and TN were calculated based on the residence time of each stormwater lake, while the theoretical mass removal efficiency for TSS was assumed to be 85%, regardless of residence time. Figures 7-2 and 7-3 show correlations developed by Bateman *et al*. (2008) that relate TP and TN mass removal, respectively, to annual residence time (detention time).

Figure 7-2. TP Mass Removal Efficiency as a Function of Annual Residence Time



Source: Bateman *et al*. (2008)

Figure 7-3. TN Mass Removal Efficiency as a Function of Annual Residence Time



Source: Bateman *et al*. (2008)

Using the equations given in Figures 7-2 and 7-3, along with an 85% mass removal efficiency for TSS, predicted removal concentrations were calculated for each stormwater lake and are given in Table 7-1. As a comparison, observed removal efficiencies are also given in Table 7-1. Observed removal efficiencies were calculated based on the difference between pollutant influent concentration and average observed pollutant concentrations in each stormwater lake. Pollutant influent concentrations were the average concentrations of the pollutants delivered to each stormwater lake, calculated as the total pollutant mass loading (including mass removals from existing BMPs) divided by the total hydrologic loading, which were both calculated as part of the hydrologic and nutrient loading models. Observed pollutant concentrations were calculated as the average of all available pollutant concentration measurements taken in each stormwater lake. Because sampling generally occurred between storm events, samples (excluding pond influent samples taken during quarterly monitoring program) were assumed to represent background conditions.

Table 7-1. Predicted and Observed Mass Removal Efficiencies

Pond	Residence Time	TSS Efficiency		TN Efficiency		TP Efficiency	
	Day	Predicted [1]	Observed [2]	Predicted [1]	Observed [2]	Predicted [1]	Observed [2]
1NW	63	85%	85%	41%	28%	70%	80%
1SE	101	85%	67%	42%	25%	74%	76%
2	29	85%	54%	38%	47%	64%	69%
3	33	85%	62%	38%	16%	65%	18%
4	34	85%	88%	38%	47%	65%	73%
5	50	85%	88%	40%	28%	68%	48%
6	103	85%	69%	42%	15%	74%	84%
7	67	85%	NA	41%	NA	71%	NA
8	89	85%	52%	42%	-3%	73%	1%
9	54	85%	27%	41%	-123%	69%	-192%
10	93	85%	-200%	42%	-18%	73%	13%
11	85	85%	79%	42%	23%	73%	51%
12	109	85%	50%	43%	-13%	75%	84%
13	26	85%	75%	37%	-7%	63%	70%
14	303	85%	-13%	44%	-34%	84%	-173%
15	152	85%	76%	43%	33%	78%	87%
16	303	85%	49%	44%	-25%	84%	67%
17	14	85%	80%	32%	12%	59%	51%
19	311	85%	62%	44%	43%	84%	73%
20	188	85%	58%	43%	2%	79%	52%
21	201	85%	87%	44%	-3%	80%	82%
22	63	85%	92%	41%	56%	70%	62%
23	144	85%	85%	43%	60%	77%	92%
24	107	85%	25%	43%	-139%	75%	-363%
25	375	85%	50%	44%	-24%	85%	54%
26	67	85%	82%	41%	56%	71%	68%
28	142	85%	55%	43%	-14%	77%	29%
31	4	85%	57%	19%	-3%	49%	27%

Prepared by: SCA Checked by: TGD
[1]Bateman *et al.* (2008)
[2]AMEC (2011)

By comparing expected performance to observed performance, each stormwater lake can be gauged in terms of how it is performing compared to its theoretical potential. Stormwater lakes that have low observed removal efficiencies are likely overloaded or saturated, while stormwater lakes that have negative removal efficiencies may have unusually elevated source loads in addition to being overloaded or saturated. Stormwater Lakes 9, 14 and 24 have negative removal efficiencies for both TN and TP.

7.4 Potential for Stratification

In addition to overall morphometry, the stratification tendencies of a wet detention system have the potential to significantly affect certain pollutant removal efficiencies. Due to differential solar heating, thermal stratification may occur, which causes vertical density gradients that may limit vertical circulation. Typical vertical zonation in a pond or lake may consist of a mixed surface layer, or epilimnion, overlying a bottom layer, or hypolimnion. The epilimnion is generally well mixed due to daily wind influences with a uniform temperature throughout. The epilimnion also has the most light availability, and therefore is where the majority of the photosynthetic algal production in a lake occurs. The predominance of algal activity in the epilimnion also maintains adequate dissolved oxygen concentrations, as photosynthesis rates are generally greater than respiration rates. In contrast, the hypolimnion can sometimes be light deficient due to shading effects from the epilimnion. This may have two significant consequences. Biologically, reduced light conditions may result in respiration rates that exceed photosynthesis rates, resulting in an oxygen deficient water column near the sediment-water interface. In addition to biological consequences of this anoxic environment, certain nutrient complexes, including orthophosphate and ammonia compounds that are generally stable and not bioavailable under oxygenated conditions, can be liberated, resulting in greater internal nutrient loads to the pond. Thermally, the predominance of suspended particles with solar energy absorbing capacity in the epilimnion may cause differential thermal absorption, resulting in a warm, less dense epilimnion overlying a cooler, more dense hypolimnion. Upon development of a stable density gradient, these two layers are highly resistant to mixing and gas exchange and anoxic conditions may persist in the hypolimnion.

Due to the positive correlation between increased primary productivity and increased thermal energy absorption capacity, more eutrophic systems tend to be more prone to thermal stratification due to differential heating of the biomass-rich epilimnion compared to the light deficient hypolimnion. If the system is deep enough to allow this gradient to develop, nutrient releasing conditions near the sediment/water interface develop.

Using the well defined correlation between observed total phosphorus and primary production (chlorophyll-a concentration), an estimation of the probable depth to stratification can be made using the following equations developed by Harper & Baker (2007):

$$\ln(chl\text{-}a) = 1.058 \ln TP - 0.934 \quad R^2 = 0.815$$

$$SD = \frac{(24.2386+0.3041\ chl\text{-}a)}{(6.0632+chl\text{-}a)} \quad R^2 = 0.807$$

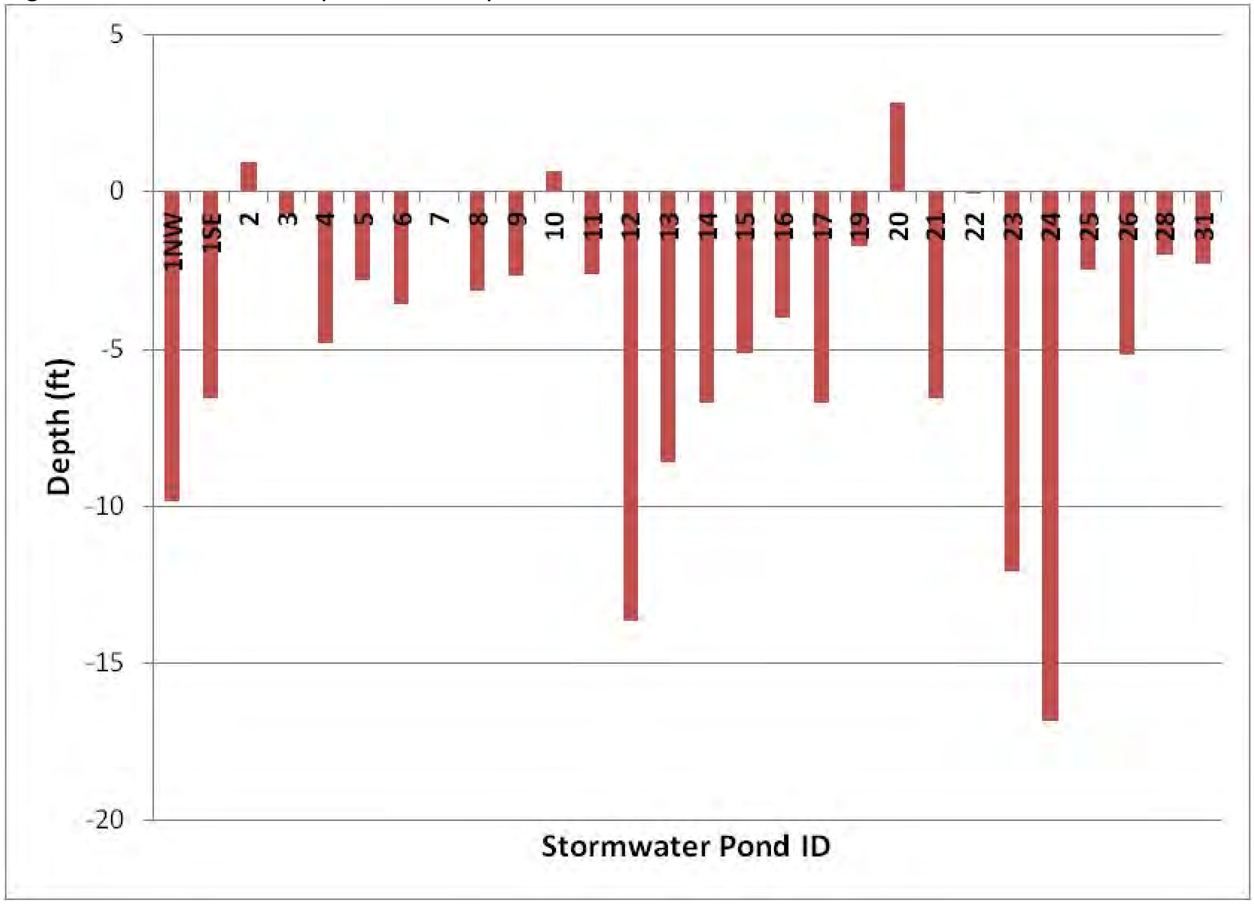
$$\text{Anoxic Depth} = 3.035 \times \text{Secchi Disk Depth (m)} - 0.004979 \times \text{Total P (ug/l)} + 0.02164 \times chl\text{-}a\ (mg/m^3) \quad R^2 = 0.951$$

where:

chl-a = chlorophyll-a concentration (mg/m^3)
TP = total phosphorus concentration (ug/l)
SD = Secchi Depth (m)
Anoxic Depth = depth of anoxia (m)

Using all available data to obtain average TP concentrations within each stormwater lake, an estimated depth of anoxia, or depth to stratification, was developed. By comparing the depth of anoxia of each pond to the observed maximum depths, an estimation of the potential for stratified conditions to develop could be made. Figure 7-4 shows the difference between the estimated depth of anoxia and maximum depths of each stormwater lake. Differences for each stormwater lake were calculated by subtracting the depth of anoxia from the observed maximum depth. A positive value indicates potential for stratification in at least a portion of the stormwater lake. No water quality data was available for stormwater lake 7, therefore depth of anoxia could not be estimated.

Figure 7-4. Maximum Depth minus Depth of Anoxia



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Based on Figure 7-4, stormwater lakes 2, 10, and 20 have maximum depths that exceed the depth of anoxia, which implies that areas of these stormwater lakes may be prone to thermal stratification and enhanced internal release of nitrogen and phosphorus. Stormwater lake 20 is the only lake to have an average depth greater than the estimated depth of anoxia, indicating even greater potential for enhanced internal nutrient release. As a method verification, DO data taken from the bottom depths of most of the 28 stormwater lakes as part of the 2009 sampling effort was consulted. There appeared to be limited correlation between low DO levels near the stormwater lake bottom and greater potential for stratification development (i.e. Lakes 2, 10 and 20), however both data sets were based on limited sample size, and should be used as more of an indication of potential tendencies rather than actual conditions. Accordingly, the potential for stratification index described here is only one of six indices, and as such is not the sole determination of impairment but an indication of probable tendencies.

Where the depth of the lake is greater than the anoxic depth there is the potential for anoxic (low DO) conditions can develop, which can cause fish kills and release of nutrients from the sediments, further contributing to reduced nutrient removal efficiencies. Most of the City's stormwater lakes would not appear to exhibit severe tendency to anoxic conditions.

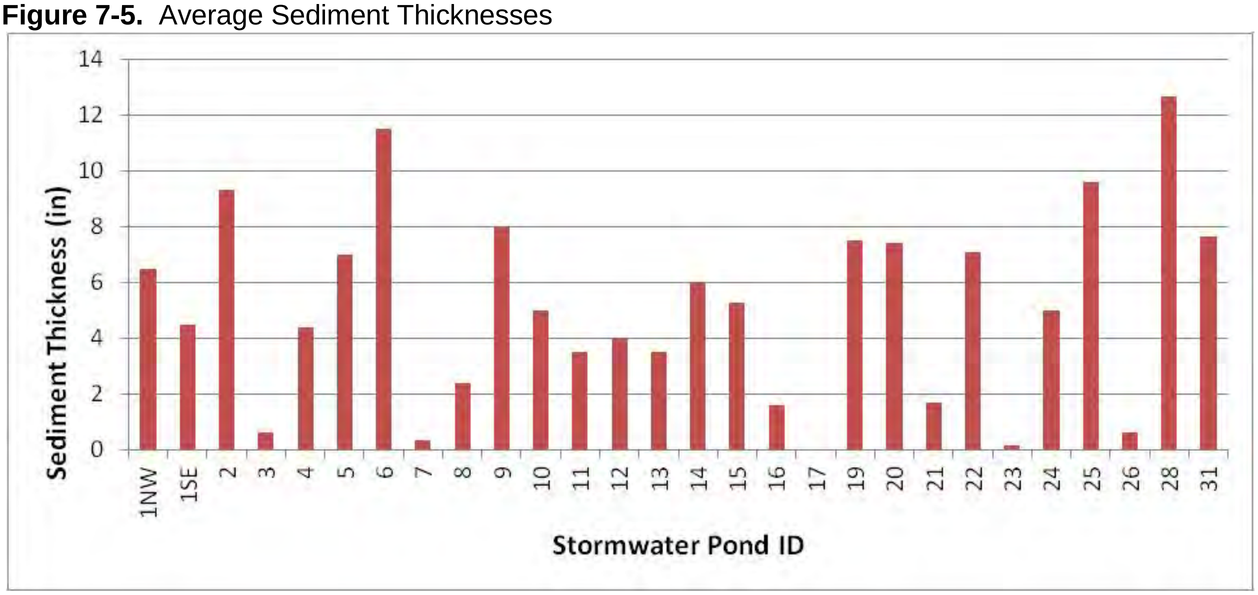
7.5 Sediment Thickness

As previously discussed, details regarding when and how the 28 stormwater lakes were constructed are not well known, but it is generally accepted that most are older than the typical 20 year wet detention life span. The combination of long life-spans and constant pollutant loads being delivered from heavily developed drainage basins has resulted in significant pollutant loads being delivered over the years. As a result of the heavy loading and the primary, long-term nutrient attenuation mechanisms at work (i.e. sedimentation), significant sediments have accumulated in many of the 28 stormwater lakes. The exact composition of these sediments is unknown; however given the high nutrient loads experienced over the years, it is a reasonable assumption that a significant portion of the sediment is composed of nutrient-rich organic matter. Also, because organic matter nutrient concentrations such as phosphorus tend to equilibrate with long term average water column nutrient concentrations, the more heavily loaded systems are more likely to have legacy nutrient sources within their sediment. This limits the effectiveness of external load reduction strategies (BMPs), because reducing the water column nutrient concentrations will typically result in nutrient release from the sediment.

