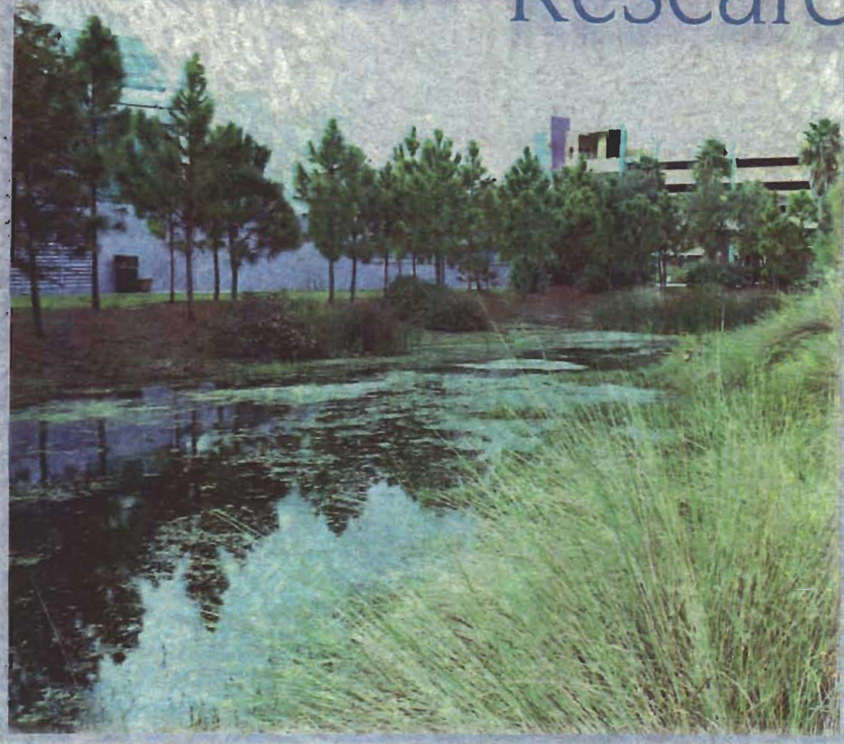
Stormwater Research



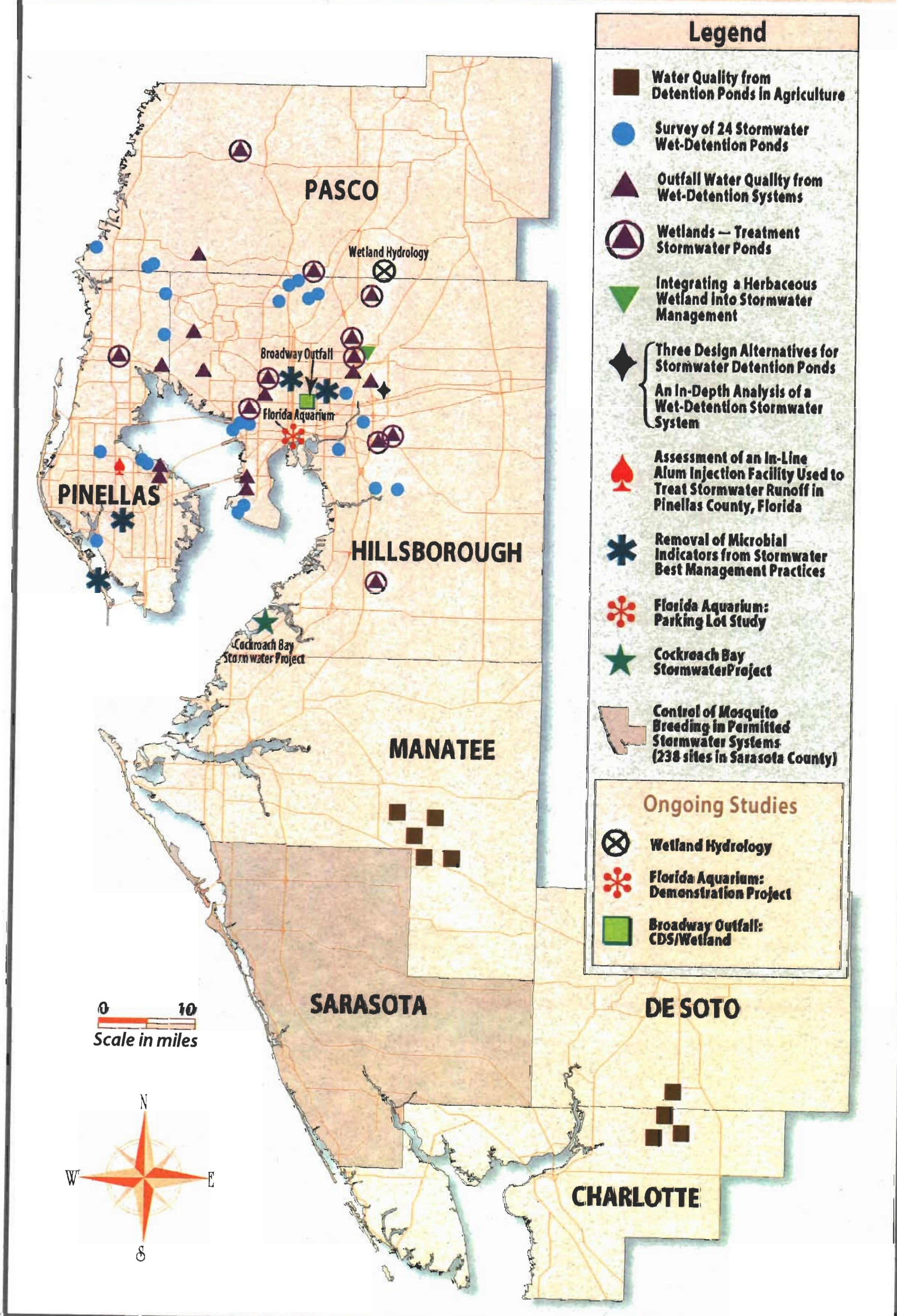
Summary of Research Projects

1990-2005

Resource Management Department, Environmental Section

Southwest Florida Water Management District

Stormwater Research Sites



Stormwater Research

Conducted by The Southwest Florida Water Management District

Summary of Projects
1990 - 2005

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EXECUTIVE SUMMARY

Introduction

Stormwater research at the Southwest Florida Water Management District (District) was initiated in mid-1988 in response to changing national and state laws requiring the District to implement non-point source pollution control technology. The cost of the research has been shared by grants from the Environmental Protection Agency (EPA) through the Florida Department of Environmental Protection (DEP), the Surface Water Improvement and Management (SWIM) program, and local governments through the District's Cooperative Funding Program. The data collected are used to evaluate the effectiveness of stormwater best management practices recommended by District rules, monitor the effectiveness of some SWIM projects, suggest water quality treatment methods to the District's Comprehensive Watershed Management (CWM) plans, and provide data for potential rule modifications, treatment systems, models, and retrofits. Finally, biennial stormwater conferences sponsored by the District's stormwater program provide for sharing of data with the regulated public, other agencies, and private consultants.

Since the inception of the research, twenty projects have been initiated (eighteen completed) to investigate stormwater pollution issues including: the efficiency of wet detention ponds and wetlands for water quality improvement, alum injection for pollutant removal, agricultural impacts to receiving waters, removal of bacteria by stormwater systems, mosquito problems in stormwater systems, reuse of stormwater, a comparison of constructed and natural wetlands used for stormwater treatment, and the impact of aerial deposition on stormwater pollution. In addition, studies recently completed provide data and recommendations about: improvements in parking lot designs, pollution reduction by swales, treatment ponds for agricultural runoff, and swirl concentrators for the removal of gross solids.

Content of Project Report Summaries

This project report describes the types of research undertaken by the District and a bibliography of the project reports that have resulted from the research. Brief descriptions of each project are included and should provide the information necessary to determine if the complete report might be useful in your application. The findings contained in the project reports have been widely used by professionals who are interested in stormwater or watershed management when they need information such as: water quality data, efficiencies of stormwater technologies, loading rates, or innovative methods to improve stormwater runoff quality and quantity. In addition, data for some of the completed studies have been entered into an international database and can be downloaded directly from the inter-net at www.bmpdatabase.org. Copies of the completed reports are available by calling the District headquarters in Brooksville at telephone number (352) 796-7211 ext. 4276 (Dr. Betty Rushton).

INTRODUCTION

This introductory chapter presents a brief overview of the Southwest Florida Water Management District, a historical perspective of District stormwater research, an indication of how the stormwater program fits into other District programs, a map with locations of projects including a brief project description, a table outlining applications of each project results, and status of the District projects. A table outlining funding sources and possible applications of the research results provides concise information. More complete results and conclusions are listed in the summaries of each project. A glossary gives definition of terms often used by environmental professionals.

District Overview

The District is one of five regional agencies, which was established by the State Legislature to manage water and water-related resources of Florida. The District's responsibilities have expanded over the years in response to a growing need for a more comprehensive approach to water management. Areas of responsibility now encompass water supply, flood protection, water quality management and natural systems management. The stormwater research program was established to supply data and make recommendations to improve water quality discharged after storm events. The purpose is to provide information to help protect our regions' rivers, lakes and estuaries.

Historical Perspective

Stormwater management is recognized as a practical method to improve water quality from non-point source pollution (i.e. pollution that runs off of our farms and neighborhoods after rain events). Initially stormwater was considered a water quantity problem solved by rapidly draining runoff into storm sewers, ditches or directly into lakes and rivers. By the mid-1970s studies showed over half the pollutant load entering Florida waters came from non-point source runoff. Serious efforts to control water quality degradation through point source control were initiated under the Federal Clean Water Act in 1972. Later revisions, known as the Water Quality Act of 1987, emphasized non-point source pollution. In 1972, the Florida Legislature enacted legislation, which greatly expanded the responsibilities of the Water Management Districts from flood control to a full range of water management activities. To meet these new responsibilities, rules were written for the Management and Storage of Surface Waters (MSSW) for new developments (40D-4) in 1984. The Surface Water Improvement and Management (SWIM) legislation was passed in 1987 to implement plans and programs to improve habitat and water quality discharged into water bodies of state significance. More recently, local governments have been mandated to improve non-point source pollution loads through Federal National Pollutant Discharge Elimination System (NPDES) permits. Additionally, data are needed to develop Total Maximum Daily Loads (TMDL) for watersheds that are to be implemented using existing federal, state and local authorities.

Purpose of the Stormwater Research Program

Stormwater research at the District is designed to provide data to achieve multiple objectives to: (1) support or modify our rules under 40D-4, (2) monitor the pollution reduction achieved by some SWIM projects, (3) quantify the efficiency achieved by stormwater best management practices, (4) provide data and advice for stormwater improvement initiatives such as the Tampa Bay Estuary program, (5) provide data for computer models, and (6) assist local governments with their own stormwater improvement programs through implementation of best management practices. The District program is also part of a coordinated statewide effort to determine effective cost efficient treatment of stormwater runoff. As part of this effort, the District sponsors biennial stormwater research and watershed management conferences, which are attended by over 250 professionals interested in water quality issues. Additionally, data from District projects are being incorporated into an international database sponsored by the American Society of Civil Engineers through an Environmental Protection Agency grant. This will make comparable stormwater data available from throughout the world. More recently the data collected are being entered into a State of Florida BMP database and an EMC database.

Research Studies

Figure 1 is a map showing the various project site locations and a legend with the project's current status. Following Figure 1 are summaries of each project with symbols that match the site location on Figure 1. Table 1 provides a list of the projects and their funding source as well as a brief description of the most pertinent conclusions and applications. Following Table 1 are individual project summaries that provide more complete details of the research as well as the conclusions/recommendations that resulted from the study.

Studies generally fall into two categories. Surveys of a large number of stormwater systems permitted by the District were conducted to determine how well our rules met state of Florida water quality objectives. In these studies grab samples were collected after rain events to compare to State standard. For the in-depth studies, automatic equipment was installed to collect flow-weighted samples. For these studies, which usually were conducted for at least a two-year period, analyses also included rainfall data, water table measurements, sediment constituents and vegetation characteristics. Other studies added information about bacteria and mosquitoes in stormwater systems.

Cooperative Funding Grants

Another source for adding to our stormwater database and achieving water quality goals are the District's cooperative funding grants. This cooperative funding helps local governments meet new challenges which have been intensified because of the impact of current federal, state and local legislation. Also, the establishment of new pollution abatement strategies such as stormwater utilities, the TMDL program and the retrofitting of urban areas have increased the need for more data promoting practical solutions.

The District's Cooperative Funding program provides a mechanism for receiving matching funds for worthwhile projects. Starting in December of each year, basin boards begin the process of selecting worthwhile proposals submitted by local governments and other public or private entities. The Basin Boards share the cost of those projects selected. These proposals are usually generated in response to priorities listed in the Comprehensive Watershed Management plans for each basin. A workshop held in November of each year is a desirable pre-requisite for guidelines about how to proceed in submitting proposals. For more information contact the appropriate Governmental Affairs Coordinator based in their representative counties.

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STORMWATER RESEARCH PROJECTS

Thumbnail description is given for each project. The symbols correspond to the legend on the site location map (inside front cover).

Completed Projects

Surveys

● **Water Quality Survey of Twenty-Four Stormwater Wet-Detention Ponds**

Grab samples taken within one to two days after rain events from effluent discharged from permitted wet-detention ponds found some exceedences (non compliance) of State water quality standards. Data were also analyzed for seasonal and flow related patterns. In addition, multivariate statistical analysis looked at relationships between constituents as well as hydrological parameters.

∆ **Outfall Water Quality from Wet Detention Systems**

This study focused on storm water quality from permitted stormwater systems before and after discharge over an outfall weir. Water quality from both constructed and natural detention ponds were compared to State standards for compliance. Relationships between variables were analyzed with statistical correlations. No statistical differences were found between the water-quality on either side of the weir during discharge (except pH and dissolved oxygen), thus representative samples can be collected from the more accessible pond side.

○ **A Survey of Water Quality of Wetlands-Treatment Stormwater Ponds**

A water-quality survey of stormwater treatment systems that employed existing wetlands and including constructed pre-treatment sedimentation basins was conducted. The survey provided regional stormwater data, and documentation of exceedence (non compliance) of State water-quality standards at points of discharge from permitted wetlands- treatment systems. Additionally, statistical analysis of relationships among survey variables provided insight about factors that affect water quality.

■ **A Survey of Outflow Water Quality from Detention Ponds in Agriculture**

This study tested outflow water quality for compliance with State water quality standards. Although exceedences (non-compliance) of water quality standards were detected, the violations were infrequent. The only parameter that alerts caution is low dissolved oxygen levels detected at almost all sites. Comparisons to similar data from other studies are included. Since most of these ponds discharged continuously samples were collected on a monthly basis and do not represent stormwater runoff.

In-depth Studies

∇ **Integrating a Herbaceous Wetland into Stormwater Management**

An analysis of 81 storm events during a 30-month period established an extensive water quality and hydrologic database for a wetland used for stormwater treatment. This report also includes sections on sediment quality and vegetation analysis. Other sections looked at relationships between variables, the first flush effect, a hydrologic water budget, and continuous measurements of dissolved oxygen, pH, conductivity and other field parameters.

♦ **An In-Depth Analysis of a Wet Detention Stormwater System**

Flow-weighted samples collected at the inflow and outflow showed the study pond removed pollutants by 30 to 60 percent for most constituents. Rainfall directly on the pond was a significant input for inorganic nitrogen and some metals. The wet detention pond was shown to be effective as a settling basin, but a better design with a longer detention time was recommended.

Three Design Alternatives for Stormwater Detention Ponds

The wet detention pond described in the study above (An In-Depth Analysis of a Wet Detention Stormwater System) was reconfigured into three different retention designs. The best design included a 14-day residence time where most constituents were reduced by at least 80%. The exceptions were organic nitrogen and ammonia. All samples met State water quality standards for metals at the outflow.

