Conservancy Filter Marsh Project
FDEP Agreement No: G0253

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

Figure | Page

LIST OF APPENDICES

Appendix | Page

EXECUTIVE SUMMARY

The primary objective of the Conservancy's Filter Marsh Project was to reduce pollutant loading entering the Naples Bay Watershed from a tributary of the Gordon River, as this urbanized watershed is currently on the impaired waters list for the State of Florida for several water quality parameters. The project included modifications to an existing ditch and the construction of a wet detention pond and filter marsh. Targeted criteria included: 1) Improve water quality by reducing annual stormwater runoff volume and pollutant load discharges; 2) Increase wetland species diversity and biological productivity through the creation of wetland vegetative cover and removal of exotics, which should increase native species use and improve the ecological value of the site; and 3) Increase public awareness of water quality problems associated with stormwater runoff and illustrate the benefits and aesthetic qualities of Filter Marshes to Conservancy visitors through several public outreach initiatives.

Stormwater flow was intercepted in an existing drainage ditch, which was modified to slow flow velocity through topographic alterations and diverted into a wet detention pond, which drains through a filter marsh, via a system of check dams, prior to discharging back into the ditch and subsequently into a tributary of the Gordon River during outgoing tides. From a construction standpoint the installation of the wet detention pond and filter marsh achieved its goal of slowing the fresh water flow and increasing the water retention time that should allow for increasing pollutant removal.

Data indicated that the Ditch West End entrance, where the stormwater flows into the project area was the most susceptible to increased nitrification as this station was significantly higher overall in nitrogen derivatives and total nitrogen levels were significantly higher in comparison to the stormwater outflow. Total phosphorus concentrations mirrored the results found concerning increased nitrification, in that the stormwater inflow had higher levels overall, but not significantly different amongst the other stations. Interestingly, orthophosphorus levels did not appear to contribute to the higher total phosphorus concentrations at the Ditch West End entrance, since levels were similar throughout the project area. Since nitrogen and phosphorus concentrations were higher at the Ditch West End entrance where the bulk of freshwater runoff enters the system, this suggests that nutrient loading was the highest at this station, indicative that installation of BMP's used in this project reduced nutrient loading by the time freshwater runoff exited the project area.

Percent Nutrient Reduction

Nutrients	Ditch West End (entrance) to Wet Detention	Ditch West End (entrance) to Filter Marsh	Ditch West End (entrance) to Ditch East end (outflow)
Total Nitrogen	-10	-14	-16
Total Phosphorous	-8	-12	-16

Water quality results hinted at the possibility of a distinct separation between geographic locations. In general, the closer the station was to the stormwater inflow the higher the nutrient concentrations and the lower the physical parameters. In most instances there was a noticeable division in parameters along an east to west increasing gradient. This is indicative that the more western parts of project area exhibited less tidal frequency and/ or amplification and therefore lower circulation and less flushing, along with more nutrient laden stormwater than the eastern sections of the project area.

This project has successfully created areas that not only reduce stormwater pollutants but have increased the ecological value to the area. The fish community gradually shifted post-construction from a system dominated by non-native introduced fishes to one with a greater abundance of native fishes. In addition, data indicated that the construction of the wetland marsh created suitable habitat for many species by creating nursery and refuge areas for juvenile gamefish species such as common snook (*Centropomis undecimalis*). Additionally a shift occurred in wading bird species composition favoring species requiring wetland habitat for foraging. Thus, the utilization of the project area by wading birds post-construction has indicated that the wetland creation was a success. Unfortunately, the construction of the County owned Gordon River Greenway removed an expansive piece of forested area that was adjacent to the project area. Adult anurans were taking refuge in the forest adjacent to the project area property pre-construction. When this forest disappeared, the Conservancy's constructed wetland could not compensate for the lack of a nearby habitat that had provided necessary refuge for anurans and thus their population level decreased overall.

As this project is small in scale its removal capabilities are logically less than other larger scale projects. However, given its size it has achieved significant reduction in nutrients. Perhaps just as important is that this project has accentuated the fact that created wetlands provide important ecological value through the creation of refugia for wildlife species in developed areas. Additionally, the educational opportunities this project affords to children and adults has proven a valuable teaching tool to inform the public about stormwater, wildlife and ways to incorporate small-scale cleanup efforts in your own backyard.

INTRODUCTION

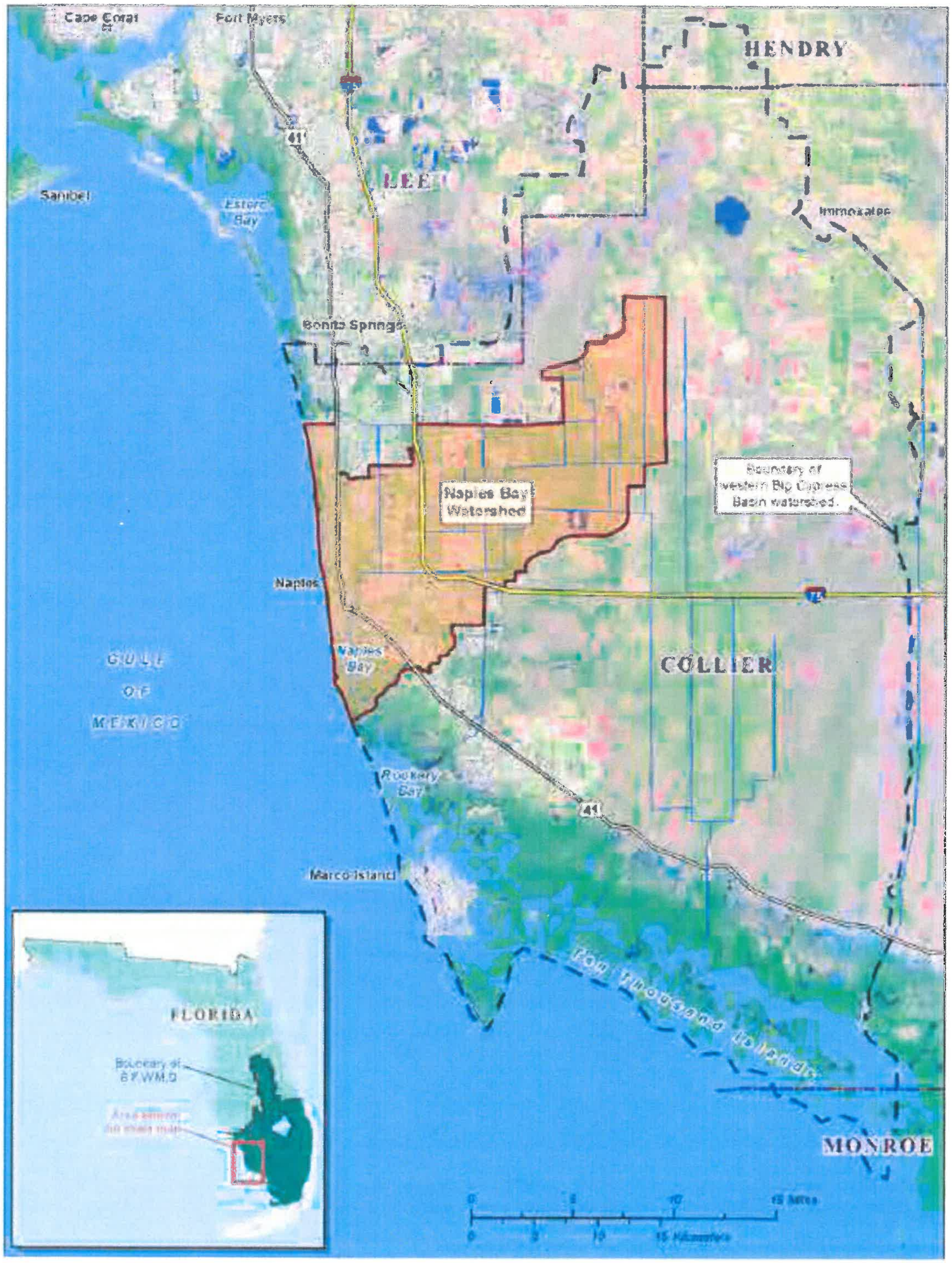
This project originated as the result of a need to reduce the pollutant levels entering Naples Bay from within the Naples Bay Watershed and improve conditions to support and restore native aquatic habitats and the wildlife that utilizes these ecosystems.

Decline of the Naples Bay Watershed

Water management districts delineate boundaries to identify and classify watersheds, basins and subbasins for purposes of management and understanding drainage areas. In reality areas such as the Gordon River South subbasin, Naples Bay Watershed, and Big Cypress Basin Watershed are intertwined, and alterations to one basin within a watershed can impact another basin within or even outside of delineated boundaries. Alterations to historic drainage patterns can negatively impact both the water quality and the aquatic ecology of these entities. The Western Big Cypress Basin Watershed encompasses all of western Collier County, and small sections of southern Lee and Hendry Counties in Southwest Florida (Figure 1). The Naples Bay Watershed encompasses 120 mi^2 and is bounded by the Gulf of Mexico to the west, to the north by Immokalee Road, to the east along Everglades Boulevard, to the southeast crossing near the I-75-CR 951 junction, and to the south by the Gulf of Mexico (Naples Bay SWIM Plan, 2007). The major hydrologic feature in the Naples Bay Watershed is Naples Bay, formed by the confluence of the Gordon River and other small tributaries that empty into the Gulf of Mexico through Gordon Pass.

Historically, the Naples Bay Watershed was characterized by surface water sheetflow that originated from the Immokalee highlands, naturally drained as surface water sheetflow through a series of strands and sloughs into tidal passes of the Gulf of Mexico or into the Ten Thousand Islands, consistent with the watershed's flat topography. The last 50 years have resulted in drastic changes to the historic water flow patterns, resulting in landscape alterations. The once vast historic vegetation communities (primarily mesic or hydric flatwoods, cypress, dry and wet prairies, marshes and other swamp forests) have been developed into primarily residential, agricultural and commercial properties. This action has eliminated natural sheetflow runoff filtering mechanisms and vastly increasing impervious surfaces.

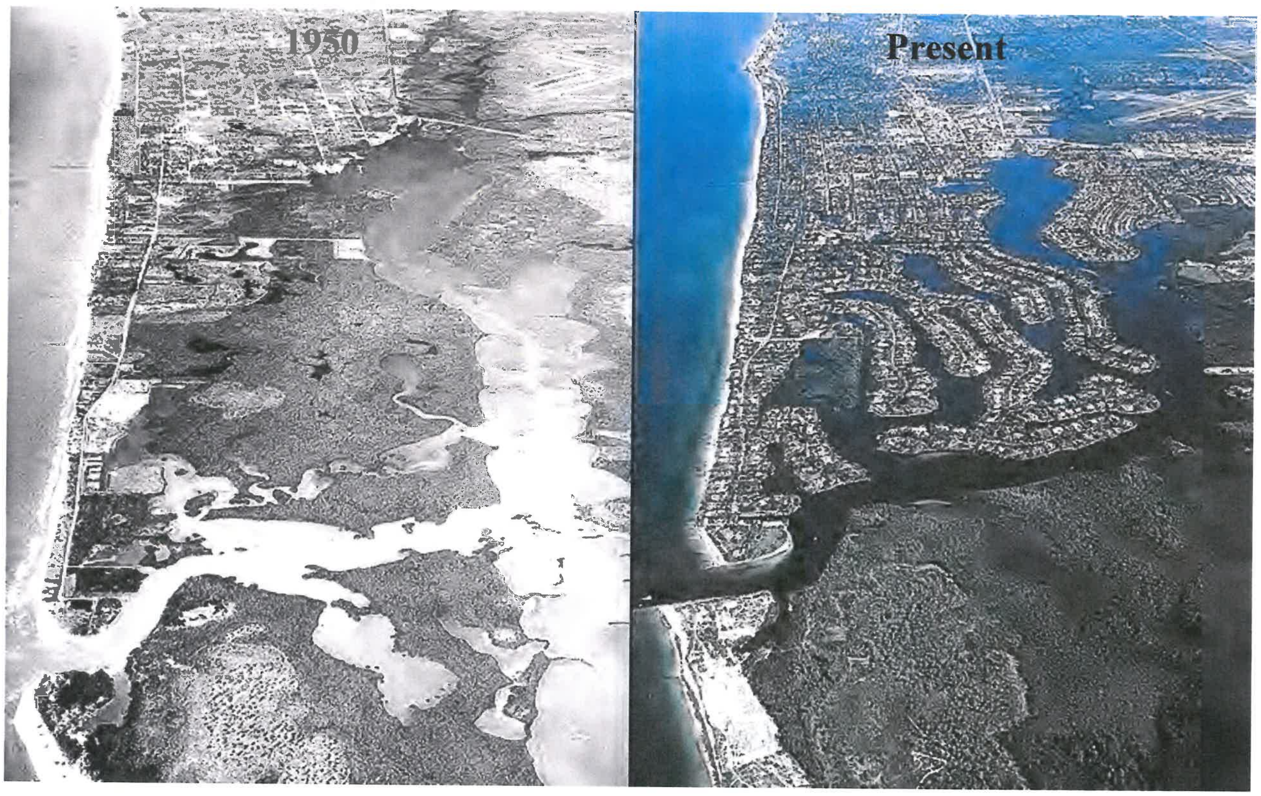
Figure 1: Western Big Cypress Basin Watershed



Source: Naples Bay Swim Plan, 2007

The first recorded human disturbance in Naples Bay was a canal that was excavated by the indigenous people inhabiting these waters over 2,000 years ago (Tebeau, 1966). The first documented settlers in the Naples arrived in the 1860's and, relatively soon thereafter, the area was being promoted as a winter resort. The construction of the pier in the late 1880's and the completion of the Tamiami Trail (i.e., U.S. Highway 41) in 1926 set in motion the urban development that now surrounds Naples Bay (Stone, 1987). The once extensive mangrove shoreline and abundant seagrass and oyster habitats within the bay have been destroyed, starting with the first dredging of the Bay in 1930 and culminating with the extensive dredge-and-fill developments that occurred during the 1950's and 1960's (Figure 2). Nonetheless, Naples Bay still functions as an estuary, albeit heavily influenced by anthropomorphic activities, and those areas that can potentially be restored need to be identified and protected to prevent any further degradation of the system.

Figure 2: Naples Bay Past and Present



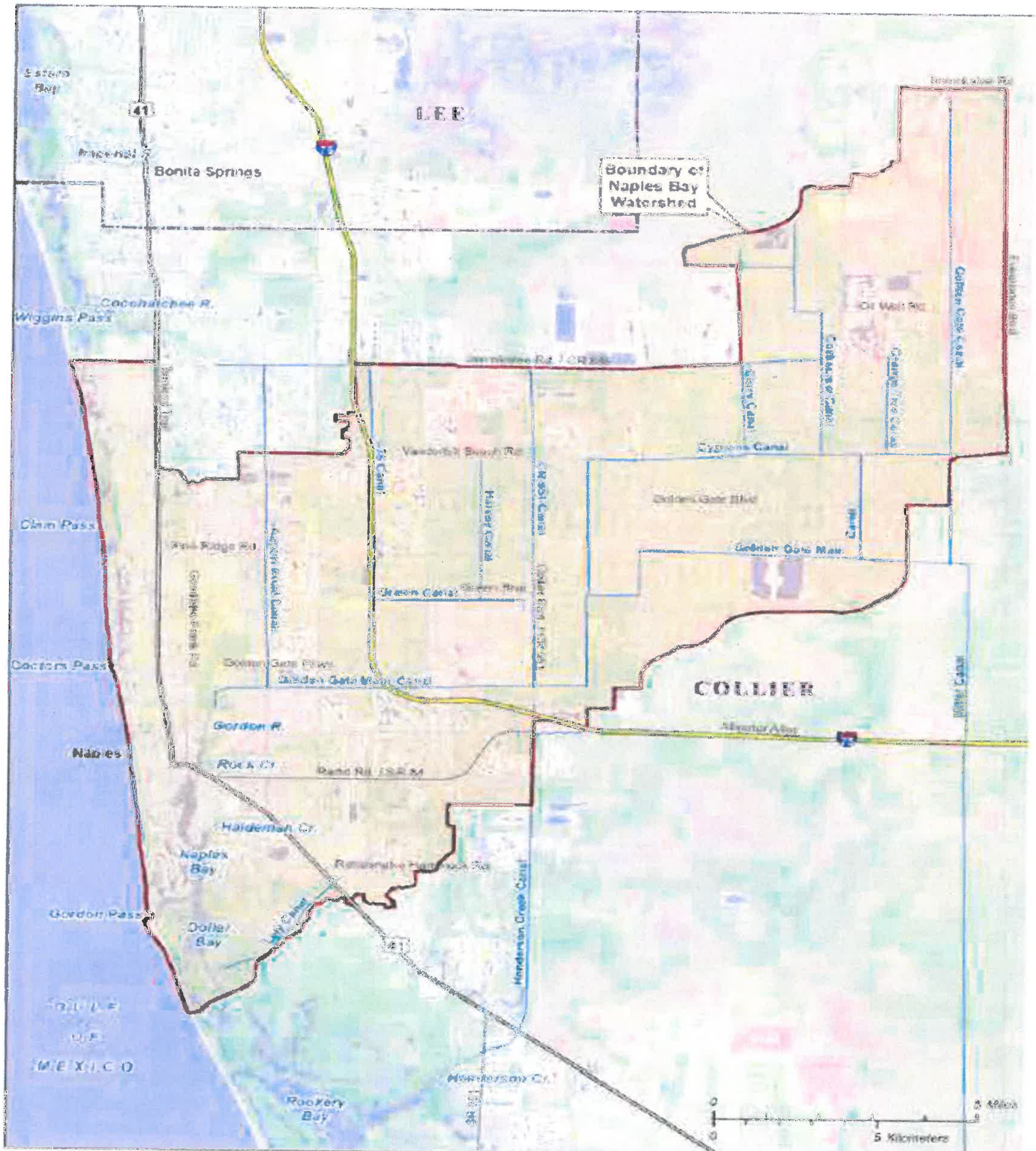
Prior to 1940, the Naples Bay watershed covered approximately ten square miles and consisted primarily of one hydrologic feature (Naples Bay) and its associated tributaries (the Gordon River, Rock and Haldeman Creeks). During this time, Naples Bay was a shallow mangrove fringed estuary that supported oyster and seagrass beds and numerous species estuarine fauna. Extensive dredge and fill operations and urban development in the 1950's and 1960's significantly changed the character and function of this watershed (Figure 3). Seventy-two percent of the mangroves, along with ninety-one percent of the seagrasses and eighty-two percent of oyster beds were lost (Schmid, et. al., 2006). The natural tributaries or the Gordon River and Haldeman and Rock Creeks were also altered by urban development and associated infrastructure resulting in a significant change in the historic flowways into Naples Bay and its biology (Naples Bay SWIM Plan, 2007).