With respect to condition assessment of the 28 stormwater lakes, sediment thickness does not provide enough information to definitively assess the potential for significant internal nutrient loads. However, it does provide an indication of probable internal loading, and as such should be viewed in conjunction with the other indices as an overall assessment.

Figure 7-5 shows average sediment thickness of each stormwater lake, as determined by the sediment probing conducted in 2009 by AMEC staff. It should be noted that data for some stormwater lakes may be incomplete, as boat access to some stormwater lakes was limited. The data can however provide one measure of heavy historical loading and potential for internal nutrient recycling. Based on the data presented, Lakes 2, 6, 25 and 28 have the greatest sediment thicknesses at 9.3 in, 11.5 in, 9.6 in, and 12.7 in, respectively. Used in conjunction with the other indices provided in Section 7.0, this may be indication of poorly functioning or overloaded systems.

Figure 7-5. Average Sediment Thicknesses



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7.6 Total Mass Loading to Volumetric Capacity

One measure of relative stormwater lake condition, that is directly related to quantified loadings and measured morphometry, is the ratio of total mass loading to volumetric capacity. Results of this analysis provide a direct indication of those stormwater lakes that may be undersized. As previously discussed, residence time is a significant factor in any waterbody's ability to provide effective pollutant attenuation. By calculating the ratio of total pollutant mass loading to volumetric capacity, a capacity normalized loading index can be obtained. As with each of the previously discussed indices, this represents a quantitative ranking that provides a direct measure of theoretical stormwater lake condition. This calculation accounts for inherent physical differences in the ability of each stormwater lake to treat the same mass loading, and as such is a valuable representation of the potential for each pond to be exhausted by consistently elevated pollutant loadings it does not have the capacity to treat.

Figures 7-6, 7-7 and 7-8 show the ratio of annual TSS, TN, and TP load to volumetric capacity, respectively. Stormwater lakes 7, 24 and 31 have the highest values for each pollutant, however note that stormwater lake 31 is directly connected to stormwater lake 11, and could potentially be viewed as an extension of that system.

Figure 7-6. Ratio of Annual TSS Loading to Volumetric Capacity

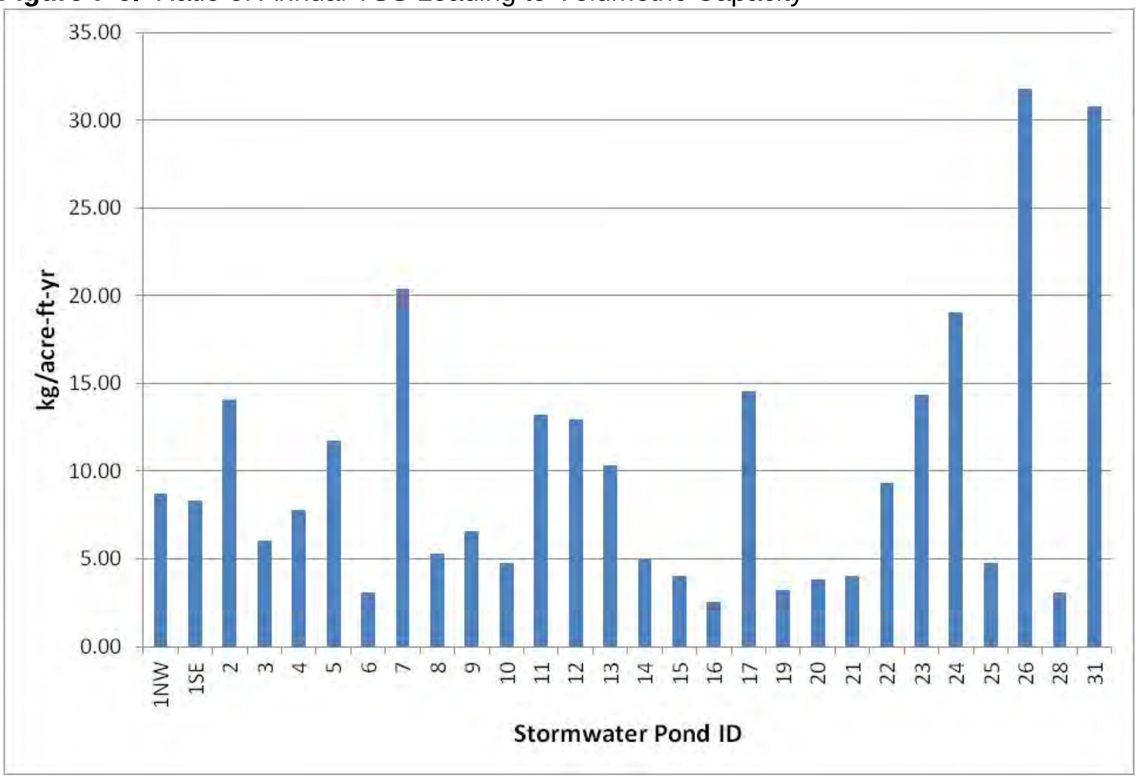

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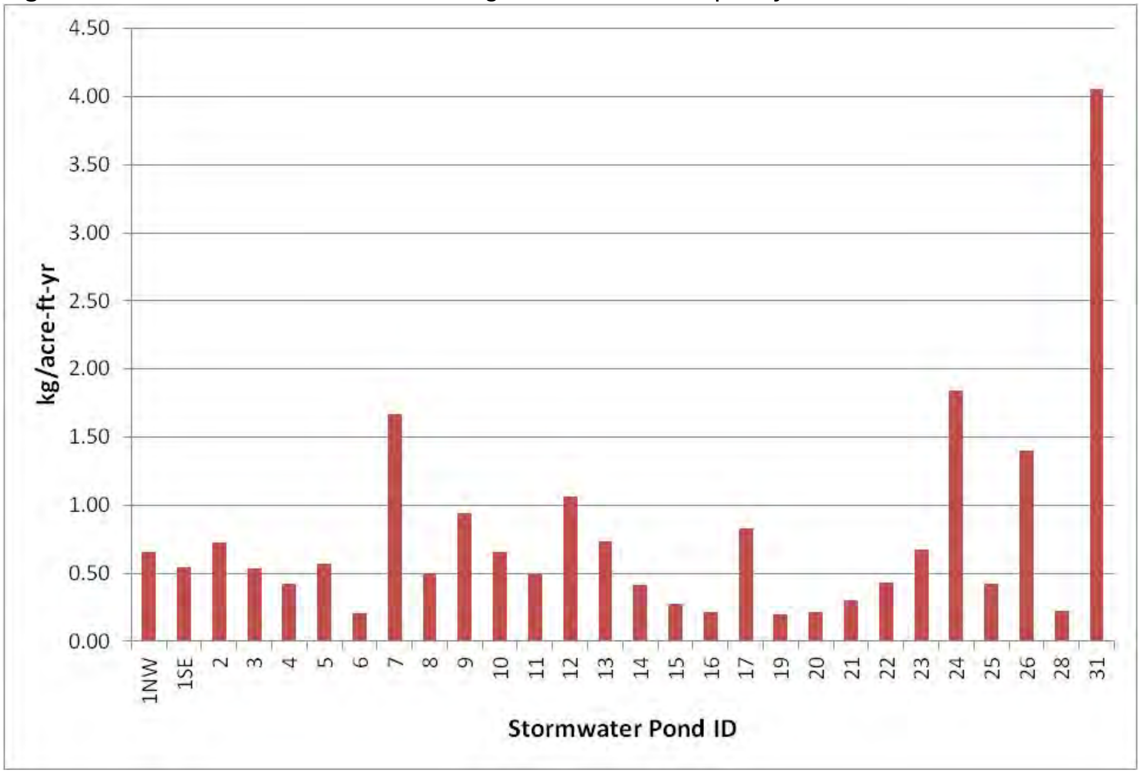
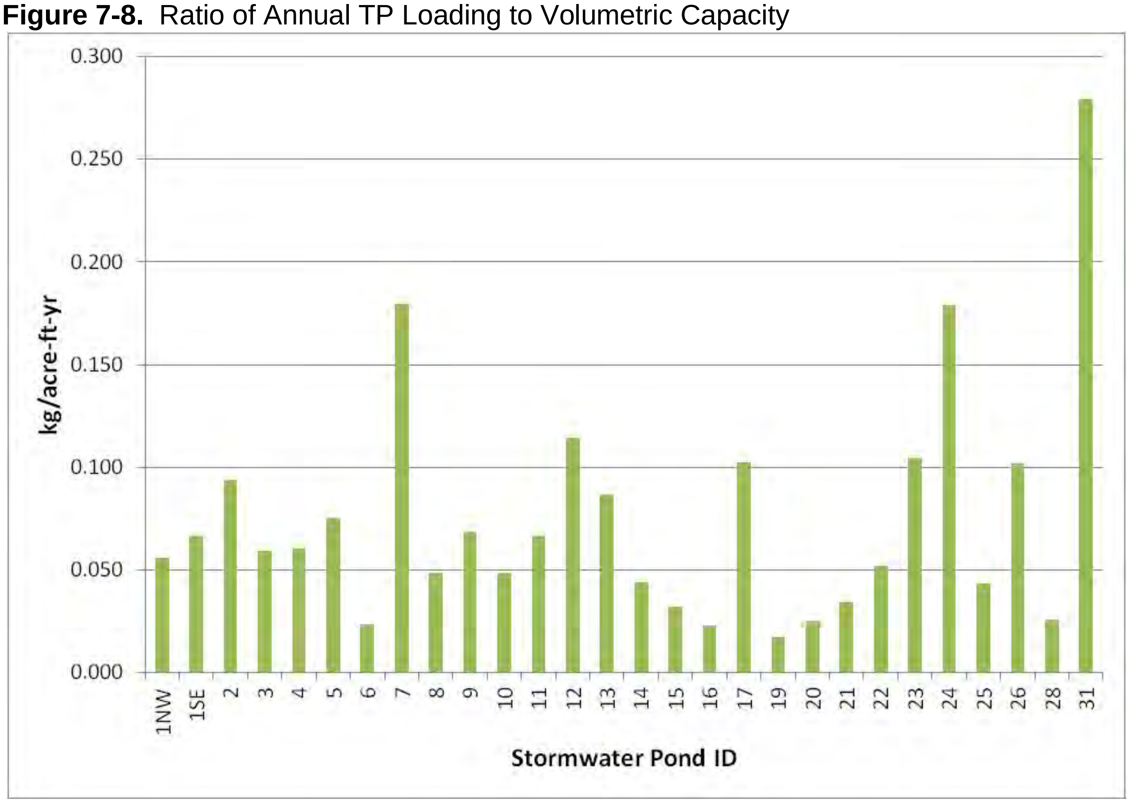
Figure 7-7. Ratio of Annual TN Loading to Volumetric Capacity



Prepared by:SCA Checked by: TGD

Figure 7-8. Ratio of Annual TP Loading to Volumetric Capacity



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7.7 Concentration Comparison

Another measure of existing stormwater lake condition is the comparison of predicted pollutant concentration to measured pollutant concentrations. Based on the removal efficiencies given in Table 7-1 along with the total hydrologic and pollutant loadings calculated in Section 6.0, predicted pollutant concentrations were calculated for each stormwater lake. These concentrations were compared to concentrations directly measured by past monitoring efforts. This comparison allows for a direct assessment of pollutant removal efficiency; if observed pollutant concentrations are greater than the predicted pollutant concentration, either the system is more heavily loaded than predicted (undetected sources within its basin) or the lake itself is not performing as well as a typical wet detention system. Figures 7-9, 7-10 and 7-11 show the predicted and observed TSS, TN and TP concentrations, respectively. It is apparent that very few of the ponds are actually removing pollutants as efficiently as they potentially could.

Figure 7-9. Predicted and Observed TSS Concentrations

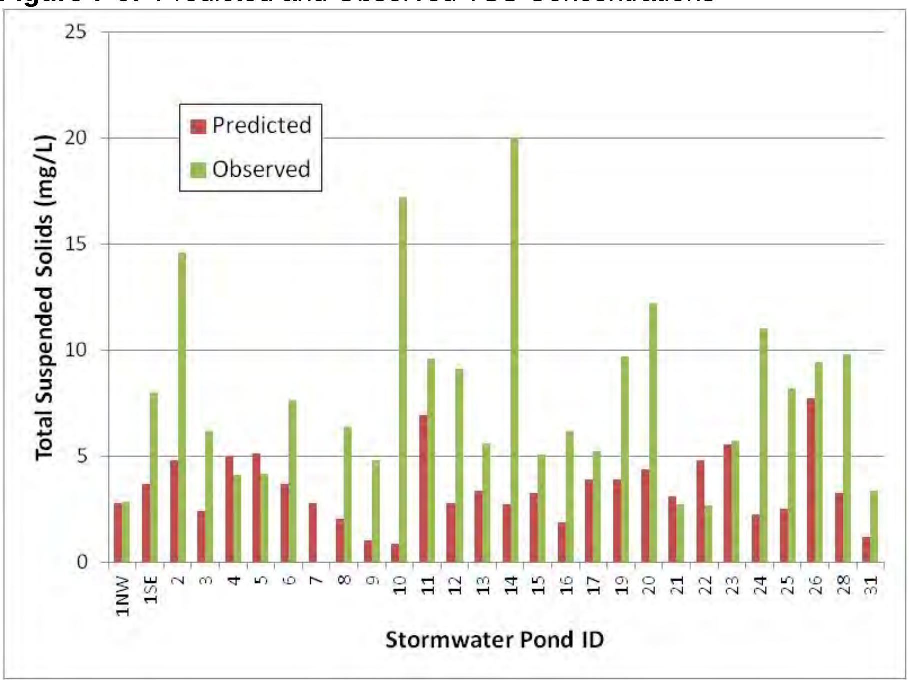

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Figure 7-10. Predicted and Observed TN Concentrations