♠ **An Assessment of an In-Line Alum Injection Facility Used to Treat Stormwater Runoff in Pinellas County, Florida**

Pre- and post- alum treated storm event water quality and flow data were collected and load reductions calculated. Comparisons to water quality standards were performed, monthly downstream water quality samples were collected, and the toxicity of aluminum in the environment was discussed. The important role that operation and maintenance played in the treatment effectiveness was also evaluated.

✶ **Removal of Microbial Indicators from Stormwater Best Management Practices**

In this study, indicators and surrogates of microbial pathogens were used to determine how well three types of stormwater systems reduced microbes using simulated storm events. The three types of systems were: sand filtration, wet detention and alum coagulation. Samples were taken before the introduction of the surrogate or indicator organisms, right after the introduction and then ten samples at timed intervals. Heavy metals, turbidity and total suspended solids were also measured using the same experimental design. Significant reductions ($p<0.05$) in total and fecal coliform bacteria, MS2, and bead concentrations were usually observed for all systems, but sometimes greater concentrations were measured in outflow samples than in inflow samples.

Control of Mosquito Breeding in Permitted Stormwater Systems

One hundred and thirty-eight SWFWMD permitted stormwater projects, which included 238 individual stormwater systems in Sarasota County, were selected for study. Systems were divided into permanently flooded and intermittently flooded. The project sites were tested for mosquito breeding. Also, materials classified as traditional insecticide (Abate), oil formulation (Golden Bear), biological (VectoBac) and a growth regulator (Altosid) were used against natural larval populations. Intermittently flooded systems produced the most mosquitoes.

Florida Aquarium Parking Lot: A Treatment Train Approach

This project examined basin-wide treatment for stormwater management. Flow measurements and water quality samples were collected for rain events to calculate volume and pollutant reductions from three pavement types (asphalt, concrete, and porous). Also evaluated were the pollutant reductions provided by swales between parking rows, a cypress strand and a small wet detention pond used for final treatment. Additionally, the monitoring effort investigated other processes taking place by measuring pollutants in rainfall and sediments as well as variations in pH, dissolved oxygen, temperature, conductivity, and redox in the pond. Most of the storm runoff was retained on site and during the year it was monitored the pond discharged off-site only once. The swales in the parking lot reduced runoff amounts from 50% in the basins with no swales to 30% and porous paving reduced runoff from 50% in the basins with no swales to 17%.

★ **Treatment of Stormwater Runoff from an Agricultural Basin**

This project assessed the effects of a wet-detention pond on the water quality of stormwater runoff from an agricultural watershed. Monitoring included flow-weighted samples collected at the inflow and outflow to the detention ponds, as well as collection of rainwater for chemical analysis. Other monitoring efforts included bi-weekly measurements of the water table and quarterly ambient monitoring of water in the pre-treatment ditch, four sediment-sampling events for the entire stormwater system, and water quality monitoring in the wells. During the four years of data collected the pond reduced pollutant loads for most constituents by at least 60 percent, and often over 80 percent. Some water quality problems still exist, for example, copper and zinc failed to meet Florida Class II and Class III marine water quality standards for all years. Also 82 percent of samples for fecal coliform bacteria taken at the outflow of the pond failed to meet standards and chlordane and endosulfan concentrations failed to meet Water Quality Standards in the pond.

_ **Stormwater Alternatives: Demonstration Project**

The project is a multifaceted research and educational effort designed to better understand the impact of urban runoff, to explore techniques that reduce stormwater pollution and to educate the public about stormwater issues. Two stormwater ponds discharging directly into Tampa Bay form the centerpiece of a demonstration project developed to inform the public about stormwater problems and provide professionals with innovative ideas that can be used for stormwater management and pond maintenance. Educational signage was installed and a booklet written to help educate the general public. In addition, a monitoring program measured pollutant loads discharged to the bay from an effluent filtration system and a modified wet-detention pond (two common stormwater treatment methods). Data for the effluent filtration system indicate that the under drains still operate seven years after construction and that pollutant levels were greatly reduced at the outflow of the pond. The under drains, however, discharge high concentrations of soluble nutrients, a common occurrence for filtration systems. A review of the literature is summarizing practical and innovative methods that can be used by professionals. Several methods identified in the literature review have been implemented and monitored to determine their effect on pollutant removal.

Ongoing Studies

⊗ **Wetland Hydrology**

In this study the hydrologic effects of a borrow pit built adjacent to six forested wetlands is being investigated. Data collection includes recording bi-weekly surface water and surficial groundwater levels, conducting detailed vegetation analyses each spring and fall, and performing quarterly surface water quality sampling.

❑

Broadway Outfall CDS Unit and Constructed Wetland

A SWIM retrofit project that installed a Continuous Deflection Separation (CDS) unit and a constructed wetland is being monitored for a two-year period. Composite flow-weighted samples are being collected before stormwater enters the system, after it leaves the CDS unit and again as it exits the wetland. Rainfall water quality and quantity is also measured as well as water levels. Pollutants in the sediments were measured before the modifications, after the modifications and will be measured again at the end of the monitoring effort. Macroinvertebrate sampling is also part of the data collection. The material removed from the CDS unit is also analyzed. During the first year of study, the CDS unit removed 413 cubic feet of gross solids including toxic levels of Polycyclic aromatic Hydrocarbons (PAHs).

● **Stormwater Pond Evaluation**

The study is being conducted to answer questions regarding the condition of stormwater treatment ponds at least fifteen years after construction. District staff is assessing 12 existing stormwater ponds that were included in an investigation 15 years ago. This project is comparing each pond's current condition with both its design and actual condition 15 years ago. The points of comparison are: calculated average pond depth, measured depth and volume of accumulated sediment, measured surface area encroachment, measured water quality for selected parameters, sediment quality, and littoral zone characteristics. Data are being analyzed using the GIS system and recent survey data.

Table 1. A list of District stormwater research projects and the application of results.

PROJECT NAME	FUNDING SOURCE	APPLICATION
Water-Quality Survey of Twenty-Four Stormwater Wet-Detention Ponds	District - $100,000	1. Documented effectiveness of MSSW Rule. 2. Identified seasonal effects & problem pollutants. 3. Found from 3% to 39% non-compliance of state WQ standards. 4. Documented more WQ non-compliance with greater imperviousness.
In-Depth Analysis of a Wet Detention Stormwater System	District - $120,000	1. Documented deficiencies in design esp. dissolved oxygen, mosquitoes. 2. Made recommendations for improvements including longer residence time. 3. Documented pollution from rainfall esp. inorganic nitrogen & some metals. 4. Identified problem pollutants in discharge water - Dissolved oxygen, some metals.
Integrating a Herbaceous Wetland into Stormwater Management	EPA - $55,000 District - $55,000	1. Identified changes when an oligotrophic marsh is used for stormwater treatment. 2. Documented exceedence of std. for copper, lead and zinc 4% to 40% of samples. 3. Found zinc in west basin sediments at toxic levels indicating the need for maintenance. 4. Showed alteration of shoreline promoted growth of nuisance plant species. 5. Documented retention of water by the marsh and ET improved removal efficiencies. 6. Showed pre-treatment basins reduced pollutant loads to the marsh but were not sufficient to reduce pollutant loads below toxic levels.
Control of Mosquito Breeding in Permitted Stormwater Systems	Sarasota Co. Mosquito Control - $20,000 Manasota Basin - $20,000	1. Found dry effluent filtration systems often create serious mosquito problems. 2. Documented organic matter in systems produced more mosquitoes (grass clippings,etc) 3. Found maintenance of structures and sediment build up a problem - needs monitoring often. 4. Recommended minnow sumps and stocking mosquito fish in stormwater systems. 5. Need a method to track the 1000s of stormwater systems - GIS, etc.
Mosquito Prevention in Stormwater Systems	Sarasota Co. Mosquito Control - $5,000 Manasota Basin - $5,000	1. Developed a brochure suitable for the general public, incl. maintenance & other ideas. 2. Provided a maintenance example of how to recontour pond to reduce mosquito problems. 3. Identified cattail, water hyacinths and water lettuce as the most troublesome plants for sheltering mosquito larvae.

PROJECT NAME	FUNDING SOURCE	APPLICATION
Stormwater Reuse, Design Curves for SWFWMD	District - $20,000	1. Developed REV (Rate-Efficiency-Volume) charts to use to calculate reuse benefits. 2. Demonstrated stormwater reuse can be used to meet 80% pollutant removal goal. 3. Based on actual rainfall record of the region.
Comparative Water Quality Data of a Deep and Shallow Wet Detention Pond	District - $40,000	1. Documented that shallow pond (3 feet deep) had better removal rates than deep pond (9 feet deep). 2. Demonstrated stratification in the deep pond but not in shallow pond.
Wetlands-Treatment Stormwater Ponds	District - $50,000	1. Documented that up to 38% of discharging samples failed to meet WQ stds for metals. 2. Identified low dissolved oxygen as a possible culprit. 2. Found dissolved oxygen in non-compliance > 50% of samples.
A Survey of Outflow Water Quality from Detention Ponds in Agriculture	District - $50,000	1. Documented that WQ better than from untreated agricultural discharge. 2. Showed non-compliance with WQ stds. for DO, lead, iron, and pH at several sites. 3. Found nutrient values below literature values for other treated agricultural runoff.
Three Design Alternatives for Stormwater Detention Ponds	EPA - $50,000 District - $50,000	1. Found Conservation Wet Detention design met all state water quality standards. 2. Documented 80% reduction for most pollutants - A State Water Policy goal. 3. Showed problem with PAHs as ponds age. 4. Identified the importance of entire drainage basin in reducing discharge.
Outfall Water Quality from Wet Detention Systems	District - $60,000	1. Documented constructed wet detention better than natural wetlands. 2. Found dissolved oxygen in non-compliance > 50% of samples. 3. Samples collected in front of outfall structure reliable for comparison to State Standards
Alum Injection for Stormwater Treatment - Pinellas Park	District - $60,000; SWIM - $249,115 (used for construction of site)	1. Documented a need for strict operation and maintenance guidelines for alum treatment. 2. Alum injection effective for removing phosphorous.

Table 1. (Continued)

PROJECT NAME	FUNDING SOURCE	APPLICATION
Assess Agricultural Best Best Management Practice Discharging to Cockroach Bay	EPA - $155,407 District - $103,604	1. Pervious drainage basin and pre-treatment ditch reduced rainy season runoff to 30% 2. About 25% of all storm input to the pond was contributed by rainfall directly on pond 3. Water quality loads were reduced by > 60%, but rainfall patterns affected this 4. Of the ten pesticides detected at the inflow only four were detected at outflow. 5. Phosphorus was measured at relatively high concentrations at inflow (avg > 1 mg/L) 6. Metals and nutrients in sediments were much higher in the pre-treatment ditch.
A Treatment Train Approach for Stormwater Management	EPA - $196,996 District - $131,331	1. Found parking lot design extremely effective in reducing amount of runoff. 2. Reduced runoff meant no pollutant discharge to Tampa Bay - The best strategy. 3. Swales reduced runoff from 50% to 30% and for porous paving to 17%. 4. Larger garden areas reduced runoff by another 50%. 5. Identified air pollution as significant source of stormwater pollution. 6. Documented treatment by swales and strands.
Removal of Microbial Indicators from Stormwater BMPs	District - $ 45,000	1. Disease causing bacteria found at inflow and outflow. 2. Systems usually reduced bacteria 3. Determined that a treatment train system would work best to treat bacteria. 4. Chlorine disinfection, ozonation, and UV light irradiation could help treat stormwater
Wetland Hydrology Pre- and Post Development	District - $ 17,398	1. Determine if wet detention pond/borrow pits dewater wetlands. 2. Document before and after effects of development on natural wetlands.
Stormwater Management Alternatives Demonstration	EPA - $181,575 District - $121,506	1. Ponds with algae problems need remedial solutions other than copper treatment. 2. Documented effectiveness of effluent filtration systems. 3. Found highest concentrations of nutrients in under drains. 4. Found maintenance of ponds the most critical problem.
BMP Data Transfer Grant	ASCE/EPA - $9,500	1. EPA grant paid for entering our data into an international database available on the internet 2. Data for over 100 stormwater studies available at www.bmpdatabase.org

Cockroach Bay (phase II)	EPA - $77,455 District - $51,647	1. Continues data collection at agricultural site for another year (four years of data in all) 2. Provides data for a more normal rainfall year
Broadway Outfall Monitoring	EPA - $162,550 District - $108,374	1. Construction completed January 2002; monitoring began November 2002. 2. Pre-construction sediment data identified problems - high PAHs, anoxic conditions. 3. CDS unit effective for removing gross solids including toxic levels of PAHs
Stormwater Pond Evaluations 15 years later	District $93,850	1. Reduction of permanent pool ranged from 5 to 24 percent for the 12 ponds 2. The stormwater ponds captured an average of 257 cubic meters of sediments each in 15 yrs 3, Up to 64% of ponds did not have the required littoral zone and 55% had no littoral vegetation

Water-Quality Survey of Twenty-Four Stormwater Wet-Detention Ponds

Author(s):	**Year Completed:**	**Project Costs:**
Mark J. Kehoe	1993	District-$100,000

Project Rationale:

As part of its stormwater management responsibility, the Southwest Florida Water Management District conducts research to implement better stormwater regulations. During 1988-89, the District conducted a water-quality survey of twenty-four stormwater wet-detention ponds that had been permitted by the District in the Tampa Bay Region. These ponds were studied to characterize the discharge effluent water quality and to determine consistency with State water quality standards.

Project Description:

The objectives of the survey were threefold: (1) to provide regional, base-line water-quality data in urban, stormwater wet-detention ponds, (2) to document whether the water quality of effluents from wet-detention ponds met State water-quality standards, and (3) to explore relationships among physical/chemical (water-quality) variables, water-level variables, and pond dimension variables. To accomplish the objectives, grab samples were collected in the pond and at the outflow within two days after a storm event.

Project Results:

- Samples collected at the outfall station (located at the point of discharge from wet-detention ponds) found exceedences (non compliance) of State water quality standards which included: dissolved oxygen (34%), zinc (31%), cadmium (10%), copper (12%), lead (9%), conductivity (6%), turbidity (3%), chromium (3%), nickel (1%) and magnesium (1%).

- Exceedence of the total suspended solids standard (20 mg/L -- for an efficient secondary sewage treatment) in 10 percent of samples, and exceedence of the turbidity standard (29 NTU) in only 4 percent of samples indicated the wet-detention ponds were effective as sedimentation basins.

- Evaluation of seasonal patterns in the data indicated that hydrologic conditions (i.e., water levels) were rainfall related, as expected. More importantly, several variables (conductivity, turbidity, cadmium, and possibly zinc and iron) were inversely correlated with rainfall-related water-level indicators (i.e., the number or percent of ponds discharging, and the bottom depth at the sample location). Also, as would be expected seasonal temperature patterns were important with regards to dissolved oxygen levels.

- The inverse relationship between the number of ponds discharging and mean outfall-station concentrations for certain water-quality variables also suggests that higher mean values and perhaps more exceedences of standards corresponded with periods of lower rainfall when fewer ponds were discharging. Thus, an exceedence during dry periods might not actually constitute a violation of water quality standards since these are designed to protect receiving waters.

- Results of multivariate statistical analyses (cluster techniques, multiple regressions, etc.) provided evidence that hydrologic conditions and pond dimensions were important for certain water-quality variables, especially suspended particles and iron. The results also suggested a relationship between water quality and primary production in wet-detention ponds since temperature, dissolved oxygen and pH were closely related.

- Data from the land-use evaluations and cluster analyses of ponds suggested that multi-family residential ponds are among those with poorest water-quality, probably caused by greater impervious areas.

Project Conclusions:

- Some additional parameters should be incorporated for more complete evaluation of water-quality data (e.g., total hardness, alkalinity, redox potential, nutrients and/or chlorophyll, and color). These variables are important because of their influence on metal concentrations and metal toxicity, as well as, on other water-quality characteristics.

