FINAL REPORT

POPPLETON CREEK WET DETENTION POND

DEP CONTRACT NO. S0278

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MARCH 2010

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1.0 INTRODUCTION

On August 14, 2006, the City of Stuart entered into Contract No. S0278 with the Florida Department of Environmental Protection (FDEP) to construct stormwater improvements in the drainage subbasin identified in the City's stormwater masterplan as the Poppleton Creek Basin. The Poppleton Creek Basin is located in the south central sector of Stuart. The longitude of the project site is 80.20828" and latitude is 27.20920". The site is within the Sections 8 and 9, Township 38 South, Range 41 East in eastern Martin County in the city limits of Stuart.

The City of Stuart is located at a critical convergence of the St. Lucie River (north and south forks) and the St. Lucie Estuary. The St. Lucie River conveys large discharges from agricultural regions and Lake Okeechobee eastward to the St. Lucie Estuary and the Indian River Lagoon. The freshwater discharges and associated pollutant loadings have significant impacts upon the health of the Estuary and Lagoon. In recent years there has been significant degradation of the water quality in the Estuary and Lagoon, causing an intense focus upon the causes of ecosystem decline.

This project discharges from Water Basin Identification (WBID) number 3210 into the St. Lucie River South, an impaired water body, or a water body that do not meet water quality standards for the State of Florida. Final TMDLs for this WBID were established in 2008, with the parameters of concern being nutrients and dissolved oxygen. The Total Maximum Daily Load (TMDL) Allocation for this WBID calls for mass annual reductions of 38.4% for Total Nitrogen (TN) and 57.2 % for Total Phosphorus (TP). FDEP is currently going through the process of developing a Basin Management Action Plan or BMAP for all of its impaired water bodies to address the implementation of TMDLs statewide.

An inline wet detention pond enhanced with extensive wetland plantings was designed and constructed to provide significant treatment of Total Suspended Solids (TSS), nutrients, heavy metals, and debris for the Poppleton Creek drainage basin.

This report provides a summary of the activities that occurred under DEP Contract No. S0278.

2.0 FUNDING

The Florida Department of Environmental Protection (FDEP) provided partial funding of the project with a TMDL Water Quality Restoration Grant in the amount of $779,000 for construction of the project proposed Best Management Practice (BMP), monitoring, and educational materials. The remaining funds for this project came from City of Stuart's Stormwater Utility as matching funds and in-kind services.

3.0 BACKGROUND

The City of Stuart has been proud of its role of environmental stewardship within the Martin County community. The City's leaders have recognized that their environmental resources are critical to the lifestyle and economy of their citizens. As a result, the City's Stormwater Utility has played a leading role in protecting and restoring water resources from pollution in stormwater runoff. In the year 2000 the City completed a stormwater masterplan called the City of Stuart Watershed Planning and Improvement Program. All of the City's watersheds were identified and analyzed, with projects identified for treating and abating stormwater pollution and restoring wetlands and waterways. As a follow up, the City completed a Surface Water Quality Assessment Report in 2004 to identify potential needs for stormwater retrofit projects to meet FDEP's Total Maximum Daily Load (TMDL) allocations. One of the projects identified in these reports, is the current project, Poppleton Creek Wet Detention Pond.

The project basin is primarily urban. However, as recently as the early 1970's much of the land within the basin consisted of agricultural operations. Since that time, the basin underwent rapid development, at which time portions of the creek and surrounding wetlands were "ditched." This land development pattern, coupled with few stormwater standards in that time period, resulted in a great extent of the land within the basin being developed without water quality treatment facilities. Increased surface water flows to Poppleton Creek created substantial erosion and silt deposition, especially in the lower reaches of Creek. Overall, Poppleton Creek has a 578-acre drainage basin. However, this project address about 55% of the watershed or, 271 acres that consists primarily of commercial and industrial property, with the remainder being mixed residential land use. About 1/3 of the basin does not have stormwater treatment facilities.

The project site is located at the headwaters of Poppleton Creek. See Figures 1 and 2. Poppleton Creek is a natural stream that runs 4,800 feet long and discharges to the South Fork of the St. Lucie River, just south of the confluence with the St. Lucie Estuary. Access to the project site is located on Central Park Avenue.

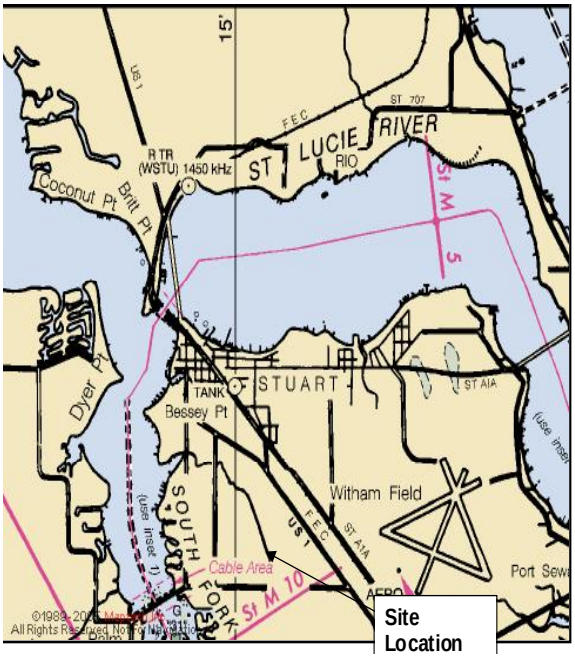

Figure 1, Location Map

La Conte Engineering provided a survey, design, and permitting for this project. Cape Canaveral Scientific, Inc. provided grant administration services for the project. An Environmental Resources Permit was obtained from the SFWMD for construction of the project. See Appendix 2.