Figure 3: Excerpts from U.S. Coast and Geodetic Survey nautical chart #1254 (Chatham River to Clam Pass) showing the Naples Bay area in (a) 1931, (b) 1957, and (c) 1968.

(a) (b) (c)

In the 1960's the construction of the Golden Gate canal system, along with other stormwater drainage conveyances, were installed to drain wetlands for urbanization and to collect stormwater runoff (flood control), which continues to this day to be discharged into the Bay or its tributaries. As a result of collection and discharge of surface waters from these canal systems, the Naples Bay Watershed suffered a ten fold increase in size and now covers an area of approximately 120 mi^2 (Schmid, et. al, 2006). The Golden Gate Canal system drains in a north-south or east-west direction (Figure 4) and consists of eleven major canals within the Naples Bay Watershed. These canals deliver an enormous amount of freshwater into Naples Bay via the Gordon River. Additional canals within the City of Naples and unincorporated urban sections of Collier County also contribute significant volumes of stormwater directly into Naples Bay. As a result of these anthropogenic watershed alterations the historic volume, quality, timing and mixing characteristics of freshwater flows reaching Naples Bay have been drastically altered resulting in reduced water clarity, increased concentrations of contaminants and nutrients, increases in freshwater and reduced dissolved oxygen levels.

Figure 4: Golden Gate Canal System



Source: Naples Bay Swim Plan, 2007

Seasonal influxes of freshwater from the Golden Gate Canal system altered the natural salinity regime of Naples Bay (Naples Bay SWIM Plan, 2007). In an estuary, freshwater inflow is necessary to regulate salinity levels (Stickney, 1984). Most estuaries are plagued by reductions in freshwater inflow. However, Naples Bay suffers from seasonal patterns of excessive freshwater inflow. In addition to upriver inflows, residential and commercial interests that now reside adjacent to Naples Bay and its tributaries have contributed to the increase in freshwater as impervious surfaces shunt runoff rapidly via stormwater drainage systems directly into the waterways. This increase in freshwater drastically changed the mixing and circulation patterns which has negatively impacted the survival and health of estuarine dependant species (Schmid, et. al., 2006). Yokel

(1979) determined that the excessive freshwater discharge has resulted in severe declines in the benthic communities, including seagrasses and oyster populations. The combination of losses of both benthic and terrestrial vegetation (seagrasses and mangroves in particular) has ricocheted through the higher trophic level organisms resulting in their decline (i.e. fisheries).

Overview of the Strategy to Improve the Naples Bay Watershed

Strategies to restore the Naples Bay Watershed have been suggested as far back as 1970, when the Conservancy of Southwest Florida (previously called The Conservancy Inc.) published the Naples Bay Study (Yokel, 1979), which recommended that seasonal influxes of freshwater runoff be reduced to mimic historic salinity regimes to improve the vitality of the aquatic ecosystem. In 2001, the South Florida Water Management District (SFWMD) ranked Naples Bay as a Tier 2 waterbody on the SFWMD priority list. In October 2002, Florida Department of Environmental Protection (FDEP) identified six waterbody identifications (WBIDs) occurring on either the FDEP's Planning or Verified Impaired Waters List in the Naples Bay Watershed (Table 1). In response, in 2003, the SFWMD Governing Board authorized the development of a Surface Water Improvement and Management (SWIM) plan for Naples Bay. A reconnaissance report was finalized in 2006. This report identified sources of existing data, data gaps, and related programs within the Naples Bay Watershed Area and served as a precursor to the Naples Bay SWIM Plan that was finalized in January of 2007.

The Naples Bay SWIM Plan identified four major goals based upon the Water Resource Implementation Rule (Ch 62-40, F.A.C.) regarding implementation of protective measures to enhance or preserve surface water resources[1]. These goals included: 1) Protect and improve watershed surface water quality; 2) Preserve and restore native ecosystems along with their water resource related functions; 3) Maintain the integrity and functions of water resources and related natural systems; and 4) Improve degraded water resources and related natural systems to their natural functionality (as possible). The SWIM plan details forty-one projects (Table 2) to improve the functionality of this system. Most of these projects address the need to control volume, timing and flow of stormwater into the Naples Bay watershed using a variety of stormwater improvements. This project was specifically listed by name in the Naples Bay Swim Plan as The Lakes to Bay Goodlette Frank Conservancy Filter Marsh System hereafter referred to as the "Conservancy Filter Marsh Project". To accomplish these projects, a partnership was formed consisting of 8 Federal, 7 State, 3 regional, 3 municipal, 1 unincorporated community and 10 stakeholders (including the Conservancy of Southwest Florida). The overall goal of this combined effort was to return the Bay to "swimmable" and "fishable" status (Table 3).

[1] Specifically pursuant to sections 62-40.425 *F.A.C.* Specific Authority 373.026(7), 373.036(1)(d), 373.043, 373.171 FS. Law Implemented 373.023, 373.026, 373.036(1)(d), 373.171, 373.1961, 373.223, 373.418, 373.451, 373.453, 403.064, 403.067, 403.0891 FS. History–New 5-7-05.

Conservancy's Filter Marsh Pollution Reduction Strategy

The Conservancy of Southwest Florida, The City of Naples, and Collier County took a holistic approach to reducing the stormwater runoff entering the southern sections of the Naples Bay Watershed. The strategy to improve the conditions within this watershed were based on the combined effects of different projects that focus on enhancing habitat and reducing freshwater inputs from the Golden Gate Canal system to achieve the goal of cleaning up the Watershed, restoring the ecosystem and removing this Watershed from the 303(d) list. Together these initiatives should ideally improve the quality of the stormwater that enters the Watershed by reducing pollutant loads and the volume of freshwater discharge.

Prior to the construction of the Conservancy's Filter Marsh, a ditch drained stormwater runoff from a mall parking lot, a major road, and adjacent residential areas, bisected the Conservancy's property and discharged into the Gordon River (Figure 5). In effort to try to reduce pollutants and slow down the volume of stormwater runoff in the ditch the Conservancy intercepted the stormwater flow in the drainage ditch and diverted the flow into a wet detention pond, which in turn, drained into a filter marsh prior to returning to the ditch and ultimately discharging into the river (Figure.6).

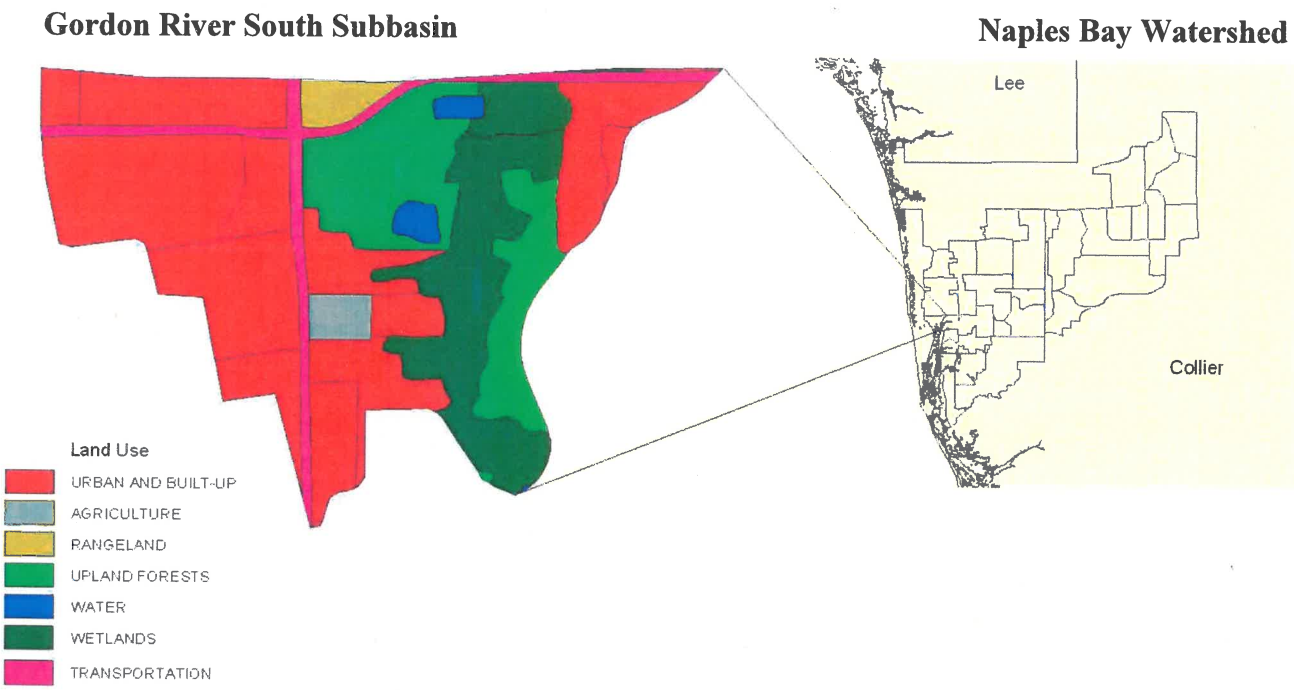
Figure 5: Conservancy Filter Marsh Site Pre-Construction

Figure 6: Conservancy Filter Marsh Post-Construction

Project Location

This project is located in Naples, Collier County, Florida and is situated within the "Gordon River South" subbasin (Figure 7), on property owned by the Conservancy of Southwest Florida. The Gordon River South subbasin is one of 32 subbasins that reside in the Naples Bay Watershed, which in turn resides within the Western Big Cypress Basin Watershed (Figure 1).

Figure 7: Map of Naples Bay Watershed (blue outline) in Collier County, Florida with land use from the Gordon River South Subbasin



The Gordon River South subbasin (approximately 456 acres), is essentially fully developed, predominantly consisting of residential and commercial structures. A large portion of that development is dominated by impervious surfaces, including the approximately 70-acre Coastland Mall site. Nonpoint source stormwater runoff from impermeable surfaces ends up in a ditch that bisects the Conservancy's property and is discharged into the Gordon River that leads directly to Naples Bay. The Conservancy Filter Marsh Project is located on what was a grassy field adjacent to the ditch (Figure 6).

OBJECTIVES

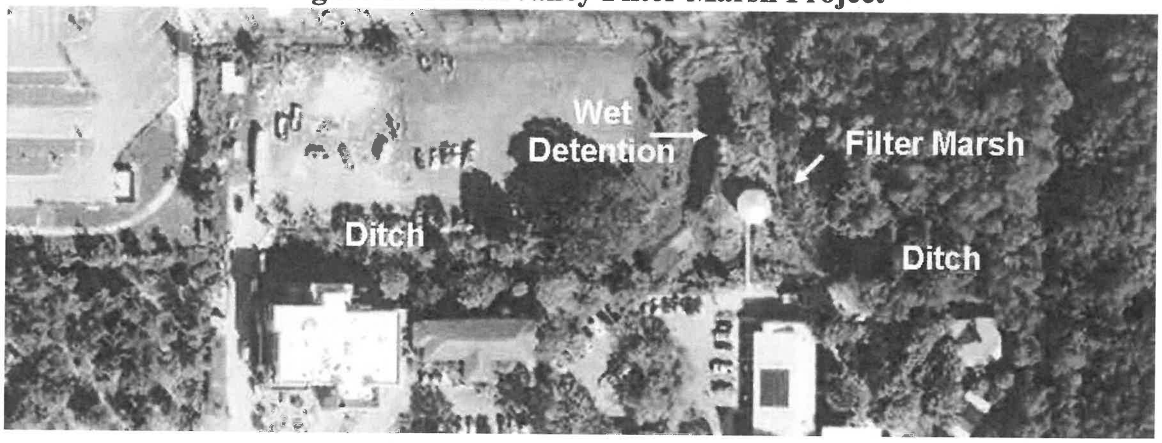
The objectives of this project were to reduce urban runoff pollution, while enhancing the wildlife and education values of the site. The project used a series of stormwater Best Management Practices (BMP's) to treat urban runoff and slow down and reduce pollution loading to the receiving waters of the Gordon River. The BMP's used in this project included treating runoff through isolation of the stormwater and the processes of sedimentation, adsorption, infiltration, biological uptake, microbial degradation, and volatilization. The Project takes advantage of the specific pollution removal capabilities of each of the BMP's combined into a treatment train.

Targeted criteria included: 1) Improved water quality by reducing annual stormwater runoff and pollutant load discharges; 2) Increased wetland species diversity and biological productivity through the creation of wetland vegetative cover and removal of exotics, thereby increasing the ecological value of the site; 3) Increased public awareness of water quality problems associated with stormwater runoff and illustrate the benefits and aesthetic qualities of Filter Marshes to Conservancy visitors through several public and school outreach initiatives.

PROJECT DESIGN AND CONSTRUCTION

To reduce pollutants and decrease stormwater runoff, the Conservancy's stormwater project was designed to intercept the stormwater flow in the drainage ditch and divert the flow into a wet detention pond, which drains through a filter marsh prior to discharging back into the ditch and subsequently into the river during outgoing tides (Figure 8). Cap rock serves as a diversion structure used to divert the first flush portion of storm drainage into the wet detention pond and filter marsh. The elevation of the cap rock is set to allow a storm's first flush to flow into the filter marsh for treatment. Higher storm stages will over flow the cap rock and continue downstream. By preventing excessive runoff from major storm events from entering the filter marsh, this type of diversion structure prevents hydraulic overloading of the system and prevents a reduction in its efficiency. Additionally, the diversion structure is a safety measure that prevents marsh overflow and flooding of adjacent lands during extreme events such as tropical storms and hurricanes.

Figure 8: Conservancy Filter Marsh Project



From the diversion structure, stormwater flows into a permanent wet detention pond. The pond slows the velocity of stormwater entering the system and increases the residence time, allowing suspended solids to settle out. Larger and denser particles will settle out first, followed by the smaller and less dense particles. The pond is also capable of secondarily removing pollutants from stormwater by adsorption to sediments, microbial decomposition, and biological uptake (Barr Engineering Co., 2001). In addition to a permanent pool, the basin includes a planted littoral shelf. The littoral shelf compromises a minimum of 30 percent of the surface area of the basin and is planted with native wetland vegetation. The shelf while reducing erosion, enhances the biological uptake of pollutants by plants, prevents re-suspension of sediments, and increases the habitat and aesthetic values of the filter marsh.

The outlet of the sedimentation basin provides sheet flow into the constructed wetland/filter marsh portion of the treatment train. Wetlands remove pollutants from water through a variety of processes including sedimentation, adsorption, biological uptake, microbial decomposition, volatilization, and infiltration to some degree. Biological uptake occurs as nutrients, metals, and other contaminants are assimilated into the plants. Microtopography within the wetland increased the habitat diversity, while acting as check dams, increasing the hydraulic residence time and efficiency of the BMP.

Other improvements included widening and decreasing the slope of the sides of the existing stormwater drainage ditch to reduce erosion of the ditch banks during high flow events. A new, large box culvert improved ditch flow characteristics and replaced the existing aging drainage culvert, which had historically overtopped during severe storm events. The drainage ditch was analyzed with HEC-RAS to see the effects the improvements would have on the existing condition during the permitting phase of the project. The results of the analysis showed that upstream head conditions were reduced dramatically by replacing the existing triple 19"X30" ERCP ditch culvert with a 5'X7' box culvert. These types of BMP improvements reduced erosion of the ditch side slopes during high flow events, decreased the risk of upstream flooding, provided a littoral zone for further improved wildlife habitat/foraging and provided additional treatment of the stormwater runoff.

A site characterization was performed that depicted the x-sectional area; general site description, sketch of site illustrating general habitat characteristics, monitoring station locations pre and post construction (Figures 9 and 10). The project area was planted with a diversity of native wetland plants suitable for each microhabitat (Figure 11) and existing native trees within the project boundary remained. Most of the plantings were emergent and either facultative or obligate wetlands that can survive periodic inundation. Those plants that were in areas that are subject to submersion were salt tolerant to increase the probability of survival in the tidally influenced waters (Table 4). Plants were employed for their nutrient removal capabilities and physical effects such as reducing flow velocity; increasing sedimentation; reducing erosion; and to increase the contact time between water and plant surfaces. Their roots and rhizomes assist in stabilizing the sediment to reduce erosion; have the ability to release of oxygen; increase degradation and nitrification; and uptake nutrients.

EDUCATIONAL COMPONENT

The Filter Marsh Project has been incorporated into our Nature Center experience, complete with signage that explains the benefits of the BMP's on display. The site serves as a demonstration project that illustrates not only the water quality benefits, but also the aesthetic qualities of Wet Detention Ponds and Filter Marshes to Conservancy visitors through guided tours by Conservancy naturalists and volunteers and through self-guided tours for visitors. The informational kiosks erected at the project site explain the purpose of wet detention and filter marshes, their role in the reduction of stormwater pollutants, and the benefits of BMP's in improving our water quality.

This project is also being utilized as a public education tool for students. The Conservancy Filter Marsh site functions as an "outdoor lab" for students to explore BMP's and analyze water quality while at the same time learning how to increase natural biodiversity through the creation of refugia for wildlife within the filter marsh. Over 600 third grade students began visiting the Conservancy Filter Marsh in the fall of 2009 and utilized it as a living laboratory to learn about pollution, perform water quality tests, survey wildlife and more. Students continue to learn to this day and will continue to learn the value of BMP's and wildlife biodiversity for years to come. The success of this program has even led to live video conferencing between Conservancy scientists and naturalist and students in the third grade students at their classroom at a local elementary school.