- Research concerning the ecological value of stormwater ponds has been mostly overlooked. With ever increasing development pressures reducing wetland and surface-water resources, biological sampling (e.g., plants, algae, and benthos) would help determined the strengths and weaknesses of stormwater ponds as fish and wildlife habitat.

- Stormwater rules should relate percent impervious area to the amount of treatment required for stormwater ponds since the greater the impervious area, the more often these stormwater systems exceed standards.

District Report Reference:

Kehoe, Mark J. 1993. Water Quality Survey of Twenty-Four Stormwater Wet-Detention Ponds. Southwest Florida Water Management District. 84 pages.

Stormwater Reuse, Design Curves for Southwest Florida Water Management District

Author(s):	**Year Completed:**	**Project Costs:**
Tom J. Harrison	1993	District $20,000

Project Rationale:

Investigations have shown that wet-detention practices with longer residence times increase pollution removal efficiencies. An alternative method of improving treatment efficiency is proposed by reducing the quantity of stormwater discharged from the pond by implementing a reuse component. Reuse conservation benefits include conservation of rainfall runoff, reduced demand for potable water for irrigation, and enhanced groundwater recharge.

Project Description:

This study developed rate-efficiency-volume (REV) charts for six rainfall stations within the District, analyzed the impact the length of the rainfall record has on the average annual removal efficiency, and compared the average annual removal efficiency for the period of record to annual and seasonal removal efficiency.

Project Results:

- The REV charts developed in this study serve as design aids to determine the relation between the reuse volume, the reuse rate, and the percent of the average annual runoff, which can be expected to be reused.
- Demonstrated that stormwater reuse can be used to meet 80% pollutant removal goal.

Project Conclusions:

- The reuse of stormwater runoff can help meet irrigation demands, increase groundwater recharge and improve the quality of surface water runoff.
- The reuse potential of stormwater is limited only by the creativity of the design engineer to capture runoff.
- The stormwater reuse rate is not a guaranteed supply therefore other water sources are necessary to meet specific needs.

District Report Reference:

Harrison, T.J. 1993. Stormwater Reuse Design Curves for Southwest Florida Water Management District. *In* Proceedings of the 3rd Biennial Stormwater Research Conference. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609.

Comparative Water Quality Data of a Deep and a Shallow Wet-Detention Pond

Author(s):	**Year Completed:**	**Project Costs:**
Jeffery Cunningham	1993	District $40,000

Project Rationale:

Stormwater treatment criteria as stated in State Water Policy 62-40 has a goal of 80% removal efficiencies for annual pollutant loads. A common method used to treat stormwater includes wet-detention. Studies have indicated that some wet-detention systems fail to meet the goal of 80% removal. As a result, this study investigated methods to improve the wet-detention system design.

Project Description:

This study examined the effect of the depth of the permanent pool on pollutant removal efficiency. Two adjacent ponds with similar parameters except for the depth (9.0 feet vs. 3.5 feet) were tested for pollutant removal. Pollutant removal efficiencies were calculated based on mass loading numbers.

Project Results:

- Removal efficiencies for copper were low in both ponds, possibly due to low concentrations entering at the inflow. The highest removal efficiencies for both ponds was for iron. Iron removal was 87% for the deep pond and 85% for the shallow pond. Since iron removal is a good predictor for the behavior of other metals, it can be assumed that efficiencies for copper and zinc would have been better if concentrations had been higher.

- Suspended solid and volatile suspended solid removal was greater in the deeper pond (77% vs 69%).

- Nitrogen removal was modest (<50%) in both ponds. Greater than 80% removal for ortho-phosphorous was recorded for both ponds.

- Low dissolved oxygen levels at the bottom of ponds were associated with thermal stratification. The deeper pond was stratified more often than the shallow pond.

Project Conclusions:

- The removal efficiencies between the two ponds were similar except for greater suspended solid removal in the deeper pond.

- Wet-detention pond depth does not seem to significantly affect removal efficiencies of nutrients and metals, but low initial concentrations of metals may have skewed this result.

- Deeper ponds may be more prone to low dissolved oxygen levels at the bottom due to increased frequency of thermal stratification.

District Report Reference:

Cunningham, Jeffery. 1993. Comparative water quality data of a deep and a shallow wet-detention pond. *In* Proceedings of the 3rd Biennial Stormwater Research Conference. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609.

Control of Mosquito Breeding in Permitted Stormwater Systems

Author(s):	**Year Completed:**	**Project Costs:**
Frederick J. Santana, John R. Wood, Ray E. Parsons and Sally K. Chamberlain	1994	Sarasota County Mosquito Control - $20,000/ Manasota Basin - $20,000

Project Rationale:

Three common stormwater system types in Sarasota County are wet detention, effluent filtration and retention ponds. Between 1984 and 1994, approximately 2,600 systems were approved for construction in Sarasota County. This study was undertaken to gain an understanding of mosquito breeding in these systems and to document the measures needed to control them. The specific objectives were to determine: 1) the relative importance of detention, effluent filtration, and retention stormwater control facilities as mosquito breeding sites, 2) the major pest and disease vector species that utilize facilities for breeding, 3) the seasonal occurrence and abundance trends for dominant species, 4) the comparison of system type and age on production patterns, and 5) the efficacy of conventional larval control materials against natural populations of mosquitoes occurring in stormwater systems.

Project Description:

One hundred and thirty-eight stormwater projects permitted by SWFWMD (including 238 individual stormwater systems) were selected for study. Systems were divided into permanently flooded (PF) and intermittently flooded (IF). Collections of larval mosquitoes were made using a standard 350 ml mosquito dipper and each dipper collection taken is termed a sampling event. Approximately 12% of the permanently flooded systems were inspected for mosquito breeding biweekly. Another 15% were inspected monthly and the remaining 72% were inspected bimonthly. Inspections of intermittently flooded systems depended on rainfall. Both short and long-term (sustained-release) materials were tested against natural larval populations occurring in stormwater systems. Materials tested can be classified as a traditional insecticide (Abate), oil formulation (Golden Bear), biological (VectoBac) and a growth regulator (Altosid).

Project Results:

- The majority of PF systems did not produce large numbers of mosquitoes when compared to IF systems.

- One hundred and eighty-six (76%) of the 238-stormwater systems surveyed for mosquito breeding between June and August 1993 were mosquito productive. When only mosquito productive systems are considered, approximately 50% of the events from PF systems and 75% from IF systems were positive for mosquitoes. Larval densities of IF systems were also greater than for PF systems.

- Twenty-one species of mosquitoes were identified from larval collections including 12 nuisance pests and 3 disease vectors. Pest and vector species comprised 95% of the total number (45,555) of mosquitoes collected. IF systems produced the most mosquitoes.

- The water retention characteristics of an intermittently flooded system determined its mosquito production potential. The majority of unproductive IF systems dried out within 3 days following significant rainfall. Generally, IF systems that retained water for more than 3 days were mosquito productive.

- An important factor which influenced some species in IF systems was the amount of decaying organic matter present. Extremely large aggregations were observed in association with decaying organic matter. Decaying vegetation came from a variety of sources and was usually associated with maintenance practices such as chopping or herbiciding vegetation with subsequent breakdown and decay.

- Short-term control materials Abate, Golden Bear and Vectobac provided between 91% - 100% control of existing larval infestations in IF systems 24 hour post treatment. The application of sustained-release materials to problem systems before the onset of the mosquito season reduces both their breeding potential and the time necessary for surveillance.

Project Conclusions:

- Careful consideration should be made before IF stormwater systems are selected as the Best Management Practice (BMP) for treating stormwater. This BMP should only be implemented at sites, which contain coarse-grained sandy soils and a minimum of 3 feet between the facility floor and the seasonal high water table level. Considering their mosquito production potential, this stormwater management method should be avoided whenever possible.

- Systems should be kept free of excess organic matter. When the perimeter or floor of a basin is mowed, the clippings should be removed. If overgrown vegetation is killed, the dead plants should be removed.

- Circumstances, which restrict the flow of water from a system should be corrected. Debris or silt build-up interfering with an outfall structure should be removed. Under drain and filtration media should be inspected periodically and cleaned out or replaced as needed.

- The facility floors of IF systems and the littoral shelves of PF systems should not contain depressions that retain isolated pools of water.

- Sustained-release larvicides should be used whenever possible. Known mosquito productive systems should be treated before the onset of the mosquito season.

- PF systems should be stocked with native mosquito fish to foster biological predation on mosquito larvae.

<u>District Report Reference:</u>

Frederick J. Santana, John R. Wood, Ray E. Parsons and Sally K. Chamberlain. 1994. Control of Mosquito Breeding in Permitted Stormwater Systems. Sarasota County Mosquito Control and Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 46 pages.

Mosquito Prevention in Stormwater Systems

Author(s):	**Year Completed:**	**Project Costs:**
Sarasota County Mosquito Control District	1994	Sarasota County Mosquito Control - $5,000/ Manasota Basin - $5,000

Project Rationale:

Using the study "Control of mosquito breeding in permitted stormwater systems" and the actual reconstruction of a stormwater pond, a brochure was developed to provide practical information to the public.

Project Description:

The brochure provided description of the problem, solutions to correct the problem, tips on maintenance for mosquito prevention, and some general information about stormwater systems.

Project Results:

An informative and useful brochure was developed with the cooperation of the District, Sarasota County Mosquito Control District, and Sarasota County Stormwater Environmental Utility. The brochure was written in easy-to-understand language for the general public. This brochure is available to any interested party for dissemination.

Project Conclusions:

- Designate responsibility for maintenance of stormwater systems.
- Avoid sediment buildup to prevent mosquito producing standing water.
- Avoid dumping grass clippings or organic debris into stormwater systems.
- Remove aquatic plants, which nourish and shelter mosquito larvae. Replace troublesome plants with beneficial aquatic plants
- Create "minnow sumps" in drought-sensitive stormwater ponds. Stock ponds with predatory "mosquito fish"

District Report Reference:

Brochure entitled "Mosquito Prevention in Stormwater Systems"

A Survey of the Water Quality of Wetlands-Treatment Stormwater Ponds

Author(s):	**Year Completed:**	**Project Costs:**
Mark J. Kehoe, Craig W. Dye, and Betty T. Rushton	1994	District-$50,000

Project Rationale:

Wetlands are associated with the transition from upland to aquatic ecosystems and provide many natural amenities to society including flood control, water quality enhancement, and fish and wildlife habitat. Although surface runoff is a natural source of hydrologic inputs to wetlands and surface waters, non-point sources of pollution associated with human activities make stormwater runoff a major source of degradation of surface waters in Florida. This study investigated the ability of natural wetlands to treat stormwater without degrading the wetland while still meeting State water quality standards at the outflow.

Project Description:

A water-quality survey of stormwater treatment systems that employed wetlands-treatment with pre-treatment and natural wetlands was conducted. The survey provided regional stormwater data, and documented the exceedence (non-compliance) of State water-quality standards at points of discharge from wetlands-treatment systems. Additionally, statistical analysis of relationships among survey variables provided insight about factors that affect water quality in wetlands-treatment systems.

Project Results:

- Total percent exceedence of water-quality standards at the twelve wetland outfalls focused attention on variables that frequently exceeded standards in the Wetlands- Treatment Survey (and also the Twenty-Four Pond Survey). Wetland treatment systems failed to meet standards while discharging for: dissolved oxygen 70%, cadmium 37%, zinc 27% and copper 2% of the time.

- The anaerobic characteristics of many wetlands may account for the fact that percent exceedence was much higher for dissolved oxygen and total cadmium in the Wetlands-Treatment survey than the exceedence for these parameters found in the 24 pond survey.

- In overall paired statistical comparisons, pre-treatment stations had greater average depths, temperature, dissolved oxygen, pH, zinc, and copper than wetland outfalls, suggesting that natural wetlands are generally effective in reducing some constituents.

- Notable water-quality relationships observed during the survey suggest that an equilibrium between primary production (i.e., photosynthesis), aerobic (microbial) respiration, and temperature are responsible for temporal and spatial dissolved oxygen distribution. Results also suggest that pH-mediated mechanisms and oxidation-reduction potential affect heavy metal concentrations.

- Numerous factors were probably involved in establishing ambient water quality at the two stations in the survey wetlands-treatment systems. There were indications of water quality variability between wetlands and of seasonal fluctuations in the data, a result that agrees with the variability noted in an earlier study of 24 wet-detention systems. The data suggest that hydrologic conditions may have a significant impact on constituent concentration and the roles of sediments in samples, internal sediment and biogeochemical cycles, plant and algal cycles, and rainfall and runoff sources of metals.

Project Conclusions:

- There is potential for both positive and negative impacts when using natural wetlands as part of a stormwater treatment system. Stormwater provides the hydrologic input that may be necessary to keep the wetland viable, but the stormwater it receives may change the character of the wetland. For example, pH and dissolved oxygen were measured at much lower concentrations in wetland water than in stormwater in the pre-treatment basin.

- Natural wetlands may not meet water quality standards as well as constructed wetlands. Dissolved oxygen, for example, was in non-compliance in the discharge water of natural wetlands 75 percent of the time compared to 40 percent, in constructed wetlands. The use of fountains in many constructed ponds likely caused this result.

- Some metals were also more problematic in natural wetlands. Toxic levels of cadmium exceeded standards in the discharge water 37 percent of the time compared to 10 percent in constructed ponds. For zinc exceedences were about the same (27% for natural vs. 31% in constructed).

- Other toxic pollutants were more common in constructed wetlands. Copper non-compliances were higher in constructed wetlands (2% for natural and 12% for constructed) probably caused by maintenance practices in constructed ponds. Lead never exceeded standards in natural wetlands but was measured at toxic levels 8 percent of the time in the discharge water of constructed ponds.

District Report Reference:

Kehoe, Mark J., Dye, Craig W. and Rushton, Betty T. 1994. A Survey of the Water-Quality of Wetlands-Treatment Stormwater Ponds. Southwest Florida Water Management District. 42p

Integrating a Herbaceous Wetland into Stormwater Management

<u>**Author(s)**</u>:	<u>**Year Completed**</u>:	<u>**Project Costs:**</u>
David W. Carr and Betty T. Rushton	1995	EPA-$55,000 / District-$55,000

<u>Project Rationale:</u>

The large number of natural wetlands and the rapid population growth in Florida make using existing isolated wetlands an attractive alternative for stormwater treatment. Uncertainty exists, however, in their ability to absorb the increased peak volumes and higher levels of pollutants found in urban runoff. This study evaluated the effectiveness of a marsh to treat stormwater, compared water quality results to State water quality standards and documented the effects of urban runoff on marsh vegetation and sediments.

<u>Project Description:</u>

This project incorporated an existing isolated wetland as part of a stormwater system at an office complex. The wetland was a 3 acre herbaceous marsh which had historically received most of its hydrologic input directly from rainfall and a small amount of runoff from surrounding native pine forests; therefore, it was characterized by low levels of nutrients, dissolved oxygen, pH and conductivity. After development, it also received hydrologic input from urban runoff (15.3 acres in an office park), which had received some pre-treatment from sedimentation basins. The 0.175-acre east sedimentation basin received its runoff from a central roadway and the 0.012-acre west basin collected runoff from a parking lot and a portion of an office building before discharging into the marsh. To study the effect of stormwater on the marsh, automatic data recording stations were installed to measure water quality and quantity as it was discharged from the sedimentation basins and again as it was discharged from the marsh. A rainfall station measured these parameters for rain. Analysis of 81 storm events during the 30-month study provided extensive water quality and hydrologic data.

<u>Project Results:</u>

- Removal efficiencies (i.e. the sum of pollutant load from rainfall and surface water inputs compared to pollutant loads at the outflow) indicate the marsh effectively reduced the following: cadmium by 92 percent, inorganic nitrogen, suspended solids and zinc by at least 85 percent, and copper and phosphorus by at least 71 percent. Removal efficiencies were good because only 27 percent of the water measured coming into the marsh was discharged from the marsh; the rest was lost by evapotranspiration and infiltration.