Figure 2, Aerial Location

4.0 PROJECT HISTORY

The conceptual plan and final design for the project prepared by LaConte Engineering for the project conveyed the construction of a wet detention pond on vacant land located between S.E. Central Parkway and the southernmost end of Poppleton Creek. The final design of the project prepared by LaConte Engineering. Grant administration was provided by Cape Canaveral Scientific and Stormwater Solutions.

This 10-acre tract of agricultural land was acquired by eminent domain. After acquisition, an environmental audit showed that the site had been used for the growing flowers and some other agricultural operations in years past, leaving toxaphene contaminants in the soil. ERP Permit No. 43-0211171-002 was obtained from FDEP for dredging and complete removal of contaminated soils from the site before construction of the stormwater pond was initiated. Phase 1 of the project was the clearing and contamination removal contract. This work was completed in October 2004. Phase 2 was dredging of Poppleton Creek downstream of the pond site. Phase 2 was completed in 2007. The cost of Phases 1 and 2 was $660,000, paid entirely by the City. Impacts from Hurricane Wilma caused delays in the dredging operations.

Phase 3 construction of this project's Best Management Practice, funded by this grant, started in 2005 by West Construction, Inc. The orginal grant application included construction of a wet detention pond, 30% littoral bank plantings, a culvert extension, and a stormwater recreation park.

One of the unusual aspects of the monitoring program was to evaluate the impacts of the wetland plantings on the pollutant removal effectiveness of the pond. It has long been theorized that littoral zones that have wetland plantings could enhance wet pond pollutant removals. A special monitoring program was implemented to determine how much benefit was obtained from the wetland plantings at this site.

Upon commencement of construction, the City experienced significant delays due to construction modifications, causing the project to continue beyond the contract limits. A second amendment was granted to the City for a time extension, with a completion date of October 20, 2007. The final construction cost of the project was $799,811.11.

5.0 PROJECT DESCRIPTION

The principal objective of the project was to construct an inline wet detention pond to provide treatment for a 271-acre drainage basin of mostly urbanized lands. Approximately half of the overall drainage basins consisted of commercial land use, with the remainder being residential and institutional land uses. Land uses in the basin are shown in Table 1.

Table 1, Land Uses in Project Basin

Land Use	Acres	%
Public Open Space	.7	.2
Medium Density Residential	40.85	15.07
Office Residential	57.7	21.29
Institutional	22.13	8.17
Commercial	133.74	49.35
Conservation	1.58	.58
Industrial	14.3	5.34
Land Use Totals (Acreage and %)	271	100

The project site is approximately 10 acres in size. In preconstruction conditions, a 108- inch pipe discharged across Central Avenue to a ditch that ran along the eastern border of the site conveying water to the headwaters Poppleton Creek. A 5.53-acre wet detention pond was constructed to the west of the original ditch. The ditch was filled in and diverted into the southeastern corner of the pond, which is roughly rectangular in shape. See Figure 4. This ditch is the only inflow into the pond. See Figure 3 for the pond configuration and photos in Appendix 5. Side slopes of the pond were 4: 1 from normal water level to the top of bank. The littoral shelf was constructed with a 10:1 slope to a depth of 2 feet.

The eastern 0.9 acres of the site is where the toxaphene contamination occurred and was removed. This area was excavated to below contamination elevations and refilled to a higher elevation than the pond so there would be no exposure of stormwater to the remnant contaminated area. Extensive sampling of both soil and water were conducted to satisfy FDEP in this regard. The 0.9 acres of uplands along east boundary of lake was cleaned up and left out of the lake for future Willoughby Extension ROW per Martin County design at that time.

The normal water surface of the pond was at elevation 6.0, with the bottom of the pond at elevation -4.0, giving a pond depth of 10 feet. A 168-foot long, concrete, broad crested weir at elevation 6.5 controlled flow out of the pond. A sheet pile weir was driven under the weir to prevent seepage and piping of lake water under the weir.

