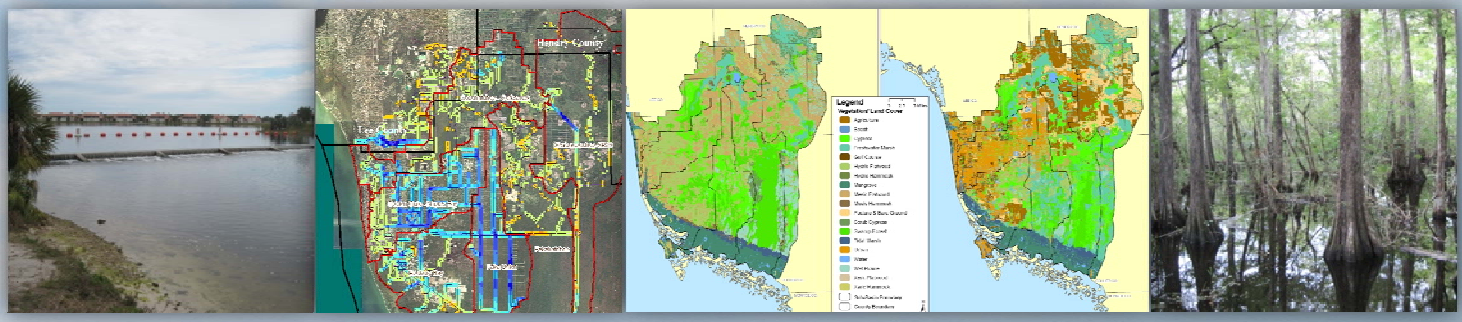
Collier County Watershed Management Plan – D R A F T



Collier County

Prepared by ATKINS

May 2011

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COLLIER COUNTY WATERSHED MANAGEMENT PLAN
COLLIER COUNTY, FLORIDA

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Acronyms and Abbreviations

BCB	Big Cypress Basin
BMP	Best Management Practice
CCWMP	Collier County Watershed Management Plan
ECM	Existing Conditions Model
EMC	Event Mean Concentration
ET	evapotranspiration
FDEP	Florida Department of Environmental Protection
FLUCCS	Florida Land Use Cover and Forms Classification System
GIS	Geographic Information System
GMP	Growth Management Plan
H&H	hydrologic and hydraulic
IWR	Impaired Waters Rule
LSI	Landscape Suitability Index
mg/L	milligrams per liter
NPDES	National Pollutant Discharge Elimination System
NSM	Natural Systems Model
PDVM	Pre-development Vegetation Map
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
SR	State Road
SWFFS	Southwest Florida Feasibility Study
TMDL	Total Maximum Daily Load
µg/L	micrograms per liter
UMAM	Uniform Mitigation Assessment Method
USACE	U.S. Army Corps of Engineers
WBID	water body identification number
WMP	Watershed Management Plan

Executive Summary

The Collier County Watershed Management Plan (CCWMP) has been developed using an integrated water resources approach to balance water needs of both the human and natural system environments in the County's watersheds and estuaries. One of the key features of this approach is that it takes advantage of opportunities for restoring the natural ability of the landscape to benefit the human environment and protect the water quality, water quantity, and natural systems in the County.

Directive

The CCWMP was prepared to address protection of the County's estuarine and wetland systems, consistent with Florida Statute (Subsection 163.3177(5)(d)). Applicable Elements of the Collier County's Growth Management Plan (GMP) addressed by the CCWMP include Conservation and Coastal Management and Drainage. The development of WMPs is specifically called out under Goal 2 of the Conservation and Coastal Management Element, Protection of surface and estuarine water resources.

Background and Purpose

Under pre-development conditions, surface waters flowed through wetlands in Collier County into the Rookery Bay and Ten Thousand Island estuaries. Extensive canal construction began in south Florida in the 1940s and the Golden Gate Canal network was constructed in the 1960s. Drainage canals and urbanization altered regional surface and groundwater flow patterns, lowered groundwater levels, increased freshwater discharges to estuaries, and drained wetlands. Associated urbanization and coastal development displaced native habitats, increased surface water discharges, reduced aquifer recharge, and increased pollutant loads to estuaries. As a result, what was historically a regional watershed, has become multiple, artificially created watersheds and restoring regional function via a County-wide watershed management approach is critical to restoring historical functions that allow the County to manage the resources for both human and natural water needs.

This CCWMP presents an evaluation of these issues with respect to pre-development conditions, performance measures by which to evaluate proposed management actions, and recommendations for water management actions that will improve the volume and timing of flows to the estuaries, reduce pollutant loads, increase groundwater recharge, and restore natural systems, to the extent possible, in the County. Recommendations were developed to:

- Restore historical water quantity and estuarine discharges
- Improve water quality within the watersheds and estuaries
- Address flood control and water supply issues

Study Area

The CCWMP was developed to address conditions in both the watersheds and estuaries (Figure ES-1). The study area includes: three high priority watersheds: Cocohatchee-Corkscrew, Golden Gate, and Rookery Bay. The eastern watersheds, Faka Union, Okaloacochee / State Road (SR) 29, and Fakahatchee watersheds, were evaluated as a single unit due to the less intensive land development and restoration activities currently underway in these watersheds. The estuaries in the study area are Wiggins Pass, Naples Bay, Rookery Bay, and the Ten Thousand Islands estuaries.

Approach

Relevant data were compiled from numerous sources, including agencies, Florida STORET data base, literature, and other reports. Two primary tools were used to model and compare pre-development with current conditions in the study area. The Natural Systems Model (NSM) was originally developed by the South Florida Water Management District (SFWMD 1989) to simulate the pre-development conditions in the Everglades.

The NSM was revised for the Big Cypress Basin model (SFWMD 2007) and used in this study. Existing conditions were modeled using the Collier County MIKE SHE/MIKE11 Existing Conditions Model (ECM). The ECM is an integrated surface and groundwater model

Differences between pre- and post-development conditions were applied to develop performance measures for assessing watershed and estuary conditions and providing a measure of improvement, or "lift," anticipated as a result of implementing proposed management actions. Performance measures were developed for surface waters in natural systems, freshwater discharges to estuaries, pollutant loads, and groundwater availability.

A series of potential capital improvement projects was identified, screened, and ranked to develop a list of recommended projects for addressing water resource issues in the County. Rankings are based on the anticipated improvements, or "lift," in the system due to proposed projects. A benefit/cost analysis was also completed, for which benefit=lift and cost=construction cost. Priority project are recommended and described for each watershed. Non-structural (policy) actions were also evaluated to support water management objectives.

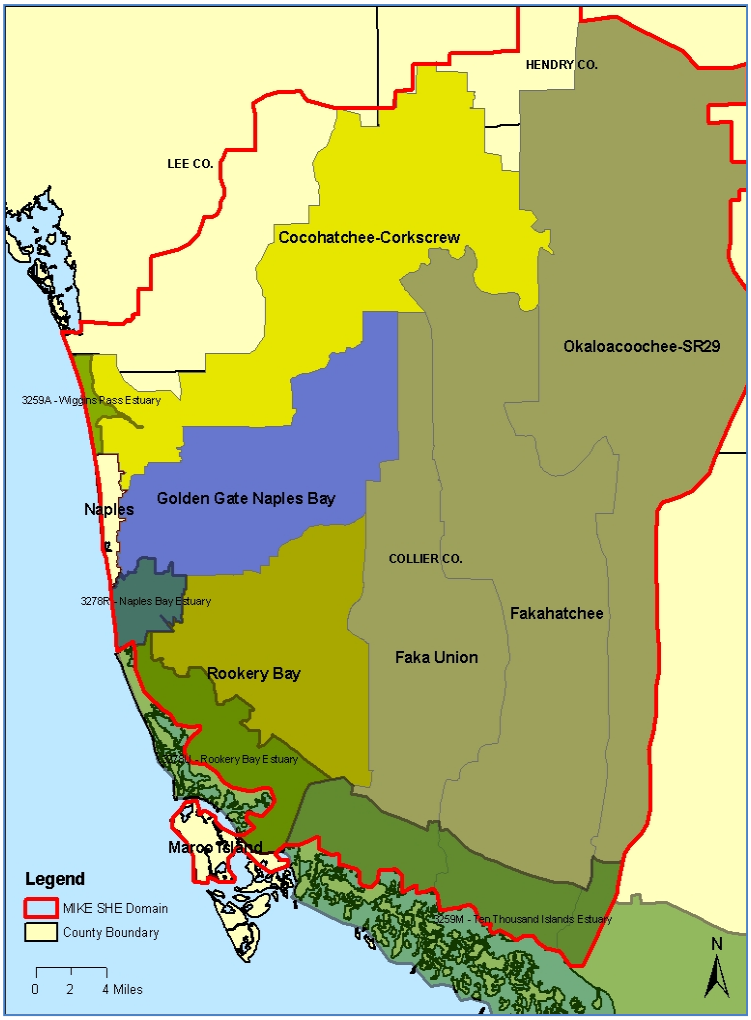


Figure ES-1. Collier County Watersheds and Estuaries

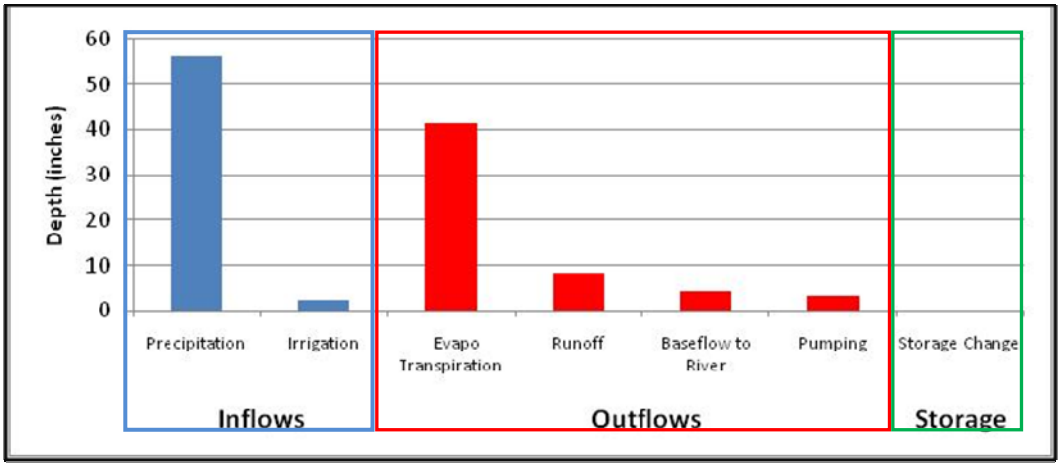


Figure ES-2. Surface Water Budget for Collier County

Results: Element 1, Existing Conditions – Watersheds

The canals have increased the freshwater discharges to the Naples Bay estuary by as much as 10 times compared with pre-development conditions and altered the timing and volume of flows to the other estuaries. Development and altered surface water flows have led to a dramatic decline in natural wetland systems in the County, including nearly 70 percent of the wetlands in the Golden Gate – Naples Bay watershed.

Watershed surface water quantity. Stormwater runoff volumes are strongly influenced by precipitation, therefore, small changes in rainfall can result in large runoff changes. Base flow contributions increase with canal density, therefore managing canal stages in response to groundwater levels can help manage freshwater discharges to estuaries. No net loss or gain in watershed storage was documented for the simulation period examined. Annual storage losses in the dry season correspond with high base flow contributions and withdrawals from the surficial and lower Tamiami aquifers for potable and irrigation water supply.

Lowering the water surface in the canal network prior to large storm events can provide storage in the canal network and mitigate flood risks. Base flow and runoff in the Naples-Golden Gate watershed is larger when compared with the others.

Instream water quality. Water quality in Collier County watersheds was evaluated with respect to Total Maximum Daily Load (TMDL) conditions per the Florida Department of Environmental Protection (FDEP) verified list of impaired waters. Multiple impairments were documented. Each of the 6 watersheds have identified dissolved oxygen impairments, possibly due to anthropogenic pollutant loads, surface water runoff from forested wetland landscapes, and groundwater contributions. Two watersheds had fecal coliform impairments and 1 was impaired for nutrients.