- Marshes can be effective at removing stormwater pollutants, but changes in the physical and chemical properties of the marsh will occur. The sedimentation basins had significantly higher levels of pH, dissolved oxygen, oxidation reduction potential and conductivity than was measured in the marsh but higher levels of these parameters were starting to be measured in the marsh by the end of the study.

- Event mean concentrations measured at the outflow exceeded State standards in effect after 1992 by the following percentages: Lead 62%, zinc 23%, copper 44%, and cadmium 2%. One reason for the high noncompliance was the result of the soft water that is typical of many natural wetlands. Soft water makes metals more toxic to organisms, therefore, the standard is hardness dependent and wetlands that receive much of their input from rainfall exceed standards more often for equal concentrations of metals.

- Rainfall was found to be a source of inorganic nitrogen and zinc to the marsh.

- Total annual rainfall on the marsh represented 45 percent of the annual hydrologic input, which approximately equaled the evapotranspiration loss of 41 percent. Surface water inflow accounted for 55 percent of total input and 27 percent of output, while net seepage accounted for 31 percent of the outflow from the marsh.

- Dominant plant species with the highest percent cover in the marsh were maidencane, pickerelweed, water lily and arrowhead. Detailed vegetation analyses and historical aerial photographs documented an increase in nuisance plant species such as primrose willow and cattail which first appeared in areas where the wetland margins had been altered with steeper slopes. Subsequently the nuisance species invaded the marsh itself.

- Soil cores indicate the marsh and sedimentation basins have mineral soils and all concentrations of pesticides, organic priority pollutants, and PCB were below detectable levels. The soils in the west basin contained toxic levels of zinc, probably from roof runoff, and the zinc was increased at the inflow station in the marsh.

- Correlation analysis showed that phosphorous concentrations increased during extended periods between rainfall events. Other relationships indicate that as total suspended solids increase so do iron, lead, copper, and ammonia.

<u>Project Conclusions:</u>

- A large wetland to drainage basin ratio should be encouraged. Significant mass pollutant removal occurred in the marsh because only 27 percent of the hydrologic input to the marsh was actually discharged at the outflow. A large wetland to watershed ratio will also protect against detrimental changes in hydroperiod.

- To maintain the existing integrity of the marsh and avoid the adverse impact of invasive plant species, emphasis should be placed on maintaining an undisturbed upland buffer zone around the wetland. Inspections and maintenance should be required to minimize the impact of non-native and invasive plant species in areas within and adjacent to natural wetlands and invasive species removed.

- Toxic levels of zinc measured in the sediments of the west basin suggests the need for an operation and maintenance guideline for the periodic removal of accumulated pollutants from pretreatment ponds.

- The problem of pollutants in atmospheric deposition needs to be addressed by source reduction.

- The low pH, conductivity and dissolved oxygen typical of many natural wetlands reduce their effectiveness for removing metals and phosphorus.

District Report Reference:

Carr, David W. and Betty T. Rushton. 1995. Integrating a Native Herbaceous Wetland into Stormwater Management. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 131 pages.

An In-Depth Analysis of a Wet Detention Stormwater System

and

Three Design Alternatives for Stormwater Detention Ponds

Author(s):	**Year Completed:**	**Project Cost:**
Betty Rushton, Charlie Miller, Clark Hull and Jeff Cunningham	1997	EPA- $50,000/ District- $170,000

Project Rationale:

Wet detention ponds are the most common method used in our District for treating stormwater runoff, but little data is available about how different designs affect pollution removal. The purpose of this study was to provide scientific documentation to support or modify certain aspects of the District's stormwater rule (40D-4). Other objectives included measuring pollutant loading from rainfall, correlating relationships between constituents, determining compliance with state water quality goals, measuring pollutants in the sediments and making recommendations for reducing non-point source pollution.

Project Description:

One pond was reshaped three different ways to compare designs that have been used or can be used to meet District surface water runoff rules. Each pond design was studied for an eight-month period from June through January of each year. The major features of each design are:

- A shallow pond was studied in 1990. It was originally one foot deep with an average 2-day wet season residence time and 100% vegetated with planted wetland species and the design followed the early parameters established by SWFWMD rules promulgated in 1988.

- The same pond was studied in 1993 except that it had been reshaped with a permanent open water pool five feet deep, which allowed a 5-day wet season residence time. An unplanted shallow shelf (littoral zone) occupied 33% of the pond and was allowed to colonize naturally from the available seed source and the largest part of the shelf was located near the outflow. Design parameters represent SWFWMD criteria in effect in our current rules.

- The pond, reshaped once again, to test the Conservation Wet Detention Design criteria (developed by SWFWMD's regulatory staff), was studied in 1994. These design criteria included a 14-day wet season residence time and a planted littoral shelf similar in area to the previous pond design. These criteria represent an alternative design that can be used by developers seeking SWFWMD permits.

The drainage basin for the pond is 6.5 acres with about 30 percent of the watershed covered by rooftops and asphalt paving, 6 percent by a crushed limestone storage compound and the remaining

64 percent is a grassed storage area. The impervious surfaces discharge to ditches that provide some pre-treatment before stormwater enters the pond. Instruments at the inflow and outflow collected flow-weighted samples for over 20 storm events during each eight-month sampling period. Rainfall amounts and water quality were also quantified. Since treatment credit is given for some of the storage in the permanent pool, the Conservation Wet-Detention design can reduce the amount of fill needed for elevating house pads and can also use less land area for the pond.

Project Results:

- The most important finding showed the Conservation Wet Detention design that included the 14-day residence time had the best removal efficiency. Also, using these criteria, the reduction of pollutants from the inflow to the outflow usually met the 80 percent pollutant reduction goal specified by the State Water policy.

- Organic nitrogen and ammonia are the most difficult pollutants to remove with wet detention ponds. Ammonia concentrations were reduced by 18% to 70% and organic nitrogen by 5% to 42%. The Conservation wet-detention design had the highest removal rates compared to the other two designs.

- Rainfall is a significant source for nitrogen and some metals.

- Low dissolved oxygen levels (< 2 mg/L near the pond sediments) increase phosphorus concentrations in the water column.

- Sediment samples indicate polycyclic aromatic hydrocarbons (PAH) concentrations present a problem in stormwater runoff and concentrations in sediments increase as ponds age.

- Iron is a controlling mechanism for pollution removal forming positive correlations with metals and phosphorus. Iron was present in higher concentrations at the inflow during the final year of the study and since it forms particles that settle easily it may have improved pollution removal for the final year.

- Macroinvertebrate sampling indicated that newly constructed wet detention ponds can be diverse and productive habitats supporting even some pollution sensitive species.

- Desirable wetland herbaceous species planted on the wide littoral shelf reduced the amount of torpedo grass that had invaded the pond. In contrast, the steep slopes of the narrow littoral shelf around the pond favored the expansion of torpedo grass.

- Much more diverse planted wetland vegetation survived on the wide littoral shelf near the outflow than on the narrow shelf that surrounded the pond.

Project Conclusions:

- The Conservation Wet Detention criteria should be recommended for all stormwater systems where deeper surficial groundwater tables and confining strata allow for adequate pond depth. In this study the effluent, which resulted from using these criteria met almost all State water quality standards and this design can also reduce the need for fill material and produce other economic benefits.

- Stormwater designs that utilize the entire drainage basin and reduce discharge to pre-development levels should be encouraged and credit given to developers who use these techniques. Although stormwater ponds reduce peak flows, only a watershed approach will significantly reduce the volume of water discharged downstream.

- Stormwater rules need to address extreme events. During 1993 in this study, from 32 to 77 percent of all pollutant loads measured during the 22 storms monitored that year were discharged during one storm.

- Source reduction is needed for stormwater improvement since atmospheric deposition was a significant source of inorganic nitrogen and some metals.

- Aerobic bottom sediments and a circumneutral pH in a permanent pool with adequate residence times are a necessary condition for stormwater ponds and designs that provide these conditions should be incorporated into stormwater systems.

- Operation and maintenance information for the care of stormwater systems is needed.

REFERENCE:

Rushton, B. T., Charlie Miller, Clark Hull and Jeff Cunningham. 1997. Three Design Alternatives for Stormwater Detention Ponds. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 59 pages.

Rushton, B. T. and C. W. Dye. 1993. An In-Depth Analysis of a Wet Detention Stormwater System. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 121 pages.

A Survey of Outflow Water Quality from Detention Ponds in Agriculture

Author(s):	**Year Completed:**	**Project Costs:**
Benjamin Bahk and Mark Kehoe	1997	District-$50,000

Project Rationale:

Agriculture is considered the major source of non-point source (NPS) pollution to water bodies in the United States. Because of the diffuse nature of NPS pollution, treatment of the discharge waters has been difficult. One method used to treat agricultural runoff is to direct the runoff from stormwater and irrigation to detention ponds. Detention ponds have been used in urban settings to treat stormwater before discharge into environmentally sensitive waters and have proven to act as a filter for pollutants such as metals, nutrients, and other water contaminants. In this study, discharges from detention ponds at nine agricultural sites over a three county area were investigated to assess the outflow water quality and compliance with State water quality standards.

Project Description:

From December 1993 through November 1994, monthly water samples were taken from the outflows of nine detention ponds in agricultural basins to assess compliance with State of Florida water quality standards. Three analyses were performed: 1) discharge water quality data were compared with State surface water and ground water standards 2) discharge water quality data were compared with treated and untreated agricultural discharge values found in literature and 3) correlations of water quality data were performed to investigate relationships and trends. For this study, it is important to consider that data was gathered from only the outflow of detention ponds. Water quality data was not gathered at the inflow and therefore, this study does not assess the treatment efficiency nor does it characterize how the detention ponds function. Since the ponds discharged almost continually the samples were collected on a monthly basis and do not necessarily represent storm runoff.

Project Results:

- Comparison with State Class III surface water standards indicates that out of nine total sites, violations occurred for lead (2 sites), iron (3 sites), alkalinity (1 site), unionized ammonia (1 site), pH (3 sites), and dissolved oxygen (8 sites).

- Comparisons to ground water were performed to provide additional insight to the water quality because the source of irrigation water which flowed into the ponds was groundwater. Comparison with ground water standards indicates that violations were noted for iron (6 sites), manganese (7 sites), total dissolved solids (7 sites), sulfates (5 sites), and pH (4 sites).

- Although violations of both surface water and groundwater standards were detected, the violations were infrequent. Some of the exceedences (non-compliance) were related to the summer rainy season and farming schedules which may have elevated certain water quality parameters.

- Comparisons of agricultural survey data with data from untreated agricultural runoff reported in the literature indicate lower values from the agricultural survey sites in almost all parameters (includes various forms of nitrogen and phosphorous, pH, dissolved oxygen, total suspended solids, and turbidity).

- Comparisons of agricultural survey data with data from treated agricultural discharges that were reported in the literature indicate similar water quality values for all parameters (includes various forms of nitrogen and phosphorous, pH, dissolved oxygen, total suspended solids, and turbidity). In some cases, the values from the agricultural survey were actually lower.

- High correlations between hardness, conductivity, total dissolved solids and various ion species such as calcium, magnesium, and sulfate confirmed expected relationships between the variables.

- Unexplained correlations (includes negative correlations) were noted between phosphorous and major ions (r_s value range of -0.77 to -0.61), and also copper and zinc to various major ions (r_s value range of -0.50 to -0.39).

Project Conclusions:

- Ponds in this study discharged almost constantly, especially in filtration systems. Designs of detention ponds should be reviewed to maximize treatment ability by increasing retention time and other design criteria.

- In agricultural systems, organochlorine and organophosphorous pesticides are used to control insects and other pests. Pesticides can be introduced into the water column, and have adverse effects on the reproductive and neurological systems of the biological community in the aquatic systems. Pesticides and other anthropogenic compounds should be addressed in characterizing water quality from agricultural sites.

District Report Reference

Bahk, Benjamin, and Mark Kehoe. 1997. A survey of outflow water quality from detention ponds in agriculture. Southwest Florida Water Management District. 42 pages.

Outfall Water Quality from Wet-Detention Systems

Author(s):	**Year Completed:**	**Project Costs:**
David W. Carr and Mark J. Kehoe	1997	District - $60,000

Project Rationale:

This survey study was conducted to statistically compare samples collected before and after discharge over the outfall structure. This was done to validate the feasibility of collecting samples before discharge for compliance monitoring. Additionally, the outfall discharge water quality from permitted wet-detention systems was evaluated against State water quality standards. This study compared the effluent water quality of two types of permitted stormwater systems: constructed wet-detention ponds and natural wetlands.

Project Description:

A survey of permitted wet detention ponds was conducted between June 1992 and April 1993. Twenty-two systems in the Tampa Bay area were sampled; nine were natural wetlands and thirteen were constructed ponds. Data collection took place during fourteen sampling events. Samples were collected during system discharge from two locations: 1) in the system just before the outflow weir (***b*** side) and 2) after the outflow weir (***a*** side) but before it entered the receiving water. The-***a*** side is also referred to as the wet detention system effluent. Water quality sampling included eight metal species, six nutrient species, turbidity, total suspended solids, temperature, dissolved oxygen, pH and conductivity. Study goals were to: 1) compare the water quality in front of the outfall weir to that of its effluent, 2) determine whether the effluent complied with class III Florida State Water Quality Standards and 3) compare the effluent from constructed and natural systems for standard compliance. Additional analyses were conducted to determine relationships between constituents.

Project Results:

- Unionized ammonia, iron, manganese (class III Standard) and nickel measured during this study complied with water quality standards 100 percent of the time. Most constituents complied >79 percent of the time except dissolved oxygen (in noncompliance 64% of the time).

- In a comparison of the metals in noncompliance between the natural and constructed systems, the natural systems had a higher percent noncompliance than the constructed systems (ranging from two to nine times higher). Despite these differences between system types, every metal complied with water quality standards >65 percent of the time.

- A comparison of the data from both sides of the weir in each of the data sets revealed that all constituents measured were not significantly different except dissolved oxygen, turbidity, temperature, and pH. Dissolved oxygen was significantly lower on the ***b***-side of the weir than the-***a*** side in each of the three data sets. The pH was significantly higher on the-***a*** side of the weir in the constructed system data set. Turbidity was significantly higher on the-***a*** side of the weir in the natural system data set. The temperature on the-***a*** side of the weir in the natural system was significantly higher.

Project Conclusions:

- The discharge from constructed systems met State water quality standards more often than discharges from natural wetland systems for copper, lead, zinc, and cadmium. Since the State standard is hardness dependent, better compliance with the metal standards observed in the constructed systems could be the result of the generally harder water found in those systems. Non-compliances in natural wetlands were: dissolved oxygen (48%), copper (35%), lead (27%). Alkalinity (27%), zinc (18%), and cadmium (9%).

- When water quality from constructed wetlands was compared to State standards, the discharge water failed to meet standards for some of the metals and other constituents. For constructed wetlands, the following were in non-compliance: dissolved oxygen (70%), copper (12%), lead (12%), and zinc (6%).

- No statistical differences were found between the water quality measured on either side of the weir during discharge (except pH and dissolved oxygen). Thus, samples can be collected from the more accessible ***b***-side of the weir (just before the water discharged across the weir located inside the pond). Current requirements dictate that samples be taken from the ***a***-side (after water exits the pond).

- Methods to increase dissolved oxygen in ponds should be considered. Examples include aeration devices (i.e., fountains) and maintenance of a deeper area devoid of vegetation immediately adjacent to outfall weirs.

District Report Reference:

Carr, David W. and Mark J. Kehoe. 1997. Outfall Water Quality from Wet-Detention Systems. Southwest Florida Water Management District. 36 pages.