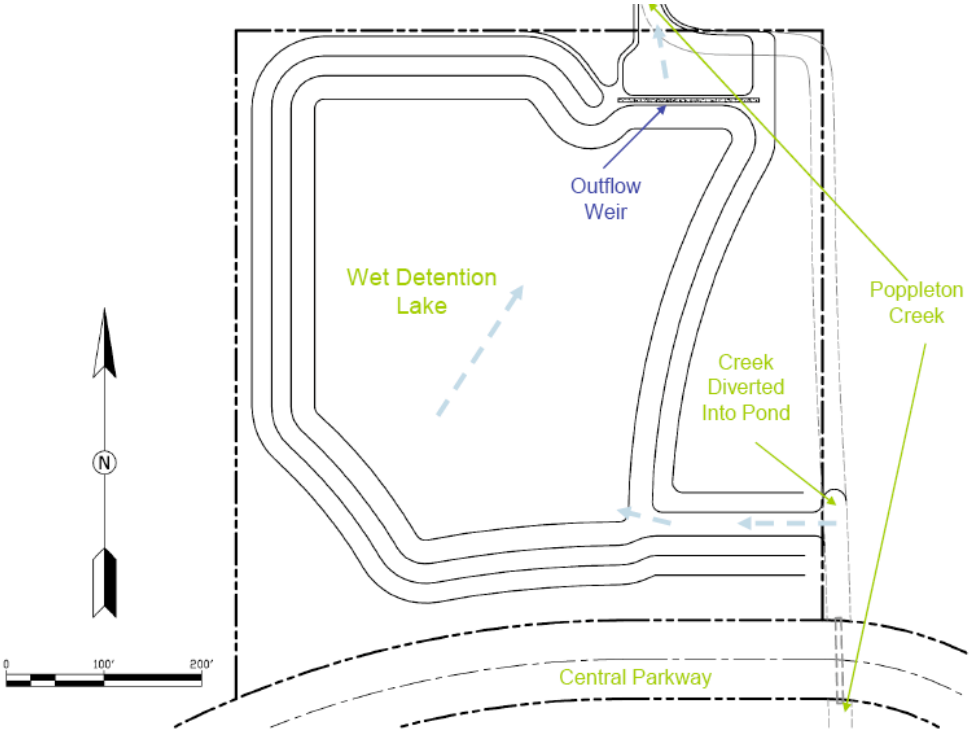

Figure 3
Schematic of Pond

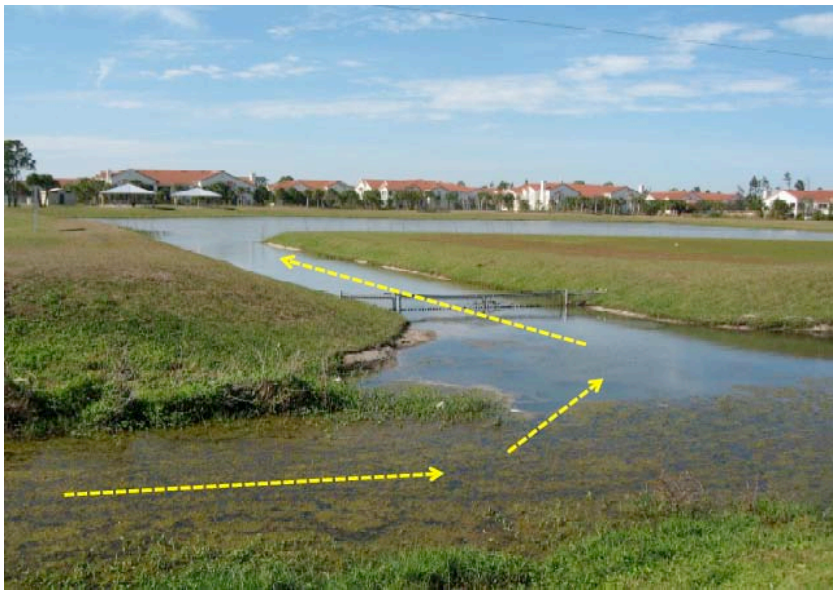

Figure 4
Ditch Diversion into Pond

Figure 5
Outfall Weir for Pond

Bleed down to the control elevation of 6.0 was obtained through six 10-foot long notches formed in the concrete. See Figure 5. The downstream conveyance is a 30-foot wide earthen channel with a bottom elevation of 3.0. Concrete rubble and filter cloth were placed at the downstream foot of the weir to prevent scour of the earthen channel. The southwest corner of the site is shared with the Water and Sewer Division, where a new wastewater lift station was constructed to serve a force main running along Central Park Avenue and will also serve as the new site for a restroom facility. Access to the site is via a driveway at the southwest corner of the site, which leads to the lift station and a parking lot for the stormwater park. The parking lot is constructed of pervious concrete to enhance infiltration of onsite rainfall.

A 45-foot wide littoral shelf is constructed around the perimeter of the pond. The shelf is on a gradual 10: 1 slope to keep the littoral zone shallow for the planted wetland species of Red Maple, Bald Cypress, Cord Grass, Pickerel Weed, Duck Potato, Spike Rush, and Tape grass. Public Works Department will maintain the littoral shelf by eradicating invasive vegetation by hand to ensure 80% coverage of the shelf area by the above plantings.

Additional facilities constructed at the stormwater park included a boardwalk over the lake, restrooms, and an information kiosk conveying the project's stormwater treatment benefits. The boardwalk was constructed adjacent to the weir to provide access to the weir during monitoring activities.

The design of the pond provided approximately 7.9 acre-ft of detention storage, which equates to 0.35 inches of treatment over the 271-acre drainage basin. The pond was constructed with 48.85 ac-ft of permanent pool volume.

Appendix 1 shows the layout of the pond and pertinent details. Photographs of the project site can be found in Appendix 5.

6.0 CONSTRUCTION

Construction of the pond could not commence until Phases 1 and 2 were completed. Even though Phase 1 work started in 2004, there were several delays due to Hurricane Wilma, difficulties with handling contaminants and associated permits, and plan revisions to assure proper littoral zone construction. Bids for construction of Phase 3 of this project were first received on March 28, 2007. Due to specification irregularities, the first bid was canceled. Bids were taken again on June 25, 2007. The low bidder was West Construction in the amount of $799,811.11. Construction of the pond was completed in September 2008.

7.0 POLLUTANT LOADINGS

A primary objective of this project was to reduce stormwater pollutant loadings from the Poppleton Creek watershed. In the grant application for this project, pollutant loadings from this basin were estimated to be 276 kg/yr for TP, 1852 kg/yr for TN, and 61,751 kg/yr for TSS. Pollutant reductions from construction of this facility would be used for credits against the City's pollutant load reduction goals to meet FDEP's Total Maximum Daily Load allocation.