We now have developed several programs that the Conservancy's education department conducts that involve the filter marsh project.

- **Watery Wonders**, a Collier County Public School sponsored field trip for the third grade. We have scheduled 17 dates for this program annually that has 2 or 3 classes attending each day. During this program the students learn about the importance of the filter marsh as a habitat and also its purpose of cleaning water that runs off of roads and parking lots. The students test water quality parameters including temperature, salinity, and pH. They also sample the fish and other aquatic species in the filter marsh using dip nets, a fish trap, and plankton net.

- **Conservancy STEM field trip Aquatic Ecosystems** offered to grades 4-12. Students test water quality parameters including temperature, salinity, pH, dissolved oxygen, and nitrates. Students also sample aquatic species using dip nets, fish trap, and plankton net.

- **Conservancy STEM Smart field trip** that involves high school students. Students test water quality parameters including temperature, salinity, pH, dissolved oxygen, ammonium, nitrates and turbidity. Students sample aquatic species using dip nets, fish trap, and plankton net. Students also survey wildlife and plant life surrounding the filter marsh.

- We have just started a **public program** that will take place on Monday afternoons at 2:00 PM called **"Catch of the Day"**. A Naturalist uses a fish trap to sample aquatic species and discuss the impacts of invasive species.

- Visiting the filter marsh gazebo with a naturalist's interpretation is part of the **adult guided group tours** of our nature center.

- Our **summer camp** also includes filter marsh exploration. Summer campers use dip nets to explore the filter marsh species and learn about the importance of the filter marsh in cleaning the water.

The filter marsh has been an amazing asset to the education department, providing a wonderful opportunity to get students and guests immersed in nature and scientific inquiry. Evaluation of the effectiveness of the educational experience speaks for itself with the continuation of programming and excellent feedback on the experience from students and guests.

EVALUATION

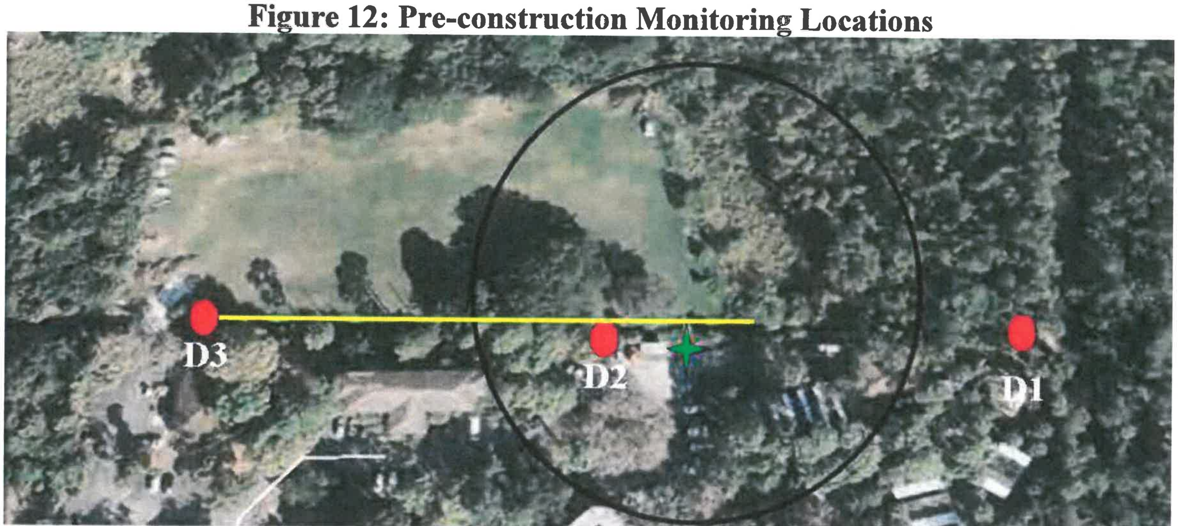
An analysis of project effectiveness was performed to demonstrate whether or not this project has yielded any environmental benefits. Project assessment essentially followed grant guideline specifications provided by the 319 Nonpoint Source Management Program. Any alterations in methodology and parameters tested were approved by FDEP's project manager prior to the onset of assessment. In addition to evaluating pollutant reduction effectiveness of the project BMP's (ditch alterations, wet pond detention, and filter marsh), hydrologic and biological assessments were also performed. Hydrologic components of the monitoring plan included flow measurements at the inflow and outflow and volume assessments pre and post-construction. Biological assessments of the faunal makeup of the area pre- and post-construction were investigated to determine the effects of this project on fish and anuran aquatic communities and avian use of the constructed resource. Fish, anuran and avifaunal communities serve as indicators of stream water quality conditions on both spatial and temporal scales. Basic information on the aquatic community structure, when coupled with a careful analysis of pre and post-construction should provide a more complete picture of the benefits (and/or negatives) of filter marshes in particular.

METHODS

Project location was selected based on acreage available and suitability for filter marsh creation and the presence of an existing stormwater ditch. The project monitoring locations were selected and evaluated in accordance with directives delineated in SOP CSWFL-401 Surface Water Hydrology – Site Selection and Characterization – Section A.

Pre-Construction Monitoring was performed in the existing ditch (Figure 12) to develop a baseline of selected hydrologic and biological parameters prior to implementing BMP improvements (Table 5).

Figure 12: Pre-construction Monitoring Locations



Weather Station

Water Level Monitoring Stations

Biological Assessment Area:

Avifauna

Fish

Anurans

Stations

D1 = Ditch East End (fresh water outflow – tidal inflow)

D2 = Mid Ditch

D3 = Ditch West End Entrance (Storm water inflow)

Image Source: Google Earth

Table 5: Pre-Construction Parameters Monitored Pre-Construction, Frequency, Method and Instrumentation at the Ditch

Parameter	Frequency	Method	Equipment
Precipitation, Temperature Humidity	Daily continuous monitoring, except during periods of construction, maintenance and/or replacement.	Automated Station	Davis Instrument Weather Station Vantage Pro 2
Water Depth	Continuous Hourly Intervals/Daily Average (accounting for tidal cycles, rainfall and stormwater influences on at least 6-24hr periods per month) except during periods of construction, maintenance and/or replacement.	Automated Acoustical	Infinity Acoustic Water Level Dataloggers
Biological (fish assessment)	Twice monthly for 6 months pre-construction (June – November 2008)	Standard Capture Techniques	Breder traps
Biological (anuran assessment)	One event monthly consisting of 3 nights for 6 months pre-construction (June-November 2008)	Audible Survey and Standard Capture Techniques	
Biological (avian assessment)	Twice monthly for 6 months pre-construction (July 2008-January 2009)	Standard Point Survey	Binoculars

Note: although water level can be can be adequately assessed post construction by comparison of inflow and outflow points (pre and post treatment), water levels will be monitored pre-construction within the ditch at periodic 24 hour intervals to assist in determining final construction design specifications to best accommodate fluctuating seasonal water levels within the created filter marsh.

Post-Construction Monitoring was performed within the ditch west end, wet detention and filter marsh at 1 site prior to treatment (fresh water inflow (Ditch West End stormwater entrance) and at 2 intermediate sites (Wet Detention and Filter Marsh) and in the ditch (fresh water outflow to the Gordon River and saltwater inflow (Ditch East End)) (Figure 13), to evaluate hydrologic, biological and water quality parameters post-construction (Table 6).

Figure 13: Post-construction Monitoring Locations

Weather Station

Water Level Monitoring Stations

Water Quality Stations

Flow Transect

Biological Assessments:

Avifauna

Fish

Anurans

Stations

D1 = Ditch East End (fresh water outflow – tidal inflow)

M = Filter Marsh

W = Wet Detention

DW – Ditch to Wet Detention

B = Ditch West End Entrance (Storm water inflow)

Image Source: Google Earth

Table 6: Parameters Monitored Post-Construction, Frequency, Method and Equipment

Parameter	Frequency	Method	Equipment
Precipitation, Temperature Humidity	Daily continuous monitoring, except during periods of construction, maintenance and/or replacement	Automated Station	Davis Instrument Weather Station Vantage Pro 2
Flow Rates Hydrologic Assessment	Bi- monthly for 4 years November-December 2009 – November 2013; 25 separate events		SonTek Flow Tracker Handheld ADV w/2D ADV probe and wading rod and Trimble Differential GPS
Water Depth	Continuous Hourly Intervals/Daily Average (accounting for tidal cycles, rainfall and stormwater influences on at least 6-24hr periods 6 mo during the year) except during periods of construction, maintenance and/or replacement. (Timeframe November 2009-November 2013)	Automated Acoustical	Infinity Acoustic Water Level Dataloggers
Biological (fish assessments)	Bi- monthly for 4 years (November 2009 – November 2013)	Standard Capture Techniques	Breder traps
Biological (anuran assessment)	One event bi-monthly consisting of 3 days for 4 years (November 2009 – November 2013)	Audible Survey and Standard Capture Techniques	
Biological (avian assessment)	Bi- monthly for 4 years (November 2009 – November 2013)	Standard Point Survey	Binoculars
Water Quality Parameters	Bi- monthly for 4 years (November 2009 – November 2013)	FDEP Standard Collection Procedures	Water Column Sampler YSI Water Quality Meters

<u>Data Collection</u>

All Pre and Post-construction monitoring was performed in accordance with monitoring protocols and SOP's delineated in the Conservancy's QAPP plan for this project.

A. Meteorological Monitoring

Weather parameters including precipitation (in), minimum and maximum temperature (°F), wind speed (mph), wind direction, humidity (%) and barometric pressure (in) were recorded by a pre-calibrated automated on site Davis Instrument Weather Station Vantage Pro System. The weather station was configured to record at hour increments throughout the duration of the project. During periods when the unit was not operational the data set was augmented with data collected by the Naples Municipal Airport, which is less than 1 mile from the project area.

B. Hydrologic Monitoring

Hydrologic measurements included surface water level and flow measurements performed using methods described in SOP CSWFL-401 Surface Water Hydrology - Flow – Section B at the freshwater inflow and freshwater outflow (salt water inflow) Water levels were measured automatically using precalibrated Infinity surface water level dataloggers at 3 stations pre-construction and 5 stations post-construction (Figures 12 and 13). This type of water level recorder provided a digital record of water level variation at hourly intervals that were downloaded in the field and transferred to a computer database directly. These loggers used a non-contact multi-pulse ultrasonic ranging sensor to electronically measure and digitally record surface water level readings over a set time interval. Surface water levels were measured by placing the logger on a 7.62 cm diameter, 180 cm tall, vented and screened PVC pipe that was leveled and supported by a 2x4 that was driven into the sediment. These measurements were calibrated using actual water levels at random intervals throughout the project.

All water flow and discharge methods employed during this project adhered to guidelines set forth in SOP CSWFL-401 Surface Water Hydrology - Flow – Section C for the current- velocity meter. A pre-calibrated SonTek/YSI FlowTracker® Handheld ADV® (Acoustic Doppler Velocimeter) featuring SmartQC™ was used to measure water flow and discharge using established USGS/ISO velocity/x-sectional area methods. The Flowtracker has a proven track record in open channel flow areas like the ditch and is capable of performing rapid, multi-point current surveys in wetland areas such as a created wet detention area and filter marsh. This equipment has an excellent performance for low and high flows with accuracy 1% of measured velocity (SonTek, 2007). The Mid Section Method was chosen to determine the discharge rate using the subsection velocity measurements as recommended in DEP-SOP-001/01 FT 1800 Field Measurement of Water Flow and Velocity and is the method of choice by USGS for calculating discharge. Measurements were made bi- monthly for 4 years post-construction from December 2009 – November 2013 at designated areas to determine freshwater inflow and freshwater outflow rates along 5 transects post-construction (Figure 13).

C. Water Quality Monitoring

Water quality sampling conformed to methodology detailed in DEP SOP's for surface water sampling and was collected by or in the presence of an individual that has been certified as completed the course, *FDEP SOP Sampling Training for Groundwater, Surface Water and Wastewater*. Surface water samples were collected using the direct grab technique or using a Van Dorn water column sampler. All samples were placed in polypropylene containers or in disposable, sterile, plastic Whirl-pak® sample bags and labeled with a unique sample number. Information including project, sample number, location of collection, date and time of collection, and sample status (non-preserved, preserved with H_2SO_4 or HNO_3, light shielded container, filtered or non-filtered) and collectors initials were recorded. Samples were placed in a cooler on wet ice in the field and were transferred the same day to Collier County Pollution Control Laboratory complete with appropriate chain of custody. Samples were collected bimonthly at 4 permanent stations post-construction for 4 years (Figure 13), prior to any other site monitoring activities (typically on an out-going tide during the dry season when tidal movements overshadow runoff events, when possible). All samples were collected in adherence with FDEP SOP FS 2100 in regards to equipment used, sampling techniques, sample preservation, container and equipment decontamination procedures, documentation and field quality control. All water samples were transported to a certified laboratory (Collier County Pollution Control Laboratory) for analysis of the following parameters:

Nutrients

Parameter	Units
Ammonia	mg/l
Nitrate (N)	mg/l
Nitrite (N)	mg/l
Nitrate-Nitrite (N)	mg/l
Total Kjeldahl Nitrogen	mg/l
Total Nitrogen	mg/l
OrthoPhosphate (P)	mg/l
Phosphorus Total (P)	mg/l

Biological

Parameter	Units
Chlorophyll a	mg/m^3
Pheophyton	mg/m^3
Fecal Coliform	cfu/100ml

Physical

Parameter	Units
Total Dissolved Solids (TDS)	mg/l
Total Suspended Solids (TSS)	mg/l
Biological Oxygen Demand (BOD)	mg/l
Color	PCU

The methods employed for the analysis of the water samples were in adherence with Standard Methods for the Examination of Water and Wastewater and protocol methodologies employed by Collier County Pollution Control and Prevention Department Laboratory.

Water quality field parameter data, including total depth (in) and sample depth (ft), temperature (°C), salinity (ppt), conductivity (ms/cm or µs/cm), dissolved oxygen (mg/l & %) were recorded at all water quality sampling sites during each scheduled water sampling event using a pre-calibrated YSI™ Model 85 datalogger. Additionally, turbidity (NTU) was measured using a pre-calibrated Hach Turbidometer, at each station during each sampling event. All equipment parameters were verified and/or calibrated prior to use in the field in accordance with individual manufacturers instrument manuals and FDEP SOP FT 1000. All measurements were performed in adherence with FDEP SOP's FT 1000, FT 1200, FT 1300, FT 1400, or FT 1500 in regards to general field testing measurement, general sampling procedures, documentation and field quality control.

D. Fish sampling

Eight clear Plexiglas Breder traps (Breder, 1960) were used prior to construction (June 2008 – November 2008), and 10 traps were used thereafter (July 2010 – November 2013). This sampling technique was chosen since Breder traps target smaller fish that tend to proliferate in the existing ditch. In addition this capture method is easily repeatable, has time constraints, and is suitable in shallow vegetative environments that exist in a constructed filter marsh. Traps were placed around the site so as to sample all available microhabitats and to maximize capture efficiency over the years (Figures 12 and 13). They were left submerged and undisturbed for 1 hour soak time. The water depth (cm) was measured prior to trap retrieval. Captured fish were collected and held in buckets or live wells for subsequent species identification, measurement (total length) and/or enumeration then released. Only the first 30 fish of a given species were usually measured and the remainder enumerated. All fish sampling, fish identification, sampling locations, and documentation procedures employed during in this project adhered to guidelines set forth in SOP CSWFL-301 Fish Sampling Techniques.

E. Avifaunal surveys

The circular plot technique (Ramsey and Scott., 1979 & Ralph. et. al., 1995) was chosen to survey avifauna since this method was more appropriate to adequately census this particular site due to its size. Since the site for this study was very small one station adequately covered the entire site encompassing the different Best Management Practices (BMP's). The area encompassed a 50 m radius of approximately two acres (0.8 ha) (Figures 12 and 13). A ten minute survey was performed at the site during each sampling event. The observer counted all birds observed within a 10 minute time interval and recorded the species, number, habitat observed in, whether the bird was sighted, heard or both, and distance estimated by the observer. All avifaunal survey census and documentation procedures employed during in this project adhered to guidelines set forth in SOP CSWFL-302 Bird Surveying Techniques.

F. Audible anuran surveys

The site was surveyed every other month (Figures 12 and 13). One 1 round of sampling consisted of surveys performed during 3 consecutive, or near consecutive, nights. Surveys began after sunset to increase the probability of observing nocturnal amphibians. A one or two person crew began by listening for anuran vocalizations for 5 minutes. The abundance of each species was categorized and enumerated as follows: no frogs calling ($n = 0$), one frog calling ($n = 1$), 2-5 calling ($n = 3$), 6-10 calling ($n = 8$), >10 calling ($n = 10$), or large chorus ($n = 16$). The intensity of the vocalizations was categorized as: no frogs calling, occasional, frequent, or continuous. After the vocalization survey there was a 20-minute visual encounter survey (VES). During this time, all individual amphibians observed were identified to species and captured if possible. The species were categorized by age (egg, larvae, juvenile, sub-adult, or adult), measurement (snout-to-vent length) and sex (if able to determine). The animal was then released at the original capture site. The substrate and estimated perch height of the animal along with several environmental variables (air temperature, relative humidity, presence of water, wind speed and cloud cover) were recorded during each survey. All anuran surveys, species identification, survey location, documentation and collection (if warranted) procedures employed during this project adhered to guidelines set forth in SOP CSWFL-303 Anuran Surveying Techniques.

DATA ANALYSIS

Water Level and Flow Assessment

Water level data were evaluated over the study period to determine the extent to which each station was affected by tides and rainfall through comparison to meteorological data and known tidal fluctuations. Water level data were summarized pre and post-construction by station. The water level data were presented using graphical representations depicting the different stations and by their quartiles using box plots.