An Assessment of an In-line Alum Injection Facility Used to Treat Stormwater Runoff in Pinellas County, Florida

Author(s):	**Year Completed:**	**Project Costs:**
David W. Carr	1998	District - $60,000 (monitoring) / SWIM - $249,115 (construction and monitoring)

Project Rationale:

This study was conducted to determine the feasibility of using an in-line alum injection facility for a stormwater treatment retrofit. Alum treatment is primarily used to remove phosphorus (usually the limiting nutrient in fresh water). Other alum treatment facilities constructed in Florida inject alum into the stormwater flow in storm sewers located upstream of receiving water bodies (e.g., a lake) with the alum floc allowed to settle in the water body. The purpose of this study is to determine the effectiveness of alum technology for an in-line system with limited storage volume for alum floc containment, and to conduct an environmental impact assessment. This study also afforded the District an opportunity to characterize the water quality of an older urban ditched system.

Project Description:

Data collection included flow-weighted storm event samples, monthly water quality samples, and hydrologic data collection. Event based load reductions were calculated, comparisons were made of pre- and post-treatment data, and event and monthly water quality were compared to State surface water quality Class III standards. Additionally, a comparison to event mean concentration (EMC) pollutant reduction was performed between predicted reductions estimated in the permit application and load reductions measured during this study. The water quality constituents analyzed included various forms of phosphorus and nitrogen, and several metals. To some degree, portions of these data were likely biased due to a backflow of alum in the inflow station samples. A detailed analysis of the potential for aluminum toxicity to various fish and benthic species was also conducted.

Project Results:

- Event load reduction calculations were performed on inflow and outflow data collected during seven storm events that were successfully treated with alum. Mean total phosphorus and ortho phosphorus load reductions were 37 and 42 percent respectively. Mean percent load reductions of ammonia and nitrate+nitrite were 24.5 and 52.2 percent respectively while, event total Kjeldahl nitrogen loads increased on average by 5 percent. Zinc loads were reduced in most events (despite the alum solution being contaminated with zinc) and when a single outlier was excluded, mean zinc removal was 41 percent. Iron and lead load reductions were variable with the mean load increasing (export). Dissolved monomeric aluminum event loads were mostly reduced with a mean 56 percent reduction. However, total aluminum mean loads revealed an increase of 258 percent. This large increase in total aluminum was attributed to inadequate storage volume for the alum floc. Generally, the load reductions outlined above are good considering the settling pond's small size.

- Lead and iron EMCs were in noncompliance less at the outflow than inflow. Copper and zinc EMCs, on the other hand exhibited higher percent noncompliance at the outflow than inflow. The increase in copper and zinc standard noncompliance at the outflow were attributed to these metals being a contaminant in the alum solution.

- Lower pH values were mirrored by increases in aluminum concentrations. This relationship exemplifies the environmental chemistry of aluminum where pH is the driving force in aluminum solubility. Zinc was the sole metal to consistently show concentrations within detectable levels and seemed unaffected by facility operations. Generally, phosphorus concentrations measured downstream of the alum facility were lower and less variable after facility installation. The data suggest that alum residual in the sediment pond tempered phosphorus concentration increases during periods when the injection facility was inoperable. TSS concentration peaks at the outflow were lower after installation. TKN concentrations at all stations showed little change throughout the study due to alum facility installation and operation.

- Inflow and outflow event mean concentration (EMC) data were compared to predicted EMC reductions calculated in the MSSW permit application. Predictions for ammonia and nitrate+nitrite agreed with measured data. Measured changes in pollutant EMCs were a 32 percent *increase* in total nitrogen, a seven percent *decrease* in total phosphorus and a 184 percent *increase* in total suspended solids. EMC predicted percent reduction should not be confused with actual percent load reduction also presented in the report.

Project Conclusions:

- The importance of operation and maintenance cannot be over emphasized. The regulatory agencies should require the permittee of an alum injection system to: a) assure sufficient funds are available for repair/replacement of inoperable equipment, b) submit semi-annual operation and inspection reports, and c) require operators to have some level of expertise appropriate for facility operations.

- It is important to maximize alum floc containment volume to minimize potential adverse environmental impacts downstream. The containment volume at this study site was inadequate.

- Despite the operation and maintenance problems experienced, event mean concentration and loads of phosphorus were reduced during alum facility operations. The data indicate the alum facility could be effective in reducing phosphorus if properly maintained.

- Monthly samples showed that phosphorus concentrations measured downstream from the alum injection facility were generally lower and less variable after facility installation.

- Potentially toxic concentrations of aluminum to aquatic wildlife were measured at stations immediately upstream and downstream of the alum facility. Aluminum concentrations at stations further downstream were below these potentially harmful levels.

District Report Reference:

Carr, David W. 1998. An Assessment of an In-line Alum Injection Facility Used to Treat Stormwater Runoff in Pinellas County, Florida. Southwest Florida Water Management District. 36 pages.

Removal of Microbial Indicators from Stormwater Using Sand Filtration, Wet Detention, and Alum Treatment Best Management Practices

Author(s):	**Year Completed:**	**Project Cost:**
Raymond C. Kurz	1998	District $ 45,000

Project Rationale:

The Environmental Protection Agency has determined that nearly 90% of fecal coliform pollution to surface waters originated from non-point sources such as urban and agricultural stormwater runoff. In the Tampa Bay watershed, several tributaries, which receive agricultural, industrial, and urban runoff exhibit consistent, elevated total and fecal coliform bacteria concentrations which often exceed State standards for shellfish harvesting and recreational exposure. Based on State water quality standards, 45% of these tributaries did not meet their intended use for recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. In urbanized areas, contaminated stormwater can impact recreational beaches in both marine and freshwater environments and can cause a number of bathing-related illnesses including eye, ear, nose, and upper respiratory ailments, skin irritation, and gastrointestinal infections.

Project Description:

Very few studies have been conducted to determine how well stormwater management systems reduce microbial indicators from stormwater. In this study, indicators and surrogates of microbial pathogens were used to determine how well three types of stormwater systems reduced microbes using simulated storm events. The indicators used were total and fecal coliform bacteria, MS2 coliphage, and fluorescent beads representing a pathogenic protozoa. The three types of systems were: sand filtration, wet detention and alum coagulation. Samples were taken before the introduction of the surrogate or indicator organisms, right after the introduction and then ten samples at timed intervals were collected to observe die-off effects. Heavy metals, turbidity and total suspended solids were also measured using the same experimental design. Additionally, gram-negative bacteria already in the water were identified during each of the sampling steps.

Project Results:

- Significant ($p < 0.05$) reductions in total and fecal coliform bacteria, MS2, and bead concentrations were observed between inflow and outflow samples for each of the three stormwater treatment systems. On a few occasions, however, greater concentrations of total coliform bacteria, turbidity and total suspended solids were found in outflow samples than at the inflow.

- Using flow-weighted sampling techniques the following reductions were measured at all three systems. For beads, the reduction was greater than 90% and for MS2 coliphage, greater than 80%. Efficiencies for total and fecal coliform varied widely with total coliform removal values consistently less than 70% while fecal coliform reductions ranged from 65 to 100%.

- Overall, alum coagulation (dose = 10 mg/L) provided the greatest removal efficiencies under controlled laboratory conditions using jar tests.

- Removal efficiencies using sand filtration were generally high for turbidity, MS2, and beads but not for total or fecal coliforms.

- Wet detention using the current regulatory standard of a 5-day bleed-down period provided consistently high removal efficiencies for fecal coliform bacteria, MS2 and beads, and had the greatest TSS removal of the three treatment systems. Water quality standards for total coliform bacteria were exceeded more often during the 14-day trials than the 5-day trials which may have been caused by heavier than normal rainfall.

- A number of gram-negative bacteria were also identified in both the inflow and outflow samples taken from the wet detention ponds including several which are capable of causing human disease. Most of the bacteria were present in both the inflow and outflow samples.

- A small proportion of bacterial removal may have occurred as a result of heavy metal toxicity.

Project Conclusions:

- Each of the three stormwater treatment systems evaluated in this study were capable of reducing microbial pollution and each had specific attributes that would make it more advantageous than the other for specific applications or site constraints.

- The use of a multiple treatment system in which several different BMPs are joined in series may offer greater reductions for a broader collection of parameters than any single BMP. Since no single BMP evaluated during this study had consistently greater removals of all the parameters, this approach would be more effective.

- The consistent presence of pathogenic strains of bacteria in both inflow and outflow samples from all of the three sites evaluated further stresses the importance of stormwater treatment to reduce potential public health risks.

- Methods commonly used for wastewater such as chlorine disinfection, ozonation, and uv light irradiation have been suggested for the removal of microbial pathogens from stormwater.

- Since resuspension of sediments can reduce the effectiveness of wet detention ponds, reducing flow rates at the inflow can be critical to achieving sanitary water at the outflow.

District Report Reference:

Kurz, Raymon C. 1998. Removal of Microbial Indicators form Stormwater Using Sand Filtration, Wet Detention, and Alum Treatment Best Management Practices. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 169 pages.

BMP Data Transfer Grant

Principal Investigator:	**Year Completed:**	**Project Cost:**
Betty Rushton, Ph.D.	2000	EPA - $9,500

Project Rationale:

Money from a BMP data transfer grant has made some of our data available on the internet. The National Stormwater BMP Database was developed by a team of stormwater experts associated with the Urban Water Resources Research Council of the American Society of Civil Engineers under a grant from the U. S. Environmental Protection Agency. Transferability of performance results and consistency, or lack of it, in the performance of various BMPs has been an ongoing problem. The data base process provides a mutually agreed upon minimum list of reporting parameters that can be used to relate the performance of BMPs to some, or all, of these parameters. Over time such standardization will conserve the resources being expended by various field investigations and eventually lead to improvements in the selection of, and the design of various BMPs.

Project Description:

The project coordinators requested that data from some of the Districts stormwater research projects be included in this database, and grant money was provided for data entry.
The database provides access to BMP performance data in a standardized format for at least 200 BMP studies conducted over the past fifteen years. The database may be searched and/or downloaded on the website listed in the reference section. The data fields include site location, watershed characteristics, climatic data, BMP design and layout, monitoring instrumentation, and monitoring data for precipitation, flow and water quality.

Project Results:

- Data from four Stormwater research projects conducted by SWFWMD have now been entered into the database under the grant received from EPA. These include: Three Design Alternatives for Stormwater Detention Ponds, Integrating an Herbaceous Wetland into Stormwater Management, Treatment of Stormwater Runoff from an Agricultural Basin by a Wet-Detention Pond in Ruskin, Florida, and Florida Aquarium Parking Lot: A Treatment Train Approach for Stormwater Management.

- The master database contains records that have undergone quality assurance review by the National Stormwater BMP database Clearinghouse and contains over 200 BMPs selected from an initial bibliography of over 800 studies.

- The data retrieval process is based on specification of one or more search parameters that may include a combination of state, country, watershed size, BMP type or water quality parameter.

- Once the data are retrieved, the user can view, print and/or export the data, revising search criteria as many times as needed. For extensive data analysis a copy of the CD and User's Guide is available on the web site.

Project Conclusions:

The database is one component of a broader project with the ultimate purposes of identifying factors that affect BMP performance, developing measures for assessing BMP performance and using the findings to implement design improvements.

Reference:

http://www.bmpdatabase.org/

Treatment of Stormwater Runoff from an Agricultural Basin by a Wet-Detention Pond in Cockroach Bay, Florida (Phase I)

Author(s):	**Year Completed:**	**Project Costs:**
Betty Rushton, Ph.D.	2001	EPA - $155,407 / District - $103,604

(Phase 2)

Author(s):	**Year Completed:**	**Project Cost:**
Betty Rushton, Ph.D.	2002	EPA $77,455 / District $51,647

Project Rationale:

Agriculture has been identified as a significant source of water pollution in the United States. The use of agricultural fertilizers and pesticides doubled from the mid 1960s to the early 1980s and may be responsible for a major portion of surface and ground water contamination. The effects of agricultural pollution are numerous and include: sediment contamination and deposition with subsequent impairment of aquatic habitat, pesticide contamination, eutrophication of surface waters, and general water quality degradation of downstream water bodies. The Environmental Protection Agency (EPA) ranks agricultural activity as the greatest threat to water quality in streams and lakes. The EPA also notes that nutrient and silt runoff are the leading causes of water quality impairment. Given the water quality problems associated with agriculture, the Southwest Florida Water Management District initiated a study on the effectiveness of a wet-detention pond to treat stormwater runoff from an agricultural basin.

Project Description:

The Cockroach Bay Restoration Project in Ruskin, Florida is an effort to reclaim over 650 acres of natural habitat in a landscape historically used for row crop agriculture. As a part of the larger reclamation landscape, two wet-detention ponds in series receive stormwater runoff from 210 acres of active row crop farmland. The monitoring of the Cockroach Bay Stormwater Project included water quality sampling of inflow and outflow to the detention ponds, as well as collection of rainwater for chemical analysis. The main goal of this project was to assess the treatment efficiency of the wet-detention ponds. The primary constituents monitored include nutrients, metals, ions, pesticides, and bacteria. Additionally, continual measurements of pond water level, temperature, pH, dissolved oxygen and conductivity were recorded in data loggers. Other monitoring efforts include bi-weekly measurements of depth to groundwater around the ponds, quarterly ambient grab samples in the pre-treatment ditch, water quality in groundwater wells and yearly samples of the sediments.

Project Results:

- A complete water budget estimated for storm events showed most (>70%) of the water enters and leaves the pond at the two control structures. In addition, about 20 percent of all storm inputs to the ponds are introduced by rainfall directly on the pond. Additional water export from the pond for the duration of storm events was estimated at 8 percent by evapotranspiration; and 15 percent by net seepage. The large storage capacity of the pond helped reduce the annual volume of runoff leaving the pond by 11 to 25 percent (26 to 45 percent when rainfall is considered an input).

- The large pervious area in the drainage basin as well as the pre-treatment ditch and sandy soils contributed to low runoff coefficients. During the rainy season when ample moisture was available the estimated runoff coefficient showed that 10 to 30 percent of rainfall was discharged from the drainage basin into the pond. During dry periods only 1 to 10 percent of rainfall ran off. The runoff coefficient would have been even lower except for irrigation water entering the pond from the fields.

- In general, inorganic nitrogen (ammonia and nitrate) had its highest concentrations in rainfall, but even with this atmospheric input, nitrate had the greatest percent reduction of all constituents measured (greater than 90% in 1999 and 2000). In contrast, organic nitrogen often increases between the inflow and outflow, probably as a result of nitrogen transformations taking place in the pond.

- Phosphorus is measured at relatively high levels at the inflow to the pond with average concentrations of total phosphorus about 1 mg/L. Although average concentrations at the outflow for phosphorus are reduced by about 40 percent, the concentrations still exceed by a factor of 5 to 8 the suggested EPA goal for streams and rivers of 0.1 mg/L.

- During the four years of study (84 rain events), over 40 percent of all the pollutant loads for potentially toxic metals entered the pond during five El Nino storms. Larger loads are more easily reduced in wet-detention ponds and the goal of 80 percent reduction is met for most metals in 1998 and 2000 and nearly so for inorganic nitrogen. Percent reduction was poorer in 1999 and 2001, which were drought years.

- Pesticides in stormwater were detected, and more were found at the inflow (10) than at the outflow (4) of the pond. Two pesticides exceeded standards (Endosulfan at the inflow and outflow and Chlordane at the inflow). Pesticides were also detected in ambient water quality samples collected in the roadside pre-treatment ditch (55 percent of samples for endosulfan; 10 percent for chlordane; 5 percent for Bromacil; and 16 percent for Diazinon. Chlordane and DDT derivatives were detected in almost all soil samples. Based on the number of pesticides detected at the inflow vs. outflow, the detention pond seems to function as a sink for pesticides.

- Chlorophyll was measured monthly at the inflow and outflow of the pond and except during periods of stagnant conditions the pond reduced all species of Chlorophyll by a significant amount (average Chlor a at the inflow 37.6 ug/L and at the outflow 8.25 ug/L). Although chlorophyll concentrations were reduced considerably as water flowed from the ditch through the pond and over the outflow structure, the pond still discharged water into the marsh in the eutrophic to hypereutrophic range.