Berryman and Henigar, Inc. calculated the stormwater loading projections in their 2004 report "Surface Water Quality Assessment." This report created a GIS-based model of pollutant loadings using the Simple Method developed by Harvey Harper. Stormwater loading rates were used from the report "Stormwater Loading Rate Parameters for Central and South Florida", Harvey Harper, 1994, as shown in Table 2.

Table 2, Stormwater Pollutant Loading Rates

	Pollutant Loading (kg/ac-yr)		
Land Use Description	**TP**	**TN**	**TSS**
Low/Medium Density Residential	0.320	2.880	31.900
Medium-Density Residential	0.594	4.680	56.100
High Density Residential	1.720	8.510	256.000
Airports, Roads, Utilities	1.320	6.690	182.000
Commercial	1.305	9.090	389.000
Industrial	0.519	7.300	383.000
Institutional	1.310	9.090	389.000
Recreational/Golf Course	0.046	1.070	7.600
Open Land/Recreational	0.046	1.070	7.600
Agricultural	0.551	3.620	74.00
Rangeland/Upland	0.876	4.540	126.000
Water	0.273	3.230	8.050
Wetlands	0.222	1.810	11.200

Pollutant removal effectiveness for this project was estimated to be 23% for TN, 63% for TP, and 88% for TSS. Projected polluant removals were 426 kg/yr, 174 kg/yr, and 54,341 kg/yr for TN, TP, and TSS respectively as shown in Table 3.

Table 3, Preconstruction Pollutant Loading Summary for Poppleton Creek Pond

BMP's Installed		**TSS kg/yr**	**TP kg/yr**	**TN kg/yr**	**Sediment kg/yr**	**BOD kg/yr**	**Other kg/yr**	**Other kg/yr**
Wet pond								
Pollutant Loads	Pre-Project	61,751	276	1852				
	Post-Project	7,410	102	1426				
	Load Reduction	54,341	174	426				
	% Reduction	88	63	23				

8.0 PROJECT MONITORING

One of the components of the TMDL grant was to provide monitoring of the BMP installation. The results of the monitoring program were used to evaluate the hydraulic performance of the wet pond with 30% littoral coverage, quantify the pollutants removed from stormwater runoff during rainfall events, and as a verification of the pollutant loading projections in Section 7.

After construction of the project was completed, Environmental Research and Design (ERD) was contracted to perform monitoring of the wet detention pond. A summary of the monitoring is provided below. The full monitoring report and accompanying photographs are shown in Appendix 7.

Field and laboratory investigations were conducted by ERD from January-October 2009 to evaluate the effectiveness of the recently constructed Poppleton Creek wet detention pond. Field monitoring was conducted at the inflow and outflow for the wet detention pond, including a continuous record of discharge rates as well as collection of flow-weighted composite inflow and outflow samples. Laboratory analyses were conducted on collected samples for general parameters and nutrients to assist in quantifying mass removal efficiencies for the system.

Prior to commencement of monitoring ERD prepared and obtained approval of the project QAPP that specified SOPs and protocols to be used. Figure 6 shows the Sigma Model 900MAX autosampler installed on the concrete outfall weir. These integral sequential samplers used an integral area/velocity flow meter to provide continuous flow measurements at 10-minute intervals into and out of the pond and to trigger flow-weighted inflow and outflow samples.

All laboratory analyses were conducted in the ERD Laboratory. The ERD Laboratory is NELAC-certified (No. 1031026).

8.1 Hydrologic Inputs

Flow measurements at the inflow ditch were performed using the area/velocity method with a flow probe. At the weir, overflow measurements were made using a pressure transducer sensor calibrated for the shallow water depth across the broad crested weir. The weir geometry was used to develop a discharge rate curve for the weir.

Figure 6, Outfall Autosampler on Weir

A bulk precipitation collector was also installed by ERD at the monitoring site to characterize nutrient concentrations in bulk precipitation. Bulk precipitation can be a

significant contributor to nutrient loadings in waterbodies and is included in this project to develop a more accurate nutrient budget.

An intensive hydrologic analysis and water budget was performed to provide an accurate analysis of water and pollutants entering and leaving the pond. Stormwater inputs were measured and calculated for direct rainfall onto the pond surface, as well as flows entering the pond through the upstream ditch through baseflow and rainfall. Inflow through Poppleton Creek contributed approximately 94% of the hydrologic inputs into the pond, with approximately 6% contributed by direct rainfall.

A total of 30.19 inches of rainfall fell in the vicinity of the wet detention pond over the 273-day monitoring period from a total of 104 separate storm events. A summary of rainfall event characteristics measured at the wet detention pond site is given in Appendix 7. Individual rainfall amounts measured at the pond site range from 0.01-2.08 inches, with an average of 0.29 inches/event. Durations for events measured at the site range from 0.01-7.4 hours, with antecedent dry periods ranging from 0.1-39.7 days. The majority of rain events were smaller than typical rainfall patterns for the area.