Water flow was assessed over the study period to determine water velocity and discharge within the BMP's at 5 transects post-construction. Data was summarized by station depicting the width, area, mean depth, mean velocity and total discharge by transect in each of the different areas (Ditch West End (entrance); Wet Detention area; entrance to the Filter Marsh, exit from the Filter Marsh, and the Ditch East End). The mean velocity and total discharge data was also presented using graphical representations depicting the different transects by their quartiles using box plots. Statistical analysis of data were performed to reveal whether or not water velocity or total discharge were significantly different between different transects.

Water Quality

The data were screened for outliers and other data errors, which were investigated and either included or excluded from analysis of the data set. To date all outliers have been confirmed as valid data. Values below the detection limit were reported as measured or given a value of "zero" if not detected at all given the restrictions of the test being employed. If the reported value failed to meet established laboratory quality control criteria or was questionable that value was eliminated from analysis.

The data were placed into one of the following three parameter categories:

Parameter Type	**Description**	**Parameters Tested**
Physical	Physical parameters such as Depth, Temperature, Salinity, Conductivity, Dissolved Oxygen, Biological Oxygen Demand, Turbidity, Total Suspended Solids, Total Dissolved Solids and True Color	Depth, Temperature, Salinity, Conductivity, Dissolved Oxygen, Biological Oxygen Demand, Turbidity, Total Suspended Solids, Total Dissolved Solids and True Color
Nutrient	Nitrogen and Phosphorus and their derivatives	Ammonia, Nitrite, Nitrate, Total Kjeldahl Nitrogen, Total Nitrogen. Ortho-Phosphorus and Total Phosphorus
Biological	Bacterial or Plant	Fecal Coliform, Chlorophyll a, Pheophytin a

Although scientific measurements are used to define a water's "quality", it's not a simple thing to say that "this water is good," or "this water is bad." since, water that is "good " enough to wash a car may not be "good" enough to drink. The Conservancy's ditch and filter marsh is located within waterbody id # 3278R5 and is considered "marine" due to the tidal influence, albeit the water is actually classified as brackish during most of the year. In estuaries and tidal ditch systems many standards are based upon whether or not the water quality parameter is within natural background levels. Natural background means the physical, biological and mineral levels that can be expected in the absence of significant human influence. If stormwater runoff that is high in nitrogen and phosphorus is introduced into an area that has nutrient levels that are within natural background, a change usually occurs overtime due to the influx of excessive nutrients. Over time nutrient levels could rise above natural background and the water quality could degrade. Currently water quality analysis is complicated since there are no State or Federal standards for many of the parameters critical to evaluation. Therefore, the methodology for interpreting water quality results is based on standards that have been established by the State of Florida and targets for those parameters that have no established State Standards as follows:

1) Criteria for evaluating water quality parameters were based upon Florida State Water Quality Standards for Class III Predominately Marine Waters for the following parameters:

Parameter	**Class III Standards for Predominately Marine Waters**
Dissolved Oxygen	Not less than 4 mg/l and normal daily and seasonal fluctuations above this level should be maintained
Turbidity	Not elevated above 29 NTU above background
Specific Conductance	Not elevated above more than 50% of background
Total Nitrogen	Standard for Naples Bay the annual geometric bay of 0.57 mg/l shall not be exceeded more than once in a 3 year period
Total Phosphorus	Standard for Naples Bay the annual geometric bay of 0.045 mg/l shall not be exceeded more than once in a 3 year period
Fecal Coliform	Not elevated above 800 cfu/100 ml in a single day
Chlorophyll a	Standard for Naples Bay the annual geometric bay of 4.9 mg/m^3 shall not be exceeded more than once in a 3 year period

2) For water quality parameters that do not have State Standards the following criteria are used to evaluate data based upon Charlotte Harbor National Estuarine Preserve (CHNEP) acceptable levels, as identified by Janicki (2003) for the 25^{th} percentile and Indian River Lagoon Program SWIM Restoration Program levels (IRL) as a not to exceed value:

Parameter	**Criteria**
OrthoPhosphorus	Greater than 0.1 mg/l could negatively impact downstream communities (CHNEP). Levels should not exceed avg 75^{th} percentile.

3) For water quality parameters that do not have State Standards or are not identified by Janicki (2003) or the Indian River Lagoon Program SWIM Restoration Program criteria for analysis are based upon the EPA Reference Nutrient Concentrations for Level III conditions for Ecoregion IX (Leib and Browne, 2002) as follows:

Parameter	**Criteria**
Nitrite	Not to exceed 0.995 mg/l at the 25^{th} percentile or for the average concentration.
Nitrate	Not to exceed 0.995 mg/l at the 25^{th} percentile or for the average concentration.

4) Water parameter levels are also compared to levels found in most Florida waters (Ramsey, 2003).

Parameter	Most Florida Waters
Biological Oxygen Demand	75% have less than 2 mg/l
Total Suspended Solids	Typical for Florida estuaries is < 17.5 mg/l
Total Kjeldahl Nitrogen	Greater than 0.51 considered a nuisance.
Total Dissolved Solids	>15000 mg/l considered unacceptable for fish

5) For parameters that are not given criteria by the State or Federal governments the following guides are used during analysis.

Parameter	Criteria
Ammonia (If sensitive species present)	If water temperature is greater than 20°C then ammonia levels should not be greater than 0.093 mg/l. If water temperature is less than 20°C than ammonia levels should not be greater than 0.053 mg/l.

6) As salinity varies primarily in this case due to freshwater inflows, stations were also classified based on their average salinity. The natural salinity range for protection of marine wildlife habitats is between 13.5 to 35 ppt (EPA Gold Book, 1986).

Salinity Modifiers (Mitsch and Gosselink, 2000)		
Salinity (ppt)	**Descriptor**	**Category**
<0.5	Fresh Water	Fresh Water
0.5-5	Oligohaline	Brackish
5.0-18	Mesohaline	Brackish
18-30	Polyhaline	Brackish
30-40	Euhaline	Marine
>40	Hyperhaline	Marine

7) Trophic category as described by chlorophyll a levels:

Chlorophyll a (mg/m^3)	Category
0 – 2.6	Eutrophic
2.6 - 20	Mesotrophic
20 - 56	Oligotrophic
56+	Hypereutrophic

Water quality data was also evaluated using standard statistical methods and t-tests were employed to determine any differences between sampling stations.

Biological Assessment

Rainfall patterns in southern Florida vary seasonally and were categorized by Shirley et al. (2004) as early dry season (December through February), late dry season (March through May), early wet season (June through August), and late wet season (September through November). Wet season rainfall is produced primarily by localized thunderstorms, although tropical cyclones can significantly increase wet season rainfall when they cross or come close to south Florida (Duever et al., 1994). Pre-construction sampling was performed every other week between June and November 2008 (i.e., wet season) and post-construction sampling was performed every other month (January, March, May, July, September, and November) from 2010 to 2013. In an effort to standardize this unbalanced sampling regime, only data collected during the wet season were used in the faunal analyses. Additionally, pre-construction data collected every other week were summed to give 3 sampling rounds corresponding to the wet season months of July, September, and November. This was consistent with the post-construction sampling schedule and each sampling round was considered a replicate within a given year.

Data were standardized for each faunal group for pre-construction and post-construction sampling rounds. Fish abundances were converted to catch per unit effort (CPUE) by dividing the sum of captured fish for a given species by the number of traps deployed during the corresponding sampling round (pre-construction – 4 sampling days per round with 8 traps deployed per day; post-construction – 1 sampling day per round with 10 traps deployed per day). Bird abundances were converted to CPUE by dividing the sum of sighted birds for a given species by the number of days surveyed in the corresponding sampling round (4 days surveyed per round pre-construction and 1 day surveyed per round post-construction); however, there were days when no birds were sighted and the effort divisor was modified accordingly for pre-construction rounds or else a replicate would be lost in the post-construction years (1 replicate in 2013). Frog call data were inconsistent in November with no vocalizations recorded for all 3 sampling days in most post-construction years (2010, 2011, and 2013). Therefore, only the call data for July and September were used in the analyses and 3 days during these months each year were considered a replicate.

PRIMER v6 statistical software (PRIMER-E Ltd., Plymouth, UK; Clarke and Gorley, 2006) and standard census data were summarized and used to analyze faunal compositions. Square root transformation was applied to fish CPUE and bird CPUE to down weight the contributions of dominant taxa. Frog call data were not transformed given the species poor (n = 7 species) composition. A Bray-Curtis similarity matrix was calculated for each faunal group and, using sampling rounds as replicates, one-way analysis of similarity (ANOSIM) was applied to the Bray-Curtis matrices to test for differences between construction status (pre- and post) and among years (2008 and 2010-13). A pairwise matrix of R values was generated in the event of a significant difference in the ANOSIM global test among years. R values from pairwise comparisons are not unduly affected by the number of replicates/permutations, unlike the significance levels (p-values), and are therefore the best measure of differences between two compositions (Clarke and Gorley, 2006; Clarke and Warwick, 2001). Large values ($R \approx 1$) indicate high differentiation of communities, while small values ($R \approx 0$) imply little or no difference. The similarity percentages (SIMPER) routine was also used to identify species contributing to any significant differences in compositions. ANOSIM indicates an undefined difference between groups but there is the *a priori* expectation that the composition of a group may change following construction, therefore a test for temporal seriation was performed for each faunal group (Clarke and Gorley, 2006; Somerfield et al., 2002). A model matrix of seriation with replicates was constructed from the Bray-Curtis matrix of each group and the RELATE routine was used to test for any ordered sequence of composition change between construction status and among years.

RESULTS

Meteorological Conditions

Draught conditions prevailed during 2009, 2011 and 2012 and the area received less precipitation that the long term historical annual average (55.67 in) during all years monitored. Temperatures measured during the sampling periods pre-construction ranged from 33.1°F to 93.9°F with a mean of 72.6°F and precipitation during these periods totaled ~25.2 inches. Over the years post-construction, temperatures ranged from 42.9°F to 94° F, averaging 66.7°F during the months of November and December 2009; 30.3°F to 96° F in 2010 averaging 75°F; 36.9°F to 101° F in 2011 averaging 73.7°F; 34.5°F to 101° F in 2012 averaging 74.7°F; and 38.1°F to 98° F in 2013 averaging 74.1°F. Precipitation varied over the study period totaling an estimated 6.06 inches in November - December of 2009; approximately 49.9 in., 31.7 in., and 36.01 in. throughout the years 2010, 2011 and 2012 respectively; and approximately 48.1 in. throughout the period of January – November 19, 2013 (Figures 14 & 15) .

Water Levels and Flow

The Gulf of Mexico has a complicated mix of tides. In the study area this consists of two distinct daily tides, which produce a mean tidal range of approximately 2.5 ft and a mean spring range of 2.8 ft, at Gordon Pass the entrance to Naples Bay (Goodman and Alleman, 2012). Tidal signatures were apparent at all stations pre-construction however, the westernmost station (Ditch West End Entrance (station D3) presented with a muted sigmoidal signal (Figure 16). Pre-construction mean water levels were consistently higher along a east to west gradient along the existing ditch, with the easternmost station illustrating the deepest water levels coincident with geographical location of the stations along the ditch and proximity to the tidal source (3.5 ft, 17.3 ft and 22.0 ft at the Ditch West End Entrance, Mid-Ditch, and the Ditch East End respectively) (Figures 16 and 17)). During the onset of the dry season (January 2009), preconstruction, water levels tended to recede as precipitation and runoff lessened. However, precipitation and runoff still had impacts on the water level along with lunar effects. Tidal signatures were still evident during the wet season particularly at Ditch West End which was situated nearest the tidal tributary. Precipitation and runoff remained a factor during the height of the wet season as water levels increased particularly in the Ditch West End Entrance (Figures 16, 17 and 18).

Tidal signatures were apparent at all stations post-construction however, the westernmost station (Ditch West End Entrance) as expected still presented with a muted sigmoidal signal (Figures 19 and 20). Post-construction mean water levels were mainly influenced by the depths that the different BPM's were configured as a result of the design and subsequent construction. Mean water levels were consistently higher in the wet detention pond (Station W) as expected coincident with the deepest excavation depth used to create this settling pond. While the filter marsh (M) and Ditch West End Entrance (station B) had the shallowest water levels respectively (Figures 19 and 20). Mean levels varied from 9.7 ft, 27.3 ft, 4.3 ft and 17.8 ft at the Ditch West End Entrance (station B); Wet Detention (station W), Filter Marsh (station M) and the Ditch East End (Station D) respectively (Figure 21). As during pre-construction water levels post-construction were influenced by season, precipitation levels and the lunar cycle. During the dry season (January), overall levels receded as precipitation and runoff lessened. However, sometimes levels are counterintuitive as during the winter dry season however, this is the time when irrigation substantially increases. Tidal signatures were still evident during the wet season particularly at Ditch East End (station D), which was situated nearest the tidal tributary. Precipitation and runoff remained factors during the height of the wet season as water levels increased particularly in the Ditch West End Entrance (station B) (Figure 22). Overall during the study period from pre and post-construction water levels increased at the Ditch West End Entrance (pre-construction station D3 (mean 3.5 inches) and post-construction station B (9.7 inches)) and decreased at the Ditch East End (pre-construction station D1(mean 22 inches) and post-construction station D (mean 17.8 inches) (Figures 17 and 21). These changes were a result of several factors including construction best management practices changes to the landscape and differences in annual rainfall and runoff volume.

Overall, flow velocity[2] ranged from 0.0001 m/s to 0.4418 m/s and an overall mean velocity of 0.045 m/s throughout the study period. Measurements obtained during high tide ranged from 0.0028 m/s to 0.0544 m/s; while measurements made during low tide ranged from 0.0001 m/s to 0.4418 m/s. Velocity had a tendency to be slower during low incoming tides and faster during low outgoing tides (Table 7). Overall, total discharge[2] at the various check dams ranged from 0.00001 m^3/s to 0.1108 m^3/s throughout the duration of the study. Measurements obtained during high tide ranged from 0.001 m^3/s to 0.0551 m^3/s; while measurements made during low tide ranged from 0.00001 m^3/s to 0.1108 m/s. Similar to velocity, overall total discharge measurements were less during low incoming tides and higher during low outgoing tides (Table 7).

I. Water Flow by Transect

At the Ditch West End stormwater entrance (B), flow velocity ranged from 0.0013 m/s to 0.2028 m/s. During high tides the lowest velocity recorded was 0.0041 m/s when the tide was outgoing, whereas during low tides the lowest velocity recorded was 0.0013 m/s when the tide was incoming. Alternatively, during high tides the highest velocity recorded was 0.0463 m/s during an outgoing tide and during low tides was 0.2028 m/s during an outgoing tide (Table 7 and Figure 23). Total discharge at the Ditch West End stormwater entrance (B) ranged from 0.00001 m^3/s to 0.0492 m^3/s. During high tides the smallest discharge recorded was 0.001 m^3/s when the tide was outgoing, whereas during low tides the smallest discharge recorded was 0.00001 m^3/s when the tide was incoming. Alternatively, during high tides the highest discharge rate recorded was 0.0046 m^3/s during an incoming tide and during low tides was 0.0492 m^3/s during an outgoing tide at the Ditch West End (Table 7 and Figure 24). This transect is the first to encounter freshwater runoff from the west and given the hydraulic head in this area, freshwater flows from the west and to the east and although it can mix with saltwater during an incoming tide that moves from east to west, the primary flow is from east to west. Additionally since tidal level fluctuations at this transect exhibited a muted tidal signal; the slowest velocity and the smallest recorded discharge rate at this transect occurred during a low incoming tide; the highest velocity and strongest measured discharge rate at this transect occurred during a low outgoing tide; had the lowest mean total discharge rate amongst the transects; and exhibited the least fluctuation between quartiles for total discharge, are not surprising and consistent with geographic location and construction design specifications (Table 7 and Figures 23 and 24).

At the entrance to the wet detention pond from the ditch (DW), flow velocity ranged from 0.0046 m/s to 0.0779 m/s. During high tides the lowest velocity recorded was 0.005 m/s when the tide was incoming, whereas during low tides the lowest velocity recorded was 0.0046 m/s when the tide was outgoing. Alternatively, during high tides the highest velocity recorded was 0.0195 m/s during an outgoing tide and during low tides was 0.0779 m/s during an outgoing tide (Table 7 and Figure 23). Total discharge at the entrance to the wet detention pond from the ditch (DW) ranged from 0.0018 m^3/s to 0.1108 m^3/s. During high tides the smallest discharge recorded was 0.0047 m^3/s when the tide was incoming, whereas during low tides the smallest discharge recorded was 0.0018

[2] Each reported value is the mean of multiple stations along a transect. See Methods.

m^3/s when the tide was outgoing. Alternatively, during high tides the highest discharge rate recorded was 0.0132 m^3/s during an outgoing tide and during low tides was 0.1108 m^3/s during an outgoing tide at the entrance to the wet detention pond (Table 7 and Figure 24). This transect is located at the first check dam and is the second area to encounter freshwater runoff from the west. This transect exhibited the least fluctuation between quartiles and the lowest mean velocity. Freshwater flows from the ditch into the wet detention pond, mixes with saltwater during strong incoming tides that enter via the filter marsh. Water flow exhibited some tidal influence, the slowest velocity and the smallest recorded discharge rate during a low outgoing tide, and the highest velocity and strongest measured discharge rate occurred during a low outgoing tide, indicative of a stronger west to east flow overall and consistent with geographic location and construction design specifications (Table 7 and Figures 23 and 24).