- Sediment samples for metals and phosphorus increased dramatically from 1997 to 1998. Phosphorus concentrations were highest in the most overgrown part of the pre-treatment ditch and in the center of the two ponds. The highest concentrations of metals occurred in the pre-treatment ditch.

- Ground water levels were measured in 12 shallow wells surrounding the pond and exhibited a close interaction with pond levels. The water table gradient is toward the pond and eventually the outflow marsh. When pond levels are high the gradient is out of the pond and when pond levels are low the surrounding water table to the north seeps into the pond.

- Ammonia was consistently measured at high levels (7 to 16 mg/L) in a well closest to the sewage lagoon of a nearby residential development and total phosphorus was often measured at higher concentrations (1.5 mg/L) in this well indicating nutrient groundwater seepage into the pond.

Project Conclusions:

- The wet-detention pond moderated the effects of agricultural stormwater runoff and reduced pollutants entering the bay by a significant amount. But even though the pond reduced pollutant loads for most constitutents by at least 60 percent, and often over 80 percent, some water quality problems exist. The average annual concentrations for copper and zinc failed to meet State Marine Water Quality Standards for all years. Thirty-two percent of the samples for fecal coliform bacteria taken at the outflow of the pond failed to meet standards. The pristine water quality levels identified for nutrient concentrations for our region by the Environmental Protection agency were not met for total nitrogen and total phosphorus. The 80 percent reduction goal for total suspended solids recommended in the State Water Policy was met for only two of the four years of study.

- The differences in efficiency of the pond to reduce pollutants during different years demonstrate the need for more long-term studies, especially those that investigate processes occurring in the stormwater system.

- Maintenance guidelines need to be developed for wet-detention ponds especially since maintaining ponds may help reduce total suspended solids and organic nitrogen, which sometimes increased from the inflow to the outflow in these ponds. Also the littoral zone at this site was transformed from a flag marsh to a cattail marsh during the four years of study, which resulted in a shift in bird utilization from flocks of wading birds to black birds.

- Ditch maintenance needs to be better quantified and improvements incorporated into county schedules. The ditch in this study appeared to significantly reduce the amount of pollutants reaching the pond but anaerobic conditions and vegetation cut and left to rot in the ditch may reduce its effectiveness.

- More data are needed to determine treatment efficiency as ponds age. This study suggests that recently constructed ponds are much better at some forms of pollution removal.

District Report Reference:

Rushton, B. T. 2002. Treatment of Stormwater Runoff from an Agricultural Basin by a Wet-Detention Pond in Ruskin, Florida. Final Report. DEP Contract Numbers WM 539 and WM 789. Southwest Florida Water Management District.

Florida Aquarium Parking Lot: A Treatment Train Approach for Stormwater Management

Author(s):	**Year Completed:**	**Project Costs:**
Betty Rushton, Ph.D. Rebecca Hastings	2001	EPA - $196,996 / District - $131,331

Project Rationale:

Impervious surfaces such as parking lots and rooftops cause more stormwater runoff and pollutant loads than any other type of land use. Low Impact Development (LID) design criteria provide alternatives that have successfully reduced runoff by reducing imperviousness, conserving ecosystems, maintaining natural drainage courses, reducing the use of pipes and minimizing clearing and grading. Providing rainfall runoff storage throughout the entire drainage basin disperses runoff uniformly throughout a site's landscape by using a variety of detention, retention, and other practices. A parking lot at the Florida Aquarium in Tampa was used as a research site and demonstration project to quantify how small alterations to parking lot designs can dramatically decrease runoff and pollutant loads.

Project Description:

An innovative parking lot design using LID techniques has been implemented for the Florida Aquarium and utilizes the entire drainage basin for stormwater treatment. The study site is an 11.5-acre parking lot serving 700,000 visitors annually. Automatic instruments collected flow-weighted water quality sample and measured flow and rainfall during storm events. The research was designed to determine pollutant load reductions measured from three elements in the treatment train: 1) different infiltration opportunities and pavement types in the parking lot, 2) a planted strand with native wetland trees and 3) a small wet-detention pond used for final treatment. (In this study swales are small depressions between parking rows and strands are larger swales). The parking lot research involved testing three kinds of paving surfaces as well as analyzing basins with and without swales. This makes four treatment types with two replicates of each type. The paving surfaces are asphalt, concrete and porous paving. A total of 59 rain events were included in the data set and represent storms that produced as little as 0.37 inches of rain to a maximum amount of 2.91 inches. The monitoring effort also investigated other processes taking place by measuring rainfall and sediments, as well as variations in pH, dissolved oxygen, temperature, turbidity, and weather conditions.

Project Results:

- The runoff coefficient is a ratio that can be converted to a percentage and for traditional parking lots a typical range is 70 to 90 percent of rain falling on the site would run off. At the Florida Aquarium site even the basins with only small garden areas and no swales measured the yearly average runoff at about 55 percent. The basins with swales and paved in asphalt or concrete reduced runoff to 30 percent and porous paving, to about 16 percent. The basins with larger garden areas reduced runoff by an additional 40-50 percent.

- When the volume of water discharged from all the different elements in the treatment train (the swales, the strand and the pond) are compared, calculations showed almost all the runoff was retained on site. Although the year sampled was during an extreme drought, it is estimated that even during a normal year, discharge would have taken place only four or five times and the amount of storm discharged to the receiving waters would have been greatly reduced.

- Pervious paving with swales is most effective for small storms and does not reduce runoff as much, and sometimes not at all, during storms with high rainfall intensity and saturated soil conditions.

- Phosphorus concentrations are highest in the basins with vegetated swales and phosphorus loads were actually increased in basins with swales, although porous paving and larger garden areas ameliorated this effect somewhat.

- Most metals (iron, lead, zinc, manganese, copper) have higher concentrations in basins paved with asphalt.

- Nitrate and ammonia most often enter the system directly in rainfall with a correlation coefficient of 0.84 for nitrates and 0.48 for ammonia measured at the basins with no swale. Nitrate-nitrogen and total nitrogen appear to be measured in fairly similar concentrations in all basins while ammonia concentrations are variable. Regression equations show increased concentrations of nitrate in rainfall cause increased nitrate concentrations in runoff for all basins.

- Polycyclic aromatic hydrocarbons (PAHs) were detected in the sediments in all the basins, but concentrations were higher in basins paved with asphalt and in those basins some values approached toxic levels.

- Pesticides were detected in the sediments in all the basins, especially DDT and its daughter products.

- Sediment samples indicate that metal pollutants are not contaminating the water table and that most metals are sequestered in the surface soils.

- Copper, iron and total suspended solids demonstrated a definite first flush effect in the asphalt basins, while the concrete basins with planted swales exhibited no consistent pattern.

- Particle size analysis for the sediments showed most sites exhibited a similar pattern and there were no obvious differences between paving types or the pond and the strand. The highest percentages of particle sizes were measured in an intermediate size range described as medium sand. In general, only a small percentage of particles were measured less than 0.063 mm. Percent organic matter ranged from 2 to 9 percent in the samples collected.

Project Conclusions:

- The whole basin approach for the parking lot was an excellent design alternative. Changing regulations by making parking spaces 0.62 meters (2 feet) shorter provided land for the swales without reducing the number of parking spaces. It also did not compromise parking since the design has the front end of the car hanging over the swale rather than the impermeable paving. Other sensible innovative strategies need to be implemented by incorporating every opportunity in the drainage basin for stormwater treatment and infiltration. Although the garden areas and the strand occupied land that could have been used for parking spaces, this was offset by the smaller size needed for the pond. Also garden areas that are often required by parking lot ordinances can be modified to act as bioretention rain gardens to increase infiltration.

- Permeable paving reduces runoff from small rain events, but swales are more effective for reducing runoff from all events.

- Controlling pollution at its source would reduce pollution in rain runoff especially for ammonia and nitrate. Power plant and automobile emissions as well as fertilizer and pesticide applications provide areas where source reduction could be especially beneficial.

District Report Reference:

Rushton, Betty T. and Rebecca Hastings. 2001. Florida Aquarium Parking Lot: A Treatment Train Approach For Stormwater Management, Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609

A short version is also available on the internet:
http://www.swfwmd.state.fl.us/documents/reports/files/9ICUD02.pdf

The Hydrologic Effect of a Large Constructed Wet Detention Pond Located Adjacent to Wetland(s)

Author(s):	**Year Completed:**	**Project Costs:**
David W. Carr	2005	District - $17,398

Project Rationale:

Developers often excavate large ponds, use the spoil as fill on-site, and utilize the ponds as wet detention systems. These ponds are commonly built adjacent to wetlands which can adversely affect wetland hydrology. This study was designed to answer several questions posed by District regulatory staff: 1) will a pond built in the above manner, located next to a wetland, alter the wetland's hydrology and impact its functions? 2) how does such a pond affect the wetland's hydrology? 3) if adverse impacts occur, what can be done to avoid these impacts? A site in southern Pasco county was chosen for the project. The site was selected from an in-house conceptual permit to allow for a minimum of one-year pre-construction data collection. Hydrologic conditions will be monitored continuously before, during, and after pond construction.

Project Description:

The monitoring and data collection process include: wetland delineation (conducted or verified by SWFWMD regulatory staff), evaluation/characterization of wetland baseline conditions by rating the wetland(s) using the wetland assessment methodology developed by the Environmental section, and conducting vegetation analyses each May/June and August/September. This assessment consists of appropriate transects and quadrats to monitor changes to vegetation. Rainfall, surface water level and water table level are monitored. Piezometers are monitored biweekly and quarterly surface water quality sampling (TSS, nutrients, metals, pH, D.O., etc.) is performed quarterly.

Project Results:

Project on-going

Conclusions:

Project on-going

District Report Reference:

Project on-going

Stormwater Management Alternatives Demonstration Project

Author(s):	**Year Completed:**	**Project Cost:**
Betty Rushton, Ph.D.	2004	EPA $181,575 / District $121,506

Project Rationale:

The Stormwater Management Demonstration Project is a multifaceted research and educational effort designed to better understand the impact of urban runoff, explore techniques to reduce stormwater pollution and to educate the public about stormwater issues. Two stormwater ponds discharging directly into Tampa Bay form the centerpiece of a demonstration project developed to inform the public about stormwater problems and provide professionals with innovative ideas that can be used for stormwater management and pond maintenance. In addition, a monitoring program measured pollutant loads discharged to the bay from an effluent filtration system and a modified wet-detention pond (two common stormwater treatment methods). A review of the literature summarized methods that can be used by professionals. Several methods identified in the literature review were implemented and monitored to determine their effect on pollutant removal. The site has become part of a package where an innovative parking lot design has already demonstrated a practical approach to reduce runoff and pollution using low impact methods that begin treating storm runoff as soon as rain hits the ground.

Since the original proposal was written and approved, construction activities at the site have necessitated requesting changes in the original scope of work and the time line. The building of a cruise ship terminal impacted the outfall structure to one of the ponds and necessitated our removing and then reinstalling monitoring equipment as well as suspending the monitoring program for seven months. In addition, a trolley to serve the downtown Tampa area was installed that has impacted parts of both of the ponds. The ship terminal removed most of the low impact infiltration opportunities for the parking lot. These modifications are over and a second year of data collection has been accomplished. Final reports are complete.

Project Description:

The project was divided into several tasks that included: The monitoring of an effluent filtration wet pond, a comparison of the outfall water quality of three types of stormwater management systems, the installation of improvements to one of the ponds, an educational program for school children, educational signage for the general public and a program guide describing the seven types of storm pollution abatement techniques installed at the site. In addition, a literature review of stormwater management methods was compiled.

Effluent Filtration Pond. The monitoring of the effluent filtration wet pond is a whole-pond study that included taking storm event samples, measuring hydrology, comparing field parameter (temperature, pH, DO, conductivity) and analyzing sediment samples. The pond has two cells, the first collects storm runoff in a sedimentation basin before it is discharged into the second cell, a filtration basin. Once in the filtration basin, most of the water is routed through side bank underground filters (sand, rock and perforated pipes), the filters are designed to remove pollutants before discharge through the outfall structure. Large storms bypass the filter system to prevent upstream flooding. A monitoring program evaluated the effectiveness of the system to remove pollutants. Equipment designed to automatically collect and preserve samples by refrigeration were activated during storm events to measures water quality at the inflow, at the outflow, in the under drain system and in rainfall. Continuous recording velocity meters, water level sensors, and rain gauges collected hydrology data. This information was used to construct a complete water budget for the pond. A separate report is available that presents all the data for this one pond.

Comparison Study. The comparison of three types of stormwater management systems sampled storm event water quality at the outfall of each pond as well as measuring hydrology and field parameters. The three types of ponds are an effluent filtration system, a wet detention pond and a pond used for the final treatment of a low impact parking lot design. Although the parking lot pond was destroyed to construct the cruise ship terminal, there was enough preliminary data to make a comparison of that pond with the two monitored later at the site. Historic data covering the interval from November 1996 to November 2003 were also compared for water quality, sediment, macroinvertebrates and fish.

Pond Improvements. The improvements to the wet detention pond include pre-treatment grate inlet skimmer boxes (drop box inserts) installed in the seven storm drain catch basins that discharge to the pond and a diversion of the treatment volume in the pond so that it travels through a shallow vegetated area (littoral zone). Grate inlet skimmer inserts capture gross pollutants such as leaves, sediments and trash and hold it in a skimmer tray above the water level in the catch basin instead of letting it flow into the wet detention pond. They require maintenance and need to be cleaned out about every three to six months when installed in urban locations. The diversion of the treatment volume in the pond is designed to utilize a dead-end littoral zone before being diverted through the outfall structure. The treatment volume in stormwater ponds depends on the type of pond and is calculated to be one-half to one inch of storm runoff, which is stored and slowly released within five days after a rain event.

Educational Program. The educational program had several objectives that include: a study guide for teachers designed to educate students about stormwater problems, educational signage at the Aquarium to educate the general public about stormwater issues and scientific reports for use by stormwater managers. In addition, the Aquarium took stormwater as their theme for their Regional Oceans Conference for Students on November 21, 2003. This program was designed to educate approximately 30 teachers and 60 students about stormwater issues.

The literature review presents over 70 stormwater management techniques in a summarized format that includes a brief description of the technique, a picture, pollutant removal efficiency data, a list of advantages and disadvantages, cost information, maintenance requirements and some useful references.

Data collection and the literature review took three years to complete. The first year collected background data from the existing ponds and investigated methods for improving the stormwater management system as well as buying and installing automatic monitoring equipment. The second year was used to make improvements to the ponds, to determine maintenance alternatives and to monitor the results. The third year completed the monitoring and produced the final reports.

Project Results: Effluent Filtration Stormwater System:

- A complete water budget for storm events revealed that most of the outflow occurred through the under drains, and this flow was increased by groundwater seepage. Ten percent more water was estimated leaving the system than entered during rain events. Since the under drain flow occurred all the time even when the pond level was below the level of the intake pipes, it is assumed the system was discharging ground water.

- The level of the outflow weir was raised in Year 2, which reduced the amount of flow that by-passed the under drains from 54 percent to 35 percent.

- Dissolved nutrient loads increased considerably in the system. For example, an increase of 84 percent was measured for ammonia and 64 percent for ortho-phosphorus; and other nutrient species were only moderately reduced (14 to 17 percent). In contrast, total suspended solids and most metal loads were reduced by a significant amount (79 to 89 percent). While soluble nutrients remain a common issue for filtration systems, the under drains did measure lower concentrations of all constituents, except ammonia, than were measured at the inflow during storm events.

- Ammonia, ortho-phosphorus and total phosphorus were measured at significantly higher concentrations when the pond level was below the bottom of the under drain intake pipes. This indicates that dissolved nutrients are flowing out of the system during base flow at higher concentrations than storm flow.

- More non-compliance with state standards for metals at the outfall occurred during year two than during year one. Lead was the only metal to exceed standards in year one with 12.5 percent of samples analyzed. In year two 26.9 percent of copper, 23.1 percent of lead and 3.8 percent of zinc failed to meet standards. The softer water caused by more rainfall during year two is one reason more samples failed the test, since the standard is hardness dependent.