Table 4
Estimated Mean Monthly Hydrologic Inputs From Poppleton Creek Into The Wet Detention Pond

MONTH	TOTAL RAINFALL (inches)	HYDROLOGIC INPUTS (ac-ft)
January[1]	0.17	3.72
February	0.19	5.80
March	1.36	9.78
April	0.35	1.05
May	7.59	27.21
June	2.43	0.42
July	6.51	23.90
August	3.57	61.88
September	6.82	83.09
October[2]	1.20	2.51
TOTALS:	**30.19**	**219.4**

1. Reflects period from January 14-31, 2009
2. Reflects period from October 1-14, 2009

8.2 Hydrologic Losses

Discharges from the pond were a sum of weir overflow volume, evaporation, and groundwater infiltration.

8.2.1 Evaporation Losses

Estimates of mean monthly hydrologic losses from the wet detention pond as a result of evaporation were calculated using field measurements of evaporation conducted by ERD at a site on Manatee Creek, south of Stuart. ERD has been conducting continuous measurements of pan evaporation at this site since December 2007 as part of a BMP monitoring project for Martin County. Evaporation data measured at this site were obtained for the period from January 14-October 14, 2009. The evaporation data collected at the Manatee Creek site were converted from pan evaporation to lake evaporation using a standard coefficient of 0.75.

Estimated hydrologic losses from evaporation over the wet detention pond surface were calculated by multiplying the measured evaporation rates at the Manatee Creek site times the mean water surface area within the pond during each month of the monitoring program. The mean water surface area for each month was calculated based upon a stage-area relationship for the pond developed by ERD from the construction plans.

Evaporation losses from the pond range from a low of 0.70 ac-ft during January to a high of 2.91 ac-ft during August. During the field-monitoring program, evaporation losses removed approximately 19.43 ac-ft of water from the wet detention pond. See Appendix 7.

8.2.2 Groundwater Losses

The overflow elevation of the weir was 6.0. Water surface elevations in the wet pond fluctuated from 6.0 to 1.0 over the study period, indicating that groundwater elevations were fluctuating and the potential for groundwater losses. Continuous pond water surface measurements are shown in Appendix 7. Groundwater losses were calculated using the equation:

$$GW_{loss} = \text{Rainfall} + \text{Inflow} - \text{Outflow} - \text{Evaporation} - \Delta\,\text{Storage}$$

The calculations summarized in this equation were performed on a monthly basis for each month of the monitoring program. The change in storage was calculated as the change in water volume within the pond from the beginning to the end of each month. A summary of estimated mean monthly hydrologic losses from groundwater infiltration at the wet detention pond is given in Table 3. Groundwater losses ranged from a low of 4.57 ac-ft during October to a high of 10.19 ac-ft during August. Significant levels of groundwater losses occurred consistently from the pond throughout the monitoring program.

Table 5, Estimated Mean Monthly Groundwater Losses From the Poppleton Creek Wet Detention Pond

MONTH	HYDROLOGIC LOSSES (ac-ft)
January[1]	5.70
February	8.64
March	9.41
April	8.68
May	8.90
June	9.33
July	9.91
August	10.19
September	9.83
October[2]	4.57
TOTALS:	**85.16**

1. Reflects period from January 14-31, 2009
2. Reflects period from October 1-14, 2009

8.2.3 Pond Outflow

Discharges from the wet pond were monitored continuously over the monitoring period. Over the monitored period there were virtually no discharges over the weir, with the exception of two events on August and September 2009. Water depth over the broadcrested weir was only 0.25 to 0.75 inches deep. The discharge was not across the whole weir width, only through four of the seven weir notches. The phenomena is indicative of 1) the difficulty of constructing weirs to be perfectly level, and 2) the difficulty of measuring and calibrating flow meters for shallow flows over weirs. Measured flows over the weir were 4 cfs and 5.5 cfs for the two discharge events.

8.3 Hydrologic Budget

Monthly hydrologic budgets were developed for the Poppleton Creek wet detention pond over the study period based on the measured or calculated inputs and losses summarized in previous sections. A tabular summary of the monthly hydrologic budget is given in Table 6. Information is provided on the volumetric inputs into the pond from Poppleton Creek inflow and rainfall, with hydrologic losses occurring as a result of pond outflow, evaporation, and groundwater infiltration. The difference between the hydrologic inputs and hydrologic losses represents change in storage within the pond. Based upon the measured inflow to the pond and rainfall at the pond site, a basin wide C factor of 0.322 was estimated.

As can be seen, the majority of the water flowing into the pond exited via groundwater infiltration. The normal water surface elevation of a wet detention pond is normally set at seasonal high ground water elevation, with the expectation that the normal water level will fluctuate with ground water level changes. Normal water levels in ponds will react to groundwater fluctuations more rapidly when the pond is

located in porous soils such as Type A or B. The soils at the Poppleton Creek Pond were moderate draining Type B and B/D sands.

Table 6, Monthly Hydrologic Budget For the Poppleton Creek Wet Detention Pond From the Time Period January 14 – October 14, 2009.