At the check dam near the exit to the wet detention pond and the entrance to the filter marsh (W), flow velocity ranged from 0.0016 m/s to 0.2697 m/s. During high tides the lowest velocity recorded was 0.0028 m/s when the tide was incoming, whereas during low tides the lowest velocity recorded was 0.0016 m/s when the tide was incoming. During high tides the highest velocity recorded was 0.0348 m/s during an outgoing tide and during low tides was 0.2697 m/s during an outgoing tide (Table 7 and Figure 23). Total discharge at the exit to the wet detention pond ranged from 0.0002 m^3/s to 0.0977 m^3/s. During high tides the smallest discharge recorded was 0.0087 m^3/s when the tide was outgoing, whereas during low tides the smallest discharge recorded was 0.0002 m^3/s when the tide was incoming. Additionally, during high tides the highest discharge rate recorded was 0.02 m^3/s during an incoming tide and during low tides was 0.0977 m^3/s during an outgoing tide at the Wet Detention exit (Table 7 and Figure 24). This transect is located at the second check dam and is the third area to encounter freshwater runoff from the west. This transect exhibited the second largest fluctuation between quartiles and mean velocity. Whereas this transect exhibited the second smallest discharge rate between quartiles, consistent with one of the purposes of the wet detention pond to retain water. Freshwater flows from the wet detention pond into the filter marsh during outgoing tides, mixes with saltwater during strong incoming tides that enter via the ditch east end. Water flow exhibited some tidal influence, the slowest velocity and the smallest recorded discharge rate during a low incoming tide, and the highest velocity and strongest measured discharge rate during a low outgoing tide, which are indicative of a stronger west to east flow overall and is consistent with geographic location and construction design specifications (Table 7 and Figures 23 and 24).

At the filter marsh exit (M), flow velocity ranged from 0.0001 m/s to 0.4418 m/s. During high tides the lowest velocity recorded was 0.0057 m/s when the tide was outgoing, whereas during low tides the lowest velocity recorded was 0.0001 m/s when the tide was incoming. During high tides the highest velocity recorded was 0.0544 m/s during an incoming tide and during low tides was 0.4418 m/s during an outgoing tide (Table 7 and Figure 23). Total discharge at the Filter Marsh transect ranged from 0.00001 m^3/s to 0.0461 m^3/s. During high tides the smallest discharge recorded was 0.0081 m^3/s when the tide was outgoing, whereas during low tides the smallest discharge recorded was 0.00001 m^3/s when the tide was incoming. Additionally, during high tides the highest discharge rate recorded was 0.0435 m^3/s during an incoming tide and during low tides was 0.0461 m^3/s during an outgoing tide at the Filter Marsh exit (Table 7 and Figure 24). This transect is located at the filter marsh exit and is the fourth area to encounter freshwater runoff from the west. This transect exhibited the highest fluctuation between quartiles for mean velocity. However, it also had a mid range fluctuation between quartiles for total discharge at this transect and the second lowest mean discharge rate amongst the stations. Freshwater flows from the filter marsh into the ditch during outgoing tides, mixes with saltwater during incoming tides that enter via the ditch east end. Water flow at this transect exhibited tidal influence, the slowest velocity and the smallest recorded discharge rate during a low incoming tide; the highest velocity during a low outgoing tide; and strongest measured discharge rate occurred during a low outgoing tide. This transect exhibited and overall west to east flow, consistent with geographic location and the shallow narrow configuration (Table 7 and Figures 23 and 24).

At the ditch east end (D), flow velocity ranged from 0.003 m/s to 0.3437 m/s. During high tides the lowest velocity recorded was 0.0056 m/s when the tide was incoming, whereas during low tides the lowest velocity recorded was 0.003 m/s when the tide was incoming. During high tides the highest velocity recorded was 0.036 m/s during an outgoing tide and during low tides was 0.3437 m/s during an outgoing tide (Table 7 and Figure 23). Total discharge at the ditch east end transect ranged from 0.0021 m^3/s to 0.0651 m^3/s. During high tides the smallest discharge recorded was 0.0068 m^3/s when the tide was incoming, and during low tides the smallest discharge recorded was 0.0021 m^3/s also when the tide was incoming. Additionally, during high tides the highest discharge rate recorded was 0.0551 m^3/s during an outgoing tide and during low tides was 0.0651 m^3/s during an incoming tide at the ditch east end (Table 7 and Figure 24). This transect is located at the ditch east end where tidal waters enter the project area and is the last area to encounter freshwater runoff from the west. This transect exhibited the second lowest fluctuation between velocity quartiles and for mean velocity. However, it also had the highest fluctuation between quartiles for total discharge and the highest mean discharge rate amongst the stations. Freshwater flows exit this area during strong outgoing tides and mixes with saltwater. Water flow at this transect exhibited the greatest tidal influence; the slowest velocity and the smallest recorded discharge rated during a low incoming tide; the highest velocity during a low outgoing tide; and the strongest measured discharge rate occurred during a low incoming tide. Tidal flow dominates this transect consistent with its geographic location closest to tidal inflows and its spatial configuration (Table 7 and Figures 23 and 24).

II. Locational Comparison of Water Flow

Stations were categorized according to their geographic location from the west to the east as follows: 1) Ditch West End Entrance (B) near the box culvert where the bulk of stormwater enters the system; 2) entrance to the wet detention from the ditch (DW) where stormwater leaves the ditch after going over the first check dam and enters the retention pond, while brackish water enters from the filter marsh on an incoming tide; 3) stormwater exits from the wet detention pond and then enters the filter marsh (W) near the second check dam; 4) Filter Marsh exit (M) where stormwater water leaves the filter marsh and re-enters the ditch and; 5) Ditch East End (D) where stormwater exits the ditch on the outgoing tide and enters a tributary leading to the Gordon River. As this is a tidal system, brackish water flows in the opposite direction from east to west on an incoming tide and considerable mixing occurs between the fresh water (stormwater discharging from the east and precipitation) and brackish water (from the tributary leading to the Gordon River) (Figure 13).

There was a significant statistical difference in the mean velocities measured along a transect, between transects B & DW ($p = 0.006$); between transects DW & W ($p = 0.007$); between transects DW & M ($p = 0.019$) as stormwater exits in the direction from west to east and between W & DW ($p = 0.007$) as brackish water moves from east to west (Appendix I). Overall water velocity is significantly reduced within the wet detention pond. Mean velocities at D were higher but not significantly different from DW Additionally, there was a significant statistical difference in total discharge rates from west to east measured along the transects between B & D ($p = 0.02$) (Appendix I). This reflects the tidal nature of the area and the stronger pull of the outgoing tide exiting to the east.

Water Quality

Physical water quality parameters from November 2009 – November 2013 were typical of nearshore ditches that have access to waterways that terminate in the Gulf of Mexico. Water temperature ranged between 15.5°C to 29.6° C (mean 24°C; geometric mean 23.7°C). Salinity ranged between 0.1 ppt to 20.2 ppt (mean 2.7 ppt; geometric mean 1.05 ppt. Salinity values were typical of a tidally influenced environment. 71.9% of the time values were typical of a brackish system, freshwater 26% of the time and typical of a marine environment 2.1% of the time. Salinity tended to have values typical of freshwater systems during the summer wet season, reflective of the higher volumes precipitation and stormwater than the dry season when the system was primarily brackish. The ditch at west end (the stormwater inflow (station B)) had the most freshwater readings and the ditch at the east end (outflow (D)) had the least freshwater readings as expected given the geographic distance from the tidal waters. Conductance ranged between 265 µs to 35600 µs (mean 5029 µs; geometric mean 2093 µs), reflective of salinity ranges. Dissolved Oxygen ranged between 0.32 mg/l to 10.5 mg/l (mean 3.5 mg/l; geometric mean 2.9 mg/l). Biological Oxygen Demand (BOD) ranged from 2 mg/l to 4.8 mg/l (mean 2.1 mg/l; geometric mean 2.1 mg/l). Turbidity ranged from 1.0 NTU to 23 NTU (mean 4.1 NTU; geometric mean 3.6 NTU). Total Suspended Solids (TSS) values ranged from 0.8 mg/l to 24.4 mg/l (mean 3.8 mg/l; geometric mean 2.94 mg/l). Total Dissolved Solids (TDS) values ranged from 2.0 mg/l to 23634 mg/l (mean 2663 mg/l; geometric mean 977 mg/l). True Color values ranged from 40 PCU to 200 PCU typifying a waterbody subject to tidal driven tannins that flush into the area from the mangroves (Table 8).

Analytical nutrient results during the period of November of 2009 through November of 2013 also were similar to other nearshore stormwater influenced systems. Ammonia ranged between 0.01 mg/l to 0.35 mg/l (mean 0.08 mg/l; geometric mean 0.05 mg/l);

Nitrite ranged between 0.0 mg/l to 0.03 mg/l (mean 0.01 mg/l; geometric mean 0.01 mg/l); Nitrate ranged between 0.01 mg/l to 0.72 mg/l (mean 0.22 mg/l; geometric mean 0.17 mg/l); Total Kjeldahl Nitrogen (TKN) ranged from 0.06 mg/l to 1.3 mg/l (mean 0.7 mg/l; geometric mean 1.7 mg/l); and Total Nitrogen (TN) ranged between 0.3 mg/l to 1.7 mg/l (mean 0.94 mg/l; geometric mean 0.9 mg/l). Orthophosphate ranged between 0.03 mg/l to 0.1 mg/l (mean 0.07 mg/l; geometric mean 0.07 mg/l) and Total Phosphorus (TP) ranged from 0 mg/l to 0.23 mg/l (mean 0.08 mg/l; geometric mean 0.08 mg/l) (Table 8).

Analytical biological results for Fecal Coliform levels during the same period ranged from 1.0 cfu/100 mg/l to 3300 cfu/100 (mean 396 cfu/100; geometric mean 170 cfu/100); Chlorophyll a levels ranged from 1.0 mg/ m^3 to 28.4 mg/ m^3 (mean 5 mg/ m^3; geometric mean 3.9 mg/ m3); and Pheophytin a levels ranged from 1.0 mg/ m^3 to 15.5 mg/ m^3 (mean 3.5 mg/ m^3; geometric mean 2.6 mg/ m3). Chlorophyll a levels indicated that the waters sampled were primarily mesotrophic indicating that the waterway has a moderate level of dissolved nutrients to support the reported levels of chlorophyll a pigments in the waterway (Table 8).

I. Water Quality Parameters by Station

Results that exceed State Standards or listed criteria (detailed below) might indicate possible water quality problems that might warrant more intensive scrutiny or were just isolated spikes that occurred over time. Additionally, overtime levels can naturally fluctuate and are often weather driven.

At the Ditch West End stormwater entrance (B), dissolved oxygen was below State Standards during 58.3% of the water quality sampling events at the surface between November 2009 and November 2013. Samples reflected a freshwater environment 37.5% of the times sampled and brackish environment 62.5% of the time. Brackish readings were leaning toward the freshwater end of the scale. Turbidity levels were within State Standards; Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) levels were comparable to most Florida waters. Biological Oxygen Demand (BOD) did not appear to be impacting dissolved oxygen levels at this station, albeit all BOD levels were slightly higher than levels typical of 50% of Florida estuaries. Ammonia levels were above levels that could impact sensitive species during 42% of the sampling events at the Ditch West End entrance (B). Nitrite and Nitrate levels were within tolerances, but Total Kjeldahl Nitrogen (TKN) was considered at nuisance levels 87% of the times sampled. Total Nitrogen at the Ditch West End entrance in all cases was higher than levels typical of 50% of Florida estuaries. Orthophosphate concentrations at this station (B) exceeded guideline criteria 8% of the times sampled and Total Phosphorus exceeded levels typical of 50% of Florida estuaries 100% of the time. Water samples at the Ditch West End entrance exceeded State Standards for Fecal Coliform in 12.5% of the samples collected during the study period. The water samples were had a mean of 442 cfu/100ml or a relatively high level of fecal coliform. Water samples at this station (B) were considered eutrophic (~ 4%); mesotrophic (~ 92%) and hypereutrophic (~ 4%) of the time, while samples also indicated that low algal bloom conditions existed 79% of the time, medium algal bloom conditions 17% of the time, and high algal bloom conditions in 4 % of the water samples collected at the Ditch West End entrance. None of the annual geometric means for Chlorophyll a exceeded suggested levels, however levels were higher in individual samples in 2010 than in other years (Table 8).

Dissolved oxygen was below State Standards during 60% of the water quality sampling events at the surface between November 2009 and November 2013 at the wet detention pond (W). Samples reflected a freshwater environment 25% of the times sampled, a brackish environment 71% and a marine environment in 4% of the water quality samples at this station. Brackish readings were leaning primarily toward the freshwater end of the scale, albeit to a less extent than at the Ditch West End entrance. Wet detention pond data reflected minimal tidal influence and dominant freshwater inputs. Turbidity levels were within State Standards and Total Suspended Solid (TSS) levels were comparable to most Florida waters. Four percent of the samples at this station exceeded levels comparable to most Florida waters for Total Dissolved Solids (TDS). While Biological Oxygen Demand (BOD) did not appear to be impacting dissolved oxygen levels at this station, albeit all BOD levels were slightly higher that levels typical in 50% of Florida estuaries. Ammonia levels were above levels that could impact sensitive species during 24% of the sampling events at wet detention pond (W). Nitrite and Nitrate levels were within tolerances, but Total Kjeldahl Nitrogen (TKN) was considered at nuisance levels in 92% of water samples. Total Nitrogen in all cases was higher than levels typical of 50% of Florida estuaries at the wet detention pond. Orthophosphate concentrations at this station (W) exceeded guideline criteria 20% of the times sampled and Total Phosphorus exceeded levels typical of 50% of Florida estuaries 100% of the time. Water samples at the wet detention pond exceeded State Standards for Fecal Coliform in 12% of the samples collected during the study period. The water samples were had a mean of 446 cfu/100ml or a relatively high level of fecal coliform. Water samples at this station (W) were considered mesotrophic during the entire sampling period, while samples also indicated that low algal bloom conditions existed 60% of the time and a medium algal bloom conditions 40% of the time within the wet detention pond. None of the annual geometric means for Chlorophyll a exceeded suggested levels, however individual samples had variable levels and were higher in 2011 and 2013 (Table 8).

Within the Filter Marsh (M) dissolved oxygen was below State Standards during 58% of the water quality sampling events at the surface between November 2009 and November 2013. Samples reflected a brackish environment 75% of the times sampled and a freshwater environment 25% of the time. Brackish readings were leaning toward the freshwater end of the scale reflective of minimal tidal influence and less retention time in the marsh than the wet detention settling pond. Turbidity levels were within State Standards; Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) levels were comparable to most Florida waters. Biological Oxygen Demand (BOD) did not appear to be impacting dissolved oxygen levels at this station, albeit all BOD levels were slightly higher that levels typical in 50% of Florida estuaries. Ammonia levels were above levels that could impact sensitive species during 21% of the sampling events within the filter marsh (M). Nitrite and Nitrate levels were within tolerances, but Total Kjeldahl Nitrogen (TKN) was considered at nuisance levels 87% of the times sampled. Total Nitrogen at the Ditch West End entrance in all cases was higher than levels typical of 50% of Florida estuaries. Orthophosphate concentrations at this station (M) exceeded guideline criteria 17% of the times sampled and Total Phosphorus exceeded levels typical of 50% of Florida estuaries 100% of the time. Water samples at the Ditch West End entrance exceeded State Standards for Fecal Coliform in 4% of the samples collected during the study period. Water samples were had a mean of 344 cfu/100ml or a relatively high level of fecal coliform. Water samples at this station (M) were considered mesotrophic (96%) and oligotrophic (4%) of the time, while samples also indicated that low algal bloom conditions existed 67% of the time and medium algal bloom conditions 33% of the time water samples collected at the filter marsh. None of the annual geometric means for Chlorophyll a exceeded suggested levels, however levels were higher in individual samples in 2010 than in other years (Table 8).

Dissolved oxygen was below State Standards during 68% of the water quality sampling events at the surface between November 2009 and November 2013 at the Ditch East End (D). Samples reflected a freshwater environment 17% of the times sampled, a brackish environment 79% and a marine environment in 4% of the water quality samples at this station. Brackish readings were leaning primarily toward the freshwater end of the scale, albeit to a less extent than at any other station. Data in the Ditch East End reflected more tidal influence than the other stations. Turbidity levels were within State Standards. Total Suspended Solid (TSS) levels and Total Dissolved Solids (TDS) exceeded levels comparable to most Florida waters by 4% and 8% respectively at this station. While Biological Oxygen Demand (BOD) did not appear to be impacting dissolved oxygen levels at this station, all BOD levels were slightly higher that levels typical in 50% of Florida estuaries. Ammonia levels were above levels that could impact sensitive species during 44% of the sampling events at Ditch East End (D). Nitrite and Nitrate levels were within tolerances, but Total Kjeldahl Nitrogen (TKN) was considered at nuisance levels in 83% of water samples. Total Nitrogen in all cases was higher than levels typical of 50% of Florida estuaries at the wet detention pond. Orthophosphate concentrations at this station (D) exceeded guideline criteria 12% of the times sampled and Total Phosphorus exceeded levels typical of 50% of Florida estuaries 100% of the time. Water samples at the Ditch East End exceeded State Standards for Fecal Coliform in 4% of the samples collected during the study period. The water samples were had a mean of 354 cfu/100ml or a relatively high level of fecal coliform. Water samples at this station (D) were considered mesotrophic 96% and hypereutrophic 4% of the times sampled, while samples also indicated that low algal bloom conditions existed 68% of the time, a medium algal bloom conditions 28% of the time, and a high algal bloom condition 4% of the times sampled (4% was representative of 1 elevated sample in May of 2011 within the ditch at the east end). None of the annual geometric means for Chlorophyll a exceeded suggested levels, however individual samples had slightly higher levels overall in 2011 and 2013 (Table 8).

II. Locational Comparison of Water Quality Parameters

Stations were categorized according to their geographic location as follows: 1) Ditch West End Entrance (B) near the box culvert where the bulk of stormwater enters the system; 2) Wet Detention (W) where stormwater leaves the ditch goes over a check dam and enters the retention pond, while brackish water enters from the filter marsh on an incoming tide; 3) Filter Marsh (M) where fresh water leaves the wet detention pond on an outgoing tide over another check dam and brackish water enters from the east end of the ditch on an incoming tide and; 4) Ditch East End (D) where water enters the ditch on the outgoing tide from the filter marsh and brackish water enters the system from a tributary leading to the Gordon River on an incoming tide (Figure 13).