Watershed pollutant loads. Areas with larger pollutant loads corresponded to areas without Best Management Practices (BMPs). Nutrient loads were higher in older urban and agricultural areas and may be due to fertilizer applications. Higher biological oxygen demand and metals loads corresponded with low/medium residential areas and urban areas, respectively.

Watershed hydrogeology (groundwater budget). The groundwater system in Collier County is a regional reservoir and varies in response to seasonal changes. Current wet season recharge in each aquifer corresponds to the current dry season withdrawals in the 4 aquifers examined (water table, lower Tamiami, sandstone, and mid-Hawthorne aquifers). The pattern of drawdown was similar among the water table, lower Tamiami, and sandstone aquifers (Figure ES-3). The mid-Hawthorne is relatively isolated from these three and exhibits a somewhat different pattern due to limited withdrawals.

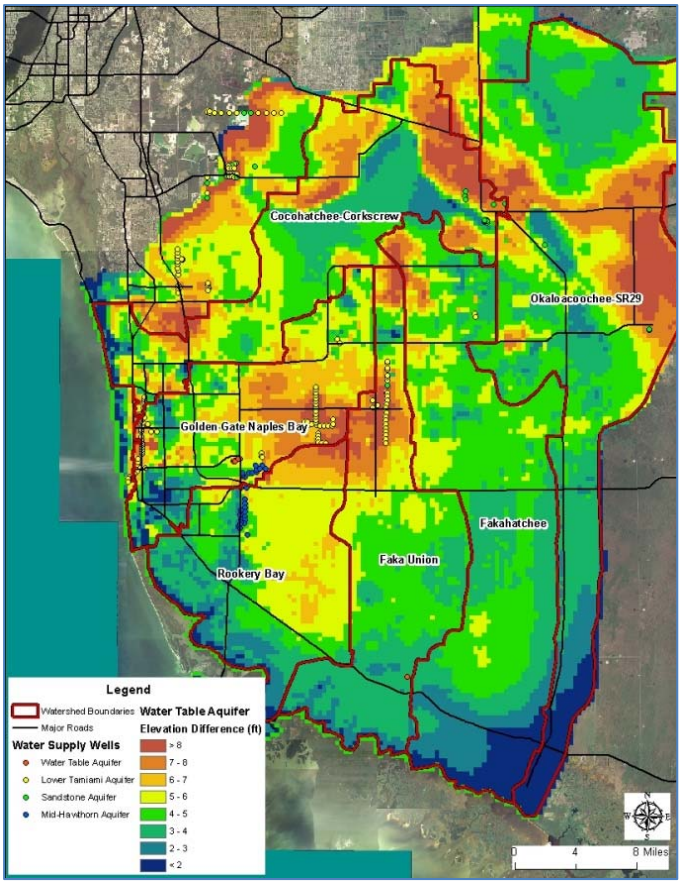


Figure ES-3. Water Table Aquifer Average Annual Groundwater Fluctuation

Structural operations changes in the Golden Gate Canal may provide opportunities to reduce groundwater losses and increase water availability. Reducing groundwater withdrawals for agricultural irrigation will increase the water available for potable supply and habitat protection.

Water uses. Changes in groundwater levels due to withdrawals were examined with respect to minimum aquifer levels established by the SFWMD. Predicted declines were more than 5 feet in many areas of the County and in all 4 of the aquifers under a scenario of a 10 percent increase in groundwater withdrawals (Figure ES-4). Predicted impacts were greater under prolonged dry season conditions.

Groundwater quality and pollutant loads. Dissolved oxygen concentrations in groundwater are less than 1.5 mg/L in most of the county and are likely a source of the dissolved oxygen impairments in the canals. Total nitrogen in most of the county and phosphorus concentrations in the north county and coastal areas exceed corresponding surface water criteria and may be a source of the nutrient impairment to Rookery Bay. Iron, but not copper, in surface waters, may be attributable to groundwater sources. No correlation was found between septic tank density and nutrient concentrations in the watersheds.

Natural systems. A landscape-level functional assessment method (modified from Florida's Unified Mitigation Assessment Method) was used to assess, and assign value to, existing natural systems conditions in the watersheds in Collier County. In general, the combined Faka Union, Okaloacoochee/ SR29, and Fakahatchee watersheds exhibited the highest functional value (the least change from pre-development) when compared with the other watersheds. Measured functional value was less in the Rookery Bay and Cocohatchee-Corkscrew watersheds, and least in the Golden Gate-Naples watershed. Landscape suitability index (LSI), vegetation, and hydrology scores provide performance measures for evaluating potential improvement projects. The functional assessment analysis also provides a means of identifying ecologically valuable lands, such that comparisons can be made with areas currently included in the County's or the SFWMD's preserved lands and supportive agricultural lands programs. Ecologically valuable and supportive lands (ES-5) were identified in the watersheds via consideration of LSI and vegetation scores. Hydrology scores (Figure ES-6) were not included in the identification of ecologically valuable lands, due to focus on natural and passive land use management rather than identification of hydrological restoration projects. However, hydrologic restoration may provide the greatest opportunity for measurable improvements.

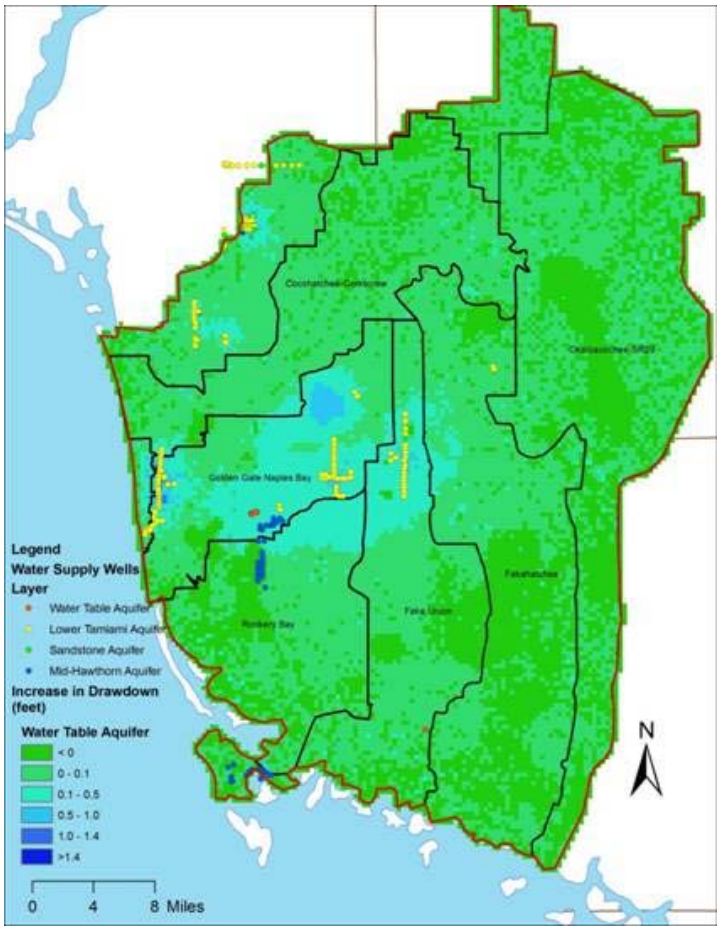


Figure ES-4. Water Table Aquifer (Prolonged Dry Season) Drawdown with 10 percent Increase in Withdrawals

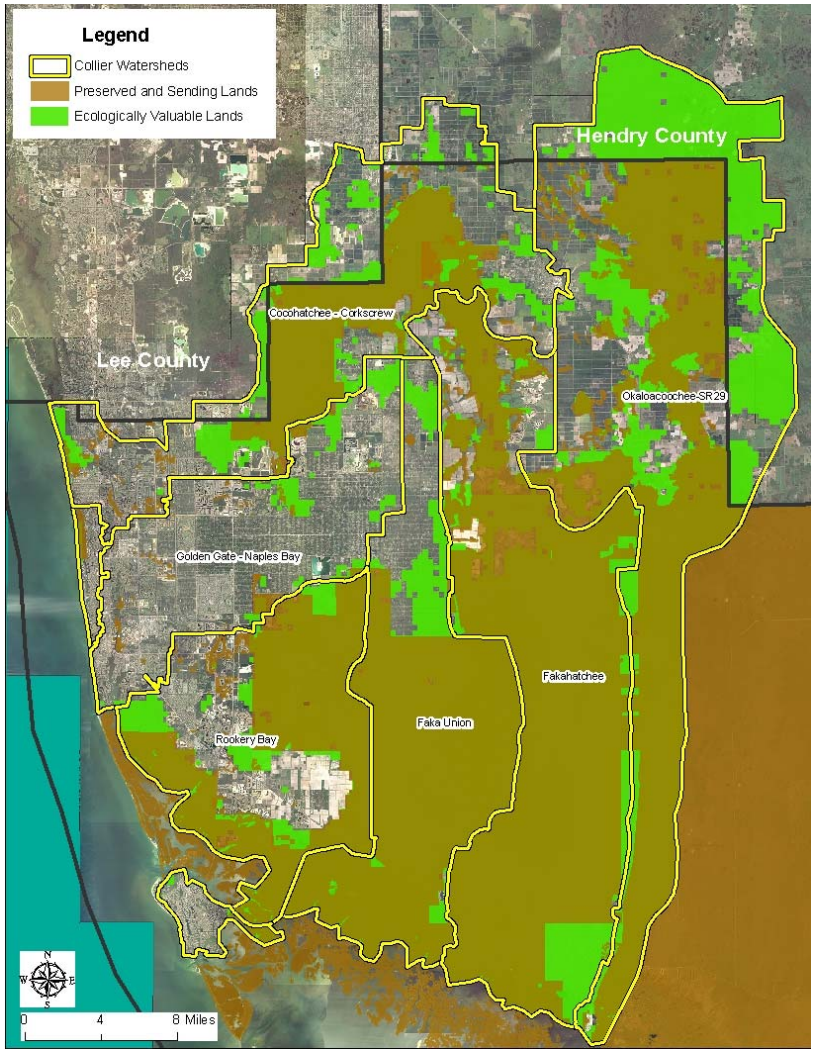


Figure ES-5. Ecologically valuable and supportive lands

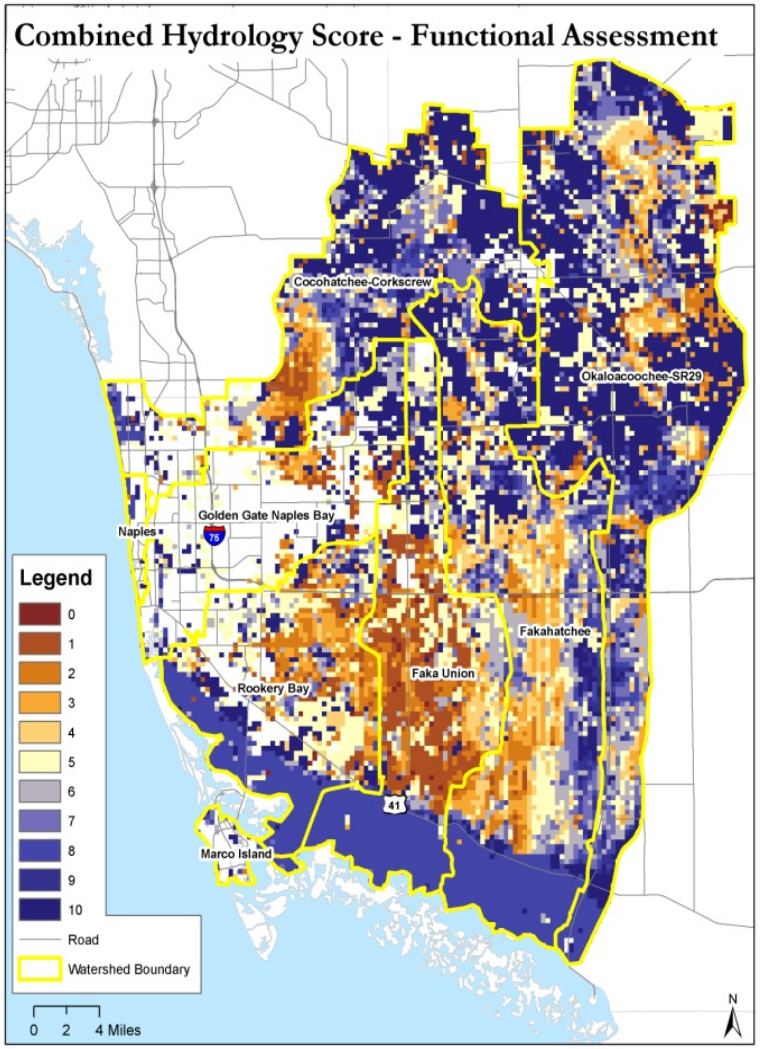


Figure ES-6. Hydrology assessment
(pre-development vs. existing conditions)

Results: Element 2, Existing Conditions – Estuaries

Volume and timing of freshwater flows. Excess wet season runoff under existing conditions (ECM), compared with pre-development (NSM) conditions is the primary issue in the Wiggins Pass, Naples Bay, and Ten Thousand Islands estuaries (Figure ES-7). For the Rookery Bay Estuary, the primary issue appears to be the timing of flow to the estuary and is due to excess water during the wet season and too little water during the dry season (Figure ES-8). Salinity model results (green bars) are consistent with differences measured by comparing pre- and post- development conditions.