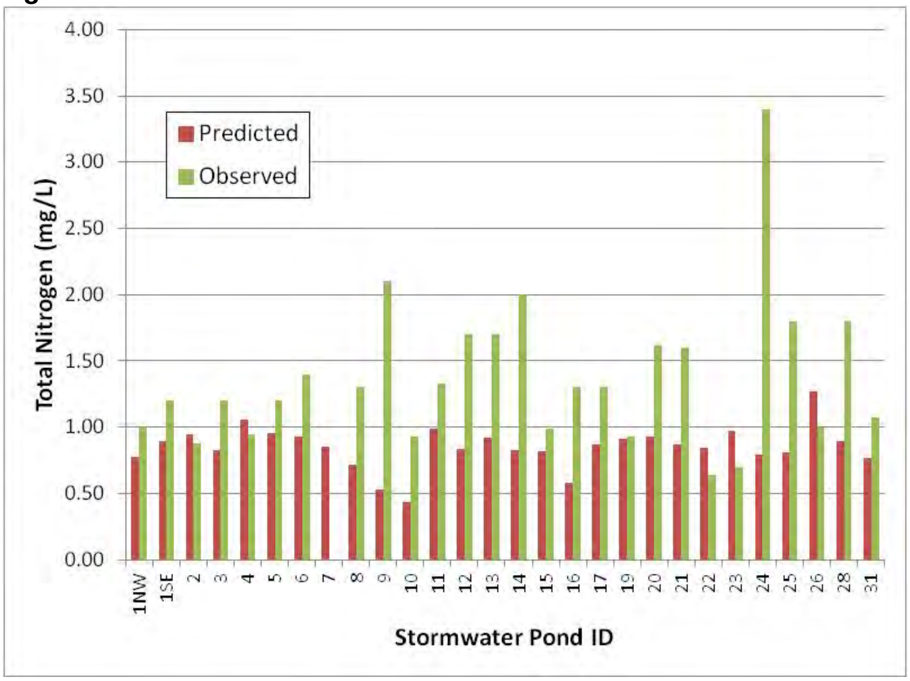

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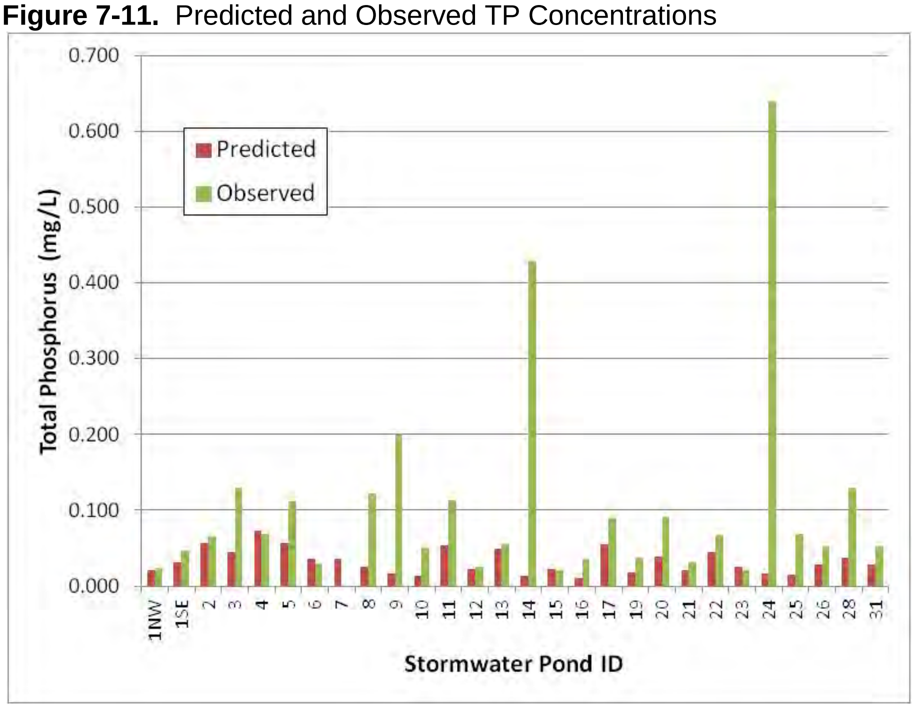
Figure 7-11. Predicted and Observed TP Concentrations



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As with each of the previously discussed indices, these data can be used as a relative ranking index that describes the observed condition of each stormwater lake. It should be noted that observed results are limited for a number of the stormwater lakes, and therefore this index is best used in conjunction with the other indices as a final measure of stormwater lake condition. Based on this analysis, Lakes 8, 9, 10, 14, 24, 25, and 28 have consistently disparate predicted and observed concentrations, which are particularly high for TN and TP concentrations; the performance of these lakes is especially poor.

7.8 Total Pollutant Loading Discharged from each Stormwater Lake

As a prioritization strategy, total pollutant loadings discharged from each stormwater lake were calculated. This is a direct measure of the total mass impact each stormwater lake imparts to the receiving waterbody. Lakes that have large watersheds (and therefore large water flow through) would be highlighted by this measure, as well as lakes that have relatively high pollutant concentrations. Calculations were based on the total hydrologic loadings obtained in Section 6.0 as well as observed stormwater lake pollutant concentrations. Also, this index accounted for copper and fecal coliform data in addition to TSS, TN and TP data. Copper and Fecal Coliform were included in this analysis as the calculations for pollutant loads discharged from each stormwater lake are based on similar data sets for all pollutants, including copper, fecal coliform, TSS, TN and TP. For all pollutants, it is assumed that measured concentrations represent concentrations that may be discharged from the stormwater lakes following rain events. By examining calculated loadings, stormwater lakes contributing the greatest mass loadings can be identified and targeted for potential remediation actions. Figures 7-12 through 7-16 show the TSS, TN, TP, copper and fecal coliform loadings, respectively, discharged on an annual basis from each stormwater lake. Stormwater lakes were color-coded according to their respective receiving waterbody.

Figure 7-12. Total TSS Load Discharged from each Stormwater Lake

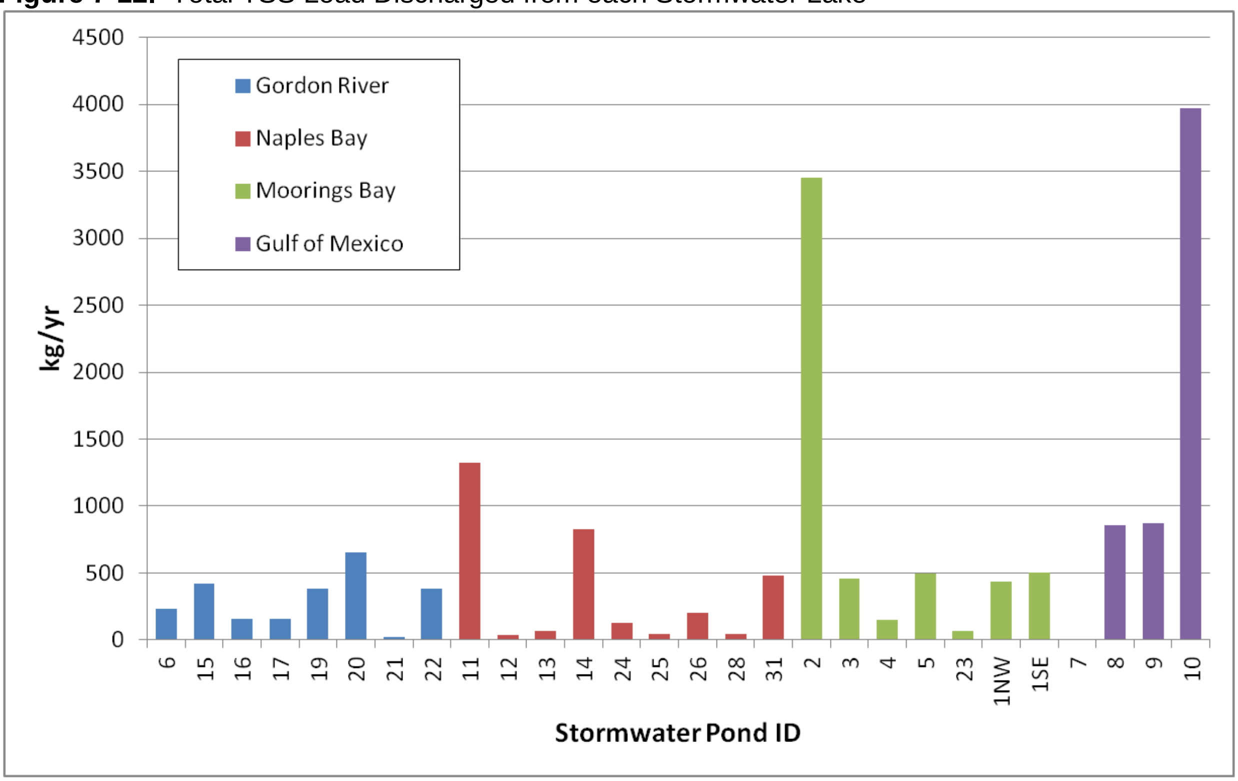

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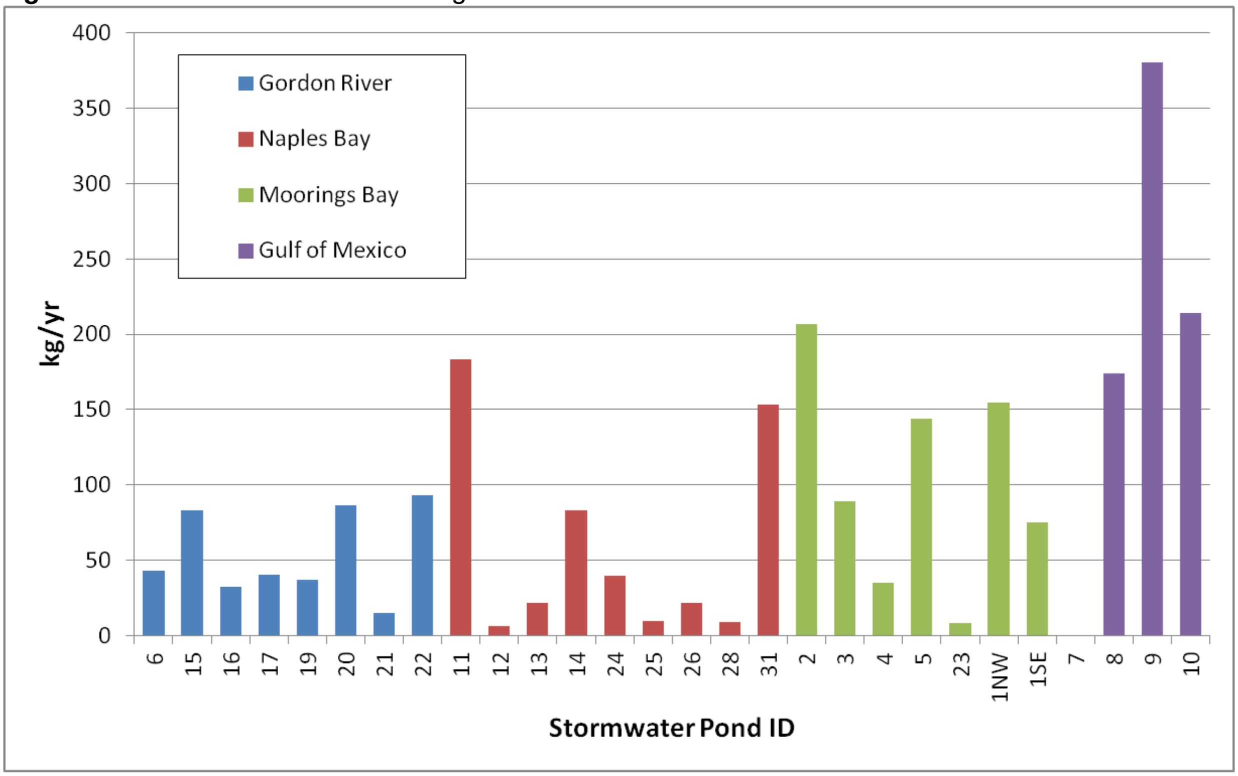
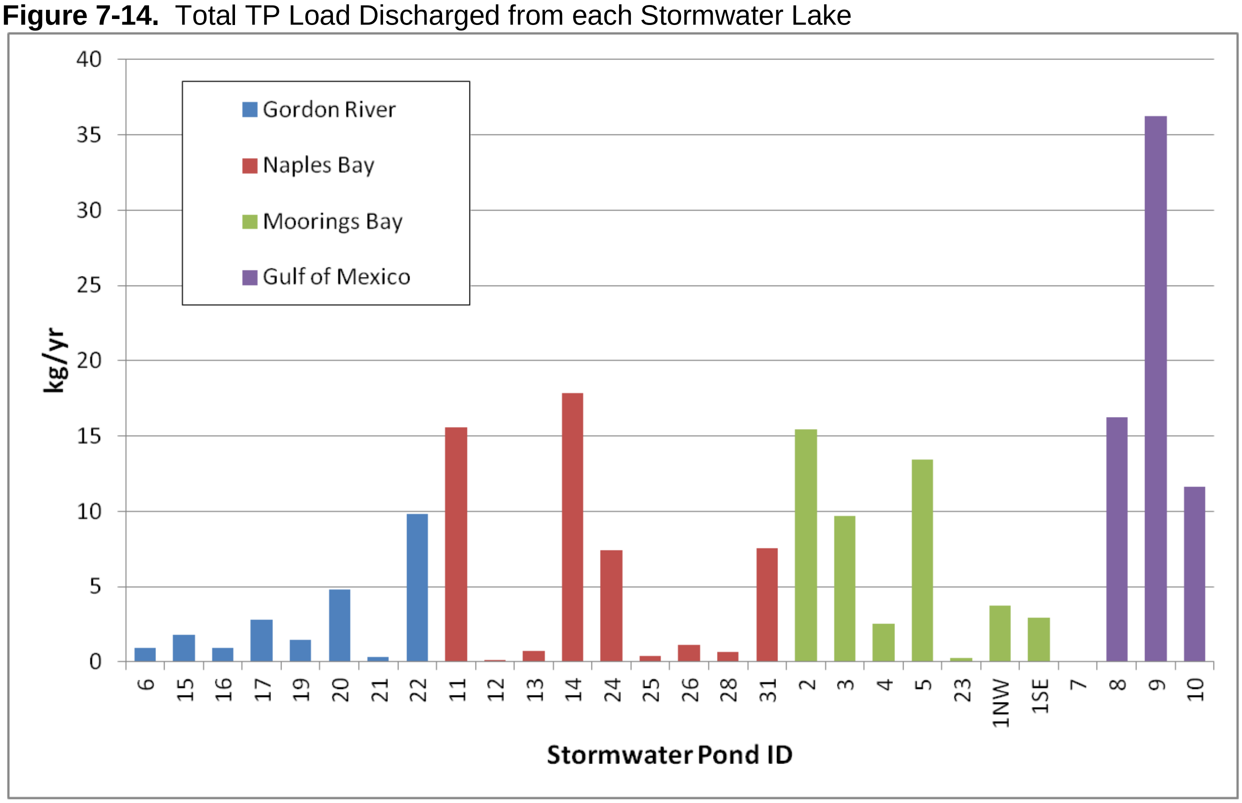
Figure 7-13. Total TN Load Discharged from each Stormwater Lake