MONTH	HYDROLOGIC INPUTS (ac-ft)			HYDROLOGIC LOSSES (ac-ft)				Δ STORAGE (ac-ft)
	Inflow	Rainfall	Total	Outflow	Evaporation	Groundwater	Total	
January	3.72	0.08	3.80	0.00	0.70	5.70	6.40	-2.60
February	5.80	0.09	5.89	0.00	1.45	8.64	10.09	-4.20
March	9.78	0.60	10.38	0.00	1.61	9.41	11.02	-0.64
April	1.05	0.15	1.20	0.00	2.60	8.68	11.28	-10.08
May	27.21	3.29	30.50	0.00	2.11	8.90	11.01	19.49
June	0.42	1.10	1.52	0.00	2.23	9.33	11.56	-10.04
July	23.90	2.97	26.87	2.06	2.64	9.91	14.61	12.26
August	61.88	1.70	63.58	51.27	2.91	10.19	64.37	-0.79
September	83.09	3.23	86.32	73.91	2.30	9.83	86.04	0.28
October	2.51	0.57	3.08	0.00	0.88	4.57	5.45	-2.37
TOTALS:	**219.36**	**13.78**	**233.14**	**127.24**	**19.43**	**85.16**	**231.83**	**3.91**

8.4 Stormwater Quality

ERD performed continuous monitoring of inflow and outflow samples over the study period. A total of 19 composite samples were collected where the ditch discharged into the wet detention pond. The results of the inflow sample collection are shown in Table 7.

As discussed in Section 8.3, there were just two rain events resulting in discharges from the pond. During those two discharges, seven outflow samples were taken, with the results in Table 8.

To more accurately analyze pollutant-loading mechanisms, water quality samples were also taken of the bulk precipitation that fell on the water surface. The nitrogen and phosphorus concentrations of the bulk rainfall were relatively low, but there was an extremely high variability for all nitrogen and phosphorus species, as much as a 500-fold difference. Taking samples of both the ditch inflows and the bulk precipitation allowed for calculation of mass pollutant loads from both sources. See Appendix 7.

Table 7, Summary of Chemical Characteristics of Pond Inflow Samples (n=19)

PARAMETER	UNITS	MINIMUM	MAXIMUM	MEAN
pH	s.u.	6.80	8.36	7.27
Conductivity	µmho/cm	130	457	214
Alkalinity	mg/l	42.0	156	70.6
NH_3	µg/l	10	459	66
NO_x	µg/l	10	859	23
Dissolved Organic N	µg/l	138	599	310
Particulate N	µg/l	69	2,604	383
Total N	µg/l	402	3,365	1,017
SRP	µg/l	1	45	7
Dissolved Organic P	µg/l	1	31	5
Particulate P	µg/l	27	677	112
Total P	µg/l	36	697	134
Turbidity	NTU	3.4	74.9	11.1
Cd	µg/l	<2	3	1.6
Cr	µg/l	3	12	5.6
Cu	µg/l	3	21	7.2
Zn	µg/l	5	118	22.6

8.5 Pond Removal Efficiencies

Removal efficiencies for the Poppleton Creek wet detention pond were calculated on both a concentration and mass load basis. Changes in concentrations between inflow and outflow sources provide an estimate of the effectiveness of the physical, biological, and chemical processes which occur within the pond that remove constituents from the water column. Mass removal efficiencies incorporate the concentration-based reductions but also include the effects of hydrologic inputs and losses from the pond.

A pond detention time of 57 days was calculated for the project period by dividing the estimated pond volume by the total hydrologic inputs summarized in Table 6.

Volume weighted concentration based removals from the Poppleton Creek wet detention pond were calculated for the 19 analyzed parameters. See Table 9. Due to the low number of discharge events and significant groundwater infiltration, only a few of the inflow and outflow samples were paired. Calculated reductions for Total N were 43% and for Total P were 87%. The increase in removal effectiveness on a mass base verses a discharge base was not surprising considering the volume of stormwater that infiltrated into the ground.

Table 8, Summary of Pond Outflow Samples (n=2)

PARAMETER	UNITS	MINIMUM	MAXIMUM	MEAN
pH	s.u.	6.75	7.26	7.01
Conductivity	µmho/cm	152	195	178
Alkalinity	mg/l	2.2	120	42.0
NH_3	µg/l	5	149	32
NO_x	µg/l	<5	10	<5
Dissolved Organic N	µg/l	256	381	303
Particulate N	µg/l	93	446	174
Total N	µg/l	446	809	556
SRP	µg/l	<1	4	1
Dissolved Organic P	µg/l	2	8	4
Particulate P	µg/l	5	24	11
Total P	µg/l	8	31	17
Turbidity	NTU	1.0	6.9	3.0
Cd	µg/l	<2	3	1.3
Cr	µg/l	4	7	5.9
Cu	µg/l	<2	5	1.7
Zn	µg/l	<2	2	1.1

In an attempt to more accurately analyze the functionality of the pond during the non-standard rainfall patterns and corresponding groundwater fluctuations of this study period, water column mass removal efficiency calculations for the tested parameters were also performed. This analysis combined the concentration based removal efficiencies from Table 8, with the hydrologic characteristics of evaporation and groundwater infiltration at the pond site. The results of this analysis showed a 48% removal of Total N and 88% removal of Total P. See Table 9.

Based upon the hydrologic and mass loading calculations described above, annual hydrologic parameters and loadings for the wet pond and its drainage basin are summarized in Table 10. The Total N mass loading is projected to be 543 kg/year and the Total P loading was estimated to be 71.5 kg/year. In the grant application for this project, Total N and Total P loadings were estimated to be 426 kg/year and 174 kg/year respectively.

Using concentration based loadings and removal efficiencies, ERD projected normal annual Total N and Total P loadings and removals shown in Tables 11 and 12.