A. Physical Parameters

Physical parameters varied slightly in some cases accordance with station locations. Mean water temperature had a tendency to be slightly higher at westernmost stations (B (24.6 °C) & W (24.7°C)) than the easternmost stations (M (23.6 °C) & D (23.6 °C)), but the differences were not statistically significant between any of the stations. Mean salinity and conductivity were significantly different between stations B & W (p=0.006 (salinity)) (p =0.003 (conductivity)); between stations B & M (p=0.003 (salinity)) (p =0.003 (conductivity)); and between stations B and D (p=0.0005 (salinity)) (p =0.0009 (conductivity)). The highest percentage of disparity of salinity or conductivity between the means occurred between stations B and D. Overall, mean dissolved oxygen levels exhibited little variation, nor were the levels significant different between any of the stations. Median dissolved oxygen values were slightly higher at the western end of the system than the eastern end. Data exceeded State Standards for dissolved oxygen approximately two-thirds of the times sampled. The number of instances when values were lower than the State standard ranged between 58% at station B to 68% at station D along a west-east gradient. Biological Oxygen Demand (BOD) was similar throughout the stations and there were no statistically significant differences between the stations. All BOD values were < 5 mg/l indicative of being at acceptable levels for natural systems and not impacting dissolved oxygen levels (Table 8; Figure 25; and Appendix I).

The westernmost station (B) had a higher mean turbidity than the other stations, primarily due to a validated data spike during the July 2013 water sampling at this station, coincident with a post flooding event from a broken pipe offsite of our property earlier in the month. Although there were statistically significant differences between stations B and M and stations W and M, there were no instances where turbidity levels exceeded State Standards. Differences in Total Suspended Solids (TSS) were minimal and means were not statistically significant between any of the stations. Interestingly, means were slightly lower at the wet detention pond (W) and filter marsh (M) than at the ditch east and west end stations (D & B). Total Dissolved Solid (TDS) means were significantly different between stations B & W (p=0.006); between stations B & M (p=0.01); and between stations B and D (p=0.002). Overall TDS levels increased as the geography moved from east to west (D>M>W>B). Spikes >10000 mg/l were found at the easternmost stations (M & D) coincident with higher tidal influence. Outliers of > 23000 mg/l TDS were verified and occurred during the May 2011 sampling event when water levels were extremely low to the extent that the filter marsh (M) and Ditch East End (D) stations were dry. Color was not significantly different between any of the stations and overall data was similar (Table 8; Figure 25; and Appendix I).

B. Nutrient Parameters

Nutrient levels overall were typical of areas that are subjected to stormwater runoff. Overall mean ammonia concentrations exhibited a west-east gradient where the highest mean concentration was in the west, albeit the easternmost station D had slightly higher means than stations M or W consistent with station D's location within a productive mangrove forest. Mean ammonia concentrations were significantly different between stations B & W (p=0.02: B>W) and between stations B & M (p=0.03: B>W). Mean ammonia was not statistically different between stations B and D, however the mean was higher at station B (freshwater inflow) than station D (freshwater outflow on an outgoing tide). Overall ammonia levels decreased as the geography moved from west to east (B>D). There was a 14% decrease between the Ditch West End (stormwater entrance (B)) and the Ditch East End (stormwater exit on an outgoing tide (D)); and a 41% decrease in ammonia between the Ditch West End (stormwater entrance (B)) and the wet detention pond (W); and a 41% decrease between the Ditch West End (stormwater entrance (B)) and the Filter Marsh (M). The percent of the time that ammonia levels exceeded concentrations that could impact sensitive species had the higher percent of exceedances at stations B and D (42% and 44% respectively) (Table 8; Figure 25; and Appendix I).

Overall mean nitrite and nitrate levels exhibited a west-east gradient where the highest mean concentration was in the west, although differences were very slight amongst stations particularly in regard to nitrite where values differed by less than thousandths of a mg/l and there were no exceedances in any of the samples. Mean nitrite concentrations were significantly different between stations B & M (p=0.01: B>W) and between stations D & M (p=0.01: D>M) and mean nitrite levels decreased 6% between the Ditch West End (stormwater entrance (B)) and the Ditch East End (stormwater exit on an outgoing tide (D)). Mean nitrate concentrations were also significantly different between stations B & D (p=0.01: B>D), with a 33% decrease in nitrate between the Ditch West End (stormwater entrance (B)) and the Ditch East End (stormwater exit on an outgoing tide (D)) (Table 8; Figure 25; and Appendix I).

Mean total Kjeldahl nitrogen (TKN) concentrations were similar between stations, where TKN levels were slightly higher at station B than the other stations. All stations had exceedances greater than 50% of the time where values were considered at nuisance levels. Mean TKN concentrations were significantly different between stations B & M (p=0.04: B>M), where mean TKN levels decreased 13% between the Ditch West End (stormwater entrance (B)) and the filter marsh (M). TKN levels between the Ditch West End (stormwater entrance (B)) and the Ditch East End (stormwater exit on an outgoing tide (D)) decreased by 7%. TKN outliers of >1.2 mg/l were verified and occurred during either the September 2010 (B & W) or November 2010 (D). Mean total nitrogen concentrations decreased 16% along a west-east gradient, where the Ditch West End (stormwater entrance (B)) had the highest mean concentration and the Ditch East End (stormwater exit on an outgoing tide (D)) had the lowest mean. All stations had 100% exceedances to FDEP's standard for Naples Bay. Mean total nitrogen concentrations were significantly different between stations B & D (p=0.01: B>D) and between stations B & M (p = 0.01: B>M) (Table 8; Figure 25; and Appendix I).

Mean orthophosphorus levels were similar during the study period and there were no significant differences between stations. However, values were higher at times than standards suggested by CHNEP. Mean total phosphorus levels decreased 16% along a west-east gradient, where the Ditch West End (stormwater entrance (B)) had the highest mean concentration and the Ditch East End (stormwater exit on an outgoing tide (D)) had the lowest mean. However, there were no statistically significant differences between stations. All stations had 100% exceedances to FDEP's standard for Naples Bay) (Table 8; Figure 25; and Appendix I).

C. Biological Parameters

There were no statistically significant differences between any of the stations for fecal coliform. Overall mean fecal coliform concentrations exhibited a west-east gradient where higher mean concentrations were in the western stations (B and W). Mean fecal coliform levels decreased 20% between stations B and D. Fecal coliform concentrations exceeded State Standards 12.5% of the times sampled at Ditch West End (stormwater entrance (B)); 12% of the times sampled at the wet detention pond (W); 4.2% of the times sampled at the Filter Marsh (M); and 4% of the times sampled at the Ditch East End (stormwater exit on an outgoing tide (D)). Fecal coliform spikes >2000 cfu/100ml were verified and occurred during the January 2011 sampling event coincident with accidental overflow of a nearby pelican rehabilitation pond (Table 8; Figure 25; and Appendix I).

There were also no statistically significant differences between any of the stations for chlorophyll a concentrations. Chlorophyll a levels exceeded State Standards for Naples Bay one time at Ditch West End (stormwater entrance (B)); two times at the wet detention pond (W); one time at the Filter Marsh (M); and 0 times at the Ditch East End (stormwater exit on an outgoing tide (D)) (Table 8; Figure 25; and Appendix I).

<u>Wildlife Assessments</u>

A. Fish Sampling

There was a significant difference (Global R = 0.38, $p = 0.033$) in the composition of the wet season fish assemblages between pre- and post-construction of the filter marsh; however, the low to intermediate R value indicates there is overlap between the compositions. SIMPER indicated an intermediate average dissimilarity (59.01%) with a decrease in CPUE for *Tilapia* sp. and *Cichlasoma urophthalamus* and an increase in that of *Poecilia latipinna* and *Gambusia holbrooki* following filter marsh construction (Table 9). There was a significant difference (Global R = 0.357, $p = 0.003$) in the fish composition among years; however, none of the pairwise annual comparisons were significantly different despite a few fairly large R values (Table 10). As indicated in the Methods sections, this is an artifact of the small number of replicates each year (n = 3) that only resulted in 10 possible permutations for the pairwise tests. The low R value for 2008 and 2010 indicates very little change in fish composition in the year following construction and this was due to less abundant taxa that were not captured in subsequent years (*Cichlasoma bimaculatum*, *Heterandria formosa*, *Jordanella floridae*, *Lucania goodei*, and *Mugil* spp.; Table 11). High R values for 2008 and 2011 and for 2008 and 2012 indicate fish compositions for the following 2 years were differentiated from that of pre-construction. However, the low R value for 2008 and 2013 indicates the compositions were once again overlapping due to increased CPUE for *Tilapia* sp. and *Cichlasoma urophthalamus* in 2013 and less abundant centrarchid taxa captured during these years (*Lepomis macrochirus*, *Lepomis microlophus*, and *Chaenobryttus gulosus*). SIMPER indicated that dissimilarities among these years were primarily due to a decrease in CPUE for *Tilapia* sp. during 2010-12 and an increase in that of *Poecilia latipinna* in 2013 (Table 12). There was a significant tendency for seriation of fish compositions between construction status ($\rho = 0.312$, $p = 0.032$) and among years ($\rho = 0.326$, $p = 0.007$), indicating an ordered change in composition following construction of the filter marsh, but the relatively small values for ρ do not suggest a strongly ordered gradient.

B. Avifaunal Surveys

Three hundred and thirty-seven birds consisting of 35 species of birds were observed during avian censuses from 2008-2013 pre and post-construction (70 birds consisting of 15 species preconstruction in 2008; and 267 birds consisting of 35 species post-construction from late 2009-2013) (Table 13). During the wet season the number of birds prior to construction was not significantly different (Global $R = 0.162$, $p = 0.151$) from that of post-construction and the low R value indicates little or no difference between overall number of birds. There was not a significant difference (Global $R = -0.028$, $p = 0.561$) in the bird numbers among years and the negative R value indicates more variation among replicates within a year than that among different years. There was no significant tendency for seriation of bird numbers between construction status ($\rho = 0.135$, $p = 0.156$) and among years ($\rho = 0.032$, $p = 0.364$).

Pre and post-construction surveys revealed a shift in the types of birds that were using the project area. There was a 42% increase in species richness pre to post-construction. Pre-construction, *Polioptila caerulea* (blue-gray gnatcatcher) were the most abundant species, followed by *Buteo lineatus* (red-shouldered hawk) and *Cardinalis cardinalis* (northern cardinal), respectively. Other species that were abundant pre-construction included *Cyanocitta cristata* (blue-jay) *Coragyps atratus* (black vulture), *Dendroica coronata* (yellow-rumped warbler), *Dendroica pinu,* (pine warbler), and *Melanerpes carolinus* (red-bellied woodpecker) (Table 13). Birds that were observed pre-construction were primarily Passeriforms that frequented the upland forested areas adjacent to the project area and the grass field. Post-construction, *Eudocimus albus* (white ibis), were the most abundant species, followed by *Cyanocitta cristata* (blue-jay), and *Mycteria americana* (wood stork), respectively. Other species that were abundant post-construction included *Zenaida macroura* (mourning dove), *Anas fulvigula* (mottled duck), *Ardea alba* (great egret), and *Dendroica spp.,* (warbler) (Table 13).

Avian species that were observed post- construction but not pre-construction included:

Scientific Name	Common Name	Order	Type
Anas fulvigula	Mottled duck	Anseriformes	Waterfowl
Anhinga anhinga	Anhinga	Suliformes	Water bird
Ardea alba	Great egret	Pelecaniformes	Wading bird
Ardea herodias	Great blue heron	Pelecaniformes	Wading bird
Buteo jamaicensis	Red-tailed hawk	Falconiformes	Bird of prey
Butorides virescens	Green heron	Pelecaniformes	Wading bird
Cairina moschata	Muscovy duck	Anseriformes	Waterfowl
Cathartes aura	Turkey vulture	Carhartiformes	Bird of prey
Egretta caerulea	Little blue heron	Pelecaniformes	Wading bird
Egretta thula	Snowy egret	Pelecaniformes	Wading bird
Egretta tricolor	Tricolored heron	Pelecaniformes	Wading bird
Elanoides forficatus	Swallow-tailed kite	Accipitriformes	Bird of prey
Eudocimus albus	White ibis	Pelecaniformes	Wading bird
Haliaeetus leucocephalus	Bald eagle	Accipitriformes	Bird of prey
Megaceryle alcyon	Belted kingfisher	Coraciiformes	Water dependent
Mycteria americana	Wood stork	Ciconiformes	Wading bird
Nycticorax nycticorax	Black-crowned night-heron	Pelecaniformes	Wading bird
Nyctanassa violacea	Yellow-crowned night-heron	Pelecaniformes	Wading bird
Phalacrocorax auritus	Double-crested cormorant	Suliformes	Waterbird

Eighty-three percent of the avifauna that began to utilize the project area post-construction were a type of wading and/or water bird that utilized the constructed water features.

C. Anuran Survey

There was a significant difference (Global R = 0.225, p = 0.012) in the composition of the wet season frog assemblages between pre- and post-construction of the filter marsh; however, the low R value indicates strong overlap between the compositions. SIMPER indicated a high average dissimilarity (76.04%) primarily due to the substantial decrease in *Hyla cinerea* after construction (Table 14). There was a significant difference (Global R = 0.14, p = 0.001) in the frog composition among years. For pairwise annual comparisons, the frog composition for 2008 was significantly different from all post-construction years but the low to intermediate R values suggest overlap in compositions. SIMPER indicated the dissimilarities were the result of the low abundance for *Hyla cinerea* during the years after filter marsh construction (Table 14). There was a significant tendency for ordered change with frog compositions between construction status (ρ = 0.186, p = 0.012) and among years (ρ = 0.164, p = 0.013), but the small values for ρ suggest a very weak gradient.

Incidental observations of wildlife utilizing the project area included a variety of species, from river otters to American alligators (Table 16).

DISCUSSION

During this study period, several unforeseen and uncontrollable factors occurred outside our realm of influence on neighboring properties. Construction occurred on the property line directly adjacent to the filter marsh where a large swath of vegetation consisting of mature trees and a healthy underbrush was removed. This had the effect of removing most shading from the area which influences water temperature and thus dissolved oxygen levels and the local ecology through removal of habitat. Additionally, during construction on the neighboring property large stormwater pipes were severed and all the water ended up in our filter marsh, which elevated flow way beyond tolerance and silted in parts of the study area within a few days.

Hydrology

Surface water levels and sheetflow are sensitive to slight changes in topography due to Florida's extremely flat landscape, as small changes in elevation can produce large fluctuations in water level inundation patterns (Ball and Schaffranek, 2002; Desmond, 2002). Therefore, significant differences in topography can result in significant differences in water levels and retention such as seen in this constructed wetland. The wet detention pond had the deepest levels consistent with excavation depths and overall the filter marsh had the shallowest levels consistent with subtle microtopography and higher dependence on sheetflow.

The hydrology of natural mangrove systems is complex and is further complicated by human induced alterations. Tidal fluctuations within this site were affected by: 1) normal tidal rhythms in conjunction with lunar cycles; 2) proximity to tidal tributaries; 3) stormwater inflow and the presence of ditches that drain adjacent residential, roadway and commercial areas; 4) and seasonal variation. Tidal ranges as expected were muted at the western end of the ditch, which is situated the farthest from tidal inflow. The Ditch East End entrance (B) had less tidal influence and was strongly influenced by rain and stormwater inflows as this station is more subject to the vagaries of stormwater inflows from outside areas. Precipitation often overshadows tidal signals as levels rise rapidly after a rain event and then slowly recede causing the tidal signal to have no effect at the western end of the area, as the freshwater signature overshadows the saltwater tide rise and fall.

By replacing the existing triple 19"X30" ERCP ditch culvert with a 5'X7' box culvert upstream head conditions were reduced, slowing down the flow velocity. Similarly, total discharge rates were significantly reduced between the Ditch West End entrance (B), where freshwater enters, and the Ditch East End (D), the last station before the freshwater exits the ditch into the tidal tributary. Similar to the effects reported by Rushton, et., al., in 2004, the increased travel time through the constructed wetland and the decreased velocity, appeared to reduce the discharge rates on a low outgoing tide. Therefore, from a construction standpoint the installation of the wet detention pond and filter marsh achieved its goal of slowing the fresh water flow and increasing the water retention time that should allow for increasing pollutant removal.

Water Quality

Many of Florida's nearshore estuaries have been altered to prevent flooding. Anthropogenic alterations to the natural hydrology included the construction of canals and ditches, channelization of natural flow-ways, and diversion of stormwater runoff. Stormwater runoff is a major contributor of pollution to nearshore waterways. It introduces nutrients, organic debris, silt, metals, oil, gas, herbicides and pesticides into nearshore ecosystems without the benefit of filtration from natural sheetflow. The diversion of stormwater runoff from roads and adjacent residential communities has altered natural sheetflow, thereby altering the natural salinity regime and often reducing habitat suitability for numerous species of estuarine flora and fauna. Destruction of mangrove shorelines for development has destroyed or impaired natural filtering mechanisms for terrestrial runoff (Boyer, et. al., 2005). Increased human usage and loss of habitat leads to degraded water quality and can create stress or even cause loss of estuarine species. Water quality degradation is among the leading stressors to estuarine and marine systems due to its numerous sources and the persistence existence of pollutants (Boyer, et. al., 2005).

Water quality physical parameters, such as salinity, temperature, dissolved oxygen, conductivity, turbidity and total dissolved solids, etcetera, all influence the type of aquatic ecosystem found in a specific area. Whereas, nutrient concentrations, such as ammonia, nitrate, nitrite, phosphorus, total Kjeldahl nitrogen (TKN), etcetera, all are important, at specific concentration ranges, to the health of the ecosystem. Alternatively, biological parameters, including bacteria, algal populations, invertebrates, vertebrates, etcetera, when maintained at proper population levels ensures balanced communities. Other considerations such as heavy metals and pesticides are not specifically addressed in this project, but if present in high concentrations can be fatal to a estuarine environment.

The effects of season and runoff are the two major causes of variation in water quality (Lietz, A.C., 2000). Season can effect water quality on an annual scale, where as runoff is often localized. Additionally, climate can influence water quality trends long-term. Physical water quality parameters in the project area varied seasonally, geographically and amongst stations. Overall, the water quality monitoring station located at the Ditch West End entrance (B) was higher in temperature, turbidity, and most nutrient parameters quantified during this study period in comparison to stations located east, closer to tidal inputs. Several additionally inflows were added to the mix during the study period which had short-term effects on the water quality including a broken water main and an additional stormwater pipe which was added to the ditch north of the project area.