<u>Project Results: The Comparison Study</u>

- In general, the bleed down structure in the building pond discharges water at a slightly more rapid rate than the under drain pipes in the Street pond, but the levels indicate that the under drain system in the Street pond is still operational seven years after construction.

- For comparable time periods, most of the storm flow was discharged through the under drains or the bleed down orifice. Out of the 80 storms over 0.20-inch depth, 28 (35%) discharged over the outfall weir in the Street pond compared to 24 (30%) in the Building pond.

- Dissolved nutrients were measured at lower concentrations in the storm discharge water in the Street pond compared to the Building pond.

- Although metal concentrations were usually lower in the Street pond, more samples failed to meet state standards because of the much softer water (the standard is hardness dependent).

For comparable years, non-compliance of the standard was found for copper (27%), for lead (27%) and zinc (4%) in the Street pond but non-compliance for copper (12%), lead (18%) and zinc (3%) discharged from the Building pond.

- For all ponds, the highest percentages (25 to 40%) of the sediment samples were measured in an intermediate size rang (0.125 to 0.25 mm) described as medium sand. The samples represented the top four inches of soil.

- Concentrations of nutrients measured in the sediments showed a considerable increase from 1997 to 2003 and the Building pond sediments had higher concentrations than the Street pond. This pattern did not necessarily hold true for the metals, which may have been the result of maintenance by Adopt-A-Pond in the Building pond, which removed the bottom sediments during maintenance operations.

- Although only about 20 percent of samples detected Polycyclic aromatic hydrocarbons (PAH) in the surface sediments in 2000 this percentage had increased to greater than 63 percent in 2003. Many of these exceeded the possibly toxic level for sensitive benthic organisms. A higher percentage of samples detected PAHs in the Building pond than in the Street pond.

- Pesticides measured in the sediments identified chlordane, diazinon, chlorphyifor ethyl and DDT derivatives with concentrations above the laboratory quantification limit. Of these, chlordane was measured above the probably toxic level and DDE was detected in the possibly toxic range.

- Chemical treatment of floating algae with copper was unsuccessful and resulted in discharges of toxic levels of copper and higher levels of nitrate as the algae died.

- Phosphorus was released from the sediments into the ponds at low dissolved oxygen levels (below 2-3 mg/L).

- Fish and other aquatic biota showed a great increase from 1997 to 2003, especially for *Gambusia* and water fleas. A reduction in some fish species may be attributed to the aggressive nature of *Gambusia*, which is viewed as an undesirable species by many ichthyologist unless it is native to the region.

- In the macroinvertebrate study, all taxa reported were those highly tolerant of polluted onditions. Low abundance of even these species was reported in the locations where possibly toxic concentrations of pollutants had been measured in the sediments.

- Most water quality concentrations for metals were near the laboratory limit of detection or in the case of TSS values were less than can be removed by sedimentation indicating the ponds are doing a good job of reducing these pollutions. Exceptions were copper and lead where 12 to 40 percent of samples at the outflow failed to meet water quality standards.

- The skimmer box inserts removed 15 cubic feet of solids from this five-acre drainage basin that were contaminated with potentially toxic pollutants before they could contaminate the pond sediments during the first year after installation.

- A diversion structure installed to increase the travel time of the treatment volume in the Building pond decreased concentrations in the discharge by a significant amount in the eight storms that were monitored compared to storms before the installation.

- Biocultures indicated that they may reduce organic nitrogen and phosphorus, but did not improve the aesthetics of the pond.

- Barley straw made no difference in water quality or the pond aesthetics.

- Scraping out the bottom sediments of the pond and removing nuisance vegetation removed toxic levels of copper and reduced organic nitrogen and organic matter, but did not permanently improve the problems with floating vegetation. Disposal of material removed was a difficult problem.

Project Conclusions The Comparison Study:

- Effluent filtration systems should not be permitted except under exceptional conditions, where they are constructed well above the water table. They are usually not properly maintained and export higher levels of dissolved nutrients than other stormwater systems. The under drains were effective for reducing metals and suspended solids.

- Stormwater ponds greatly reduce pollution from rain runoff, but problems exist and toxic levels of metals and high levels of nutrients are still being discharged. Even under the best projections, current rules allow 20 percent more pollutant loads to be added to our receiving waters each year.

- One method to reduce these pollutant loads is to design with more opportunities in the drainage basin for infiltration by using some treatment train techniques that allow for infiltration. Stormwater was only discharged once from the parking lot with swales and strands compared to 20 to 40 times a year from the more traditional stormwater ponds at the site. On the other hand, more study is needed to test infiltration effects. Highly soluble nitrogen and phosphorus were measured in flow that had passed through the under drain filters in the effluent filtration system than in the surface stormwater discharge.

- Of some concern are the toxic levels of metals, pesticides and PAHs sequestered in the sediments of stormwater systems with no plans for their disposal or the long-term effect on wildlife. Also ponds treated with algicides are probably increasing copper and nitrogen discharged to receiving waters.

District Report References:

Rushton, Betty T. 1997. Processes that Affect Stormwater Pollution. In Proceedings of the 5th Biennial Stormwater Research Conference. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609

Rushton, Betty T. 1998. Sources and Sinks for Stormwater Pollutants. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609.

Rushton, B. T. 2003. Traveling the Stormwater Trail: Some Facts and Figures. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 22 pages.

Teague, Kara, Dwayne Huneycutt and Betty Rushton. 2004. Stormwater Runoff Treatment by a Filtration System and Wet Pond in Tampa, Florida. 2004. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609.

Rushton, B. T., Kara Teague and Dwayne Hunneycutt, 2004. Characterization of Three Stormwater Ponds. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 234 pages.

Rushton, B.T. and K. Teague. 2005. Performance of a Stormwater Wet Pond with Side Bank Filters. In Proceedings of the 8th Biennial Stormwater Research and Watershed Management Conference. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 10 pages. 197 pages.

Rushton, B.T. and J.D. Buchanon. 2004. Urban Stormwater Treatment: A Summary of Management Practices. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 10 pages. 238 pages.

Broadway Outfall Stormwater Retrofit Project (Phase II – Monitoring)

Author(s):	**Year Completed:**	**Project Cost:**
Betty Rushton, Ph.D.	2006	EPA $162, 550 / District $108,374

Project Rationale:

This project is a joint project between the City of Temple Terrace and the District's Surface Water Improvement and Management (SWIM) Program and was built to reduce stormwater loading in the Tampa Bay watershed. Tampa Bay is a District SWIM priority waterbody. The project was implemented in two phases. Phase I constructed the stormwater treatment system and Phase II is monitoring the effectiveness of the treatment system. The system consists of a 32 cfs capacity continuous deflective separation (CDS) stormwater treatment device installed in series with a marsh constructed to retrofit approximately 132 acres of highly urbanized land within the City of Temple Terrace. This basin formerly discharged untreated stormwater directly into the Hillsborough River upstream of the City of Tampa's drinking water reservoir.

Project Description:

A CDS unit is an underground stormwater treatment method used to capture gross pollutants in urban areas by intercepting stormwater runoff in the conveyance pipe system. The mechanism by which the unit separates and retains gross pollutants is by deflecting the inflow and associated pollutants away from the main flow stream into a pollutant separation and containment chamber. The chamber is cleaned out with a VAC truck when needed and the gross solids are sent to a landfill or disposed of in some other appropriate manner. Gross solids consist of human trash, plant debris and coarse sediments. The constructed marsh continues to treat stormwater runoff after it leaves the CDS unit and before it is discharged to the Hillsborough River. The CDS stormwater treatment system specifically targets large particles, oils and greases, and the associated contaminants.

Construction of the retrofit (Phase I) was completed in November 2001; and the evaluation effort (Phase II), was initiated in November 2002. Monitoring at the site is designed to determine how well the system removes pollutants before they are discharged to the Hillsborough River. Specifically, the project will measure: 1) how much and what kind of gross solids (>64microns) are collected by the CDS unit, 2) the concentration of constituents in the flow stream for the suspended and dissolved particles (< 64 microns), 3) the accumulation of pollutants in the sediments, 4) the characterization of the macroinvertebrates in the sediments, and 5) the hydrology of the system including storm flow, base flow and rainfall.

Project Results (preliminary):

- The runoff coefficient for the drainage basin using preliminary calculations is 0.34 typical for an urban area that is 35 to 50 percent impervious.
- The CDS unit is effective in removing gross solids and 413 cubic feet were removed during the first year of the study.

- Polycyclic aromatic hydrocarbons (PAHs) were measured at toxic levels in the material collected by the CDS unit.

- About 60 to 70 percent of the material collected by the CDS unit was measured as leaves.

- The CDS unit effectively collects particle sizes much smaller than the screen size of 2400 um.

- Concentrations of PAHs measured in the soils before construction of the retrofit were similar to concentrations removed by the CDS unit.

- The amount of litter collected in the CDS unit during the first year included over 100 pounds of assorted material, which measured a total volume of 32 cubic feet. Plastics contributed the largest amount of litter (73 pounds).

- Water quality data indicate that the CDS unit is only minimally effective for reducing the suspended and dissolved constituents routinely measured in traditional stormwater studies using automated equipment.

Preliminary Project Conclusions: (data collection and analysis still in progress)

- The CDS unit is effective for removing gross solids from the storm water flow stream, but it is less successful in removing the dissolved and suspended constituents.

- The CDS unit effectively removed polluted material that could have caused long-term detrimental effects in the Hillsborough River by re-suspension of bottom sediments, leaching of sequestered pollutants, smothering of benthic habitat and other problems associated with sediment transport.

District Report References:

Rushton, B. T. 2004. Broadway Outfall Stormwater Retrofit Project (phase II): Monitoring CDS Unit and Constructed Marsh, Year One Progress Report. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609

Stormwater Pond Evaluation

Author(s):	Year Completed:	Project Costs:
Chris Zajac Randy Smith	2006	District $93,850

Project Rationals:

The Southwest Florida Water Management District (District) became involved in the regulation of stormwater runoff in 1982 when it first received delegation of Chapter 17-25 F.A.C. from the Florida Department of Environmental Protection (FDEP). District Rules and Basis of Review specify performance standards to be met in the design and function of stormwater ponds. The ponds selected for this study were constructed using design criteria as set forth in Chapter 17-25 F.A.C. Wet detention ponds constructed using these design criteria were required to treat the first one-inch of runoff from the contributing area. The ponds were designed with a permanent pool and also a littoral zone that covering a minimum of 35 % of the pond's surface area at the control elevation.

There is limited information available about the physical condition and treatment performance of stormwater ponds that have been in service for many years. This study was conducted to answer three major questions regarding the performance of stormwater treatment ponds: (1) Has the treatment capacity of wet detention ponds been compromised due to the infilling of the pond basin over time? (2) How much material have the ponds captured since construction? (3) How does the current littoral zone development compare to design criteria?

Project Description:

The District chose 12 stormwater ponds for this study that had been included in a water quality survey of newly constructed ponds 15 years ago. The ponds were located in Pasco, Hillsborough, and Pinellas counties. These ponds were constructed in the late 1980s and early 1990s and range in size from 0.09 to 4.25 acres.

The District hired a consultant in 2004 to survey each pond. The purpose of the survey was to identify the amount of sediment that had accumulated within each pond's basin. This was accomplished through linear transects using a standard 25-foot graduated survey rod with a 6-inch disc attached to the end of the rod. Probes were logged at the first noticeable point of resistance. The survey also included points along the top of bank, toe of slope, and pond bottom at each transect.

District staff researched permit files to determine control elevations, normal pool elevations, and percent coverage of littoral areas for each pond. Each site was visited on several occasions to photograph and document littoral shelf coverage. GIS software was used to determine the volume of sedimentation that had developed since pond construction, as well as verify vegetative cover (where applicable).

District staff conducted an extensive literature search to determine previous studies that involve stormwater pond sediment accumulation. Staff identified a study that was conducted in 1994 by Schuler and Yousef that quantified stormwater pond sediment density as well as the amount of nitrogen and phosphorus contained in a given amount of sediment. These data were used to estimate metric tons of nitrogen and phosphorus deposited in the accumulated sediments.

Preliminary Project Results:

- The survey data provided by the consultant was analyzed to determine the volume of sedimentation that occurred in each pond. Over half of the ponds studied showed more than 10% permanent pool reduction with a maximum of 24% permanent pool reduction in one pond.

- One of the larger ponds (3.73 Ac) had captured over 1100 metric tons of sediment since it was constructed. The smallest pond (0.09 Ac) captured over 40 metric tons of sediment. Using literature values, the amount of nitrogen removed from stormwater runoff via the wet detention pond sediments ranged from 0.02 to 3.31 metric tons. Phosphorus removal ranged from 0.00 to 0.66 metric tons.

- Up to 64% of the 12 ponds studied did not maintain the required 35% littoral zone, with 55% having little to no littoral vegetation at all

Preliminary Project Conclusions:

- In wet detention ponds, pollutant removal occurs primarily within the permanent pool. Sedimentation is the primary mechanism for the removal of particulate forms of pollutants. The permanent pool also extends the residence time of water passing through the treatment pond. All of the ponds studied have lost permanent pool volumes to some degree, therefore their ability to treat stormwater has also been reduced. The magnitude of lost treatment capacity varies from pond to pond and there are varying opinions as to how much permanent pool loss is significant.

- Wet detention ponds are in need of periodic maintenance that should include sediment removal and the preservation of vegetated littoral areas. How often this maintenance should occur varies for each pond. Further analysis of pond sedimentation is needed to determine how much sedimentation is too much and when it should be removed.

District Report References:

Zajac, Chris and Randy Smith. 2005. Stormwater Pond Evaluation. In Proceedings of the 8th Biennial Stormwater Research and Watershed Management Conference. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609. 7 pages.

CONCLUSIONS

Research at the District over the past fifteen years indicate permitted stormwater systems greatly reduce pollutant load to our rivers, lakes and estuaries. But some changes to the rules could improve stormwater quality and quantity problems. These changes do not necessarily represent a new mandate or regulation, but instead should provide strong economic and market incentives that benefit the public, local governments, developers, and the environment. Enforcing and strengthening the rules already in place will also reduce stormwater pollution. Of some concern is the fact that discharge waters from permitted systems still exceed water quality standards for dissolved oxygen and metals. For example, overall average non-compliance of State standards for constructed wet-detention are: 12% to 27% for copper and lead, and 4% to 6% for zinc. The percentages are also high for dissolved oxygen (30 to 60% non-compliance). Another concern is that as population increases and more impervious areas are created even low concentrations of pollutants will continue to increase loads because the volume of runoff will increase. Present rules only reduce peak flows. Also, little studied aspects of stormwater pollution such as bacteria and priority pollutants may present potential threats to people and the environment and warrant further investigation. In addition, the removal rate for total nitrogen is highly variable and sometimes it increases from the inflow to the outflow of ponds. Even if stormwater systems meet the presumptive rule criteria of 80 percent removal, 20 percent of the pollutant load is still discharged.

- Basin wide stormwater treatment, where every opportunity in the drainage basin is utilized for infiltrating runoff, will reduce storm volumes and pollutant loads. Low impact designs for stormwater treatment should be encouraged and developers given credit when they use these techniques. Designs should be based on percent pervious area and guidelines adopted for stormwater reuse, permeable paving, roadside swales, reducing soil compaction or other methods used to offset increased impervious area. Other solutions include using the Conservation wet detention design, which can reduce pond size and require less fill for raising the level of houses.

- Almost all studies identified atmospheric deposition as a major source of nitrogen and some metals. The District should work with other agencies to try to clean up this input of pollution at the source.

- Wetlands can be used as part of a stormwater system but stormwater should be treated by conventional methods before discharge to the wetland. Stormwater will change the physical and chemical properties of oligotrophic isolated wetlands that historically receive most of their input from rainfall. A buffer area large enough to discourage the invasion of nuisance species should be left around the wetland.