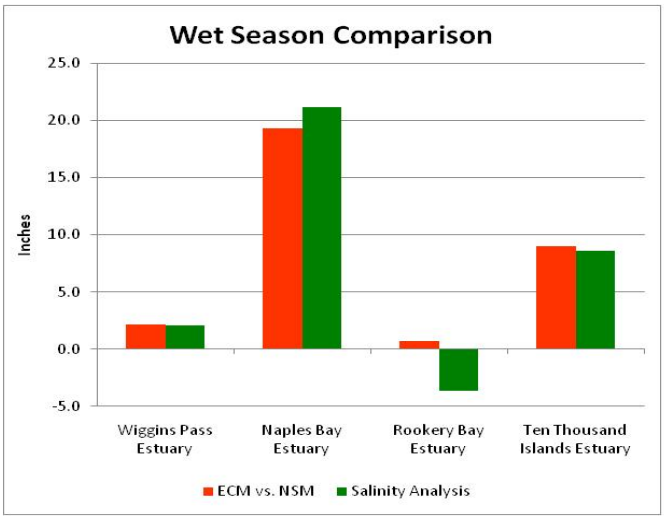


Figure ES-7. Wet season runoff (inches) in Collier County estuaries

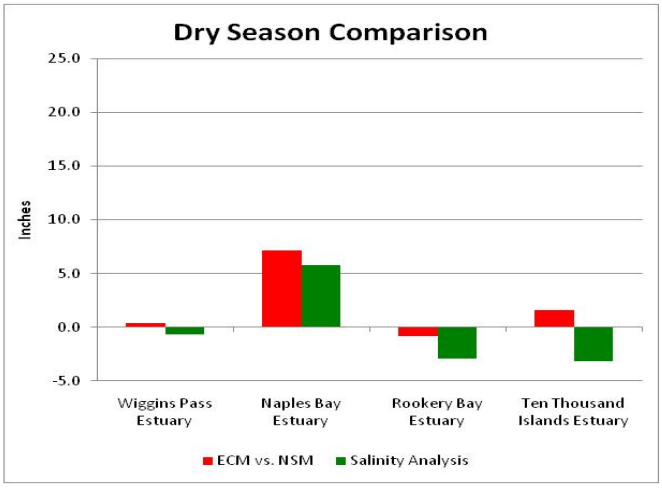


Figure ES-8. Dry season runoff (inches) in Collier County estuaries

Water quality of discharge. Collier County estuaries are typically impaired (with respect to state water quality criteria) for dissolved oxygen and fecal coliform bacteria. Rookery Bay is also impaired for nutrients. Concentrations of dissolved oxygen and fecal coliform bacteria in the discharges to the estuaries also exceed water quality criteria. Consequently, the watershed conditions are likely impacting the receiving estuaries. While causes of low dissolved oxygen are often attributed to nutrients, groundwater influence, and water color, the causes in these estuaries are not clear and would require further study. Fecal coliform bacteria may not be an appropriate indicator for pathogenic diseases in the sub-tropical climate and further source identification efforts are warranted.

Other parameters of impairment concern are iron and copper. Iron appears to result from the groundwater discharges throughout the canal network, although other sources are possible. High copper concentrations may be the result of anthropogenic impacts such as the use of copper sulfate as an algaecide to prevent algae growth in ponds or leaching from boardwalks and pilings that are constructed from pressure-treated lumber.

Quality of receiving waters. Water quality impairments identified as part of the Florida Department of Environmental Protection (FDEP) total maximum daily load (TMDL) program were confirmed with a single exception: the Rookery Bay impairment for chlorophyll-a was not confirmed and should be addressed with FDEP. The Wiggins Bay, Naples Bay, and Rookery Bay estuaries were found to be impaired for dissolved oxygen and fecal coliforms. Wiggins Bay was also found to be impaired for iron, and Naples Bay was found to be impaired for iron and copper. The Ten thousand Islands estuary is not listed as, and was not found to be, impaired for any water quality parameter. Collier County should consider working with the Florida Department of Environmental Protection (FDEP) to determine the sources