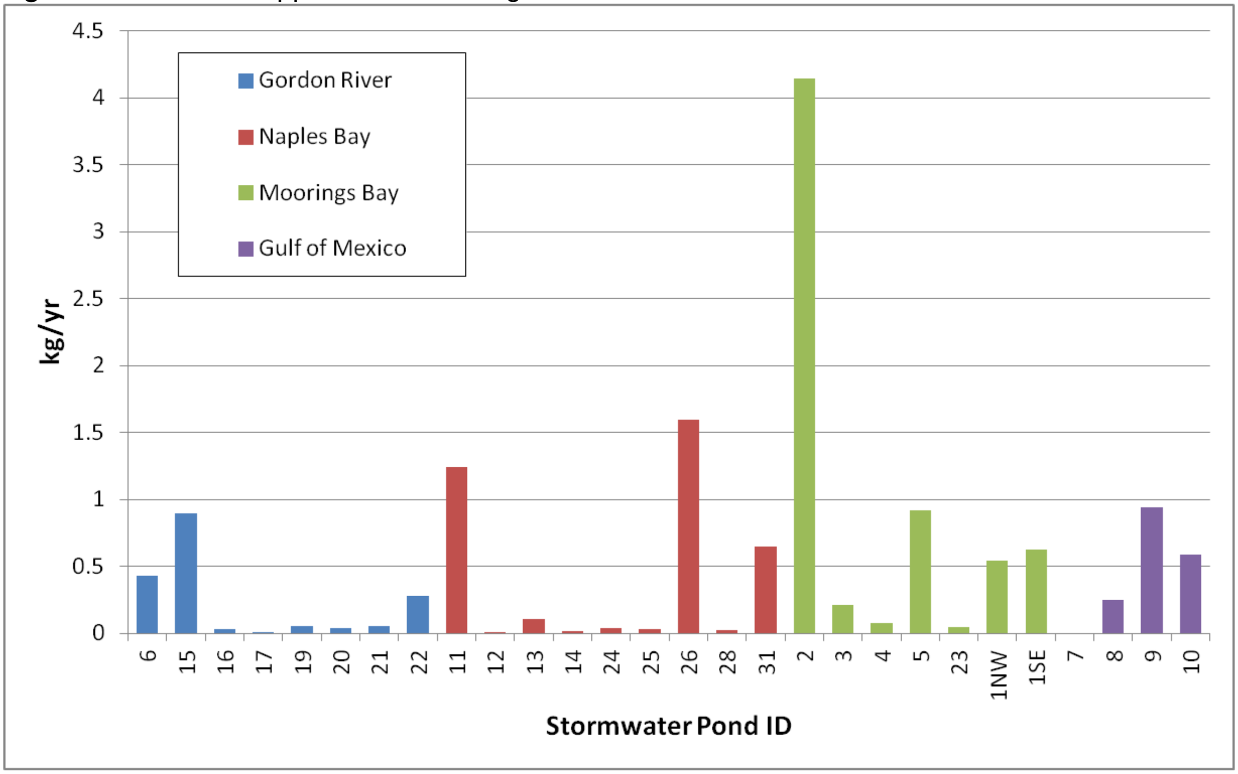
Prepared by: SCA Checked by: TGD

Figure 7-14. Total TP Load Discharged from each Stormwater Lake



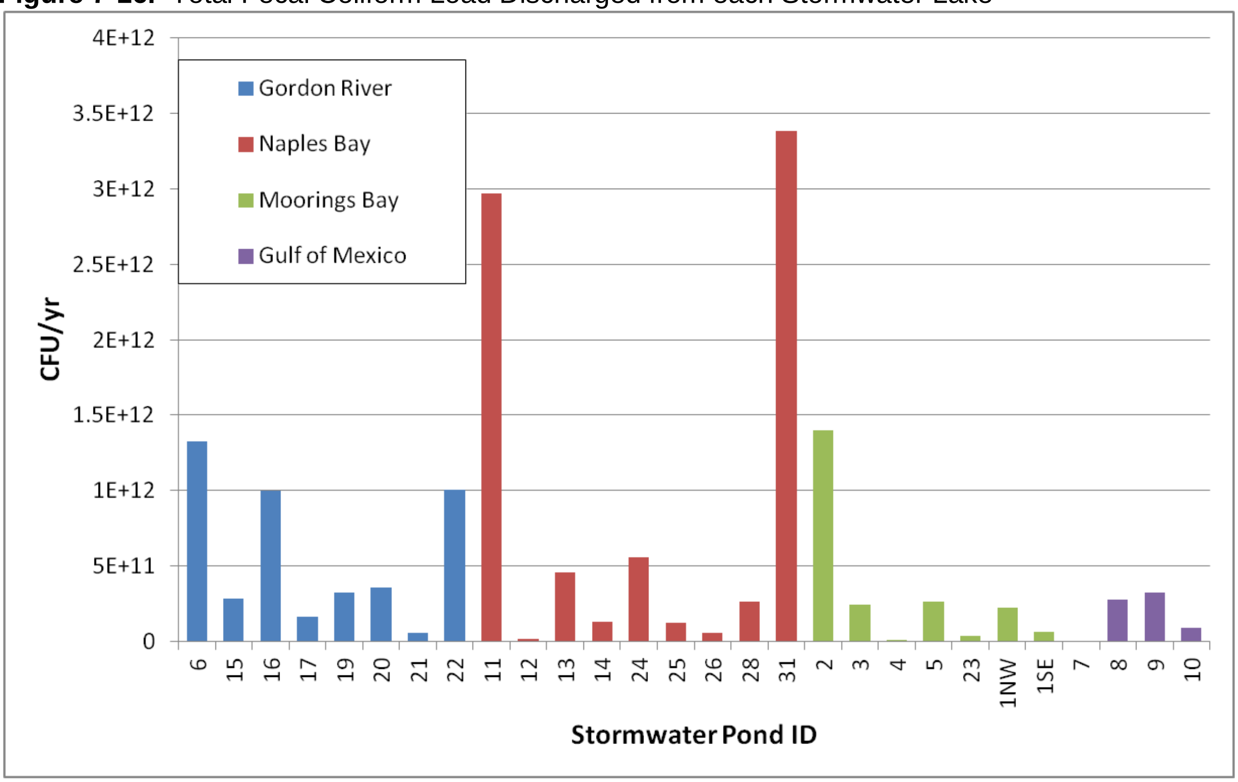
Prepared by: SCA Checked by: TGD

Figure 7-15. Total Copper Load Discharged from each Stormwater Lake



Prepared by: SCA Checked by: TGD

Figure 7-16. Total Fecal Coliform Load Discharged from each Stormwater Lake



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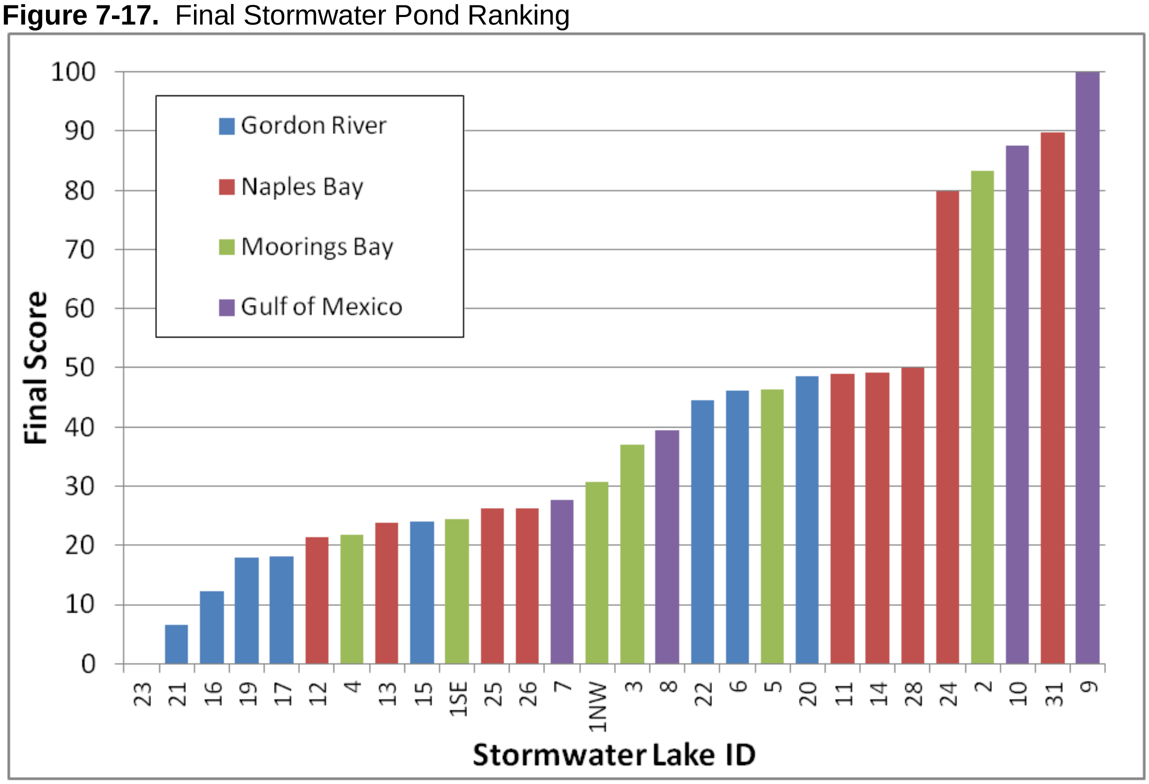
Based on Figures 7-12 through 7-14, Lakes 2, 10, 11 and 14 represent significant sources of downstream mass loadings for the primary pollutants TSS, TN and TP. Lakes 8 and 9 are also somewhat high, but final discharges flow through Lake 10, which is the final discharge to the Gulf of Mexico. Also, potential loadings from Lake 31 may be significant as well, but the majority of these loadings may be attributable to Lake 11, which is much larger than Lake 31 and is directly connected.

Based on Figure 7-15, Lakes 2, 11 and 26 represent the greatest mass contributors of copper to downstream waterbodies. Lake 2 represents the greatest contribution, both due to its high hydrologic throughput, as well as the consistently elevated concentrations observed within the lake. Based on Figure 7-16, Lakes 2, 6, 11 and 31 represent the greatest mass contributors of fecal coliform to downstream waterbodies. Fecal coliform loadings are however highly variable and dependent upon many factors, and particularly deserve increased sampling efforts to better characterize downstream contributions.

7.9 Condition Rankings

In order to provide a final assessment of stormwater lake condition, the indices described in Sections 7.2 through 7.8 have been combined into a final ranking system. Not only does this allow for a comprehensive ranking system based on all available data at this time, it minimizes the potential error that may occur in relying on one single variable, as some of the previously described individual analyses are based on sometimes limited data availability. Rankings were all based on relative values for each data set; the highest scoring stormwater lakes were the highest scoring relative to all other 27 stormwater lakes. For each index, results were normalized to a scale of 1 to 100. The final ranking of each stormwater lake is given Figure 7-15. A low score represents a relatively good condition, whereas a high score represents a stormwater lake that warrants immediate action to address poor condition and pollutant removal performance. This ranking format will allow the City to readily identify data gaps and effectively focus corrective actions on those systems that are most in need.

Figure 7-17. Final Stormwater Pond Ranking



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8.0 Impacts to Downstream Waterbodies

An important function of the City's stormwater lakes is pollutant removal from stormwater to mitigate the effects of urbanization on the anthropogenic eutrophication of the receiving waterbodies. As discussed, there are four primary receiving waterbodies, which include the Moorings Bay system, the Gulf of Mexico, Naples Bay and the Gordon River. Of these waterbodies, both Naples Bay and the Gordon River are impaired for DO, among other constituents, which is a direct result of nutrient mass loadings above what the system can naturally assimilate. The only clearly defined pollutant reduction requirements come from the Gordon River TMDL Report, which states that TN loadings from stormwater discharges with an MS4 permit (the City of Naples) must be reduced by 29% (Baily, 2008). However, defined pollutant reduction requirements for other pollutants and waterbodies may be developed in the future, and the results of this analysis can be used as a baseline data-set to prioritize resources allocated to remediation efforts.

The results of the data and loading analyses have been used to summarize the total pollutant loadings being delivered to each of the four (4) downstream waterbodies. Also calculated are the potential removals that could occur if each of the City's 28 stormwater lakes were functioning to their full potential. The difference between these two (2) removal rates can be used to determine the approximate gains in pollutant removal efficiencies that may be applied towards defined reduction requirements.

By determining the final discharge location of the outflow conveyances of each stormwater pond, total observed and theoretically achievable loads can be calculated. Table 8-1 lists the total observed and predicted pollutant loads by receiving waterbody. Observed loads were based on calculated hydrologic loadings and observed water quality, while predicted loads were based on calculated hydrologic loadings and pollutant removal efficiencies that assume the stormwater ponds function to their full potential.

Table 8-1. Observed and Predicted Pollutant Loads Discharged from Stormwater Ponds

Downstream Waterbody Loading						
Downstream Waterbody	TSS (kg/yr)		TN (kg/yr)		TP (kg/yr)	
	Observed	Predicted	Observed	Predicted	Observed	Predicted
Gordon River	2186	1544	387	335	22	17
Naples Bay	1837	1544	343	218	36	9
Moorings Bay	4914	2423	603	565	42	37
Gulf of Mexico	3967	198	214	105	12	4

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Tables 8-2 through 8-4 build upon the data presented in Table 8-1 by calculating total removal efficiencies. Observed and predicted removal efficiencies were calculated using the same data from Table 8-1. Given the requirements currently imposed by the state for pollutant load reductions, the observed efficiencies can be viewed as existing conditions, while the difference between observed and predicted efficiencies is the gain in removal efficiency that could be obtained following theoretically achievable improvements to the 28 stormwater lakes, particularly those with higher rankings.

Table 8-2. Observed and Predicted TSS Removal Efficiencies

Downstream Waterbody	TSS Removal Efficiencies		
	Observed	Predicted	Difference
Gordon River	79%	85%	6%
Naples Bay	50%	58%	8%
Moorings Bay	70%	85%	15%
Gulf of Mexico	-200%	85%	285%

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Table 8-3. Observed and Predicted TN Removal Efficiencies

Downstream Waterbody	TN Removal Efficiencies		
	Observed	Predicted	Difference
Gordon River	33%	42%	9%
Naples Bay	-8%	31%	39%
Moorings Bay	35%	39%	4%
Gulf of Mexico	-18%	42%	60%

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Table 8-4. Observed and Predicted TP Removal Efficiencies

Downstream Waterbody	TP Removal Efficiencies		
	Observed	Predicted	Difference
Gordon River	67%	74%	8%
Naples Bay	-34%	66%	100%
Moorings Bay	61%	67%	5%
Gulf of Mexico	13%	73%	61%

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In general, all systems reviewed in this analysis may have the potential for treatment efficiency improvement given the implementation of adequate remediation actions. There are however differences in the total impacts to the four primary receiving waterbodies with respect to TSS, TN and TP mass loading.

Table 8-3 shows the predicted and observed pollutant removal efficiencies for TN. Of the four (4) major receiving water bodies, the Gulf of Mexico has the greatest potential for improvement. It should be noted however that the only stormwater lake in this assessment that discharges directly to the Gulf of Mexico is Lake 10. This stormwater lake does however represent a significant pollutant mass loading, as it is served by three additional upstream stormwater lakes as well as its own drainage basin (see Figure 4-2). The next largest potential gain in TN removal efficiency may be realized in the stormwater lakes that discharge to Naples Bay. As previously discussed, there is no formal TMDL for Naples Bay as of yet, however it has been determined to be impaired (see Section 1.2) and will likely require remediation efforts in the near future.