Table 9, Summary of Volume Weighted Concentration Based Removals

PARAMETER	WEIGHTED CONCENTRATION (µg/l)		PERCENT CHANGE (%)
	Inputs	Outflow	
NH_3	71	32	-54
NO_x	26	3	-88
Dissolved Organic N	295	303	3
Particulate N	368	174	-53
Total N	977	556	-43
SRP	7	1	-85
Dissolved Organic P	5	4	-19
Particulate P	105	11	-90
Total P	126	17	-87
Cd	1.6	1.3	-17
Cr	5.6	5.9	5
Cu	7.0	1.7	-76
Zn	24.2	1.1	-95

Table 10, Mass Removal Efficiencies For The Poppleton Creek Wet Detention Pond

PARAMETER	MASS INPUTS (kg)			MASS LOSSES (kg)			MASS REMOVAL	
	Inflow	Precip.	Total	Outflow	G.W.	Total	kg	%
NH_3	17.92	2.29	20.21	5.09	3.41	8.50	11.71	58
NO_x	6.13	1.35	7.48	0.48	0.32	0.80	6.68	89
Dissolved Organic N	83.89	0.86	84.75	47.62	31.87	79.49	5.26	6
Particulate N	103.66	1.98	105.64	27.31	18.28	45.58	60.06	57
Total N	275.0	5.65	280.7	87.25	58.40	145.7	135.0	48
SRP	1.94	0.04	1.98	0.16	0.11	0.26	1.72	87
Dissolved Organic P	1.47	0.03	1.50	0.66	0.44	1.11	0.39	26
Particulate P	30.22	0.06	30.27	1.70	1.14	2.84	27.44	91
Total P	36.18	0.13	36.30	2.64	1.76	4.40	31.90	88
Cd	0.43	0.02	0.45	0.20	0.14	0.34	0.11	25
Cr	1.51	0.09	1.60	0.92	0.62	1.54	0.06	4
Cu	1.96	0.05	2.01	0.27	0.18	0.44	1.57	78
Zn	6.12	0.80	6.92	0.17	0.12	0.29	6.63	96

Table 11, Estimated Annual Hydrologic and Mass Loadings for the Poppleton Creek Wet Detention Pond

PARAMETER	VALUE
Hydrologic Inputs	
Runoff C Value	0.322
Annual Rainfall	59.53 inches
Inflow Volume	432.9 ac-ft/yr
Total Nitrogen	
Mean Inflow Concentration	1017 µg/l
Mass Inflow	543 kg/yr
Total Phosphorus	
Mean Inflow Concentration	134 µg/l
Mass Inflow	71.5 kg/yr

Table 12, Estimated Annual Load Reductions for Total N and Total P for the Poppleton Creek Wet Detention Pond

PARAMETER	ANNUAL LOADING (kg/yr)	REMOVAL IN POND (%)	ANNUAL LOAD REDUCTION (kg/yr)
Total Nitrogen	543	43	233.5
Total Phosphorus	71.5	87	62.2

9.0 PUBLIC EDUCATION

A critical ingredient to this project was the public education component. The plan to address public education had four components. When working on retrofit projects, it is important to involve the affected homeowners at all stages in the project. Public meetings were held to introduce the project to the citizens of Stuart prior to commencement of construction. The goal of improved water quality was explained.

In addition, a brochure promoting stormwater quality benefits was included in the 2005 utility billings that went out to all 27,388 property owners in the Stormwater Utility.

A sign identifying the funding source for the project were installed at the entrance near the parking area of the stormwater park. It was constructed of wood and painted. The sign was 4 foot in width and 5 feet high. The sign was created at a cost of $480.

The combination of these three components effectively introduced the property owners in the immediate vicinity of the project, as well as throughout the City, to its purpose to abate and treat stormwater pollution, sources of project funding, and lifestyle changes that could be undertaken by citizens to prevent pollution in their everyday activities.

The City will continue to update and utilize its extensive web site for the City Watershed Protection and Restoration Program, known as one of the most comprehensive in Florida. On the City's website, visitors can view the City's

comprehensive power point slide program to learn about the City's Stormwater Improvement Program and its numerous projects to treat stormwater. Furthermore, visitors can learn about the various elements of the program, including recurring street sweeping in areas like old downtown where there is no room for more extensive projects, and vacuuming baffle boxes of accumulated sediments captured from stormwater at outfalls to the River and Creeks. The City has retrofit baffle boxes to every outfall, all 34 pipes, that convey stormwater from City jurisdiction directly from uplands to tide. Please visit the link to learn more about the City's comprehensive stormwater program at:

http://cityofstuart.us/index.php?option=com_content&view=article&id=237&Itemid=323.

10.0 PROJECT SUMMARY

Funding for the Poppleton Creek Wet Detention Pond was obtained from a Florida Department of Environment Protection TMDL Water Quality Restoration Grant in the amount of $779,000.

This project demonstrated typical types of challenges that face municipalities when undertaking stormwater retrofit projects. Land was acquired through the condemnation process. After acquiring the land, a legacy contamination issue regarding the growing flowers was brought to light. The City addressed contamination by dredging and disposal of considerable amounts of soil. In addition, dredging of the channel downstream of the wet pond was undertaken to improve hydraulic capacity for flood reduction. Neither of these components was funded by the FDEP grant.

A driving concept of this project was to incorporate components of a gazebo, an elevated boardwalk over the project site, vegetated littoral zones, and walking trail to create a multiuse stormwater park to serve a multitude of public needs.

Projects of this magnitude often present opportunities for other agencies to upgrade infrastructure. In this case, the capacity of an older sanitary sewer line adjacent to the pond was increased by construction of a new lift station in the parking lot of the stormwater park at this site. This lift station will also serve as a new restroom facility for the park.