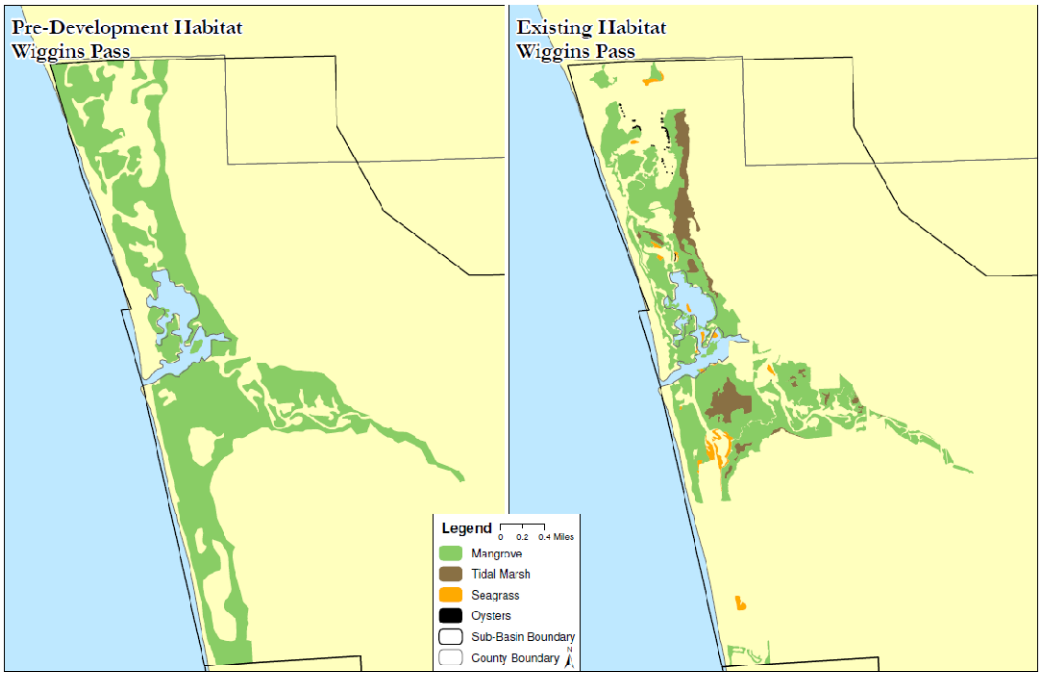


Figure ES-9. Wiggins Pass Habitat

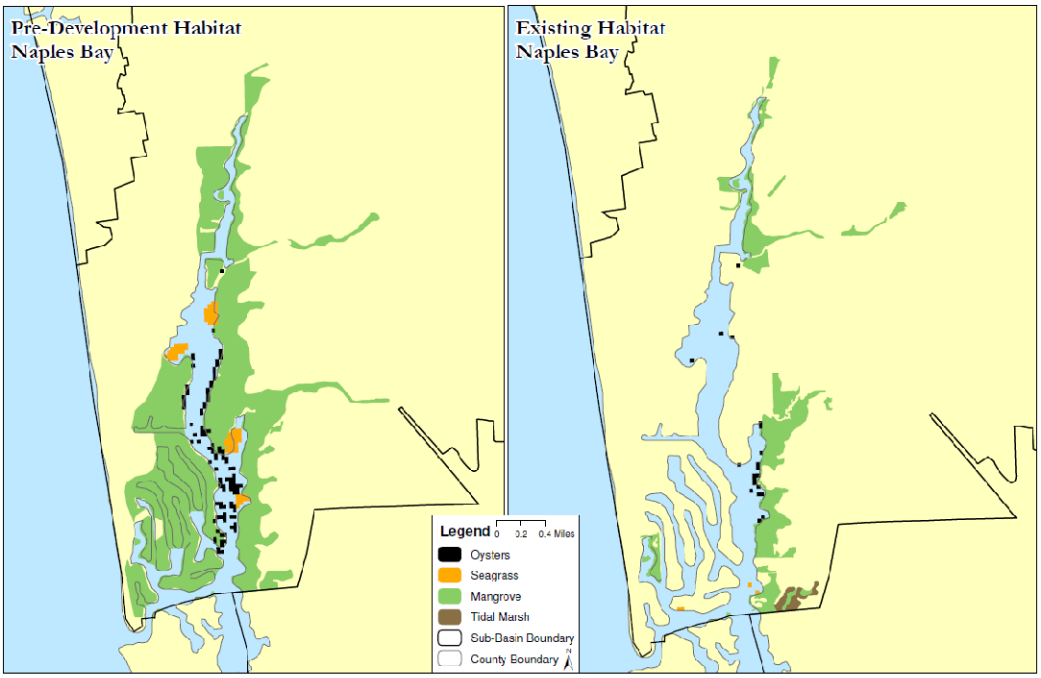


Figure ES-10. Naples Bay Habitat

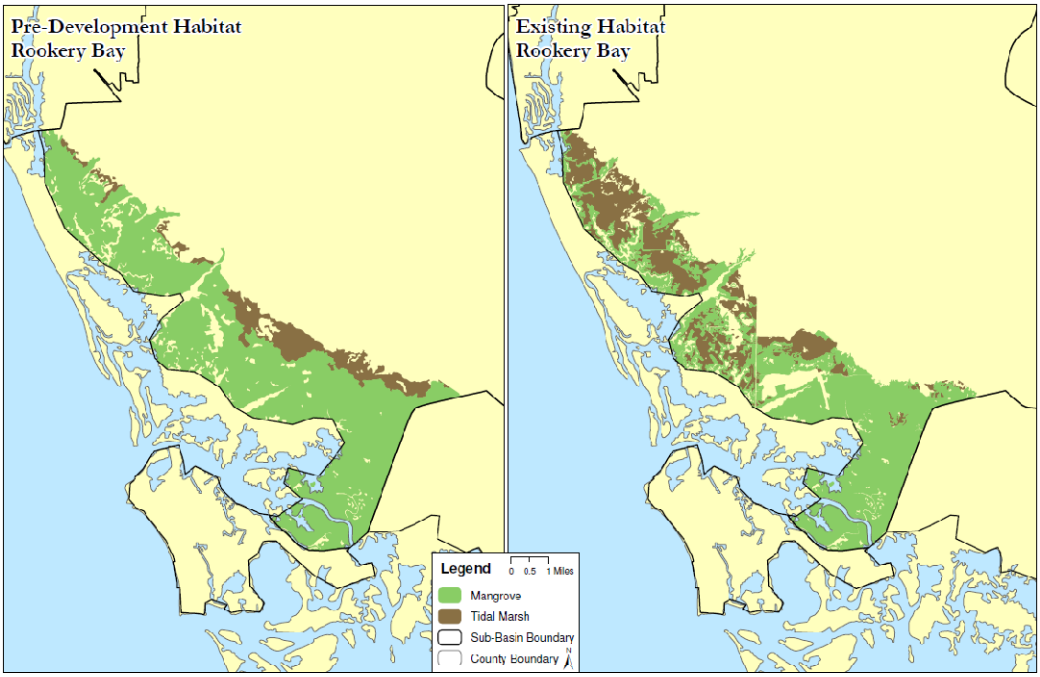


Figure ES-11. Rookery Bay Habitat

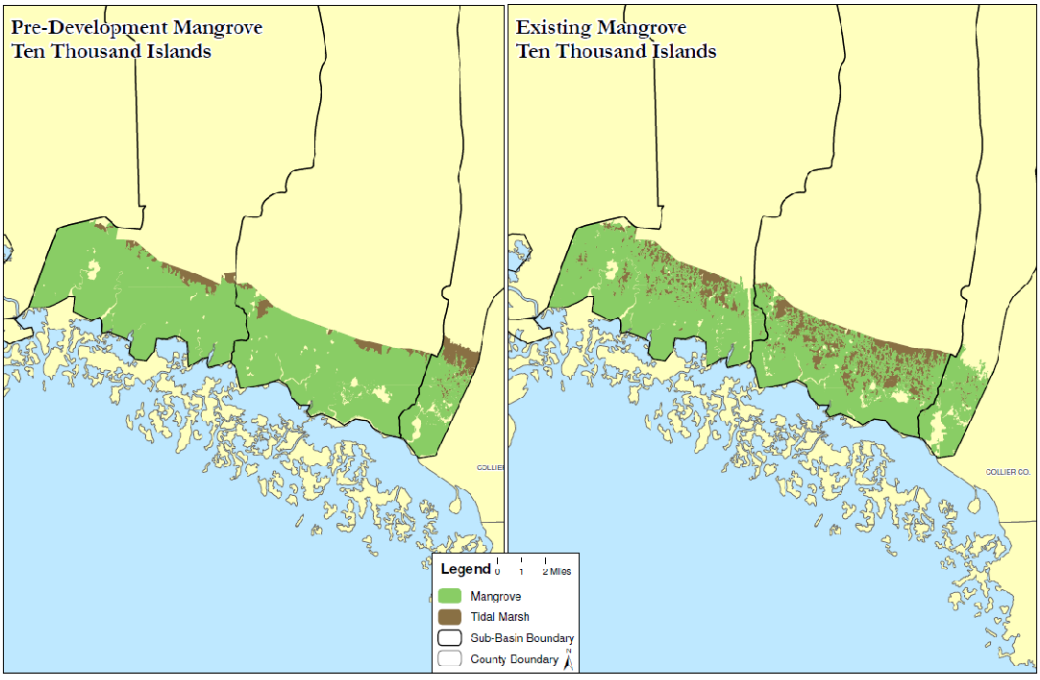


Figure ES-12. Ten Thousand Islands Mangrove

for the identified impairments in Wiggins, Naples, and Rookery Bay estuaries.

Coastal habitats. The reduction in areal extents of oyster bars, seagrass beds, mangrove forests and salt marshes in the estuaries is attributable to direct physical loss associated with coastal development. Habitat loss in Wiggins Pass and Naples Bay estuaries (Figures ES-10 and ES-11) is substantially greater when compared with the Ten Thousand Islands and Rookery Bay estuaries (Figures E-12 and E13), due to greater urbanization in Wiggins Pass and Naples Bay estuaries. In the Wiggins Pass estuary, the combined acreage of salt marsh and mangroves has declined by 29 percent over pre-development conditions. Acres of salt marsh and mangrove have declined by approximately 76 percent in Naples Bay. In contrast, the less-impacted estuaries of Rookery Bay and the Ten Thousand Islands have experienced salt marsh and mangrove declines of 12 and 5 percent, respectively.

Results: Element 3, Performance Measures

Performance measures were developed as a baseline against which to measure the improvement, or "lift" due to implementation of a proposed project. Performance measures were developed with respect to seasonal water levels for natural systems, for freshwater discharges to estuaries, pollutant loads, and groundwater aquifers.

Natural systems. Functional assessment scores, or performance measures, are presented below (Table ES-1) for the watersheds in Collier County. Higher scores indicate greater similarity to pre-development conditions. Average scores are lower in the Golden Gate-Naples Bay watershed due to extensive canals systems and development and indicate that hydrologic restoration may provide the greatest opportunity for measurable improvement in functional value in Collier County.

Freshwater discharge to estuaries. Performance measures (scores) are based on comparisons of timing and volume of discharges to estuaries for modeled pre- (NSM) and post- (ECM) development conditions. Average monthly discharge volumes from the NSM and ECM models were used to define the baseline distribution and total volume of flow from each watershed. Higher scores indicate greater similarity to pre-development conditions. The Golden Gate – Naples Bay watershed had the lowest annual score of 1.6 and is indicative of the year round flow surplus into Naples Bay. The scores for the Rookery Bay indicate dry season freshwater deficits, likely due to the reduced watershed caused by construction of the Golden Gate Canal. The wet season surplus is likely due to stormwater runoff from the Lely area and from the agricultural lands in the southeastern watershed.

Table ES-1. Average Functional Values (Performance Scores) for Non-Urban Lands, by Watershed

Watershed	Non-Urban Acres	Vegetation Score	Hydrology Score	LSI Score
Cocohatchee-Corkscrew	111,250	7	7	8
Golden Gate-Naples	36,627	5	6	6
Rookery Bay	83,105	8	6	9
Faka Union/ Okaloacoochee SR 29/ Fakahatchee	431,414	9	6	9

Table ES-2. Discharge to Estuary Performance Scores

Watershed	Annual Score	Dry Season Score	Wet Season Score
Golden Gate-Naples Bay	1.6	1.9	1.0
Cocohatchee-Corkscrew	5.4	6.9	2.5
Rookery Bay	4.3	3.1	6.8
Faka Union, Okaloacoochee / SR 29, and Fakahatchee	5.6	7.4	2.0

Scores for the Cocohatchee-Corkscrew, and eastern watersheds suggest that the operational controls used to manage dry season flows are reasonably effective at matching pre-development flow conditions. This contributes to the higher scores during the dry season. Low wet season

scores in all watersheds point to the effect of development on the natural drainage system.

Surface water pollutant loads. Pollutant load performance measures (scores) for watersheds were based on data for the individual basins (as designated by FDEP water body identification numbers, or WBIDs) that make up each watershed. Scores were calculated as a function of pollutant loads relative to medium density residential reference loads (in contrast to NSM vs. ECM model results). Current scores indicate that the WBIDs of most concern are in the Cocohatchee – Corkscrew and the Golden Gate – Naples Bay watersheds, particularly the coastal segment of Naples Bay and the Gordon River Extension. The Golden Gate – Naples Bay watershed received the lowest average scores for the other pollutants because of the presence of areas of urban development with no treatment. Lake Trafford WBID had a score of zero because the WBID includes only the lake itself.

Surface waters. As described previously the eastern watersheds exhibited the highest functional value, i.e. performance measure, therefore the least change from pre-development conditions, when compared with the other watersheds. In the estuaries, functional value was less in the Rookery Bay and Cocohatchee-Corkscrew watersheds, and least in the Golden Gate-Naples watershed (see table below).

Aquifer recharge/yield. Weighted average performance scores for each WBID in each watershed are based on the average dry season water levels with respect to differences between existing (ECM) and pre-development (NSM) conditions. Low performance scores were typically associated with wellfield locations, agricultural irrigation concentrations, and canals. Scores are mapped for the water table aquifer in Figure ES-13: high scores (10) indicate high performance or relatively little change in dry season condition when compared with the NSM. Low scores (1) indicate areas where water demand to meet agricultural and potable water supply needs reduce the performance scores relative to historic groundwater levels against which they are measured. Areas that score poorly tend to correspond to wellfield locations.

Flood risk. Design storm simulations were used to evaluate flood inundation and the Level of Service (LOS) for roads in Collier County. Roads in the county are identified as either evacuation routes or other surface streets. Most evacuation routes meet 25-year/72-hour storm event criteria, while most surface streets fail. There is no effective means available to rank (assign priority) projects to address flooding. Therefore:

1. The first priority for the County is to further evaluate evacuation route segments identified under the proposed LOS analysis to ensure the route can remain open for large storm events.

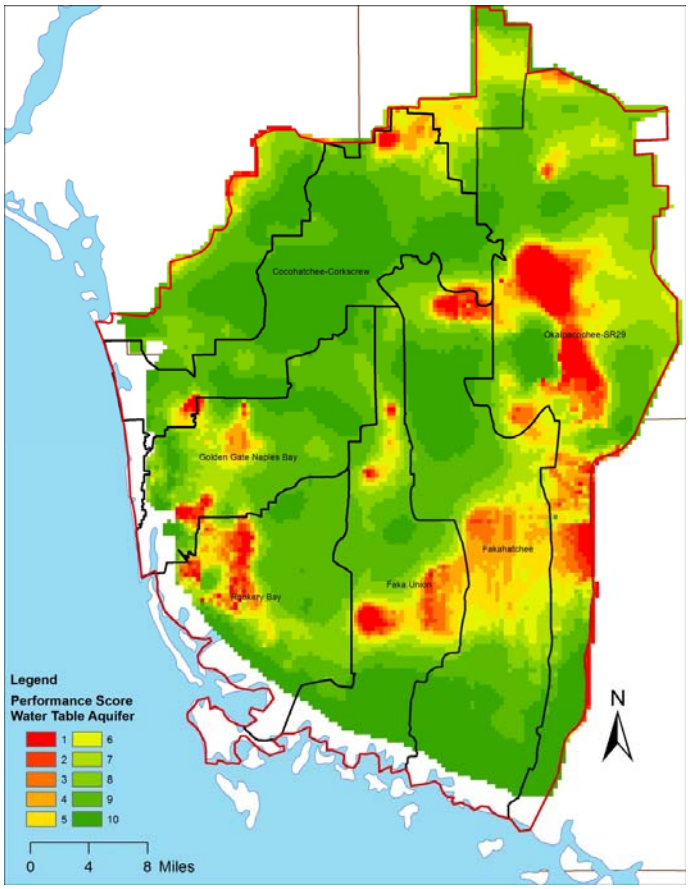


Figure ES-13. Performance scores for surficial aquifer

2. The second priority is further evaluation of existing arterial, collector, and neighborhood roads that, based on proposed LOS for the 10-year design storm, meet the 10-year LOS and may also meet the LOS criteria for the 25- and 100-year storm events.

Results: Element 4, Analysis of Alternatives and Recommendations

Structural and non-structural projects were identified as potential solutions to existing and anticipated water resource and natural systems issues in Collier County based on analyses completed as part of this study, as well as previously completed studies.

Non-structural (policy) recommendations. Non-structural recommendations offer long-term regulatory benefits critical so a sustainable watershed management plan Benefits due to non-structural (policy) recommendations are anticipated to substantially improve watershed conditions in Collier County.

Non-structural planning controls include land use ordinances, development regulations, mitigation banking, and other incentives for improving watershed conditions (benefits). Non-structural BMPs for watershed management focus on preserving and protecting natural features of the landscape to manage stormwater at its source. Evaluation of these BMPs includes an analysis of the applicable regulatory framework. Recommended non-structural initiatives address issues that range from land development guidelines to water quality monitoring and are listed below.

- Low Impact Development Program
- Stormwater Retrofit Program
- Fee-Based Stormwater Utility
- Allowable Maximum Site Discharges
- Flood Protection Levels of Service Criteria
- Volume Control for Large Storm Events
- Golden Gate Estates Transfer of Development Rights Program
- Golden Gate Estates Watershed Mitigation Program
- Modified Operations of Water Control Structures
- Water Quality Monitoring
- Additional Watershed Protection Programs

Structural improvement recommendations. In contrast with non-structural recommendations, structural (engineered) improvements offer short term improvements. They are not a long term solution and the lift associated with these projects ranged from only 10 to 15 percent.