Naples Bay, like the Gordon River, is a saline environment and as such is typically nitrogen limited. Table 8-4 shows the predicted and observed removal efficiencies for TP, which is typically the limiting nutrient in freshwater systems such as the 28 stormwater lakes. Although TP and TN removal efficiencies are not directly related, the TP removal efficiency of a freshwater system is often indicative of its overall trophic health, and can be used to identify eutrophic systems that are also likely to be exporting similarly large quantities of TN. Table 8-4 indicates that the greatest increase in TP removal efficiencies may be realized in those systems that discharge to Naples Bay. The poor observed removal efficiencies calculated for systems that discharge to Naples Bay are most likely due to those systems being overloaded or saturated, which is further substantiated by the results shown in Figure 7-17, as four of the seven highest ranked stormwater ponds discharge to Naples Bay. Conversely, systems discharging to Gordon River have better overall pollutant removal efficiencies. Again, this is substantiated by the results shown in Figure 7-17, with none of these systems scoring higher than 50 in the final ranking.

9.0 Conclusions and Recommendations

The results of this report show that the City has at its disposal a valuable resource in the 28 stormwater lakes. Unfortunately, due to decades of heavy urbanization of the surrounding drainage basins and historically limited maintenance efforts, these resources have lost aesthetic value and no longer provide the pollutant removal services they were once capable of. The USEPA currently recommends that major maintenance activities to remove significant sediment deposits occur on a 20 to 50 year schedule, or "when the pool volume has become reduced significantly or the pond becomes eutrophic" (EPA, 2006). Removal of sediments is often necessary, as these systems lose their ability to effectively reduce pollutant concentrations in the water column when nutrient concentrations in the sediment become too high. Other strategies exist, including *in-situ* sediment inactivation, enhanced littoral zone vegetative buffers, and homeowner education, however these efforts may be too ineffective given the legacy sediment that exists in most of these stormwater lakes.

Based on analysis efforts and data collection performed up until now, AMEC proposes the following course of action for addressing the valuable stormwater lake resources within the City of Naples:

1. **Address Current Data Gaps**
   The loading analysis and prioritization strategy proposed is based on disparate levels of data availability for each of the 28 stormwater lakes. AMEC recommends that, of the stormwater lakes that have been sampled less than two times in the past two years, at least two (2) more samples be obtained to better characterize outflow pollutant characteristics. Data collection should include similar laboratory analysis to past surveys (TSS, TN, TP, Copper, Fecal Coliform and enterococci) and should be grab samples taken within the lake, near the point of discharge. Lakes included in this recommendation are Lakes 1NW, 1SE, 3, 4, 6, 7, 8, 9, 12, 13, 14, 16, 17, 21, 23, 24, 25, 26, and 28, with priority given to those lakes characterized as high priority in Section 7. This would reduce the chance of natural data variability significantly affecting condition assessment calculations, and would allow for more targeted remediation efforts.

2. **Revise Prioritization Analysis**
   If results from Item #1 provide reason to alter the priority ranking analysis conducted in Section 7, this should be completed. This effort would be relatively minimal, as the models and framework for performing these calculations have been completed, and minimal data analysis would be required.

3. **Develop Remediation Strategies**
   Although somewhat disadvantaged in that the majority of City property is highly developed, the City is fortunate that it already has 28 rather large stormwater lakes at its disposal. As shown in Section 7.3, many of the 28 stormwater lakes have the potential for significant improvements in their pollutant removal efficiencies. Ultimately, the accumulated sediment in many of these systems may require removal or chemical inactivation before additional corrective actions such as vegetative buffers or homeowner education are implemented. AMEC recommends that, following finalization of the prioritization analysis described above, sediment removal efforts be considered for medium and high priority stormwater lakes.

10.0 References

Bailey, Nathan. 2008. TMDL Report: Dissolved Oxygen TMDL for the Gordon River Extension, WBID 3278K (formerly 3259C). Florida Department of Environmental Protection. August 19, 2008.

CH2M Hill. 1981. Citywide Drainage Study Submitted to the City of Naples. Naples, Florida.

Environmental Research and Design, Inc. (ERD). 2007. Butler Chain-of-Lakes Hydrologic/Nutrient Budgets and Management Plan. Prepared for Orange County Environmental Protection Division. January, 2007.

Everglades West Coast (EWC). 2009. Everglades West Coast Group 1 Basin/ South District Verified List of Impaired Water Bodies.

FDEP. 2010. Environmental Resource Permit Stormwater Quality Applicant's Handbook. March 2010 Draft.

George, I., Anzil, A., Servais, P. (2004) Quantification of fecal coliform inputs to aquatic systems through soil leaching. *Water Research.* **38.**

Haag, K. H., Miller, R. L., Bradner, L. A., McCulloch, D. S. 1996. Water-Quality Assessment of Southern Florida: An Overview of Available Information on Surface- and Ground-Water Quality and Ecology. US Geological Survey, Water Resources Investigations Report 96-4177. Tallahassee, FL, 1996.

Harper, H., Baker, D. 2007. "Evaluation of Current Stormwater Design Criteria within the State of Florida". Florida Department of Environmental Protection, Contract # SO108.

Marino, R. P., Gannon, J. J. (1991) Survival of Fecal Coliforms and Fecal Streptococci in Storm Drain Sediment. *Water Research*, **25**(9).

Naples, 2009. GIS Data Packet. City of Naples GIS Department. Received 2009.

Natural Resources Conservation Service (NRCS). 2010. *Soil Survey Geographic Database for Collier County, FL. 2010.*

Schoonover, J. E., Lockaby, B. G. (2006). Land cover impacts on stream nutrients and fecal coliform in the lower Piedmont of West Georgia. *Journal of Hydrology*. **331**, 371-382.

Skinner, J. F., Guzman, J., Kappeler, J. (2010) Regrowth of Enterococci and Fecal Coliform in Biofilm. *Stormwater,* **11** (5).

South Florida water Management District (SFWMD). 2011. NAPCON_R Weather Station. http://www.sfwmd.gov/. Accessed Oct. 1, 2011.

United States Department of Agriculture (USDA). 1986. *Urban hydrology for small watersheds*. Technical Release 55 (TR-55) (Second Edition ed.). Natural Resources Conservation Service, Conservation Engineering Division. ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf.

United States Environmental Protection Agency (EPA) Stormwater Menu of BMPs. 2006. http://cfpub.epa.gov/npdes/home.cfm?program_id=6. Accessed November, 2011.

Wright Water Engineers, Inc. (WWE) and Geosyntec Consultants, Inc. (GC). 2011. International Stormwater Best Management Practices (BMP) Database, Pollutant Category Summary: Metals. WERF, FHA, EWRI, ASCE. August 2011.

Appendix A
Supplemental Figures and Discussion

Quarterly Results and Discussion

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March 30, 2011

Mr. Ron Wallace, P.E.
The City of Naples
295 Riverside Circle
Naples, Florida 34102

Subject: **Quarterly Monitoring Results and Future Plans**

Dear Mr. Wallace:

Included in this letter, as requested by Mr. Gregg Strakaluse, P.E., is a clarification of the quarter 1 (Q1) sampling result qualifiers, a discussion of automated composite stormwater sampling locations and plan for moving forward with the quarterly monitoring program. Q1 sampling results were submitted to the City of Naples on January 13, 2011, and the quarter 2 (Q2) sampling event was completed on March 18, 2011.

Results of Q1 sampling indicated several locations had bacteria and copper concentrations that exceeded water quality standards for Class II Surface Waters. Although no sampling locations are located within Class II surface waters, most locations either directly or indirectly discharge into Naples Bay, which is a Class II surface water and is impaired for copper. The fecal coliform results from the Lantern Lake conveyance (14A), Spring Lake sub-basin conveyances (11A, 11B), and Public Work Pump Station (PW-Pump) all exceeded the allowable daily maximum for Class II surface water bodies of 800 CFU/100 mL, and runoff from each of these locations is eventually discharged into Naples Bay. Copper concentrations either at these sampling locations or at nearby, hydraulically connected locations also exceeded the Class II surface water quality standard of 3.7 µg/L. Based on these results and discussions between MACTEC and the City of Naples, it was decided to locate the automated stormwater samplers (Optional Task) at the Port Royal Pump Station, the Public Works Pump Station, and at a conveyance just upstream of Spring Lake in order to assess storm related loadings to Spring Lake and Naples Bay. Adjustments were also made to several Q2 sampling locations based on Q1 results. Results from Q1 locations 11A, 11B, 14A and PW-Pump all exceeded Class II surface water quality standards for fecal coliform, so the decision was made to move the corresponding Q2 sampling locations farther upstream to evaluate the source(s) of the loadings (see attached figure).

Also, as a clarification of Q1 lab results, the following is a description of the various laboratory reporting qualifiers. Descriptions are taken directly from Florida Administrative Code Chapter 62-160: Quality Assurance.

U – Indicates that the compound was analyzed for but not detected

This symbol shall be used to indicate that the specified component **was not** detected. The value associated with the qualifier shall be the laboratory method detection limit. Unless requested by the client, less than the method detection limit values shall not be reported.

I – The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit

"Method detection limit (MDL)" is an estimate of the minimum amount of a substance that an analytical process can reliably detect. An MDL is analyte-and matrix-specific and is laboratory-dependent. The MDL for an analyte is determined from the preparation and analysis of a sample in a given matrix containing the analyte. MDLs shall be determined for each matrix/analytical technology/analyte combination reported by the laboratory. MDLs shall be calculated following the procedures specified in "New and Alternative Analytical Laboratory Methods", DEP-QA-001/01 (February 1, 2004) which is incorporated by reference in Rule 62-160.800, F.A.C., or by any other technically justifiable and scientifically sound method. A specific method must be used when mandated by a Department program.

"Practical quantitation limit (PQL)" is the lowest level of measurement that can be reliably achieved during routine laboratory operating conditions within specified limits of precision and accuracy. For Departmental use, if a laboratory fails to report a PQL, the PQL shall be calculated as four times the MDL.

V – Indicates the analyte was detected in both the sample and the associated method blank

Indicates that the analyte was detected at or above the method detection limit in both the sample and the associated method blank and the value of 10 times the blank value was equal to or greater than the associated sample value. Note: unless specified by the method, the value in the blank shall not be subtracted from associated samples.

J3 – Estimated value; value may not be accurate. Spike recovery or RPD outside of criteria

A "J" value shall be accompanied by a detailed explanation to justify the reason(s) for designating the value as estimated. Where possible, the organization shall report whether the actual value is estimated to be less than or greater than the reported value. A "J" value shall not be used as a substitute for K, L, M, T, V, or Y, however, if additional reasons exist for identifying the value as an estimate (e.g., matrix spiked failed to meet acceptance criteria), the "J" code may be added to a K, L, M, T, V, or Y. Examples of situations in which a "J" code must be reported include: instances where a quality control item associated with the reported value failed to meet the established quality control criteria (the specific failure must be identified); instances when the sample matrix interfered with the ability to make any accurate determination; instances when data are questionable because of improper laboratory or field protocols (e.g., composite sample was collected instead of a grab sample); instances when the analyte was detected at or above the method detection limit in a blank other than the method blank (such as calibration blank or field-generated blanks and the value of 10 times the blank value was equal to or greater than the associated sample value); or instances when the field or laboratory calibrations or calibration verifications did not meet calibration acceptance criteria.

If you have questions, please contact me via email, abshortelle@mactec.com, or telephone (352) 333-2623.

Sincerely,

MACTEC Engineering and Consulting, Inc.

for Ann B. Shortelle, Ph.D.
Project Manager
with permission

Sam Arden, E.I.
Staff Engineer

Parameter	Nitrogen, Kjeldahl	Nitrate Nitrite as N	Nitrogen, Total	Phosphorus, Total	Total Suspended Solids	Copper, Total	Fecal Coliform	Enterococcus
Units	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(MF)	(MPN)
Location								
14-A	2.2	0.94	3.1	0.71	4.4	1.2I	2900	2420
14-Pump	0.87	.68J3	1.6	0.48	2.4	5	360	1730
11-A	1.1	.11I	1.2	0.23	6	2.3I	2000	1990
11-B	0.99	.12I	1.1	0.15	4.4	2.3I	1190	534
11-C	0.71	.24I	0.95	0.046	1.6	1.6I	520	866
11-D	1.2	0.5	1.7	0.12	1.2	2.5U	727	914
11-Pump	1	0.53	1.5	0.13	1.6	1.4I	390	215
PW-Pump	1.3	.34I	1.6	0.22	8	8.6	855	1300
26-Out	0.91	.27I	1.2	0.089	24	6.7	600	43
8-A	1.2	.5U	1.2	0.24	3.2	1.1I	326	40
10-Outfall	0.97	0.5U	0.97	0.042	10J3	2.5U	40	166
BC-Outfall	2.7	.5U	2.7	0.26	6	8.2	54	122
22-A	0.74	.5U	0.74	0.091	1.6	1.3I	560	225
22-B	0.63	.5U	0.63	0.061	1.0U	1.0I	208	63
20-A	1.8	.5U	1.8	0.099	16	2.5U	152	47
20-B	1.5	.5U	1.5	0.092	12	2.5U	370	111
19-Out	0.65	.27I	0.92	0.03	1.2	2.5U	410	52
US41	1.1	2.5	3.6	0.92	1.0U	2.7V	60	691
15-A	1.2	0.41I	1.6	0.063	5.2	4.0V	220	173
15-B	0.9	0.50U	0.9	0.025	5.6	3.9V	380	204
5-A	0.85	.22I	1.1	0.12	3.6	8.3V	66	45
5-B	1	.21I	1.2	0.13	5.2	12V	88	61
2-A	1	.5U	1	0.11	4.4	8.7V	230	961
2-B	0.48	.5U	0.48	0.033	11	5.2V	62	961

U- Indicates that the compound was analyzed for but not detected

V- Indicates the analytee was detected in both the sample and the associated blank

I- Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit

J3 - Estimated value; value may not be accurate. Spike recovery or RPD outside of criteria