Anecdotal evidence suggested that water during times when stormwater is flowing has had an effect on the water quality of the inflow, particularly during high rainfall events when this new input overflows into the ditch. The stormwater coming down the ditch from Lake Park and the mall was flowing strong and had clear water, whereas the pipe that connects to the gopher tortoise preserve "filter marsh" had a weaker flow and the water was dark colored. The two flows were distinct coming into the box culvert and then mixed thereafter. This new unanticipated input could have an effect on the water quality parameter concentrations during thunderstorms.

One factor which can influence water quality is precipitation. A period of heavy precipitation, combined with less tidal mixing from the Gulf, can result in a decrease in salinity which can influence the type of species that reside in the area, dependant upon their salinity tolerances. Also, precipitation increases runoff and erosion which can increase nutrient concentrations such as ammonia, nitrate, TKN and phosphorus. Nutrient loading in turn, can accelerate algal growth. As the algae deplete the nutrient source, they die off, releasing toxins which can cause fish kills. Also, as algae decompose dissolved oxygen levels drop, sometimes to a level that can prove fatal to aquatic inhabitants.

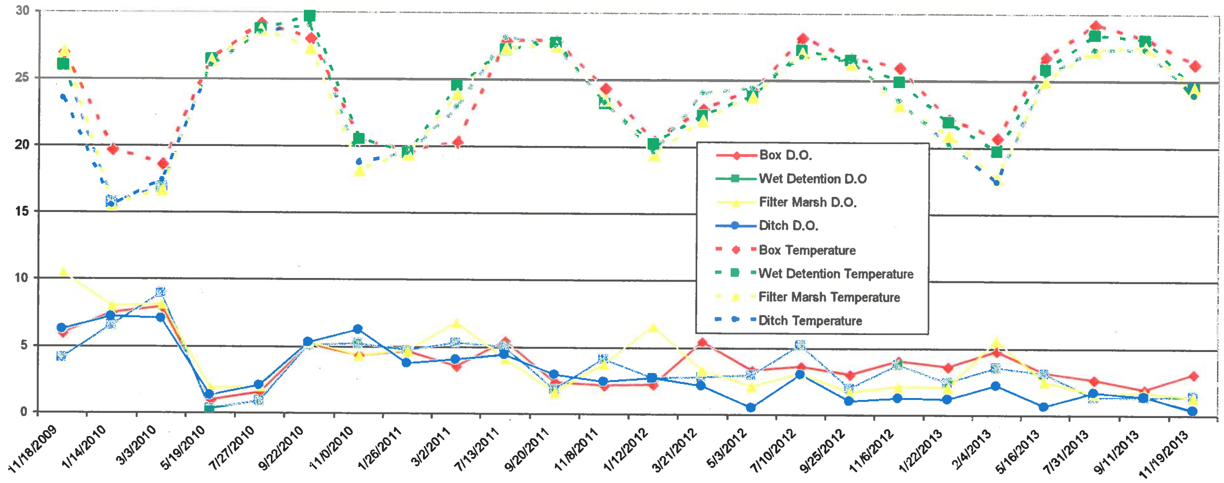
Changes in nutrient concentrations are influenced by numerous factors including: season, precipitation, temperature, dissolved oxygen, runoff, erosion, algal blooms, bacteria levels, sewage outfall and pollutant levels introduced to our waterways from fertilizers and improper waste disposal. These factors, and numerous others, all vary continuously and their combined effects influence water quality.

A. Temperature, Dissolved Oxygen & Biological Oxygen Demand

Natural communities have adapted to seasonal environmental conditions. The annual climatic cycle in southwest Florida typically consists of a dry season, where periodically severe drought conditions may persist resulting in higher salinities in near shore areas. In the wet season to prevent potential flooding in developed areas, stormwater is shunted off of roadways and land as quickly as possible usually into waterways. In the dry season, watering of lawns, lowers aquifers more than natural – thus creating two extremes.

Temperature is a factor that affects the amount of dissolved oxygen present in waterways. Dissolved oxygen has an inverse relationship with temperature. As expected, due to the inverse relationship between water temperature and dissolved oxygen, during the summer when water temperatures increased, dissolved oxygen decreased in most cases, and this trend was reversed during the winter due to normal seasonal temperature patterns (Figure 26).

Figure 26: Water Temperature vs Dissolved Oxygen Levels



Other factors, besides temperature, can influence the amount of dissolved oxygen, including algal blooms (which increases the dissolved oxygen, during the bloom, and depletes the oxygen in the water as the algae decompose) and salinity (freshwater holds more oxygen that saltwater). Additionally, flowing water is more apt to have higher dissolved oxygen levels than stagnant water. Low dissolved oxygen levels are usually indicative of higher than normal rates of decomposition often found in mangrove areas. This eastern side of the project area terminates in a mangrove forest, which could explain why dissolved oxygen levels were slightly lower in the Ditch East End (D). Mangrove soils have been described as highly anaerobic, sulphidic, inundated muds, whose physicochemical properties vary with elevation and forest type (Alongi and Sasekumar, 1992).

Since dissolved oxygen levels were not recorded over a 24-hour period, interpretation of data is slightly constrained. Surface water dissolved oxygen typical to this area usually exhibit a strong diel cycle with concentrations ranging from 0 mg/l in the early morning to 12 mg/l in the late afternoon (U.S. EPA, 2000). Low dissolved oxygen concentrations that were below State Standards could be indicative of shallow water and/or higher water temperatures typical to the area and, therefore, may not be indicative of impaired water quality. Alternatively, instances of low dissolved oxygen readings during the wet season could be indicative of heavy algal concentrations or vegetative decomposition of plants that has been exacerbated by heavy point source freshwater inflows carrying excess nutrients into this system. Dissolved oxygen readings were below State Standards 50% of the time sampled and there were no significant differences between the stations. Dissolved oxygen levels are often naturally lower during the summer, particularly during times when water levels were shallow. The danger occurs when levels drop to levels that are extremely anoxic, which is indicative of higher than normal natural decomposition levels and if persistent can kill aquatic organisms. The levels found in this site were low, but did not persist long enough to cause a die-off of aquatic organisms that were present in the area.

Biological Oxygen Demand is a measurement of the amount of dissolved oxygen needed by aerobic organisms to break down organic detritis. If BOD levels are high enough dissolved oxygen decreases in the water since it is being utilized by bacteria. BOD measurements were similar throughout the project area and were not at levels that could cause any substantial impact to dissolved oxygen levels. All BOD values were less than concentrations reported for National and Florida mean concentrations in residential and commercial stormwater runoff (Martin and Coffey, 1991).

B. Salinity & Conductivity

Salinity measures the amount of dissolved salts in a measured volume of solution and is closely related to the amount of total dissolved solids. It is an important factor often delineating the distribution of aquatic species in estuaries and brackish areas such as the project area. Temperature and salinity can affect the toxicity of chemicals. Estuarine and brackish waters are particularly sensitive, since the toxicity can increase in some cases and be compounded by tidal variations (United States Department of the Interior, 1998).

Higher values for conductivity and salinity, as expected occurred in areas located in closer proximity to tidal waters. These areas have a larger volume of tidal exchange than the other areas. Conversely, as expected, lower salinity and conductivity measurements were found at stations located the greatest distance from tidal influence. Overall, the project area had brackish water that tended to lean toward the freshwater end of the scale. Although this fact seems to be indicative that precipitation and freshwater inputs were stronger than marine tidal influence, this is not likely the case. Tidal waters that entered the project area were brackish, consisting of a mixture of many freshwater inputs and mixing that occurs throughout the Gordon River, which feeds the tidal tributary into the project area.

C. Turbidity & Total Suspended Solids (TSS) & Total Dissolved Solids (TDS) & Color

Turbidity is made up of organic and inorganic material and the velocity of the water largely determines the composition of the suspended load. High turbidity levels can be caused by large amounts of particulate such as carbonate mud, sands, peat, detritus, algae and bacteria present in the system. Many factors can increase turbidity including natural events such as rainfall and wave action. Natural turbidity levels can be exacerbated by human activities that cause increased soil erosion, water discharge, urban runoff, excessive algal growth and stirred up sediments from dredging or boating etcetera. Chronic turbidity by suspended organic and inorganic particles can have a detrimental effect on many aquatic communities by decreasing the amount of sunlight able to penetrate the water column. There were no instances where turbidity was higher than the State Standard and only one instance where turbidity was higher than 20 NTU at the Ditch West End entrance. This instance, albeit verified was likely due to sediment resuspension in the water column that was created during sampling or an isolated incident since this level was not representative of particulate matter regularly present in the water column at this station.

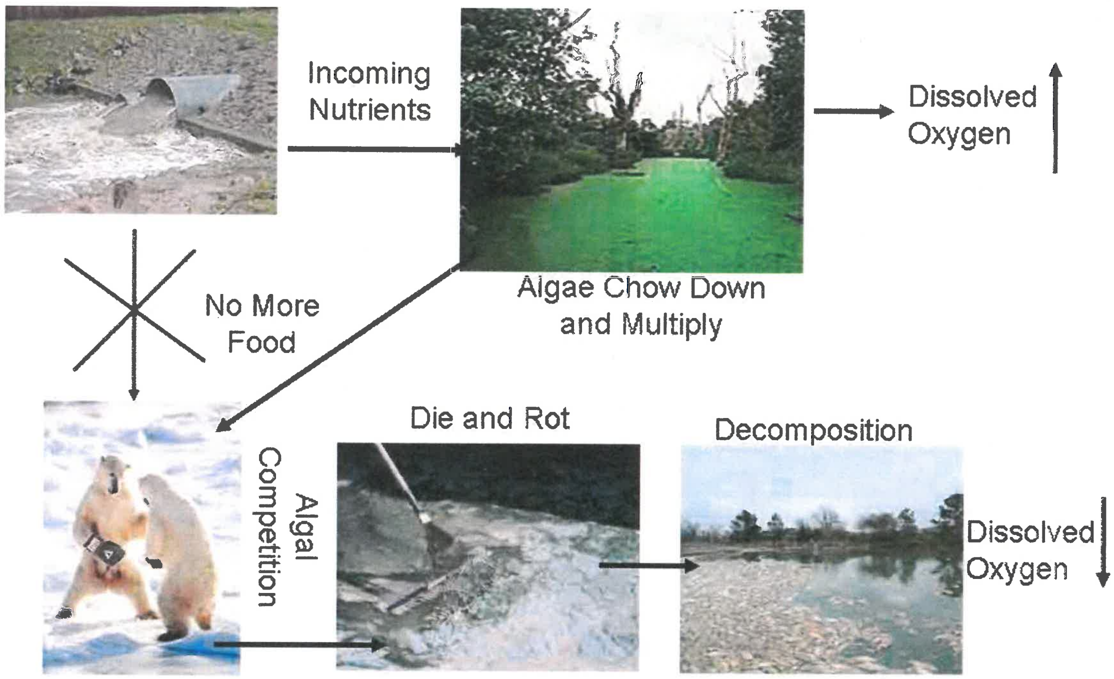
TSS consists of all particulates that will not pass through a filter and has an inverse relationship with the ability to support aquatic life. As TSS levels increase the suspended solids adsorb heat, increasing the water temperature and decreasing the dissolved oxygen present in the water column. Highly turbid water full of suspended solids has many detrimental effects on an estuarine environment if allowed to continue for an extended period of time. Solids can settle on bottom habitats blocking sunlight to aquatic vegetation that can lead to their demise. Very high TSS concentrations clog fish gills causing asphyxiation, reduce the survival of sensitive species, reduce growth rates in fish and alter egg and larval development, foul filter feeder animals, hinder the ability of aquatic predators from spotting and tracking down their prey and can carry adsorbed pollutants (Ruston, et., al., 2004). All TSS values were less than typical concentrations for Florida estuaries (Ramsey, 2003) and less than National and Florida mean concentrations in residential, commercial and urban roadway stormwater runoff (Martin and Coffey, 1991).

TDS is a measurement that consists of all inorganic and organic substances dissolved in the water such as minerals and nutrients in molecular or micro-granular forms. Changes to TDS can affect organisms at the cellular level and if the TDS levels are too low or too high then growth can be negatively affected. Factors that influence TDS can include: 1) geology as TDS will increase if the rocks are subject to dissolution such as limestone; 2) stormwater runoff; 3) soil erosion from natural or anthropogenic causes and; 4) decaying plants and animals. Normally TDS is measured in freshwater systems since salinity ions in salt or brackish waters can contribute to the TSS levels. Thus, since this site is primarily brackish, salt ions might have had some influence on TDS levels. Interestingly, however there were significant decreases in TDS levels along a west to east gradient where salinity levels were higher in the east than the west. There were two instances at the Ditch East End (D) and one instance at the wet detention pond (W) when TDS levels were greater than 15000 mg/l, which could have been detrimental to some fish species if levels had continued to be elevated.

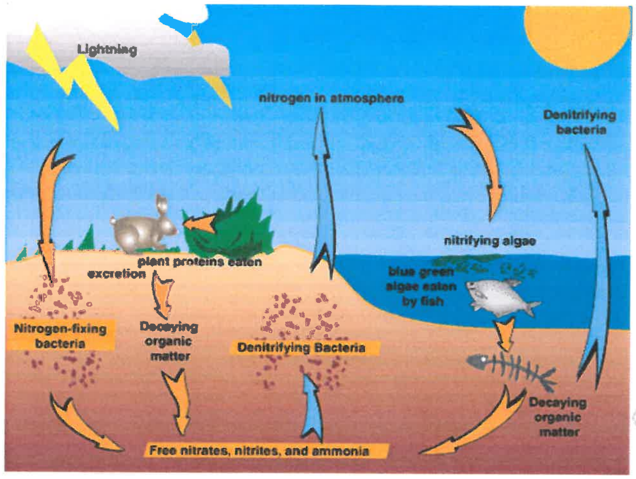
True color is determined primarily from dissolved organic matter such as tannins which give water a weak tea color and are found in mangrove areas like this site. Color was similar throughout the site and did not appear to have any effect on system biota.

D. Nutrient Concentrations

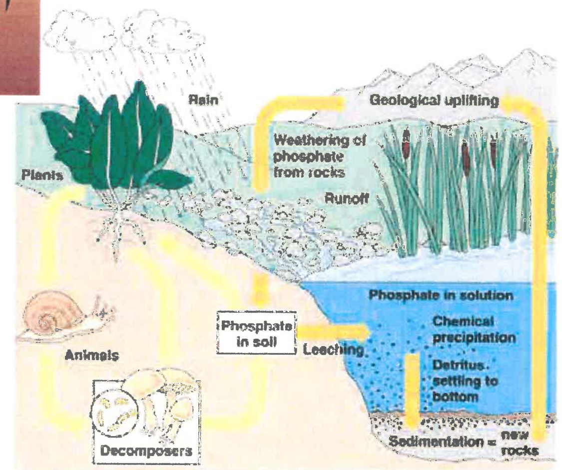
Nitrification increases primary production in plants. An increase in primary production can spur competition among and between primary producers that can lead to a shift in species assemblages. For example, if nutrients are introduced into the water through a storm pipe this will accelerate primary production. Primary production within the water column is not necessarily detrimental since some nutrients are necessary for growth in plants that form the base of the food chain. The problem lies when the influx of nutrients is above natural requirements or excessive. Excessive nutrients can trigger huge algal blooms. If this occurs, sooner or later the nutrients in the water will be unable to sustain exponential algal growth rates. Competition among the algae ensues and the algae begin to die-off and decompose. The decomposition process removes oxygen from the water and if the oxygen levels go low enough a fish kill could occur.



Some practices that contribute to nitrogen and phosphorus pollution include: 1) Overuse of fertilizers in both residential and agricultural settings; 2) Rainfall flowing over cropland and pastures, picking up animal waste that runs off into the water; 3) Rainfall flowing over urban areas like parking lots, lawns, rooftops, and roads; 4) Discharge of nitrogen and phosphorus from waste-water treatment plants; 5) Overflow from septic systems.



Nitrogen Cycle
www.fossweb.com



Phosphorus Cycle
phos-cyclenc.tripod.com

Data indicated that the Ditch West End entrance (B), where the stormwater flows into the project area, was the most susceptible to increased nitrification as this station was significantly higher overall in nitrogen derivatives and total nitrogen levels were significantly higher in comparison to the stormwater outflow at the Ditch East End (D). Total phosphorus concentrations mirrored the results found concerning increased nitrification, in that station B had the higher levels overall, however they were not significantly different amongst the other stations. Interestingly, orthophosphorus levels did not appear to contribute to the higher total phosphorus concentrations at the Ditch West End, since levels were similar throughout the project area. Since nitrogen and phosphorus concentrations were higher at station B, this suggests that nutrient loading was the highest at this station, indicative that installation of BMP's used in this project reduced nutrient loading.

Water quality results hinted at the possibility of a distinct separation between geographic locations. In general, the closer the station was to the stormwater inflow the higher the nutrient concentrations and the lower the physical parameters like salinity and conductivity, particularly during the wet season. In most instances there was a noticeable division in parameters along an east to west gradient. This is indicative that the more western parts of project area exhibited less tidal frequency and/ or amplification and therefore lower circulation and less flushing, along with more nutrient laden stormwater than the eastern sections of the project area.

a) Ammonia

Ammonia is naturally formed through the fixation of atmospheric nitrogen and hydrogen by microbes, through the decomposition processing of plants and animals, and excretion by fish and other aquatic animals. Factors which can increase ammonia concentrations include heavy applications of fertilizers, which are delivered to our waterways by runoff and erosion. Higher ammonia levels present during the summer can most likely be attributed to increased use of fertilizers. Ammonia concentrations throughout the project area were at levels that could impact the growth rate of sensitive aquatic species less that 50% of the times sampled.