After an initial screening of more than 150 projects, 27 potential structural improvement projects were evaluated with respect to permitting, constructability, environmental benefits, and costs in the Collier County watersheds. Permitting constraints reduced the number of projects for further evaluation to 18.

The 18 projects were evaluated against corresponding performance measures developed for each of the 4 performance criteria (freshwater discharge, water quality, wetland hydrology/ habitat, and groundwater recharge). Project benefits were measured by the "lift," or the improvement in performance criteria anticipated as a result of the proposed project, as described earlier. Weighting factors were integrated into the selection process to address both individual watershed characteristics (e.g. watershed size) and the relative importance of the watershed issues (e.g. extent of development). Cost, equal to the construction cost of the project, was estimated and benefit/cost (B/C) ratios were developed. Performance sores normalized to a 0 to 10 scale and were averaged for each of the 4 criteria. Each

combined scores is the quotient of the average performance score divided by the cost. Combined, normalized project scores with respect to performance criteria, cost, and B/C ratio are listed in Table ES-3.

The final 10 projects, in order of B/C ratio, range in cost from $96,000 to approximately $7 million (Table ES-4). Priority projects, in order of preferred implementation, are briefly outlined below.

1. **Northern Golden Gate Estates Flow-way Restoration**. The project ranks second in B/C, but first in benefits. It has the most lift anticipated for each of the 4 performance criteria, but only minimal lift for the discharge to estuary criteria.
2. **North Belle Meade Spreader Swale project** provides lift with respect to each of the 4 performance criteria. The primary benefit is lift in discharge to estuary in the Golden Gate and Rookery Bay watersheds, based on an anticipated 10 percent reduction in flows to Naples Bay and increased flows to Rookery Bay. Moderate lift is expected for the other 3 performance measures.
3. **The Henderson Creek Diversion project** is considered the third most important project to implement. It ranks fourth in the B/C ratio and, similar to the North Belle Meade project, it provides lift to estuary discharge for the Golden Gate and Rookery Bay watersheds. It does not provide lift to the 3 other performance criteria.
4. **The Corkscrew Regional Ecosystem Watershed Restoration** has the greatest B/C ratio among the 10 projects. However, the anticipated lift in wetland hydrology is local and does not address some of the more important issues facing the county. Consequently, the project was assigned a lower priority for implementation despite the higher B/C ratio.

Table ES-3. Normalized Performance Scores and B/C Ratios for the Four Performance Criteria

Project Name	Discharge to Estuary	Water Quality	Wetland Hydrology/ Habitat	Ground-water	Total Score	Estimated Cost ($ million)	Benefit-to-Cost Ratio
Corkscrew Regional Ecosystem Watershed	0.00	0.00	2.01	0.00	2.01	0.10	20.95
North Golden Gate Estates Flowway Restoration	0.05	10.00	10.00	10.00	30.09	2.37	12.71
North Belle Meade Spreader Swale	8.60	2.58	2.70	2.76	25.24	7.03	3.59
Henderson Creek Diversion	10.00	0.00	0.00	0.00	20.00	5.71	3.50
South I-75 Canal Spreader Swale	0.13	1.04	7.81	1.38	10.49	3.13	3.35
Wolfe Road Wetland Treatment System	0.00	0.11	0.00	3.34	3.45	1.42	2.44
Upper Golden Gate Estates Canal Weir Constuction	0.00	0.00	0.00	0.67	0.67	0.55	1.21
Orange Tree Canal Control Structure Installation	0.00	0.00	0.00	0.67	0.67	0.55	1.21
Henderson Creek Off-Line Storage Reservior	1.06	0.14	0.00	0.07	2.33	2.93	0.79
US HWY 41 Stormwater Treatment Area	0.00	0.03	0.12	0.00	0.15	0.54	0.28

Table ES-4. Cumulative Benefit (Performance Scores) and Cost of Project

Project Name	Cocohatchee-Corkscrew Cumulative Lift				Golden Gate - Naples Bay Cumulative Lift				Rookery Bay Cumulative Lift				Cumulative Cost (Millions of Dollars)
	Discharge to Estuary	Water Quality	Hydrology	Groundwater	Discharge to Estuary	Water Quality	Hydrology	Groundwater	Discharge to Estuary	Water Quality	Hydrology	Groundwater	
Corkscrew Regional Ecosystem Watershed	0.000	0.000	0.031	0.000									$0.096
North Golden Gate Estates Flowway Restoration Project					0.010	0.682	0.118	0.002					$2.464
North Belle Meade Spreader Swale[(1)]					0.900	0.682	0.118	0.002	1.250	0.435	0.036	0.200	$9.490
South I-75 Canal Spreader Swale									1.289	0.523	0.088	0.250	$12.621
Henderson Creek Diversion [(1)]					1.345	0.682	0.118	0.002	2.124				$18.329
Wolfe Road Wetland Treatment System					1.345	0.690	0.118	0.007					$19.745
Henderson Creek Off-Line Storage Reservior									2.282	0.547	0.088	0.255	$22.674
Upper Golden Gate Estates Canal Weir Constuction					1.345	0.690	0.118	0.008					$23.226
Orange Tree Canal Control Structure Installation					1.345	0.690	0.118	0.009					$23.778
US HWY 41 Stormwater Treatment Area									2.282	0.553	0.089	0.255	$24.322
Total Benefit or Cost	0.000	0.000	0.031	0.000	1.345	0.690	0.118	0.009	2.282	0.553	0.089	0.255	$24.322

Conclusions

Canal construction and urban development in Collier County have altered what were historically regional surface and groundwater patterns, resulting in multiple, artificially created watersheds that have reduced water quality, altered freshwater flows to estuaries, reduced groundwater recharge, and altered natural ecosystems.

The CCWMP provides an analysis of existing conditions in the County with respect to changes from pre-development conditions and provides County-wide recommendations to:

- Restore historical water quantity and estuarine discharges
- Improve water quality within the watersheds and estuaries
- Address flood control and water supply issues

NSM and ECM results were successfully used to evaluate changes and develop performance measures that were, in turn, used to quantify relative benefits anticipated from implementing proposed structural projects. Several projects were recommended as part of the benefits and B/C analysis. Structural projects recommended, in order of preferred implementation are:

- Northern Golden Gate Estates Flow-way Restoration
- North Belle Meade Spreader Swale
- Henderson Creek Diversion
- Corkscrew Regional Ecosystem Watershed Restoration

Nonstructural, policy recommendations that have longer term, sustainable ecosystem benefits were also developed. These non-structural measures offer an alternative to structural measures and emphasize a more-integrated approach to managing water resources in Collier County. Recommendations include actions related to low impact development (LID) regulations, transferrable development rights, retrofit programs, better management and/or improvements of existing control structures, and monitoring.

Introduction

Collier County is developing Watershed Management Plans (WMPs) to protect the County's estuarine and wetland systems, consistent with Florida Statute (Subsection 163.3177 (5)(d)). Under the statute, "a Conservation Element that addresses the conservation, use, and protection of natural resources in the area . . . is required as part of Local Government Comprehensive Plans." This WMP specifically addresses the Conservation and Coastal Management Elements of the County Comprehensive Growth Management Plan.

The Collier County Watershed Management Plan (CCWMP) has been developed using an integrated water resources approach to balance water needs of both the human and natural system environments in the County's watersheds and estuaries. One of the key features of this approach is that it takes advantage of opportunities for restoring the natural ability of the landscape to benefit the human environment and protect the water quality, water quantity, and natural systems in the County. This chapter discusses the County's directive for the CCWMP, the general process by which it was developed, and the organization of this document.

Historically, south Florida, including Collier County, was characterized by overland water flow through interconnected sloughs and wetlands. Most water flowed south into the Rookery Bay and Ten Thousand Island estuaries. In 1947, Congress formed the Central and Southern Florida (CS&F) Flood Control Project under which 1,400 miles of canals, levees, and water control devices were constructed to provide a means of growth in south Florida. More than six million people subsequently moved to South Florida between 1940 and 1965 alone (Grunwald 2006). In Collier County, construction of the Golden Gate Canal network in the 1960s and subsequent development along the west coast changed regional flow patterns to the estuaries, lowering groundwater elevations, draining wetlands, and increasing pollutant loads to the estuaries.

Water control projects, particularly canal systems, have severely impacted small- and large- scale processes throughout Collier County. Canals drain surface waters and groundwater and subsequently alter freshwater discharges to estuaries. Urbanization and coastal development physically replaced native habitats, increased surface water runoff, and reduced water infiltration to the aquifers (aquifer recharge). Consequences of these early water control actions include poor water quality, reduced water supply availability, and fish and wildlife habitat losses in many areas throughout the County. The CCWMP is intended to evaluate these issues with respect to pre-development conditions and develop recommendations for water management actions that will improve surface water quality and freshwater flows, groundwater quality and recharge, and the condition of natural systems in the County.

The canals have increased the freshwater discharges to the Naples Bay estuary by as much as 10 times compared with pre-development conditions and altered the timing and volume of flows to the other estuaries. The decline in groundwater elevations has led to a dramatic decline in natural wetland systems in the County, including nearly 70 percent of the wetlands in the Golden Gate – Naples Bay watershed.

The CCWMP was developed to address conditions in the three highest priority watersheds: Cocohatchee-Corkscrew, Golden Gate, and Rookery Bay. In addition, the plan included an assessment of the Faka Union, Fakahatchee, and Okaloacochee / State Road (SR) 29 watersheds as a single unit due to the lower existing level of land development coupled with the on-going implementation of significant restoration projects. The plan includes the assessment of all estuary systems in Collier County. These include Wiggins Pass, Naples Bay, Rookery Bay, and the Ten Thousand Islands.

Watershed Management Plan Directive

Collier County is developing the watershed management plans with the purpose of protecting the County's estuarine and wetland systems, consistent with Florida Statute (Subsection 163.3177 (5)(d)). The goal is to develop a mechanism for *the conservation, use, and protection of natural resources in the area, including air, water, water recharge areas, wetlands, water wells, estuarine marshes, soils, beaches, shores, flood plains, rivers, bays, lakes, harbors, forests, fisheries and wildlife, marine habitat, minerals, and other natural and environmental resources.* Applicable Elements of the Collier County's Growth Management Plan (GMP)

addressed by the plan include Conservation and Coastal Management and Drainage.

The development of WMPs is specifically called out under Goal 2 of the Conservation and Coastal Management Element, Protection of surface and estuarine water resources, by which the County committed to complete the prioritization and begin the process of preparing Watershed Management Plans, which contain appropriate mechanisms to protect the County's estuarine and wetland systems. All but four (denoted with an asterisk) of the 13 goals identified (and listed below) in the Conservation and Coastal Management Elements are addressed in the CCWMP.