Parameter	Type	In/Out	Flow	Date	Time	Sample Type	Temp	DO	Conductivity
Units			(Y/N)				(°C)	(mg/l)	(µS/cm)
Location									
14-A	Conveyance	In	N	12/7/2010	9:30	Grab - Direct	17.39	2.35	1347
14-Pump	Pump		N	12/7/2010	9:45	Grab - Bailer	20.34	4.75	6820
11-A	Conveyance	In (res)	N	12/7/2010	11:05	Grab - Bailer	22.08	1.84	793
11-B	Conveyance	In (com)	N	12/7/2010	10:35	Grab - Direct	20.95	2.64	767
11-C	Conveyance	Out	Y	12/7/2010	10:15	Grab - Bailer	15.08	5.74	666
11-D	Conveyance		Y	12/7/2010	8:55	Grab - Bailer	24.71	3.28	1174
11-Pump	Pump		N	12/7/2010	8:30	Grab - Bailer	24.33	2.75	1453
PW-Pump	Pump		N	12/7/2010	7:40	Grab - Bailer	24.39	5.44	847
26-Out	Conveyance	Out	Y	12/7/2010	14:45	Grab - Bailer	24.04	6.16	953
8-A	Lake	In	N	12/7/2010	12:50	Grab - Bailer	17.28	5.37	955
10-Outfall	Lake	Out	N	12/7/2010	12:00	Grab - Direct	18.88	11.39	34412
BC-Outfall	Conveyance	Out	Y	12/7/2010	14:15	Grab - Direct	20.39	1.13	2435
22-A	Lake	In	N	12/7/2010	13:10	Grab - Bailer	18.97	2.91	1213
22-B	Lake	Out	N	12/7/2010	13:45	Grab - Direct	17.89	5.27	1308
20-A	Lake	In	N	12/8/2010	13:30	Grab - Pump	18.01	9.81	416
20-B	Lake	Out	N	12/8/2010	13:00	Grab - Direct	18.14	9.30	416
19-Out	Open Ditch	Out	Y	12/8/2010	14:30	Grab - Pump	20.00	6.03	1076
US41	Conveyance		N	12/8/2010	13:50	Grab - Pump	21.21	6.74	1117
15-A	Lake	In	N	12/8/2010	11:15	Grab - Pump	17.17	4.51	615
15-B	Lake	Out	N	12/8/2010	10:50	Grab - Pump	17.53	7.69	517
5-A	Lake	In	N	12/8/2010	7:45	Grab - Bailer	17.35	7.77	522
5-B	Lake	Out	Y	12/8/2010	8:00	Grab - Direct	16.91	7.42	518
2-A	Lake	In	Y	12/8/2010	9:00	Grab - Bailer	16.20	7.58	520
2-B	Lake	Out	Y	12/8/2010	9:50	Grab - Bailer	18.56	4.36	49989

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May 26, 2011

Mr. Ron Wallace, P.E.
The City of Naples
295 Riverside Circle
Naples, Florida 34102

Subject: **Quarterly Monitoring Results**

Dear Mr. Wallace:

Included in this letter is a discussion of quarter 2 (Q2) sampling results. The laboratory data as well as the field measurement data is included as an attachment to this letter. The Q2 sampling event was completed on March 18, 2011. As discussed in the quarter 1 (Q1) submission, the Class II surface water quality standard for copper is 3.7 µg/L, while the standard for fecal coliform states that concentrations (CFU/100 mL) shall not exceed a median value of 14 with not more than 10% of the samples exceeding 43, nor exceed 800 on any one day.

Following Q1 data analysis, several sample locations were relocated in an attempt to identify the potential sources of high fecal coliform and copper loadings. Sample locations 11A2, 11B2, 14A2, 14B2, and PW-2 were all revised sampling locations that assessed upstream conditions from Q1 sample locations 11A, 11B, 14A, 14B, and PW-Pump (see attached Figure 1). The following are results of this investigation:

11A/11B – Q1 results from 11A and 11B indicated copper concentrations of 2.3 µg/L at each location and fecal coliform concentrations of 2000 and 1190 CFU/100mL, respectively. Because 11A was directly upstream of 11B, it was decided to relocate Q2 locations upstream of 11A. From the Q2 data, it is clear that the high fecal coliform loading is coming from the conveyances east of 11B2 (4700 CFU/100 mL), which was located on the southeast corner of 6th St. S and 4th Ave. N. The copper concentration from sample location 11B2 (16 µg/L) was also higher than Q1 results in the area, indicating that significant copper loading may be coming from the areas east of the intersection of 6th St. S and 4th Ave. N. The fecal coliform and copper concentrations reported at 11A2 (33 CFU/100 mL and 2.2 µg/L, respectively) indicated minimal bacterial and copper loading from the areas north of the intersection of 6th St. S and 4th Ave. N.

14A/14B – The highest Q1 fecal coliform concentration was reported at sample location 14A (2900 CFU/100 mL). Because this location is directly upstream of the Lantern Lane Pump Station which discharges directly into Naples Bay, Q2 locations were moved upstream of 14A in order to identify potential point sources. Q2 results at sample locations 14A2 and 14B2 indicated minimal copper loading (2.0 and 2.7 µg/L, respectively) however fecal coliform results indicated higher loading from 14B2 (1320 CFU/100 mL). Sample location 14B2 was located on the northeast corner of Galleon Dr. and Gordon Dr. and collects runoff from Gordon Dr. The fecal coliform concentration from 14A2 (134 CFU/100 mL), located on Lantern Ln. just north of Galleon Dr., was lower than that from Gordon Dr., indicating that the potential source of high bacterial loading may be from the Gordon Dr. area.

PW-Pump – Q1 results from the Public Works Pump Station (PW-Pump) indicated elevated levels of copper and fecal coliform (8.6 µg/L and 855 CFU/100 mL, respectively). Due to the placement of an automated ISCO sampling device at PW-Pump, it was decided to move the Q2 sampling location farther upstream from the Q1 location. Q2 sample location PW-2 was located on the north side of Riverside Cr. just east of the Goodlette Rd. intersection. Although the copper concentration (3.9 µg/L) was lower than the Q1 PW-Pump concentration, the fecal coliform concentration at PW-2 was 5800 CFU/100 mL, indicating that a probable source of bacterial loading to the Public Works Pump Station was upstream of the intersection of Goodlette Rd. and Riverside Cr.

In addition to the elevated loadings previously discussed, several other sampling locations had elevated copper concentrations. Copper concentrations at Lake 2 (sample locations 2-A and 2-B) were much higher than Q1 results and far exceeded the WQ criteria for Class II water bodies, with a concentration of 73 µg/L at the inflow (2-A) and 63 µg/L (2-B) at the outflow. At the time of sample collection, there was noticeable flow into and out of the lake, indicating that the lake was heavily loaded but was providing some level of copper reduction.

As requested by Mr. Gregg Strakaluse, the data collected thus far was compared to existing Total Maximum Daily Load (TMDL) guidance for fecal coliform set forth by the Florida Department of Environmental Protection (FDEP). Although the scope of this project does not address the full multitude of data acquisition necessary for developing a TMDL, the steps currently being taken to assess point and nonpoint sources associated with Municipal Separate Storm Sewer Systems (MS4s), illicit sewer connections and possible Sanitary Sewer Overflows (SSOs) are consistent with portions of FDEP guidance and are an integral part of the overall TMDL development process. Also, data from this and other similar monitoring efforts can be readily incorporated into any future TMDL work. The steps that the City has taken to implement a system of stormwater ponds are also consistent with standard recommended load reduction strategies in watersheds that feed impaired waters.

Based on preliminary water quality results and a discussion on bacterial loadings from residential and commercial areas from the FDEP TMDL Protocol document, bacterial loadings from within the City of Naples appear to be less than FDEP published typical loadings and the existing BMPs appear to be functioning appropriately. In the FDEP TMDL Protocol document, a multi-state, multi-year study was cited that reported median concentrations of fecal coliform in MS4 monitoring samples of 8,000 to 11,000 MPN/100ml (MPN≈CFU). By comparison, the median concentration of fecal coliform from all Q1 and Q2 samples is 250 CFU/100mL. Although 250 CFU/mL is above the numeric criteria of 14, the ultimate mass loading that any future TMDL would address is difficult to assess without detailed flow information.

If you have questions, please contact me via email, abshortelle@mactec.com, or telephone (352) 333-2623.

Sincerely,

MACTEC Engineering and Consulting, Inc.

WA Tucker for

Ann B. Shortelle, Ph.D. with permission
Project Manager

Sam Arden, E.I.
Staff Engineer

References:

FDEP, 2006. Florida Department of Environmental Protection TMDL Protocol. Task Assignment 003.03/05-003. June 2006, version 6.0.

Quarter 2 Sampling Results

Parameter	Nitrogen, Kjeldahl	Nitrate Nitrite as N	Nitrogen, Total	Phosphorus, Total	Total Suspended Solids	Copper, Total	Fecal Coliform	Enterococcus
Units	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(MF)	(MPN)
Location								
11-A2	0.66	0.24 I	0.90	0.084	2.4	2.2	33	461
11-B2	7.90	0.12 I	8.00	0.94	7.2	16	4700	11800
11-C	1.30	0.10 U	1.30	0.016	3.6	4.3	260	613
11-D	0.96	0.64	1.60	0.15	1.2	1.1	310	1100
11-Pump	1.30	0.44 I	1.70	0.11	1.6	1.6	82	1000
14-A2	3.10	0.10 U	3.10	0.62	1.0 U	2	134	100
14-B2	2.40	0.15 I	2.60	0.98	5.6	2.7	1320	2990
15-A	1.40	0.10 U	1.40	0.087	22	5.6	310	2420
15-B	0.94	0.10 U	0.94	0.028	5.2	4.3	86	83
19-Out	0.59	0.24 I	0.83	0.041	9.2	1.6	34	1990
20-A	1.40	0.10 U	1.40	0.11	12	0.71	330	411
20-B	1.40	0.10 U	1.40	0.22	20	0.95	118	164
22-A	1.80	0.10 U	1.80	0.13	6	2.2	390	1200
22-B	0.70	0.10 U	0.70	0.056	3.2	2.6	200	201
26-Out	0.77	0.32 I	1.10	0.6	3.2	0.85	76	630
2-A	0.88	0.10 U	0.88	0.16	4.4	73	480	691
2-B	0.26	0.10 U	0.26 I	0.054	20	63	40	1010
5-A	0.69	0.18 I	0.87	0.14	3.2	7.9	66	168
5-B	0.73	0.19 I	0.92	0.13	4	8.6	58	56
8-A	1.20	0.10 U	1.20	0.24	4.8	1.4	122	727
10-Outfall	0.70	0.10 U	0.70	0.056	26	7.8	40	2420
BC-Outfall	3.00	0.10 U	3.00	0.31	18	6.2	210	100
PW-2	1.60	0.43 I	2.00	0.058	4.8	3.9	5800	3830
US41	0.72	0.32 I	1.00	0.16	1.2	2.7	86	510

U- Indicates that the compound was analyzed for but not detected

I- Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit

Quarter 2 Ambient Results

Parameter	Type	In/Out	Flow	Date	Time	Sample Type	Temp	DO	Conductivity
Units			(Y/N)				(°C)	(mg/l)	(µS/cm)
Location									
11-A2	Conveyance	In	N	3/18/2011	9:00	pump	21.85	6.35	1058
11-B2	Conveyance	In	N	3/18/2011	9:30	pump	21.95	1.40	990
11-C	Conveyance	Out	Y	3/18/2011	8:30	bailer	22.44	4.45	701
11-D	Conveyance		Y	3/18/2011	8:15	bailer	22.95	5.94	1111
11-Pump	Pump		N	3/18/2011	7:45	bailer	23.17	3.47	1332
14-A2	Conveyance	In	N	3/18/2011	10:30	pump	24.51	1.83	2451
14-B2	Conveyance	In	N	3/18/2011	11:00	pump	24.57	1.99	1352
15-A	Lake	In	N	3/17/2011	11:30	pump	21.93	6.92	578
15-B	Lake	Out	N	3/17/2011	11:15	Grab	23.17	7.52	569
19-Out	Open Ditch		Y	3/17/2011	12:00	pump	22.56	2.73	1067
20-A	Lake	In	N	3/17/2011	8:30	grab	21.91	6.81	439
20-B	Lake	Out	N	3/17/2011	8:00	pump	21.39	5.34	443
22-A	Lake	In	N	3/16/2011	13:00	grab	23.24	7.30	810
22-B	Lake	Out	N	3/16/2011	13:30	grab	23.89	5.97	865
26-Out	Conveyance	Out	Y	3/17/2011	9:30	bailer	23.43	5.90	1032
2-A	Lake	In	Y	3/16/2011	9:00	bailer	22.90	7.45	452
2-B	Lake	Out	Y	3/16/2011	9:15	bailer	22.38	4.03	51207
5-A	Lake	In	N	3/16/2011	7:45	bailer	21.81	5.50	483
5-B	Lake	Out	Y	3/16/2011	8:15	grab	22.56	5.75	471
8-A	Lake	In	N	3/17/2011	13:30	bailer	24.40	5.72	767
10-Outfall	Lake	Out	N	3/17/2011	13:15	pump	26.42	8.22	23660
BC-Outfall	Conveyance	Out	N	3/17/2011	14:00	grab	22.80	2.45	1885
PW-2	Conveyance		N	3/17/2011	9:00	pump	21.49	4.88	1175
US41	Conveyance		N	3/17/2011	10:30	pump	23.70	5.46	1181

August 31, 2011

Mr. Gregg Strakaluse, PE
The City of Naples
295 Riverside Circle
Naples, Florida 34102

Subject: **Quarterly Monitoring Results**

Dear Mr. Strakaluse:

Included in this letter is a discussion of Quarter 3 (Q3) sampling results as well as the results from the automated stormwater sampling event. The laboratory data as well as the field measurement data is included as an attachment to this letter. Also attached are maps of the revised Q3 sampling locations. The Q3 sampling event was completed on June 23, 2011, and the automated stormwater sampling event was completed on May 16, 2011. As discussed in the Quarter 1 (Q1) submission, the Class II surface water quality standard for copper is 3.7 micrograms per liter (µg/L), while the standard for fecal coliform states that concentrations (CFU/100 mL) shall not exceed a median value of 14 CFU/100 mL with not more than 10% of the samples exceeding 43 CFU/100 mL, nor exceed 800 CFU/100 mL on any one day.

Following Q1 and Q2 data analysis, several sample locations were relocated in an attempt to identify the potential sources of high fecal coliform and copper loadings. Sample locations 11A3, 11B3, 14A3, 14B3, and PW3 are the revised Q3 locations and are indicated on Figures 1 through 4. The following are results of the Q3 monitoring event:

11A/11B – Q2 results from 11A2 and 11B2 indicated copper concentrations of 2.2 µg/L and 16 µg/L and fecal coliform concentrations of 33 and 4,700 CFU/100mL, respectively. Because 11B2 concentrations were significantly higher than 11A2 concentrations, it was decided to relocate Q3 locations upstream of 11B2. Specifically 11A3 was collected from the outfall structure of the underground stormwater facility located at 6^{th} St. S and 4^{th} Ave. S, and 11B3 was collected from the junction of the 11A3 discharge and the main conveyance that runs along 4^{th} Ave. S. The Q3 data indicates that a probable source of high copper and fecal coliform loading is coming from the underground stormwater facility located at 6^{th} St. S and 4^{th} Ave. S. The copper concentration coming from the discharge of this facility (11A3) was 25 µg/L and the fecal coliform concentration was 3,600 CFU/100mL. In addition to high copper and bacterial concentrations, the nutrient loadings coming from this facility are the highest of all sampling locations, with the exception of the total phosphorus concentration measured at 14B2 (Q2). Total nitrogen and total phosphorus concentrations coming from this stormwater facility were 4.5 mg/L and 0.5 mg/L, respectively.