There was a significant decrease (41%) in ammonia concentrations between the Ditch West End entrance (B) and the wet detention pond (W) and also the Filter Marsh (M). Additionally, there was a decrease (14%) between the Ditch West End entrance (B) and the Ditch East End (D). Higher than normal ammonia levels can occasionally appear in tidal waters like those found at the Ditch East End (D) and can be attributed to an increase bacterial activity in the water column adjacent to the organic rich soils of the mangrove forest that fringes the east end of the ditch. This phenomenon could explain why there was less of a decrease between the stormwater inflow and outflow stations than at the middle stations along the treatment train.

b). Nitrite-Nitrate & Total Kjeldahl Nitrogen (TKN) & Total Nitrogen

Nitrite and nitrate are produced by different natural processes. Ten percent of nitrate comes from fixation of nitrogen (gas) to ammonia or nitrate. Nitrate is the product of high energy fixation by lightning, cosmic radiation and meteorite trails. In this process atmospheric nitrogen combines with oxygen to form nitrates, which consists of nitric acid in rainfall. Approximately 90% of nitrate is formed through biological fixation. Blue-green algae can "fix" nitrogen present in the water into ammonia. Nitrification is the process where ammonia is oxidized into nitrite and nitrate. Nitrite in turn is short-lived and quickly oxidizes into nitrate.

Nitrate and nitrite can originate from nonpoint sources and point sources. Nonpoint sources are usually over a widespread area and often difficult to trace. Residential and urban nonpoint sources include nitrogenous fertilizers on lawns and gardens, leaky on site wastewater disposal and septic systems, sewage treatment system and bypass outfalls and domestic pet and wildlife excretion. Point sources in residential areas may include glass and heat transfer fluid and heat storage medium for solar heating applications, offshore sewage pipe and bypass outfalls and sewage treatment systems during heavy flow periods.

Nitrite concentrations, albeit not significant, were only slightly higher at the Ditch West End entrance than the Ditch East End (stormwater exit), while significantly higher at the Ditch West End entrance than at a mid-station in the treatment train, the filter marsh (M). Nitrite oxidizes rapidly, therefore samples that were higher than average, most likely, were collected close to a source of decomposition. Stations located in the eastern end of the project area are likely subjected to organic matter decomposition, while the western stations could possibly be contaminated from a sewage and/or stormwater outfall and/or concentration of material from lack of circulation. Nitrate concentrations were significantly greater at west stormwater inflow than at the east stormwater outflow. Nitrate levels within the project area decreased 33%. Higher nitrate levels are often present during the summer, which can usually be attributed to an increase in the use of fertilizers.

TKN measures the amount of organic nitrogen and ammonia. An increase in TKN concentration level is an indication of nutrient loading, which could trigger algal blooms. TKN levels are influenced by fertilizers delivered to waterways by runoff and erosion. TKN concentrations as expected mirrored nitrogen derivative and ammonia results in that levels were higher near the stormwater inflow in the west and overall TKN levels decreased thirteen percent from the stormwater inflow to the stormwater outflow. TKN values were often at nuisance concentrations that could increase algal growth (Ramsey, 2003), however concentrations were less than National and Florida mean concentrations in commercial and urban roadway stormwater runoff, but slightly higher than mean residential concentrations (Martin and Coffey, 1991).

Nitrogen compounds are transported into waterways mostly from overflow runoff and also via ground water and precipitation. Since, cold prohibits nitrification, the highest nitrogen fixing activity occurs in the spring and summer. Nitrogen containing fertilizers are applied to agricultural and residential lawns and gardens and are assimilated by plants. In estuaries, nitrogen is the primary limiting factor in algal production (phosphorus is the limiting factor in freshwater). So, high nitrogen levels increase algal growth. There was nitrogen reduction of 16% between the stormwater inflow and outflow. Of note is that all of the geometric means were higher than the standard set for Naples Bay.

c). Ortho-phosphorus & Total Phosphorus

The eleventh most abundant mineral in the earths crust is phosphorus. Natural inorganic phosphorus deposits are found as phosphate in apatite (mineral) found in rocks. When released into the environment phosphate becomes orthophosphate (in accordance with the pH of the surrounding soil). In marine systems phosphorus exists as either a particulate or in dissolved form. Particulate matter includes living and dead plankton or precipitates of phosphorus. Dissolved phosphorus includes inorganic and organic phosphorus excreted by organisms and macromolecular colloidal phosphorus. The organic and inorganic particulate and soluble forms of phosphorus undergo continuous transformations. Dissolved phosphorus (orthophosphate) is assimilated by plankton becoming organic phosphorus which is in turn ingested by detritivores or zooplankton and excreted as inorganic phosphorus. Sediments often serve as sinks which remove phosphorus from circulation until the sediment is disturbed or upwellings occur, which puts it back into circulation.

Phosphorus sources can be both nonpoint and point sources present in water as orthophosphate, polyphosphate and organic phosphate. Nonpoint sources include natural phosphorus deposits and phosphate rich rocks which release phosphorus during weathering, erosion and leeching. Sediment upwellings can re-release phosphorus into circulation. Additionally, manmade nonpoint sources such as runoff from phosphate mines and use of phosphorus containing fertilizers on agricultural and residential areas are easily dissolved into water and transported in runoff. Another nonpoint source is phosphorus containing sewage. Point sources include sewage treatment plants, industrial products such as toothpaste, detergents, pharmaceutical and food treating compounds. Humans alone excrete 1.3 to 1.5 grams per day. Water treatment systems remove only 10% of phosphorus in the waste stream and if a secondary treatment exists it removes only 30% and the rest goes into the water. Phosphorus is transported to waterways directly by sewage treatment plants and indirectly by overland flow. Most phosphorus is converted to orthophosphate by biological oxidation and removal can occur through adsorption, precipitation, complexation and precipitation. Additionally phosphorus can be retained in substrates long-term (Vymazal, 1998).

Recycling of phosphorus can often stimulate algal blooms. Interestingly ortho-phosphorus levels were similar throughout the project area, whereas total phosphorus had a 16% reduction from the Ditch West End stormwater inflow and the Ditch East End stormwater outflow. Of note is that all total phosphorus levels are higher than concentrations reported for National and Florida mean concentrations in residential and commercial stormwater runoff (Martin and Coffey, 1991) and all of the geometric means were higher than the standard set for Naples Bay.

E. Biological Parameters

a). Fecal Coliforms

Bacteria are among the simplest, smallest and most abundant organisms on the earth. Coliform bacteria serve as an indicator of potential bacteria pathogen contamination in our waterways. It has been estimated that 40% of private and 70% of spring fed water supplies contain coliform bacteria. Fecal coliform originate in the intestinal tract of warm blooded animals. Every day the average human excretes billions of coliform bacteria. Although not a direct impact on natural communities, the presence of these bacteria and viruses can pose a health threat to humans who enjoy the water for recreation. Coliform enter our waterways through point and nonpoint sources. Point sources include such methods as water discharged through pipes and overflow from sewers. Nonpoint sources include agricultural sources such as livestock excrement and land applications of manure and sewage. Residential sources can include failed on site waste disposal or septic systems. Bacteria is transported by leeching into the groundwater which seeps via subsurface flow into the surface waters or rises to the surface and transported by overland flow. The amount of fecal coliform that is attributed to runoff is very high 90% nationally, more often than not high enough to exceed the criteria for swimming (Martin and Coffey, 1991).

Although not significant, fecal coliform levels were higher in the westernmost stations closer to the stormwater inflow and concentrations decreased by 20% from the stormwater inflow to the stormwater outflow.

b). Chlorophyll a

Chlorophyll a is the type of chlorophyll pigment that is used in aerobic photosynthesis by plants and is often used as an indirect measurement of the amount of photosynthetic plants found in a waterbody. Sunlight, temperature, nutrients, wind and many other factors often affect the density of aquatic plants in the water and thus the amount of chlorophyll a. Chlorophyll a levels within the project area overall were similar and reflect conditions that rank as low algal bloom conditions and a mesotrophic state.

b). Algae

There are no standards for algae in water systems. Algal growth is correlated to the levels of phosphorus and nitrogen in the water. Generally, 0.01 mg/l of phosphorus will support plankton while 0.03 to 0.10 mg/l of phosphorus will trigger algal blooms. Excessive algal production causes algal mats, decaying algal clumps, odors and water discoloration which interferes with recreation and aesthetic water uses. Extensive growth of rooted macrophytes can interfere with aeration and waterway capacity. Dead algae settle at the bottom stimulating microbial decomposition which depletes the oxygen in the water which in turn can hamper or even kill aquatic life. Algal blooms also shade submerged vegetation reducing or even eliminating photosynthetic processes and productivity of these species.

To avoid algae blooms the nitrogen level should be between 0.10 to 1.00 mg/l while the phosphorus level is 0.01 to 0.10 mg/l. The Ditch West End stormwater entrance exceeded these guidelines for nitrogen over 50% of the times sampled, while the Ditch East End, at the end of the stormwater treatment train, exceeded the guidelines less than 25% of the times sampled, The Ditch West End stormwater entrance exceeded these guidelines for phosphorus 25% of the times sampled, while the Ditch East End, at the end of the stormwater treatment train, exceeded the guidelines 16% of the times sampled. Total nitrogen and total phosphorus levels exceeded these guidelines at the same time 20 % at the Ditch West End stormwater inflow and 12% at the Ditch East End, stormwater outflow.

Wildlife Assessments

A. Fish

The fish community gradually shifted post-construction from a system dominated by non-native introduced fishes to one with a greater abundance of native fishes. The bathymetric profile changes provided by the construction activities and associated vegetative cover that established along the edges of the filter marsh could account for the increase in native fishes. Introduced fishes caught in Breder traps were removed from the filter marsh during the study and fed to rehabilitating animals in the Conservancy's wildlife hospital. This activity along with the removal of adult sized cichlids from a concurrent study in the filter marsh could account for the drop in numbers of non-native introduced fishes post-construction. In addition, juvenile common snook (*Centropomis undecimalis*) were collected in the filter marsh post-construction. This fish was not documented during the pre-construction monitoring phase thereby implying that the construction of the filter marsh created suitable habitat for this economically important, estuarine dependent, game fish species.

B. Avifauna

Wetlands are the primary foraging habitat for wading birds and species richness depends largely on the quality and quality of wetlands (Edelson, et. al., 1990). All bird species recorded pre-construction were also found during post-construction surveys. However, all birds recorded during post-construction were not found pre-construction. Rankings reflect a species shift as the vegetative area and created water feature allowed for the influx of water dependent birds, substantially increasing species richness. Foraging preferences are largely responsible for determining areas where wading birds can be found. The ditch and wet detention littoral zones along with the filter marsh were important foraging sites for wading birds at the end of the spring dry-down, typically in March – May during this study period, when water levels were lowered, and broad mud bands, or "Halos" appeared around the ponds. Prey became concentrated in shallow parts ditch and filter marsh ponds as the water levels decreased during the dry season. Thus, exploitation of these areas was usually brief, as birds quickly depleted fish populations sometimes within a week or less. Fortunately ponds do not all dry down at the same time, and wading birds will move to wherever prey is available. As draught conditions ensue, birds take advantage of available refugia. The processes of hydroperiod, habitat productivity and dry-down are not mutually exclusive. If an increase in fish population is followed by a strong dry-down, high quality patches are created. However, high quality patches that concentrate fish populations as a result of dry-down conditions are different from fish population increases that arise as a result of an increased hydroperiod of nutrient inputs, in the early wet season, since seasonal dry-down produces small-scale shallow water patches that are clumped in space and move across the landscape over time (Gawlik, 2002). As water levels drop, fish are forced to amass in shallower water zones as the deeper areas become desiccated and hold a smaller number of fish, making them more vulnerable to predation by birds.

During periods of high ecological density, when fish density is at its peak, is when fish are most available to wading birds (Kahl, 1964). Studies by Hoyer and Canfield (1994) indicated that average annual bird numbers were positively correlated to pond trophic status in regards to total phosphorus, total nitrogen and chlorophyll. This suggests that wading birds were also perhaps taking advantage of nutrient enriched areas during the early wet season in the project area when phosphorus, nitrogen and chlorophyll a levels were rising.

When prey is depleted avian species will show habitat partitioning based on water depth due to their distinctly different morphological foraging adaptations. Great egrets for example can forage in both shallow and deep water, whereas shorter stature snowy egrets are restricted to foraging at the waters edge (Collopy and Jelks, 1989). Longer-legged great egrets and wood storks were able to take advantage of prey in deeper man-made structures, like the wet detention pond. Since wood storks, are a species of special concern, their utilization of the project area post-construction is reflective of the success of the project. Wood storks were especially related to the occurrence of high quality patches that were isolated pools with high densities of prey during seasonal water level recession.

The wading bird species that were observed during project evaluation are important indicator species in the study of water bird refugia. Their presence or absence yields valuable data about water depth and prey concentration, as different species occupy different niches in regard to foraging areas. Different species are constrained by different anatomical attributes that have led to different foraging strategies and sociability levels. The water-margin habitat, whether brackish or fresh, marsh covered or bare contains a plethora of invertebrate and fish prey items that are attractive to wading birds (Martin, 1961). This project has successfully created areas that not only reduce stormwater pollutants, but have increased the ecological value to the area. A shift occurred in wading bird species composition favoring species requiring wetland habitat for foraging. Thus, the utilization of the project area by wading birds post-construction has indicated that the wetland creation was a success.

<u>C. Anurans</u>

Anuran community composition of the filter marsh changed during the course of the study. The original hypothesis was that wildlife habitat would be improved for both anurans and other aquatic fauna since the habitat was being altered to improve water quality. However, while increasing suitable habitat for native fish, altering the landscape appears to have created less suitable habitat for anurans. One possible explanation for this change could be from the result of an intensive construction project that took place to the north and immediately adjacent to the filter marsh. The construction of the County owned Gordon River Greenway removed an expansive piece of forested area in which adult anurans may have taken refuge.

Green treefrog abundance values declined and squirrel treefrogs were not documented post-construction. Both of these values could be explained by the absence of surveys during the month of June with the exception of 2008. The June 2008 survey (Table 15) was not included for statistical use in this study due to the need to standardize the data. However, by removing it, a typically heavy calling month for green treefrogs was not included in the analyses. It is also important to note that green treefrogs were documented the following month of July, but both squirrel treefrogs and oak toads were not recorded.

There are a few additional possible explanations for the decrease in abundance values for anurans post-construction. All survey methods have some bias. A limitation for the VES is a difference in the probability of detecting different species since they all inhabit unique niches. Alterations of the micro-habitat features within the riparian and littoral zone could have also been contributing factors to a decline in the population of certain species of anurans (Woodford and Meyer, 2003). Furthermore, keeping the filter marsh free from course woody debris, along with occasional sediment alterations to increase its nutrient filtering capabilities and flow may negatively affect both eggs and tadpoles during development (Hawkins et. al., 1988; Gillespie, 2002).

Three non-native, introduced species of anurans (Cuban treefrog, greenhouse frog and marine toad) were documented in the filter marsh. Both the Cuban treefrog and greenhouse frog were identified both pre-construction and post-construction, however the marine toad was recorded post-construction. It is unknown if the habitat was made more suitable for this species or if it they were expanding their range in Southwest Florida at the time of this survey and were observed invading the greater area. It would also not have been expected that the creation of the filter marsh would have had any effect (positive or negative) on their populations.

Concluding Remarks

Many consider stormwater runoff to be the biggest threat to our waterways, accounting for greater than half of the pollutants that enter our waterways (Martin and Coffey, 1991). There are wide disparities in the pollution removal ability of natural and created wetlands to remove pollution, usually as a result of seasonal variation, nutrient recycling (Carr, et., al., 1995) and are tied in part to differences in design and the length of time the water is retained in the system (Rushton and Dye, 1993). Increased travel time, slowing of stormwater volume to allow nutrients to be adsorbed by plants and infiltrate the substrate, appeared to reduce the discharge concentrations in comparison to pre-construction conditions and reduced nutrient concentrations between stormwater inflow and outflow points in this project.

Since this project is small in scale it's removal capabilities are logically less than other larger scale projects. However, given its size it has achieved significant reduction in nutrients. Perhaps just as important is that this project has accentuated the fact that created wetlands provide important ecological value through the creation of refugia for wildlife species in developed areas. Additionally, the educational opportunities this project affords to children and adults has proven a valuable teaching tool to inform the public about stormwater, wildlife and ways to incorporate small-scale cleanup efforts in your own backyard.

RECOMMENDATIONS

1. Although not required by the granting agencies, a longer sampling period to develop a baseline will lead to more accurate results. Given unforeseen factors such as draughts, floods, etcetera, more data will counteract short-term climatic changes that can skew results. Additionally, a longer period of baseline development will create a more balanced statistical balance for analysis.

2. Plan for unforeseen events such as flash floods (due to broken pipes upstream) that transport substantial amounts of sediment into the project area. The area leading to the wet detention pond had to be dredged out ahead of daily maintenance schedules. Flexibility in maintenance and funding reserves are necessity to sustain the project long-term.

3. It is necessary to harvest aquatic plants to improve absorption rates else the nutrients are cycled back into the environment.

4. Plan to schedule frequent exotic species removal activities long-term, along with harvesting and replanting initiatives.

5. Develop guidelines over time to improve planting schemes tailored to maximize the growth and productivity unique to the project area. Identify which species have the most potential for long-term viability suited to the individual site; can maximize nutrient uptake, and can be sustained through draughts and floods by re-evaluating plant sensitivities to the current physical and chemical makeup.

6. If the goal of a project is to increase wildlife usage along with pollutant reduction, when possible investigate future plans for areas adjacent to the project area. During the course of the study period a forest that was outside of the Conservancy's northern property line, adjacent to the project area was removed. This had an effect on the wildlife usage, anuran and avian usage in particular. An effort will be made to plant more trees and add some woody debris in areas that will not block flow to encourage tadpole recruitment.

7. During periodic maintenance, when excavation of accumulated sediment is required, tailor littoral zones and shelves to match different foraging capabilities of avian species.

8. Recommend use of audible anuran surveys over VES surveys. Audible anuran surveys proved more accurate reliable than VES surveys in this project since a large portion of forested habitat adjacent to the project area was removed, making visual encounters less likely.

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