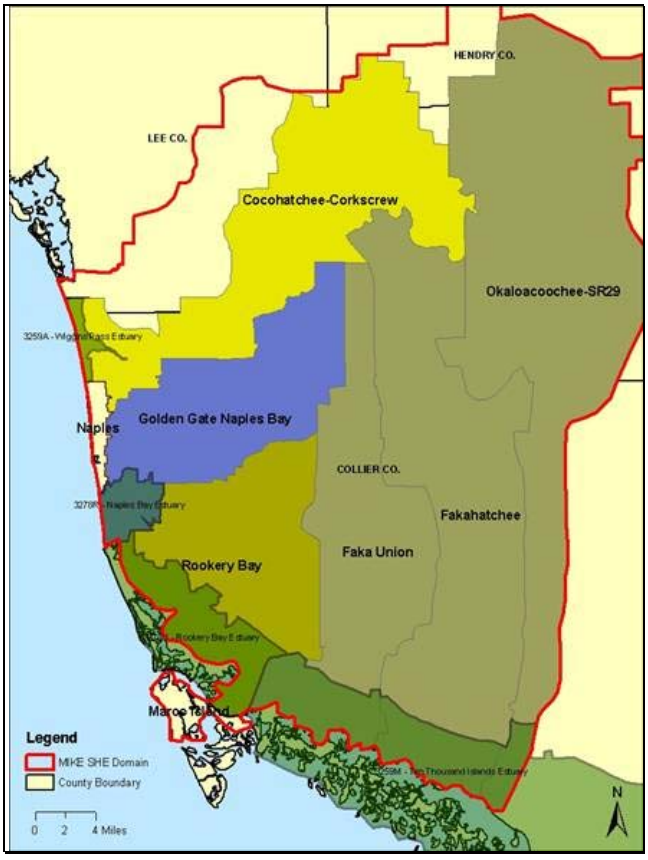


Figure 1-1. Collier County Watersheds

1. Protection of natural resources
2. Protection of surface and estuarine water resources
3. Protection of groundwater resources
4. Protection of freshwater resources
5. Protection of mineral and soil resources*
6. Protection of native vegetation and wildlife habitat
7. Protection of fisheries and wildlife
8. Maintenance of existing air quality*
9. Management of hazardous materials and hazardous wastes*
10. Protection of coastal resources
11. Protection of historic resources*
12. Hurricane evacuation and sheltering
13. Avoiding duplication of regulations

Watershed Management Plan Development

This CCWMP was developed following completion of the Southwest Florida Feasibility Study (SWFFS). The SWFFS was developed by the U.S. Army Corps of Engineers in cooperation with the South Florida Water Management District (SFWMD) and is a continuation of the earlier Southwest Florida Study (USACE 2000) that provided a framework to address aquatic ecosystems health; water flows; water supply; wildlife, biological diversity and natural habitat; the region's economic viability; and property rights in southwest Florida. The SWFFS includes a preliminary feasibility analysis of alternative solutions to issues identified in the SWFFS so that a viable plan can be authorized and funded.

The CCWMP development consisted of an assessment of existing and pre-development conditions, development of performance measures to evaluate anticipated success of proposed projects, analysis of alternatives, and a list of recommendations for implementation of specific watershed management projects and initiatives for both the watersheds and estuaries intended to:. More specifically, CCWMP is intended to:

- Restore historical water quantity and estuarine discharges
- Improve water quality within the watersheds and estuaries
- Address flood control and water supply issues

Water Management Plan Document Organization

This WMP describes the link between water quality, water quantity, and natural systems issues in Collier County watersheds and estuaries and provides recommendations for projects intended to address these issues and comply with Federal, State, and local regulations. Proposed improvements anticipated as a result of the proposed projects, as well as planning

level cost estimates for the recommended projects, are included in this CCWMP. The document is divided into chapters and organized for consistency with the work elements outlined in the County's Scope of Work, as outlined below.

Introduction. The introduction outlines the purpose of the CCWMP and presents an overview of the purpose and development of the CCWMP.

Element 1, Assessment of Existing Conditions – Watersheds. Existing and pre-development conditions are characterized for the Cocohatchee-Corkscrew, Golden Gate – Naples Bay, Rookery Bay, and the combined Faka Union, Okaloacoochee / State Road 29 (SR 29), and Fakahatchee watersheds to assess changes in the systems and the potential for restoration via management actions. This element addresses surface and groundwater quantity and quality, as well as natural systems in the watersheds.

Element 2, Assessment of Existing Conditions – Estuaries. Similarly, existing and pre-development conditions in Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Islands estuaries were characterized and evaluated in terms of potential management actions. This section addresses volume, timing, and quality of freshwater inflows to the estuary, quality of receiving waters in the estuary, and coastal habitats.

Element 3, Development of Performance Measures. Performance measures were developed for assessing watershed and estuary conditions and providing a measure of improvement, or "lift," anticipated as a result of implementing proposed management actions. Performance measures were developed for surface waters in natural systems, freshwater discharges to estuaries, pollutant loads, and groundwaters.

Element 4, Analysis of Alternatives and Recommendations. The identification, screening, evaluation, and ranking of recommendations for addressing water resource issues in the County are presented. Rankings are based on the anticipated improvements, or "lift," in the system due to proposed projects. Priority project are recommended and described for each watershed and include both structural and non-structural (policy) actions.

Summary of Conclusions and Recommendations. The conclusions and recommendations reached during the development of the CCWMP are briefly outlined in this section.

Literature Cited. Literature and previously prepared reports used to develop the CCWMP are listed in this chapter.

Element 1: Assessment of Existing Conditions – Watershed

1.1: Surface Water

Runoff and base flow account for about 15 and 8 percent, respectively, of annual rainfall in Collier County watersheds. Groundwater that enters the canal network as base flow makes up approximately 36 percent of the total fresh water discharged into the canals. Potable water irrigation demand during the dry season represents about 85 percent of the annual water budget.

1.1.1: Water Quantity

Introduction

Surface water budgets, based on results from the Collier County MIKE SHE/MIKE11 Existing Conditions Model (ECM) and the Big Cypress Basin (BCB) Natural Systems Model (NSM), are summarized here. Potential issues identified during the water budgeting process are presented. Water budget components, surface and groundwater budgets, base flow and structure operations, and canal capacity are also presented.

The water budget schematic presented below illustrates the primary inflows to the watershed are precipitation and applied irrigation. Water accumulates on the land surface as basin storage, runs off as overland flow, or seeps into the ground (infiltration/percolation). Overland flow can evaporate, discharge into the canal, or be conveyed across watershed boundaries. Water that seeps into the soils can be assimilated by plants or percolate into the water table (surficial) aquifer. Water can subsequently be assimilated by plants, flow across the watershed boundary, be pumped for potable water supply (PWS) and irrigation, or percolate into underlying aquifers. Residual water is stored in the aquifer. Similar processes occur in each of the deeper aquifers.

Methods

Data from the MIKE SHE/MIKE11 model results were extracted and processed to create water budgets for the entire study area and each of the watersheds. Water budgets were prepared for a wet and a dry year relative to average annual conditions and for the simulation period of January 1, 2002, through October 31, 2007. Budgets were developed for different time periods based on data availability. Finally, seasonal water budgets were developed for each watershed.

Results for Study Area

Average water year and seasonal water budgets were generated for each of the watersheds in Collier County. The average water year budget for the entire study area is graphed below and indicates that rainfall during the 4-month wet season represents about 54 percent of the total annual amount and that most is lost through evapotranspiration (ET), which ranges between 50 and 60 percent in the wet season for all watersheds. During the dry season, ET losses equal precipitation in all watersheds except Golden Gate – Naples Bay. In this watershed, ET is about 80 percent of precipitation due to the high level of urban development, as water is quickly routed to the drainage network.

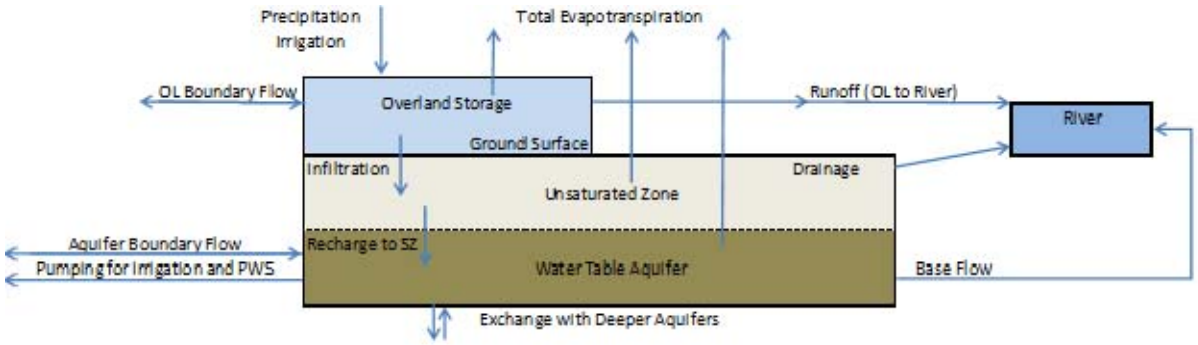


Figure 1-2. Surface Water Flow Schematic

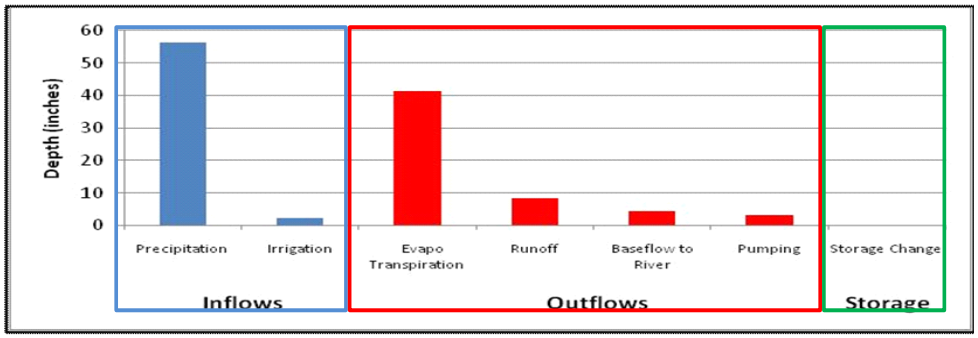


Figure 1-3. Average Water Year (2003–2007) Water Budget

Runoff and base flow are important components of the water budget and represent about 15 and 8 percent of annual rainfall (8.3 and 4.7 inches, respectively): the volume of groundwater that enters the canal network as base flow makes up approximately 36 percent of the total fresh water discharged into the canals. During the wet period, runoff is about 70 percent of the total water contributions to the canal network. In the dry season, the runoff volume declines to about 44 percent of the total contribution to the canals. Therefore, most of the canal flow is base flow, and is explained by the response of runoff to varying meteorological conditions, while base flow is relatively stable. The ratio of average runoff to average rainfall ranges from 20 percent in the wet season to 6 percent in the dry season. On the other hand, baseflow (wet season = 2.62 inches and dry season = 1.93 inches) remains at about 8 percent of rainfall. Pumping and irrigation demand during the dry season represents about 85 percent of the annual water budget.

Finally, the water budget also includes watershed storage. Change in storage as an annual average is negligible: about 2.5 inches of storage is lost in the dry season, but that volume is recovered in the wet season.

To assess system characteristics under critical conditions, water budgets were developed for both the driest dry season and the wettest wet season in the simulation period. Total precipitation during this totaled about 17 inches, or about 33 percent less than the average dry season rainfall for the entire simulation period.

Results confirm that the change in runoff volume is much larger than the change in precipitation. Results of the annual and seasonal water budgets indicate that management of both runoff and base flow are key to reducing the volume of water discharged to the estuaries. During the dry season, reduced base flow to the canal network appears to be more critical.

During extreme dry weather, irrigation and pumping for PWS increase substantially and watershed storage decreases substantially. Similar to the annual average analysis, irrigation and pumping are drastically reduced during extreme wet weather conditions and the watershed storage is quickly recovered.

Results for Watershed

Cocohatchee-Corkscrew Watershed. Model results indicate that the annual average runoff volume is approximately 14 percent of rainfall, mostly from urban and agricultural development. For example, the 2003 wet season results indicate that runoff was more than 9 inches, of which 8.5 inches came from urban and agricultural development. The average water year budget for the watershed is graphed below.

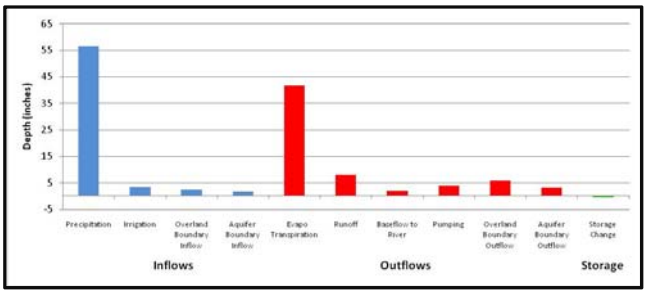


Figure 1-4. Average Water Year Budget – Cocohatchee-Corkscrew Watershed

Water runoff contributions from natural areas are small because most water is stored in Corkscrew Swamp. In addition, there is a large component of overland runoff flow that leaves the Cocohatchee-Corkscrew watershed and enters the Golden Gate–Naples Bay, Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds during large rainfall events due to the little difference in elevation at the watershed ridges. In terms of baseflow, the amount relative to runoff is only half of that computed for the entire study area. This can be attributed to the low density of canals in the watershed.