14A/14B – Q3 monitoring locations in the vicinity of the Lantern Lane pump station basin were revised due to high concentrations of copper and fecal coliform that were found in Q1 and Q2 locations. 14A3 (Q3) was moved to a conveyance south of 14A (Q1) on Lantern Lane, while 14B3 (Q3) was moved to a location upstream of the 14B2 (Q2) sampling location on Gordon Dr.

Correspondence:
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Both locations indicated elevated levels of copper and fecal coliform, with copper concentrations particularly high at 14 µg/L and 8.7 µg/L for 14A3 and 14B3, respectively.

PW-3 – The PW-3 sampling location was relocated to a conveyance that receives runoff from several commercial/industrial areas along Goodlette-Frank Road and Central Ave. Q1 and Q2 sampling locations in this area indicated elevated concentrations of copper and/or fecal coliform. The Q3 monitoring location does not discharge to the Public Works Pump Station, however it is in a nearby basin and discharges directly to Naples Bay. Results from sampling location PW-3 (Q3) indicate elevated levels of copper loading, with a copper concentration of 12 µg/L.

Other notable findings of the Q3 monitoring event were high copper concentrations at stormwater ponds 15 and 2 and sampling location US41. Fecal coliform concentrations were generally higher during Q3 than either of the previous monitoring events, with particularly high concentrations measured at 11-Pump (18,700 CFU/100mL), 22A (27,000 CFU/100mL), BC-outfall (12,800 CFU/100mL), and US41 (20,000 CFU/100mL).

If you have questions, please contact me via email, william.tucker@amec.com, or telephone (352) 333-2609.

Sincerely,

AMEC E&I, Inc.

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Quarter 3 Water Quality Data

Parameter	Nitrogen, Kjeldahl	Nitrate Nitrite as N	Nitrogen, Total	Phosphorus, Total	Total Suspended Solids	Copper, Total	Fecal Coliform	Enterococcus
Units	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(MF)	(MPN)
Location								
10-outfall	1.1	0.10 U	1.1	0.043	22	0.82	40	100
11a3	4.30	0.15 I	4.50	0.5	3.6	25	3600	7330
11b3	4.20	0.14 I	4.30	0.47	3.2	22	4200	6110
11c	1.30	0.1 U	1.30	0.052	3.6	4.5	580	2420
11d	1.00	0.38 I	1.40	0.2	6.8	2.7	2520 B	4050
11-Pump	1.50	0.33 I	1.80	0.21	13	2.7	18700 B	510
14a3	1.10	0.1 U	1.10	0.39 J3	17	14	1530 B	4710
14b3	1.40	0.1 U	1.40	0.16	30	8.7	2000	4820
15a	0.91	0.10 I	1.00	0.11	3.6	14	600	1730
15b	0.82	0.10 U	0.82	0.025	4.4	20	755	579
19-out	0.59	0.16 I	0.75	0.12	9.6	3.2	4100	1440
20a	1.90	0.10 U	1.90	0.08	12	0.99	141 B	411
20b	1.70	0.39 I	2.10	0.089	11	1	520	1300
22a	0.54	0.10 U	0.54 I	0.015	3.2	12	27000	300
22b	0.60	0.10 U	0.60 I	0.039	2.4	1.4	1660 B	461
26-out	0.86	0.20 I	1.10	0.11	2.8	0.53	5200	1320
2a	1.30	0.10 U	1.30	0.076	8.4	13	380	961
2b	0.93	0.10 U	0.93	0.052	25	14	190	1990
5a	1.10	0.21 I	1.30	0.16	3.2	5.7	230	43
5b	1.10	0.23 I	1.30	0.14	2.8	6.1	220	56
8a	1.40	0.10 U	1.40	0.071	4.8	3.2	1830 B	148
BC-outfall	3.80	0.10 U J3	3.80	0.15	2.8	4.3	12800 B	98
PW-3	0.60	0.20 I	0.80	0.068	27	12	2300	1480
US41	0.55	0.39 I	0.94	0.15	4	9.6	20000	1600

U- Indicates that the compound was analyzed for but not detected

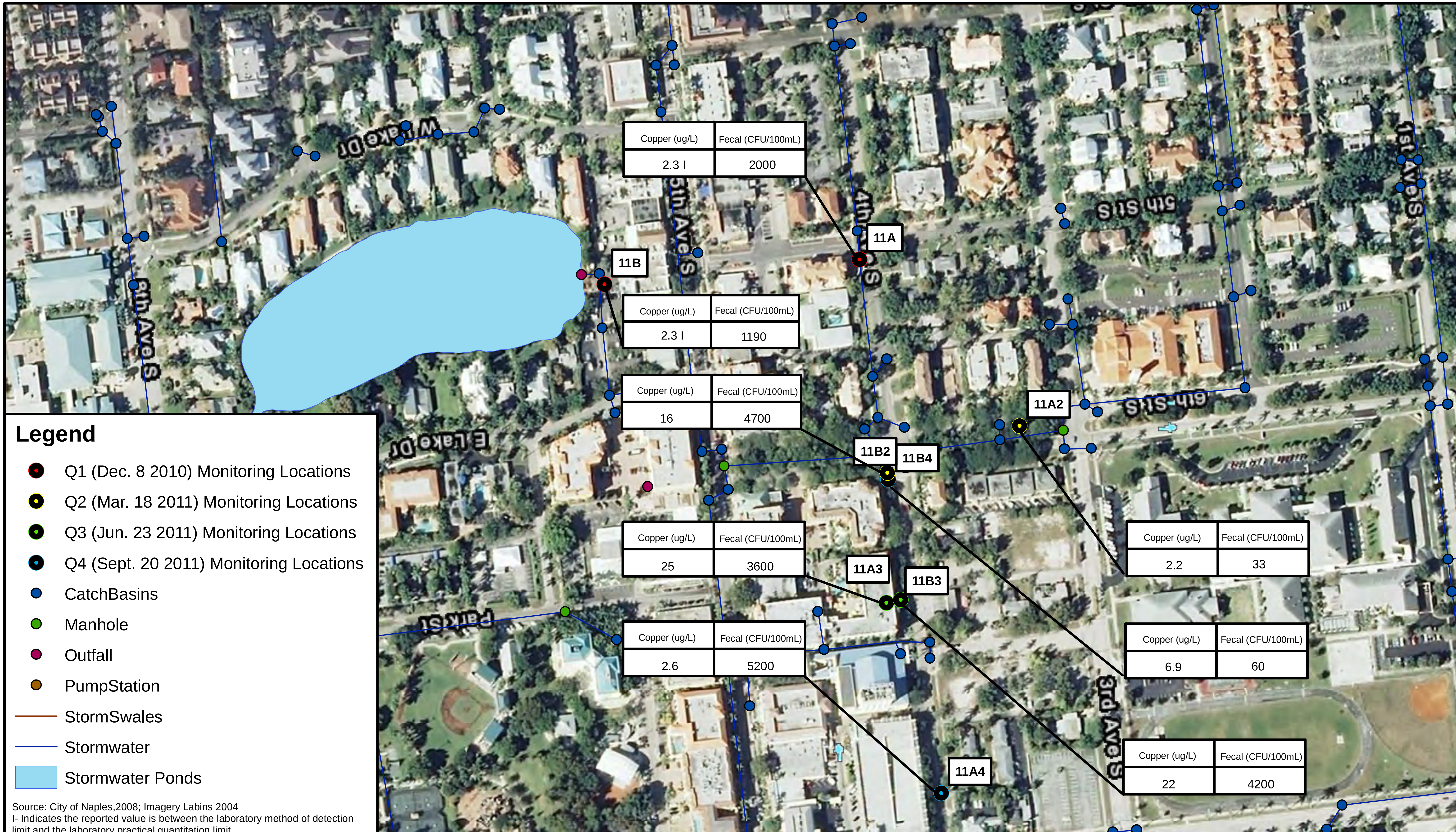
I- Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit

B- Results based upon colony counts outside the acceptable range

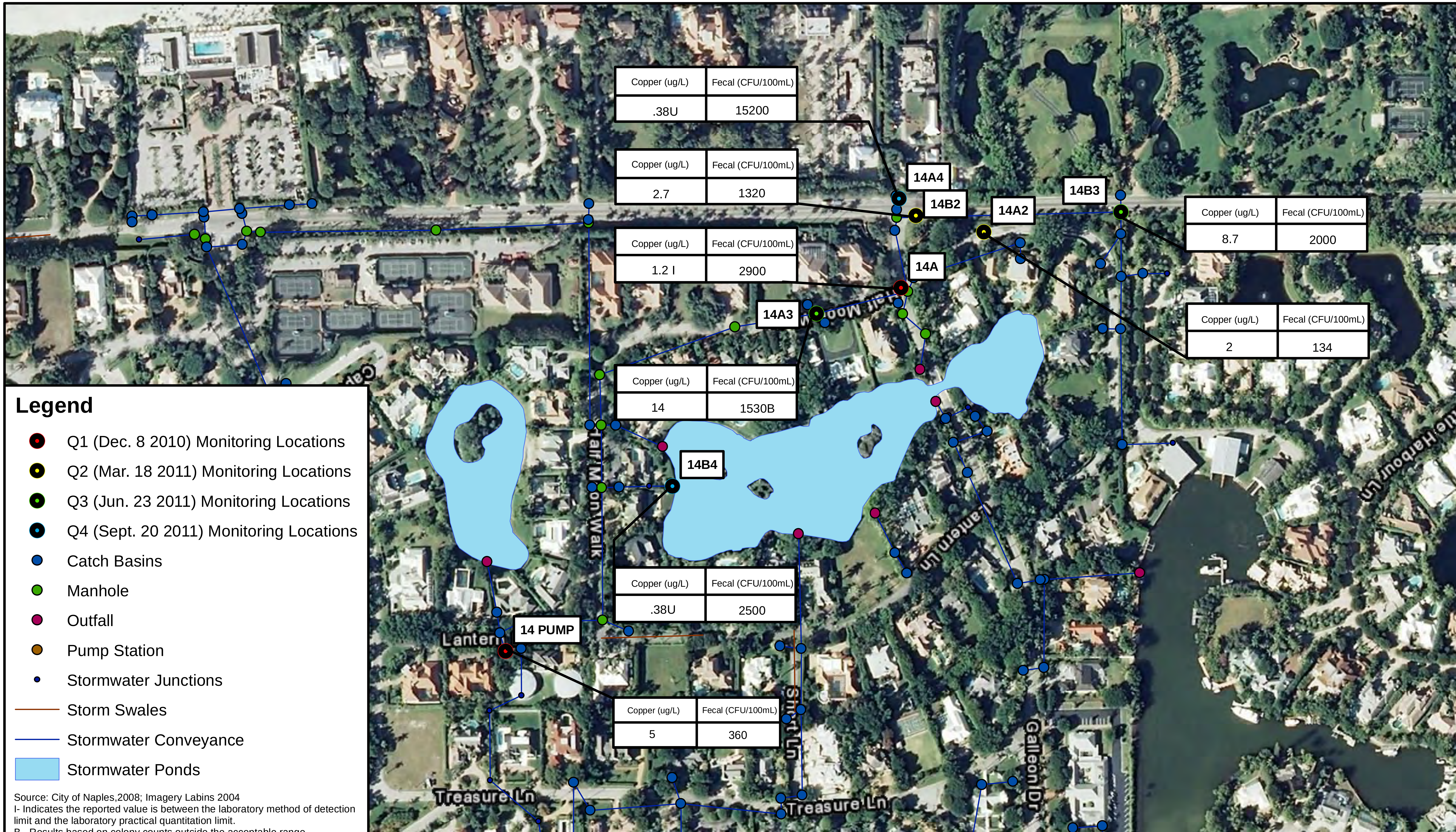
Quarter 3 Ambient Water Quality Parameters

Parameter	Type	In/Out	Flow	Date	Time	Sample Type	Temp	pH	DO	Conductivity
Units			(Y/N)				(°C)	(s.u.)	(mg/l)	(µS/cm)
Location										
10-outfall	Lake	Out	N	6/22/2011	11:30	grab	32.93	8.17	5.4	34518
11a3	Conveyance	In	Y	6/22/2011	9:45	pump	27.51	7.41	2.13	274
11b3	Conveyance	In	Y	6/22/2011	10:20	pump	28.63	7.36	3.16	289
11c	Conveyance	Out	Y	6/22/2011	9:20	bailer	28.54	7.12	1.64	745
11d	Conveyance		Y	6/22/2011	8:30	bailer	27.98	7.63	5.63	1043
11-Pump	Pump		N	6/22/2011	8:50	bailer	27.35	7.36	2.05	2029
14a3	Conveyance	In	Y	6/22/2011	8:00	pump	31.25	7.46	3.43	10030
14b3	Conveyance	In	Y	6/22/2011	8:20	pump	27.94	7.18	1.32	5179
15a	Lake	In	N	6/23/2011	9:30	pump	28.53	7.02	3.93	468
15b	Lake	Out	N	6/23/2011	9:15	grab	30.97	7.69	4.75	528
19-out	Open Ditch	Out	Y	6/23/2011	8:45	pump	28.67	7.01	5.61	370
20a	Lake	In	N	6/23/2011	11:00	bailer	31.50	10.38	9.72	367
20b	Lake	Out	y	6/23/2011	10:45	grab	31.02	8.64	8.60	365
22a	Lake	In	N	6/23/2011	10:00	grab	30.50	7.14	4.44	380
22b	Lake	Out	N	6/23/2011	10:15	grab	30.91	7.19	3.54	605
26-out	Conveyance	Out	Y	6/22/2011	11:00	bailer	27.55	7.33	5.18	1058
2a	Lake	In	N	6/22/2011	14:15	bailer	34.49	9.11	9.40	360
2b	Lake	Out	Y	6/22/2011	13:30	bailer	32.04	8.55	6.55	43213
5a	Lake	In	Y	6/22/2011	13:00	bailer	33.17	7.30	4.25	423
5b	Lake	Out	Y	6/22/2011	13:20	grab	32.08	7.47	5.12	413
8a	Lake	In	N	6/22/2011	12:30	bailer	32.27	8.33	7.02	793
BC-outfall	Conveyance	Out	N	6/22/2011	12:00	grab	29.87	6.72	0.64	2315
PW-1	Conveyance		N	6/23/2011	12:10	pump	31.56	7.07	1.01	49097
US41	Conveyance			6/23/2011	8:10	pump	28.25	7.12	4.25	538

Source Tracking Sample Locations



N 0 155 310 Feet	Quarterly Stormwater Monitoring City of Naples, Florida	amec	Quarters 1 - 4 Data Results Project 6063-10-0182.01 Figure A-1	Created/Date:DA 11/04/2011 Checked/Date: SCA 11/04/2011