A wet detention pond was designed to reduce stormwater pollution from a 271-acre urbanized drainage basin that was mostly developed prior to current stormwater regulations. A wet detention design was chosen due to high groundwater elevations and low conveyance channel elevations. To provide additional treatment, the parking lot of the stormwater park was constructed of pervious concrete. Pollutant removal effectiveness of the pervious paving was not monitored or quantified in this report.

Another goal of this project was to demonstrate the effectiveness of incorporating littoral vegetation into a wet pond in order to enhance pollutant removal through the unit process of vegetative uptake. Thirty percent of the pond's surface area was constructed with a shallow bench and planted with wetland vegetation. At this site

groundwater el evations ex perienced a f ive-foot f luctuation th at r arely a llowed stormwater to rise to the level of the littoral zone. During the nine-month monitoring period there was no apparent treatment provided by the littoral vegetation.

Based upon t he m onitoring unde rtaken, t he c onstruction e xpense, m aintenance expense, a nd additional l and r equirements of a l ittoral z one a t t his s ite w ere not justified. If t he l ittoral z one ha d not be en c onstructed, a dditional pe rmanent pool volume could have been incorporated into the pond design that probably would have given increased treatment capability under all ranges of groundwater elevations.

It is the recommendation of the grant administrators, specifically Stormwater Solutions, Inc. that littoral zones not be used for wet ponds when the difference between normal groundwater level and seasonal groundwater level exceeds 12 inches. If planting ve getation a t a w et pond i s de sired, t hen t he us e of f loating wetland i slands m ay b e m ore ef fective, w here vegetative r oot m ass i s in c onstant contact w ith pol luted s tormwater a nd a llows f or pol lutant upt ake on a continuous basis.

Monitoring of this wet detention pond w as hampered by a drought that produced 19 small s torm e vents c ausing r unoff t o e nter t he pond, but onl y gave t wo s torms o f sufficient runoff volume to discharge over the outfall weir. The drought also caused the ground water and corresponding normal water level in the pond to drop as much as five feet.

Therefore, t he n ormal procedure o f cal culating p aired E MC co ncentrations a nd removals w as not f easible. Instead, pol lutant removal e ffectiveness o f t he w et detention pond w as m easured w ith t wo di fferent m ethods. Volume w eighted concentration ba sed c alculations g ave r emoval e fficiencies of 43% f or T otal N a nd 87% f or T otal P. A n a lternative m ass b ased efficiency calculation f or t he w ater column w as de veloped t o a ccount f or s ignificant w ater vol ume r emoval b y evaporation and groundwater i nfiltration. T his m ethod e stimated s lightly hi gher removal e fficiencies of 48% a nd 88% r emoval efficiency f or T otal N a nd T otal P , respectively. S ince t he t wo m ethods pr ovided s imilar r esults, E RD c oncluded t hat during a year of normal rainfall patterns groundwater elevation changes would not be dramatic a nd t he pond w ould ha ve t he r emoval e ffectiveness cal culated u sing t he concentration based method.

Calculated annual mass loading rates based on monitoring results in this project were significantly less than loading rates estimated in the grant application and the original City of Stuart Storm Water Quality Assessment Report. The Assessment used loading rates expressed a s m g/L ba sed on H arper's 199 4 s tudy. Those l oading rates w ere based on a verages of m any projects i n C entral and S outh F lorida. T he soils i n t he Poppleton Creek basin are Type B and B/D soils. When ground water levels drop as occurred during the sampling regime, Type B/D soils function as moderate draining Type B s oils.. T ype B s oils i nfiltrate hi gh vol umes of r ainwater a nd a ssociated pollutants, s o l ow pol lutant l oading r ates f or t he P oppleton C reek ba sin a re not unexpected. U se of l oading r ate c alculations unde r t he pr oposed S tatewide Stormwater Rule would more accurately account for Type A soils and infiltration and would be more accurate than previous methods.

A final summary of project costs is shown in Table 13.

Table 13, Project Costs

PROJECT FUNDING ACTIVITY	TOTAL PROJECT COSTS ($)	DEP GRANT FUNDS ($)	CITY OF STUART FUNDS ($)
BMP Implementation	872,161.12	704,742.93	167,418.19
Monitoring	59,263.69	53,096.66	6,167.03
Public Education	1,513.00	1,513.00	--
Grant Adm/Reports	10,780.00	10,780.00	--
Contractual Services	886,023.97	--	886,023.97
TOTAL:	**$ 1,829,741.78**	**$ 770,132.59**	**$ 1,059,609.19**
PERCENTAGE MATCH:		**42**	**58**

ERD also performed a analysis for this project to estimate costs per kg of Total N and Total P removed. See Table 14.

Table 14, Evaluation of Load Reduction Costs for Poppleton Creek Wet Detention Pond

PARAMETER	TOTAL NITROGEN	TOTAL PHOSPHORUS
Annual Mass Removed (kg/yr)	233.5	62.2
Present Worth Cost per kg Removed ($)	435	1632

11.0 REFERENCES

Harvey Harper, Ph.D. P.E., 1994. Stormwater Loading Rate Parameters for Central and South Florida. Environmental Research and Design.

Harvey Harper, Ph.D. P.E., 2007. Evaluation of Current Stormwater Design Criteria with the State of Florida, Environmental Research and Design.