Golden Gate-Naples Bay Watershed. The most conspicuous feature of this watershed is that baseflow is the primary source of water to the canals and often makes up more than 70 percent of the dry season flows. This can be attributed to the high density of canals in the watershed. Reducing base flows to the canals may substantially reduce the volume of water discharging to the Naples Bay estuary. The average water year budget for the watershed is graphed below.

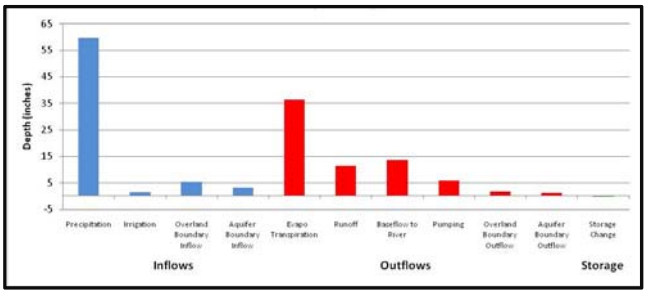


Figure 1-5. Average Water Year Budget – Golden Gate-Naples Bay Watershed

Runoff exceeds 19 percent of rainfall and occurs primarily during the rainy season. As in the Cocohatchee – Corkscrew watershed, most of the runoff is from coastal urban development. The volume of water leaving the watershed via overland and aquifer flow is low and is directly influenced by the canal network that drains the surficial aquifer and directs water to the estuary.

The Rookery Bay watershed has urban development west of the Henderson Creek Canal, while the central portion of the watershed is mostly undeveloped and includes Henderson Strand and portions of the Picayune Strand State Forest. The southeast portion of the watershed is agricultural. In general, the proportion of runoff relative to precipitation (11 percent) is low compared to the other watersheds and is most likely due to the lack of development in large parts of the watershed (below).

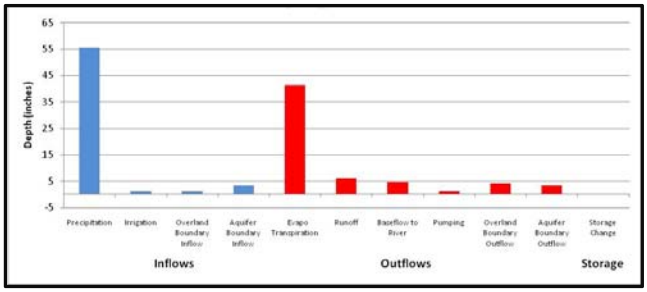


Figure 1-6. Average Annual Water Budget – Rookery Bay Watershed

Seasonally, surface water runoff makes up 60 percent of canal flow during the wet season and base flow contributes more than 70 percent of canal flow during the dry season. Wet season runoff is due primarily to urban and agricultural areas; while dry season base flow contributions are primarily in the Henderson Creek Canal.

Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds. The northern portion of the Okaloacoochee/SR 29 and Fakahatchee watersheds include large areas of agriculture, while the northern part of the Faka Union watershed includes more rural residential areas. The remainder of the watershed consists of wetlands or other natural areas. However, portions of the Golden Gate canal network drain large portions of the natural areas in the southern Faka Union watershed. The average water year budget for the watershed is graphed below.

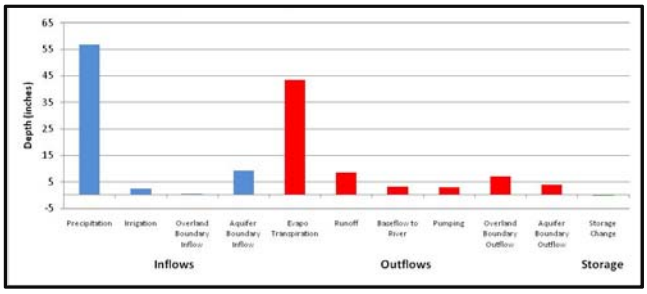


Figure 1-7. Average Water Year Budget – Faka Union, Okaloacoochee/SR 29, and Fakahatchee Watersheds

In the wet season, base flow in these watersheds is equal to approximately 120 percent of runoff, but during the dry season, the volume of base flow is more than 8 times that of runoff. Model results indicate that base flow is primarily in the Faka Union watershed, although there are base flow contributions to the State Road 29 Canal in the Okaloacoochee/SR 29 watershed. The Picayune Strand Restoration Project is expected to greatly reduce the volume of base flow in these combined watersheds.

Water budget results indicate a small loss in stored water over the simulation period, likely a result of high base flow contributions to the canal network in the Faka Union watershed, although groundwater pumping for potable water supply and agricultural irrigation in the northern parts of the watershed may contribute to loss of water.

Conclusions

Stormwater runoff and groundwater discharges to the canal network via base flow are critical water budget processes in the watershed as a whole. Management actions that alleviate impacts of increased development are necessary to reduce the adverse effects of the existing, limited conveyance capacity of the canal system.

- Annual and seasonal average stormwater runoff volumes are greatly influenced by precipitation and, consequently, relatively small variations in precipitation result in large changes in the volume of runoff.
- Base flow contributions increase with canal density. Reducing base flow would alter the volume and timing of water delivered to the estuaries.
- Based on the relationship of base flows and difference in ground and surface water elevations (see graph below), managing canal stage to groundwater elevations is important to reducing base flows to the canals.
- Existing control structures limit the ability to stage water at higher elevations in canals and new and replacement structures that can be changed with seasonal groundwater head elevations are recommended. Greater flexibility in managing water levels in the canals to reduce base flow contributions to estuaries should be part of the design for new or replacement control structures.

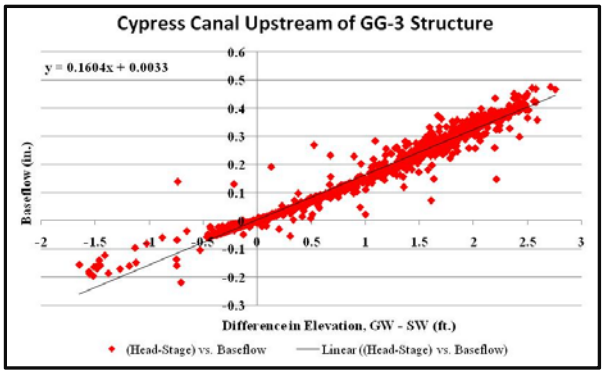


Figure 1-8. Relationship of Base flow and (Head – Stage) Elevation Difference

- No net loss or gain in watershed storage was documented for the simulation period. Annual storage losses in the dry season corresponded with high base flow contributions and pumping from the surficial and lower Tamiami aquifers for potable and irrigation water supply needs.
- Lowering the water surface in the canal network prior to large storm events is an important management tool to provide storage within the canal network and to mitigate flooding risks.
- Water inflow and outflow patterns among watersheds are similar. The notable exception is the large base flow and runoff component in the Naples-Golden Gate basin when compared with the other watershed.

1.1.2: In-Stream Water Quality

Water quality in the Cocohatchee-Corkscrew, Golden Gate – Naples Bay, Rookery Bay, and combined Faka Union, Okaloacoochee/ SR 29, Fakahatchee watersheds in Collier County were evaluated in the context of the Total Maximum Daily Load (TMDL) impairment conditions per the Florida Department of Environmental Protection's (FDEP) verified list of impaired waters. Dissolved oxygen is the main parameter of concern in the watersheds as a result of anthropogenic pollutant loads, surface water runoff from forested landscapes, and groundwater contributions.

Introduction

In-stream water quality was characterized with respect to TMDLs established by the FDEP for the 6 priority watersheds in Collier County: Cocohatchee-Corkscrew, Golden Gate – Naples Bay, Rookery Bay, and combined Faka Union, Okaloacoochee/SR 29, Fakahatchee. Analysis included: 1)review of relevant reports from local, state, and regional agencies, 2) review of relevant water quality data, 3) an assessment of water quality "impairments" that may require further verification, 4) identification of factor(s) likely responsible for the impairment, 5) identification of factors likely responsible for phytoplankton growth, and 6) an overview of factor(s) that most strongly influence water quality in Collier County's priority watersheds.

Methods

Basins were evaluated for potential impairments by first characterizing long term water quality in each of the six watersheds and then evaluating water quality with respect to FDEP thresholds for water quality impairments. Water parameters examined included color, dissolved oxygen, chlorophyll-*a*, total nitrogen, total phosphorus, iron, fecal coliform bacteria, and un-ionized ammonia.

Results

Fourteen basins (identified by water body identification numbers, or WBIDs) previously verified as impaired by FDEP were also identified as impaired in this study. An additional 16 WBIDs were identified as potentially impaired, or "watersheds of concern" by FDEP standards. Additional potential impairments may be due to the additional data available and differences in the timeframe used in the analysis. With the exception of Lake Trafford, watersheds are not characterized by high levels of total nitrogen or total phosphorus. Therefore, further study is called for prior to implementing potential water quality improvement projects. Impairments were due primarily to low dissolved oxygen concentrations. Chlorophyll-*a*, total phosphorus, and total suspended solids concentrations were within the range of the regulatory standards and screening levels for all six watersheds.

Cocohatchee-Corkscrew Watershed

Water quality analysis indicated 3 potential parameters of concern: color, dissolved oxygen, and fecal coliform bacteria. Chlorophyll-*a* and nutrients were not found to be elevated in the watershed. An evaluation of the cause of the low dissolved oxygen levels revealed: high nutrient concentrations, impact of wetland systems, and groundwater contributions to the drainage system. Elevated chlorophyll-*a* and nutrients were not observed in the Lake Trafford basin during this study in spite of its FDEP impairment designation. Water quality has improved since the earlier designation, likely due to sediment removal projects in the lake.

Golden Gate-Naples Bay Watershed

Based upon the evaluation of the long term stations within the watershed, 3 parameters of "potential concern" were identified: dissolved oxygen, color, and iron. The extensive development (61 percent) of the watershed, significant ground contributions to flows, and runoff from forested areas may all influence dissolved oxygen concentrations in the watershed. However, further site-specific analyses are required for verification.

Rookery Bay Watershed

Based on the evaluation of the long term water quality data, 1 parameter (dissolved oxygen) was identified as being of "potential concern," although none of the WBIDs that comprised the Rookery Bay watershed were identified by FDEP as impaired for dissolved oxygen. Consistently elevated chlorophyll-*a* and nutrient values were not observed in the watershed.

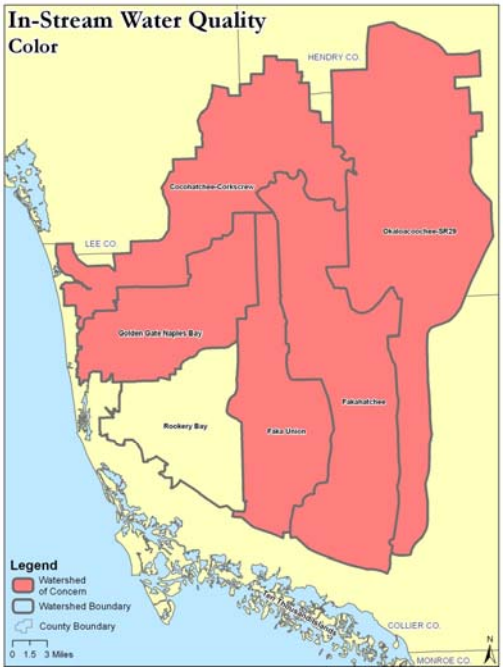


Figure 1-9. In-Stream Water Quality, Color

Similar to the Cocohatchee-Corkscrew watershed, much of the Rookery Bay watershed is comprised of natural areas (69 percent), predominantly in the north and central portions. The relationships of dissolved oxygen and total nitrogen, total phosphorus, and color, suggests that total phosphorus may be indirectly responsible for the low dissolved oxygen by stimulating algae growth that in turn may deplete waters of oxygen.