- Careful consideration should be made before intermittently flooded stormwater systems are selected for stormwater treatment. Necessary conditions should include coarse-grained sandy soils, the bottom of the pond at least three feet above the seasonal high water table and an adequate maintenance plan.

- Effluent filtration systems should not be an option for stormwater treatment unless the systems can meet stringent requirements. These systems, which cease to function properly when filters clog, create intermittently flooded conditions that cause mosquito problems. The discharge water from the under drains also have some of the highest levels of dissolved nitrogen and phosphorus and have the potential to continuously discharge groundwater. Perhaps an enhanced filter material can be developed that will trap dissolved consitituents.

- Although stormwater treatment systems reduce pathogenic strains of bacteria, bacteria were still present at the inflow and outflow of all three of the stormwater systems studied. More effective treatment of pathogenic strains of bacteria needs to be investigated.

- Operation and maintenance guidelines for stormwater systems are an urgent need. Chemical treatment of floating algae is usually unsuccessful and often results in discharges of toxic levels of copper and higher concentrations of nitrate. Often as a result of poor maintenance, ponds with low dissolved oxygen levels release phosphorus and some metals from the sediments. Conditions conducive to an oxygenated water-sediment interface should be part of the pond design and maintenance plan. These conditions include an open water permanent pool, good wind fetch and good mixing by maximizing the distance between the inflow and outflow. A survey of ponds 15 years post-development showed more than 10% permanent pool reduction with a maximum of 24% permanent pool reduction. Also up to 64% of the 12 ponds evaluated did not maintain the required 35% littoral zone, with 35% having little or no littoral vegetation at all.

- Low Impact Development (LID) designs need to be incorporated into the landscape especially in parking lots and for big box stores. Greater reliance on runoff interception and treatment at several points in a drainage basin should be encouraged in siting stormwater facilities. More study is needed to determine if infiltrated stormwater is contaminating the surface water aquifer and if enhanced filter material can be used to reduce the amount of nitrate infiltrated.

GLOSSARY

Aerobic - Refers to situations where oxygen is relatively abundant and organisms dependent on its availability can survive.

Alum - Aluminum sulfate is a clear, odorless, light green or amber liquid used for water quality treatment.

Alum Coagulation - A small floc produced when alum mixes with stormwater which attracts suspended and dissolved pollutants. The pollutants become bound to the floc, which settles and becomes incorporated into the sediment.

Alum Injection - Consists of flow meters, which measure stormwater flowing in the storm sewers, and injectors which periodically add a predetermined dose of alum to the stormwater as it moves through the storm sewer.

Anthropogenic Compounds - Compounds originating from human activity.

Ambient- Surrounding.

Ammonia - Inorganic nitrogen species (NH_3) is essential as a nutrient.

Aquatic - Pertaining to flooded environments. Over a hydrologic gradient, the aquatic environment is the area waterward from emergent wetlands and is characterized by the growth of floating or submerged plant species.

Aquatic Plants - Plants indigenous to aquatic environments

Atmospheric Deposition - Refers to the introduction of substances from the air. Can include both wet (rain, snow) and dry (dust) deposition.

Base Flow - The flow of water that is continuous in streams and storm drains even without the input of recent rainfall.

Best Management Practices (BMPs) - Refers to the practices used for a given set of conditions (e.g., soil type, water shed area, and land-use) that will achieve a satisfactory water quality and water quantity at a minimum cost.

Biogeochemical Cycles - Constituent cycling through various chemical, physical, and biological transformation processes.

BMP- Best Management Practices (see above definition).

Buffer Zone (for wetlands) - An area adjacent to wetlands which protects wetland function and minimizes adverse impacts of upland development on wetland function.

Continuous Deflective Separation Technology (CDS) - Uses fluid flows and a perforated screen to cause a natural separation of solids from fluids. Installed underground in the flow path, the pollutants are deflected away while the water passes through a fine separation screen.

Conservation Wet Detention Design - Design criteria developed by SWFWMD's Technical Services staff which can be used as an alternative design for wet-detention ponds to treat stormwater runoff. It includes a 14-day residence time, credit for stormwater storage in the permanent pool, and other criteria that may make it possible to use less land area for the pond and reduce the amount of fill necessary for raising building pads. The entire procedure is available from SWFWMD's Regulatory department or in the publication "Three Design Alternatives for Stormwater Detention Ponds" summarized in this report.

Constructed Wetland - A wetland that is purposely constructed by humans in a non-wetland area.

Correlation Analysis - Measurement of the intensity of association observed between any pair of variables and to test whether it is greater than could be expected by chance alone.

Disease Vector Species - An organism such as a mosquito that carries pathogens from one host to another.

Dissolved Oxygen - The concentration of oxygen held in solution in water.

Drainage Basin - A subdivision of a watershed.

Dry Effluent Filtration - See Filtration

Effluents - A liquid or gas that flows out of a process or treatment system. Effluent can be synonymous with wastewater after any level of treatment.

Effluent Filtration - See Filtration

Evapotranspiration (ET) - The combined processes of evaporation from the water or soil surface and transpiration of water by plants.

Event Mean Concentration (EMC) - The amount of a single pollutant concentration measured on a flow-weighted basis and composited together for a single storm event, i.e. more sample aliquots are collected proportionally when flow is high and fewer samples are collected when flow is low. EMC's represent the entire storm in concentration per volume of sample and are usually reported as mg/L or *u*g/L.

Eutrophication - The processes that result from high concentration of dissolved nutrients in a water body.

Fecal Coliform - Aerobic and facultative, Gram-negative, non-spore forming, rod-shaped bacteria capable of growth at 44°C (112°F) and associated with fecal matter of warm-blooded animals.

Federal National Pollutant Discharge Elimination System (NPDES) - Federal legislation aimed at regulating pollutant discharges to surface waters.

Filtration - A family of practices in which the runoff from a rain event is allowed to percolate into the soil rather that discharge off-site. Infiltration practices include basins, trenches, dry wells, pervious pavement, and to a certain extent, swales. **Effluent filtration** or exfiltration is the water that percolates out of the system. The amount of infiltration depends on permeable soils and a seasonal high water table or bedrock at least three feet beneath the bottom of the pond. Wet filtration systems have a permanent wet pool and **dry filtration** ponds dry out completely within three days after a storm event.

Flow-Weighted Sample - Stormwater samples collected proportionately to the amount of flow generated by a storm.

Grab Sample - Water sample collected at a specific time during the hydrograph, not based on flow.

Gross Solids (Coarse Solids) - Gross solids refers to particles transported in stormwater that are larger than 75 microns and they are divided into three categories: 1) litter includes human derived trash, such as paper, plastic, Styrofoam, metal and glass; 2) debris consists of organic material including leaves, branches, seeds, twigs and grass clippings; and 3) coarse sediments are inorganic breakdown products from soils, pavement or building materials.

Groundwater Recharge - The replenishment of the groundwater from infiltration of water from the ground surface.

Herbaceous Wetland - A wetland characterized by herbaceous (non-woody) vegetation.

Hydroperiod - The period of wetland soil saturation or flooding. Hydroperiod is often expressed as a number of days or a percentage of time flooded during an annual period, i.e.- 25 days or 7 percent.

Inorganic Nitrogen - Non-organic nitrogen often necessary as an essential nutrient.

Intermittently Flooded (IF) - Not flooded continuously.

Impervious Area - Land surfaces which do not allow, or minimally allow , the penetration of water; examples are buildings, non-porous concrete and asphalt pavements, and some fine grained soils such as clays.

Isolated Wetlands - Any wetland without a direct hydrologic connection to a lake, stream, estuary or marine waters.

Littoral Zone - The shoreward zone of a lake or wetland. The area where water is shallow enough to allow the growth of emergent vegetation.

Load Reductions - See Pollutant Reduction.

Loads - See Pollutant Loads.

Low Impact Development (LID) – Combines a hydrologically functional site design with pollution prevention measures to reduce development impacts. The goal is to maintain the predevelopment stromwater runoff volume, peak runoff rates, and frequency to mimic predevelopment runoff conditions.

Macroinvertebrate - Invertebrates (organisms without backbones) visible to the eye unaided by a microscope.

Macrophytes - Macroscopic (visible to the unassisted eye) vascular plants.

Major Ion Concentrations - Concentrations of ions of such elements as calcium, magnesium, sodium, potassium, etc. found in water.

Mean - Average

Microbial Pathogens - Bacteria, viruses, or protozoans, which can cause disease.

Monomeric Aluminum - A reactive and toxic form of aluminum represented by the chemical notations of Al^{+3} and $Al(OH)_2^{+}$.

MSSW Rule - Legislation relating to Management and Storage of Surface Waters.

Natural Wetland - A wetland ecosystem that occurs without the aid of humans.

Non-point Source Pollution (NPS) - Refers to diffuse pollution that results from many unspecified sources of emission or discharge to the atmosphere or waterways (e.g., auto emissions).

Nuisance Plant Species – Vegetation, which dominates areas and does not allow for establishment of other species.

Oligotrophic - Water quality characterized by a deficiency of nutrients.

Organic Nitrogen- Nitrogen that is bound in organic compounds.

Organic Priority Pollutants - Organics such as pesticides, petroleum based hydrocarbons, and other complex organic compounds. The source list for organic pollutants is long ranging from common household items, to industrially produced by-products. Recent medical advances show correlations between these organics and potential harm to human health.

Organochlorine Pesticides - Compounds in which chlorine is bound to a hydrocarbon group. Used as a pesticide.

Organophosphorous Pesticides - Compounds in which phosphorous is bound to a hydrocarbon group. Used as a pesticide.

ORP- Oxidation Reduction Potential.

Oxidation Reduction Potential (ORP) - (or Redox potential expressed as E_h or E_7), refers to the standardized measurement of the potential for electron loss (oxidation) or for electron gain (reduction) under present systems (Fe^{2+} to Fe^{3+}), although the oxidized and reduced states exist together in equilibrium. Removing free electrons causes further oxidation, while adding electrons inhibits oxidation and promotes reduction (Fe^{3+} to Fe^{2+}). ORP is proportional to the equivalent free energy change per mole of electrons associated with a given reduction.

Peak Flows - The highest point of a hydrograph during which maximum flow occurs.

Permanent Open Water Pool - A permanent water pool in stormwater BMPs such as a detention pond. It is the water stored below the outflow discharge elevation.

Permeable Pavement (Porous Pavement) – Pavement, which allows for the infiltration of water.

Pervious Area - An area that allows for the infiltration and percolation of water through the ground.

Phosphorus - An essential nutrient to vegetation.

Photosynthesis- The biological synthesis of organic matter from inorganic matter in the presence of sunlight and chlorophyll.

Pollutant Loads - Calculated from event mean concentrations (EMC) and storm volume over a representative time period.

$$\text{Pollutant Loads} = \Sigma\ \text{EMC} * \text{storm volume}$$

Where EMC is the event mean concentration for the storm and storm volume is the amount of runoff measured flowing into or out of the system. The mass loading rates can be expressed as kilogram per square kilometer per year or pounds per acre per year.

Pollutant Reduction (efficiency) - Analysis of Event Mean Concentrations and pollutant loads provide the basis for calculating the pollutant removal capability of the stormwater system. This is often referred to as the efficiency of the system to remove pollutants.

Concentration efficiency:

EMC efficiency (%) =((concentrations in - concentrations out)/(concentrations in))*100

Where: Concentrations is the event mean concentration (EMC) for each storm event

Load efficiency

Load efficiency (%) = ((SOL in - SOL out)/(SOL in))*100 where: SOL is the sum of loads in cubic feet or cubic meters for a representative time period.

Polyclorinated Biphenyls (PCBs) - PCB's were used in a number of throw-away applications and also extensively employed as an electrical insulating fluid. Environmental concerns have lead to strict controls on the use of PCB's and standards for cleanup of PCB discharges.

Polycyclic Aromatic Hydrocarbons (PAHs) - Priority pollutants of concern containing benzene rings, which tend to be biodegradable and adsorbable on solids.

Potable Water - Drinking water. Water whose chemical constituents do not exceed the limits set fourth in the State Safe Drinking Water Act.

REV (Rate-Efficiency-Volume) - REV stands for reuse rate, efficiency of reduced discharge, and volume of temporary storage. Variables used in descriptive charts (i.e.- measuring aspects of a reuse pond).

Reclamation- The practice of converting land use back to a natural state.

Redox - Refers to the oxidation-reduction potential.

Removal Efficiency- The difference between the mass/volume input and mass/volume discharge for a pollutant; or the change in concentration from the input to the output, usually on a flow weighted (total mass/total volume) basis over the duration of a storm event.

Residence Time - The average amount of time water stays in detention before being discharged.

Restoration- Reclaiming an ecosystem from a disturbed or altered condition to a previously existing natural condition as a result of human action, i.e.- fill removal.

Retention Ponds- The prevention of direct discharge of storm runoff into receiving waters; included as examples are systems which discharge through percolation, exfiltration, and evaporation processes and which generally have residence times less than 3 days (see filtration).

Retrofits - The reconstruction of existing stormwater facilities to improve or comply with current needs and standards.

Reuse - The application of reclaimed water for a beneficial purpose.

Sand Filtration System - The filtration of stormwater through sand for water quality treatment.

Secondary Sewage Treatment - After removal of solids in primary treatment, secondary treatment attempts to reduce nutrients (N and P) and organic material using bacteria and other microbes in activated sludge or trickle filter systems.

Sedimentation Basins - Settling basins that are usually incorporated as pre-treatment basins in stormwater systems to help reduce sediment deposits in receiving waters or in constructed or natural wetlands used in stormwater treatment.

Seepage - Areas of discharge of groundwater to the ground surface.

Soil Cores - Samples of the vertical profile of sediment or soil layers.

State Water Policy- The comprehensive statewide policy as adopted by DEP pursuant to 373.026 and 403.061 setting forth goals, objectives, and guidance for the development and review of programs, rules, and plans relating to water resources. All Water Management District's programs and rules must be consistent with State Water Policy.

State Water Quality Standards - Water quality criteria set by the State of Florida for it's surface waters (Chapter 62-302 F.A.C.).

Stormwater - The flow of water that results from, and that occurs immediately following rainfall events.

Stormwater Utilities – Utility, which relies on user fees rather that the government's limited general tax revenues.

Stratification - The formation of a boundary layer in lakes from differences in water temperature or density.

Street Drain Trash Basket - Baskets placed in street stormwater drains used to catch trash in runoff.

Swales - A gently sloping depression in the land surface designed to transport intermittent runoff from storm events.

Total Kjeldahl Nitrogen - A measure of reduced nitrogen equal to the sum of Organic Nitrogen and Ammonia Nitrogen.

Total Maximum Daily Load (TMDL) - The greatest amount of a pollutant that a water body can receive without violating water quality standards.

Total Suspended Solids (TSS) - A measure of the filterable matter in a water sample.

Treatment Train - The use of multiple stormwater best management practices to provide a series of water quality treatments.

Upland - Any area that is not an aquatic, wetland, or riparian habitat. An area that does not have the hydrologic regime necessary to support hydrophytic vegetation.

Urban Runoff - Stormwater runoff generated in urban areas typically characterized by high impervious areas.

Volatile Solids - The weight loss on ignition (550°C) of the dissolved solids fraction for the solids laboratory analysis is called “volatile solids”. Although the test does not distinguish precisely between inorganic and organic matter since it also includes some mineral salts, it is sometimes used for this purpose.

Watershed Management - The integration of land use, infrastructure and water resources throughout an entire watershed.

Water Table - The upper surface of the groundwater or saturated soil.

Weir - A device used to control and measure water or wastewater flow.

Wet-detention Pond - A water quality treatment system that utilizes a design water pool in association with water-tolerant vegetation to remove pollutants through settling, adsorption by soils and nutrient uptake by the vegetation. The bottom elevation of the pond must be at least one foot below the control elevation.

Wetland - An area that is inundated or saturated by surface or groundwater at a frequency, duration, and depth sufficient to support a predominance of emergent plant species adapted to growth in saturated soil conditions.