N
0 200 400 Feet

Quarterly Stormwater Monitoring
City of Naples, Florida

amec

Quarters 1 - 4 Data Results
Project 6063-10-0182.01
Figure A-2

Created/Date: DA 11/03/2011
Checked/Date: SCA 11/04/2011

N
0 205 410 Feet

Quarterly Stormwater Monitoring
City of Naples, Florida

amec

Quarters 1 - 4 Data Results
Project 6063-10-0182.01
Figure A-3

Created/Date: DA 11/04/2011

Checked/Date: SCA 11/04/2011

Appendix B
Water Quality Analysis Results

Table B-1

Location				Nitrogen, Kjeldahl				Nitrate Nitrite as N				Nitrogen, Total				Phosphorus, Total		
Units				(mg/L)				(mg/L)				(mg/L)				(mg/L)		
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
10-Outfall	10-outfall	10-outfall	10-outfall	0.97	0.70	1.10	0.97	0.5U	0.10 U	0.10 U	.1U	0.97	0.70	1.10	0.97	0.04	0.056	0.043
11-A	11a2	11a3	11a4	1.10	0.66	4.30	1.00	.11I	0.24 I	0.15 I	.1U	1.20	0.90	4.50	1.00	0.23	0.084	0.5
11-B	11b2	11b3	11b4	0.99	7.90	4.20	0.42	.12I	0.12 I	0.14 I	.23I	1.10	8.00	4.30	.65I	0.15	0.94	0.47
11-C	11c	11c	11c	0.71	1.30	1.30	0.97	.24I	0.10 U	0.1 U	.1U	0.95	1.30	1.30	0.97	0.05	0.016	0.052
11-D	11d	11d	11d	1.20	0.96	1.00	0.99	0.50	0.64	0.38 I	.22I	1.70	1.60	1.40	1.20	0.12	0.15	0.2
11-Pump	11-Pump	11-Pump	11-Pump	1.00	1.30	1.50	1.00	0.53	0.44 I	0.33 I	.27I	1.50	1.70	1.80	1.30	0.13	0.11	0.21
14-A	14a2	14a3	14a4	2.20	3.10	1.10	1.60	0.94	0.10 U	0.1 U	.1U	3.10	3.10	1.10	1.60	0.71	0.62	0.39 J3
14-Pump	14b2	14b3	14b4	0.87	2.40	1.40	1.80	.68J3	0.15 I	0.1 U	.1U	1.60	2.60	1.40	1.80	0.48	0.98	0.16
15-A	15a	15a	15a	1.20	1.40	0.91	1.20	0.41I	0.10 U	0.10 I	.1U	1.60	1.40	1.00	1.20	0.06	0.087	0.11
15-B	15b	15b	15b	0.90	0.94	0.82	0.99	0.50U	0.10 U	0.10 U	.1U	0.90	0.94	0.82	0.99	0.03	0.028	0.025
19-Out	19-out	19-out	19-out	0.65	0.59	0.59	1.10	.27I	0.24 I	0.16 I	.26I	0.92	0.83	0.75	1.40	0.03	0.041	0.12
20-A	20a	20a	20a	1.80	1.40	1.70	0.84	.5U	0.10 U	0.39 I	.1U	1.80	1.40	2.10	0.84	0.10	0.22	0.089
20-B	20b	20b	20b	1.50	1.40	1.90	1.60	.5U	0.10 U	0.10 U	.1U	1.50	1.40	1.90	1.60	0.09	0.11	0.08
22-A	22a	22a	22a	0.74	1.80	0.54	0.95	.5U	0.10 U	0.10 U	.17I	0.74	1.80	0.54 I	1.10	0.09	0.13	0.015
22-B	22b	22b	22b	0.63	0.70	0.60	0.66	.5U	0.10 U	0.10 U	.1U	0.63	0.70	0.60 I	.66I	0.06	0.056	0.039
26-Out	26-out	26-out	26-out	0.91	0.77	0.86	0.72	.27I	0.32 I	0.20 I	.38I J3	1.20	1.10	1.10	1.10	0.09	0.6	0.11
2-A	2a	2a	2a	1.00	0.88	1.30	1.80	.5U	0.10 U	0.10 U	.1U	1.00	0.88	1.30	1.80	0.11	0.16	0.076
2-B	2b	2b	2b	0.48	0.26	0.93	1.70	.5U	0.10 U	0.10 U	.1U	0.48	0.26 I	0.93	1.70	0.03	0.054	0.052
5-A	5a	5a	5a	0.85	0.69	1.10	0.95	.22I	0.18 I	0.21 I	.30I	1.10	0.87	1.30	1.30	0.12	0.14	0.16
5-B	5b	5b	5b	1.00	0.73	1.10	0.80	.21I	0.19 I	0.23 I	.28I	1.20	0.92	1.30	1.10	0.13	0.13	0.14
8-A	8a	8a	8a	1.20	1.20	1.40	1.40	.5U	0.10 U	0.10 U	.1U	1.20	1.20	1.40	1.40	0.24	0.24	0.071
BC-Outfall	BC-outfall	BC-outfall	BC-outfall	2.70	3.00	3.80	2.70	.5U	0.10 U	0.10 U J3	.1U	2.70	3.00	3.80	2.70	0.26	0.31	0.15
PW-Pump	PW-1	PW-3	PW-4	1.30	1.60	0.60	0.67	.34I	0.43 I	0.20 I	.12I J3	1.60	2.00	0.80	0.79	0.22	0.058	0.068
US41	US41	US41	US41	1.10	0.72	0.55	1.00	2.50	0.32 I	0.39 I	.24I	3.60	1.00	0.94	1.20	0.92	0.16	0.15

U- Indicates that the compound was analyzed for but not detected

I- Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit

B- Results based upon colony counts outside the acceptable range

Table B-1 (continued)

Location				Nitrogen, Kjeldahl				Nitrate Nitrite as N				Nitrogen, Total				Phosphorus, Total		
Units				(mg/L)				(mg/L)				(mg/L)				(mg/L)		
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
10-Outfall	10-outfall	10-outfall	10-outfall	0.97	0.70	1.10	0.97	0.5U	0.10 U	0.10 U	.1U	0.97	0.70	1.10	0.97	0.04	0.056	0.043
11-A	11a2	11a3	11a4	1.10	0.66	4.30	1.00	.11I	0.24 I	0.15 I	.1U	1.20	0.90	4.50	1.00	0.23	0.084	0.5
11-B	11b2	11b3	11b4	0.99	7.90	4.20	0.42	.12I	0.12 I	0.14 I	.23I	1.10	8.00	4.30	.65I	0.15	0.94	0.47
11-C	11c	11c	11c	0.71	1.30	1.30	0.97	.24I	0.10 U	0.1 U	.1U	0.95	1.30	1.30	0.97	0.05	0.016	0.052
11-D	11d	11d	11d	1.20	0.96	1.00	0.99	0.50	0.64	0.38 I	.22I	1.70	1.60	1.40	1.20	0.12	0.15	0.2
11-Pump	11-Pump	11-Pump	11-Pump	1.00	1.30	1.50	1.00	0.53	0.44 I	0.33 I	.27I	1.50	1.70	1.80	1.30	0.13	0.11	0.21
14-A	14a2	14a3	14a4	2.20	3.10	1.10	1.60	0.94	0.10 U	0.1 U	.1U	3.10	3.10	1.10	1.60	0.71	0.62	0.39 J3
14-Pump	14b2	14b3	14b4	0.87	2.40	1.40	1.80	.68J3	0.15 I	0.1 U	.1U	1.60	2.60	1.40	1.80	0.48	0.98	0.16
15-A	15a	15a	15a	1.20	1.40	0.91	1.20	0.41I	0.10 U	0.10 I	.1U	1.60	1.40	1.00	1.20	0.06	0.087	0.11
15-B	15b	15b	15b	0.90	0.94	0.82	0.99	0.50U	0.10 U	0.10 U	.1U	0.90	0.94	0.82	0.99	0.03	0.028	0.025
19-Out	19-out	19-out	19-out	0.65	0.59	0.59	1.10	.27I	0.24 I	0.16 I	.26I	0.92	0.83	0.75	1.40	0.03	0.041	0.12
20-A	20a	20a	20a	1.80	1.40	1.70	0.84	.5U	0.10 U	0.39 I	.1U	1.80	1.40	2.10	0.84	0.10	0.22	0.089
20-B	20b	20b	20b	1.50	1.40	1.90	1.60	.5U	0.10 U	0.10 U	.1U	1.50	1.40	1.90	1.60	0.09	0.11	0.08
22-A	22a	22a	22a	0.74	1.80	0.54	0.95	.5U	0.10 U	0.10 U	.17I	0.74	1.80	0.54 I	1.10	0.09	0.13	0.015
22-B	22b	22b	22b	0.63	0.70	0.60	0.66	.5U	0.10 U	0.10 U	.1U	0.63	0.70	0.60 I	.66I	0.06	0.056	0.039
26-Out	26-out	26-out	26-out	0.91	0.77	0.86	0.72	.27I	0.32 I	0.20 I	.38I J3	1.20	1.10	1.10	1.10	0.09	0.6	0.11
2-A	2a	2a	2a	1.00	0.88	1.30	1.80	.5U	0.10 U	0.10 U	.1U	1.00	0.88	1.30	1.80	0.11	0.16	0.076
2-B	2b	2b	2b	0.48	0.26	0.93	1.70	.5U	0.10 U	0.10 U	.1U	0.48	0.26 I	0.93	1.70	0.03	0.054	0.052
5-A	5a	5a	5a	0.85	0.69	1.10	0.95	.22I	0.18 I	0.21 I	.30I	1.10	0.87	1.30	1.30	0.12	0.14	0.16
5-B	5b	5b	5b	1.00	0.73	1.10	0.80	.21I	0.19 I	0.23 I	.28I	1.20	0.92	1.30	1.10	0.13	0.13	0.14
8-A	8a	8a	8a	1.20	1.20	1.40	1.40	.5U	0.10 U	0.10 U	.1U	1.20	1.20	1.40	1.40	0.24	0.24	0.071
BC-Outfall	BC-outfall	BC-outfall	BC-outfall	2.70	3.00	3.80	2.70	.5U	0.10 U	0.10 U J3	.1U	2.70	3.00	3.80	2.70	0.26	0.31	0.15
PW-Pump	PW-1	PW-3	PW-4	1.30	1.60	0.60	0.67	.34I	0.43 I	0.20 I	.12I J3	1.60	2.00	0.80	0.79	0.22	0.058	0.068
US41	US41	US41	US41	1.10	0.72	0.55	1.00	2.50	0.32 I	0.39 I	.24I	3.60	1.00	0.94	1.20	0.92	0.16	0.15

U- Indicates that the compound was analyzed for but not detected

I- Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit

B- Results based upon colony counts outside the acceptable range

ISCO Sampling Results

Parameter	Nitrogen, Kjeldahl	Nitrate Nitrite as N	Nitrogen, Total	Phosphorus, Total	Total Suspended Solids	Copper, Total	Fecal Coliform	Enterococcus
Units	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(MF)	(MPN)
Location								
C3 Spring Lake	1.2	.19I	1.4	0.078	5.6	11	10600B	199000
C2 Lantern Lane	0.90	.19I	1.10	0.4	27	12	18800B	101000
C4 Public Works	1.20	.39I	1.60	0.25	80	32	16800B	173000

I- Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit

B- Results based upon colony counts outside the acceptable range

Appendix C
RCN Table

Appendix C – NRCS (SCS) Curve Number Lookup Table

Description	FLUCCS	A	B	C	D	B/D	W
Residential Low Density	1100	50	68	79	84	81.5	100
Residential Medium Density	1200	57	72	81	86	83.5	100
Residential High Density	1300	77	85	90	92	91	100
Commercial General	1400	89	92	94	95	94.5	100
Commercial Limited	1450	85	90	93	94	93	100
Industrial	1500	81	88	91	93	92	100
Institutional Public, Semi-Public	1700	69	81	87	90	88.5	100
Recreation Public, Semi-Public, Private	1800	49	69	79	84	81.5	100
Vacant	1900	39	61	74	80	77	100
Water	5100	100	100	100	100	100	100
Commercial Highway	8100	81	88	91	93	92	100

Appendix D
Runoff Coefficients for Swale Pollutant Removal Calculations

NDCIA CN	Percent DCIA																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.002	0.043	0.083	0.123	0.164	0.204	0.244	0.285	0.325	0.366	0.406	0.446	0.487	0.527	0.567	0.608	0.648	0.688	0.729	0.769	0.809
35	0.004	0.044	0.085	0.125	0.165	0.205	0.246	0.286	0.326	0.366	0.407	0.447	0.487	0.528	0.568	0.608	0.648	0.689	0.729	0.769	0.809
40	0.007	0.047	0.087	0.127	0.167	0.207	0.248	0.288	0.328	0.368	0.408	0.448	0.488	0.528	0.569	0.609	0.649	0.689	0.729	0.769	0.809
45	0.01	0.05	0.09	0.13	0.17	0.21	0.25	0.29	0.33	0.37	0.41	0.45	0.49	0.53	0.57	0.61	0.65	0.69	0.729	0.769	0.809
50	0.015	0.055	0.095	0.134	0.174	0.214	0.254	0.293	0.333	0.373	0.412	0.452	0.492	0.531	0.571	0.611	0.651	0.69	0.73	0.77	0.809
55	0.022	0.061	0.101	0.14	0.179	0.219	0.258	0.298	0.337	0.376	0.416	0.455	0.494	0.534	0.573	0.613	0.652	0.691	0.731	0.77	0.809
60	0.03	0.069	0.108	0.147	0.186	0.225	0.264	0.303	0.342	0.381	0.42	0.459	0.498	0.537	0.576	0.615	0.654	0.693	0.731	0.77	0.809
65	0.042	0.08	0.119	0.157	0.195	0.234	0.272	0.311	0.349	0.387	0.426	0.464	0.502	0.541	0.579	0.618	0.656	0.694	0.733	0.771	0.809
70	0.057	0.095	0.133	0.17	0.208	0.245	0.283	0.321	0.358	0.396	0.433	0.471	0.509	0.546	0.584	0.621	0.659	0.697	0.734	0.772	0.809
75	0.079	0.116	0.152	0.189	0.225	0.262	0.298	0.335	0.371	0.408	0.444	0.481	0.517	0.554	0.59	0.627	0.663	0.7	0.736	0.773	0.809
80	0.111	0.146	0.181	0.216	0.251	0.285	0.32	0.355	0.39	0.425	0.46	0.495	0.53	0.565	0.6	0.635	0.67	0.705	0.74	0.774	0.809
85	0.16	0.192	0.225	0.257	0.29	0.322	0.355	0.387	0.42	0.452	0.485	0.517	0.55	0.582	0.614	0.647	0.679	0.712	0.744	0.777	0.809
90	0.242	0.27	0.299	0.327	0.355	0.384	0.412	0.44	0.469	0.497	0.526	0.554	0.582	0.611	0.639	0.664	0.696	0.724	0.753	0.781	0.809
95	0.404	0.424	0.444	0.464	0.485	0.505	0.525	0.546	0.566	0.586	0.606	0.627	0.647	0.667	0.688	0.708	0.728	0.749	0.769	0.789	0.809
98	0.595	0.605	0.616	0.627	0.638	0.648	0.659	0.67	0.68	0.691	0.702	0.713	0.723	0.734	0.745	0.756	0.766	0.777	0.788	0.799	0.809