Faka Union, Okaloacoochee/SR 29, and Fakahatchee Watersheds

The evaluation of the long term water quality data from this watershed indicates 2 parameters of "potential concern": color and dissolved oxygen in the Faka Union watershed. Eighty-six percent of the watershed is comprised of natural areas and the high color water discharged from upstream forested areas, as well as groundwater contributions, and anthropogenic pollutant loads are all factors influencing, and possibly causing, the low dissolved oxygen concentrations observed. However, the presence of areas where hydrologic processes have been altered (i.e., the Southern Golden Gate Estates drainage canals) suggests that further analysis is necessary to determine the actual cause of the observed low dissolved oxygen concentrations.

The Fakahatchee watershed has been identified by FDEP as a reference area due to the limited hydrologic impacts and absence of large-scale nutrient inputs in the system. The evaluation of the long term water quality data available for the watershed indicate 3 parameters of "potential concern": dissolved oxygen, fecal coliform and color. Fakahatchee Strand (WBID 3278G) was declared verified impaired by FDEP for both dissolved oxygen and fecal coliform. Regression analyses suggest that low dissolved oxygen concentrations in discharge waters in the watershed may be due to color.

Conclusions

The FDEP has identified multiple impairments of individual WBIDs for several water quality parameters in Collier County. Results of water quality analyses at the watershed level suggest that dissolved oxygen is the main parameter of concern in the context of FDEP's TMDL program and may be due to anthropogenic pollutant loading in more urbanized watershed, color effects in less impacted natural landscapes, and groundwater influences The data analyses for individual WBIDS conducted as part of this project are consistent with the FDEP findings, although additional potential water quality impairments were also identified.

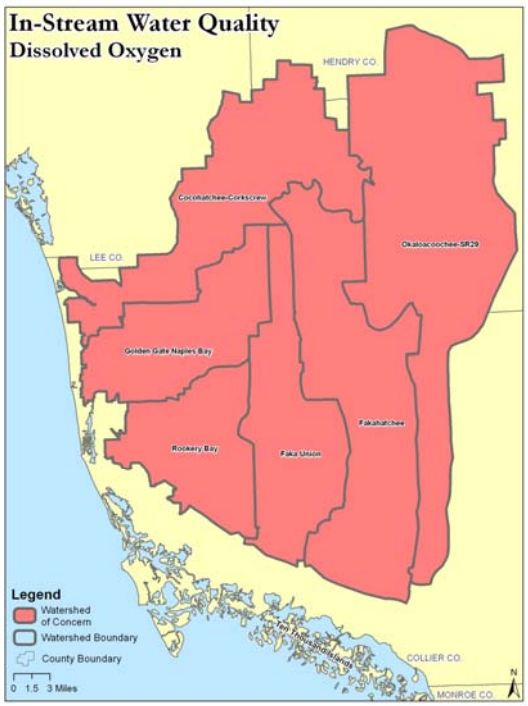


Figure 1-10. In-Stream Water Quality, Dissolved Oxygen

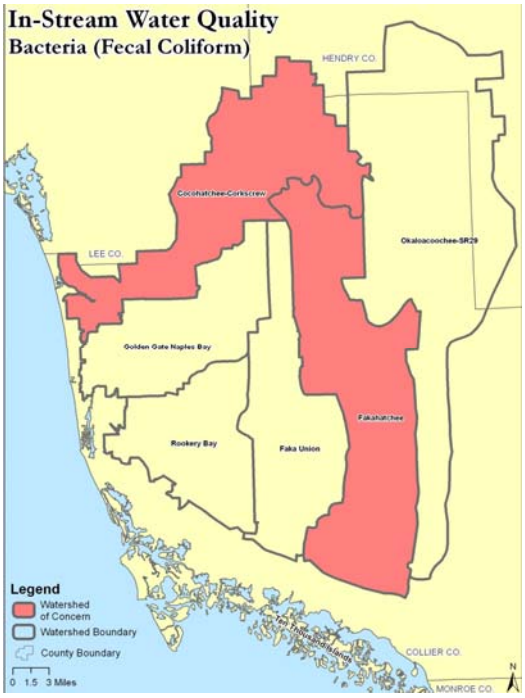


Figure 1-11. In-Stream Water Quality, Bacteria

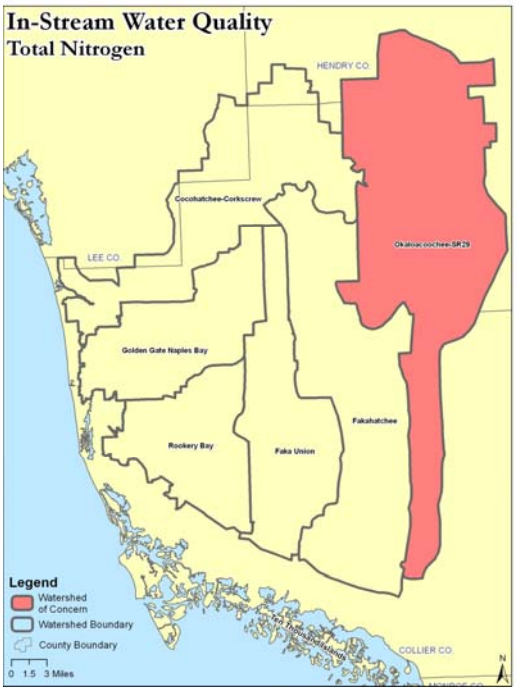


Figure 1-12. In-Stream Water Quality, Total Nitrogen

1.1.3: Pollutant Loads

Net surface water pollutant loads were quantified for priority watersheds in Collier County. Nutrient loads were greatest for the Cocohatchee-Corkscrew and Golden Gate – Naples Bay watersheds. Nutrient loads were higher in older urban areas, golf courses, and agriculture due to fertilizers. Higher biological oxygen demand and metals loads corresponded with low/medium residential areas and urban areas, respectively, and no treatment facilities.

Introduction

Net pollutant loads, i.e., post treatment loads, were calculated for the Cocohatchee-Corkscrew, Golden Gate-Naples Bay, Rookery Bay, and the combined Faka Union-Okaloacoochee/SR 29, and Fakahatchee watersheds. The pollutant loads provide a means of examining the relative contribution o f land use types to total pollutant loads and a baseline against which to measure the effects of improvement projects. The calculation of pollution loads addressed strictly anthropogenic loads, based on the focus on mitigation of anthropogenic impacts in the watershed management plan.

Methods

Pollutant loads to Collier County receiving waters were estimated using a Pollutant Loading and Removal Model based on the U.S. Environmental Protection Simple method. The MIKE SHE / MIKE 11 hydrologic and hydraulic (H&H) existing conditions model (ECM) was used to estimate runoff volumes. Pollutant loads were estimated for the parameters of concern identified in the Southwest Florida Feasibility Study (SWFFS): total suspended solids, total nitrogen, total phosphorus, biological oxygen demand, copper, zinc, and lead.

Gross pollutant loads were estimated for each cell in the model domain. These loads were then modified to reflect the pollutant removal effect of Best Management Practices (BMPs) for stormwater treatment, such as detention ponds typical of treatment throughout the County. The net loads are pollution loads that enter the drainage network, and therefore discharge into the estuary systems.

Results

The magnitude of the estimated pollutant loads is meaningful when compared to a reference standard. The reference for this analysis was the average pollutant load in the County from a medium density residential development without treatment facilities. The standard was developed by averaging the annual runoff from all model cells with a predominant medium density residential land use (8.3 inches) and multiply it by the corresponding event mean concentration (EMC) associated with a chemical parameter. The ratio of the net (post BMP) load of a cell to the standard load was scored as indicated in the following table. A score of 10 indicates no anthropogenic pollution, while a score less than 2 indicates areas (e.g., urban or agriculture) that exhibit pollutant loads equal to or greater than those from a typical residential development with no stormwater runoff treatment.

Table 1-1. Pollution Load Scores

Score	Ratio of Net Load to Standard Load
10	< 10% of standard
9	10% < standard < 20%
8	20% < standard < 30%
7	30% < standard < 40%
6	40% < standard < 50%
5	50% < standard < 60%
4	60% < standard < 70%
3	70% < standard < 80%
2	80% < standard < 90%
Less than 2	> 90% of standard

The distributions of pollutant load scores in Collier County are mapped below. Areas with higher pollutant loads are generally those without BMPs. For example, areas with low scores (high loadings) for total suspended solids correspond to the older urban developments located along the coast where total suspended solids are a consequence of the re-suspension of sediments accumulated on roads and drainage facilities.

Conclusions

Nutrient pollutants (total nitrogen and total phosphorus) are greater in older developments, golf courses, and agriculture, most likely a consequence of fertilizer application. Higher metal loadings are associated with urban areas that have few or no stormwater treatment facilities. Notably, the largest EMC pollutant value used in the SWFFS analysis is for agricultural land uses. Further wet weather sampling is necessary to better define areas of agricultural nutrient concern.

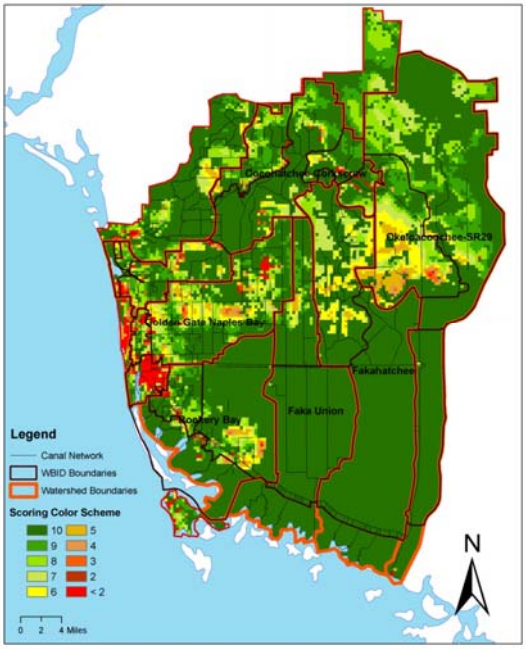


Figure 1-13. TSS Pollution Load Scores

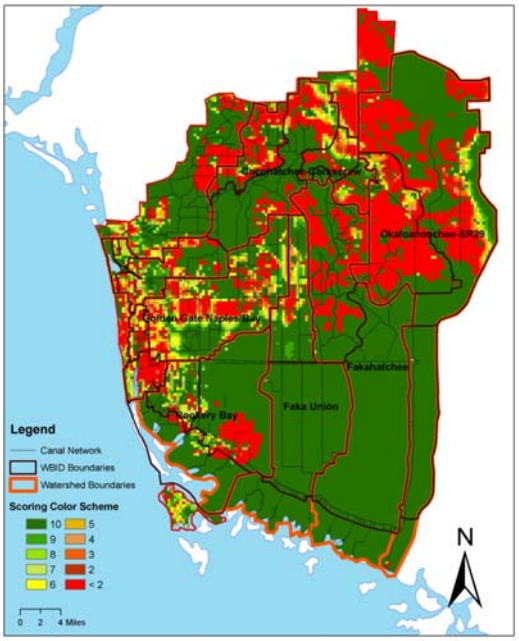


Figure 1-15. Total Phosphorus Pollution Load Scores

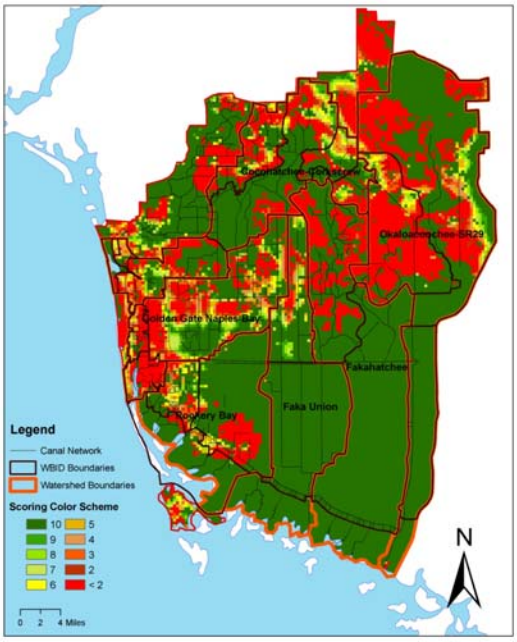


Figure 1-14. Total Nitrogen Pollution Load Scores

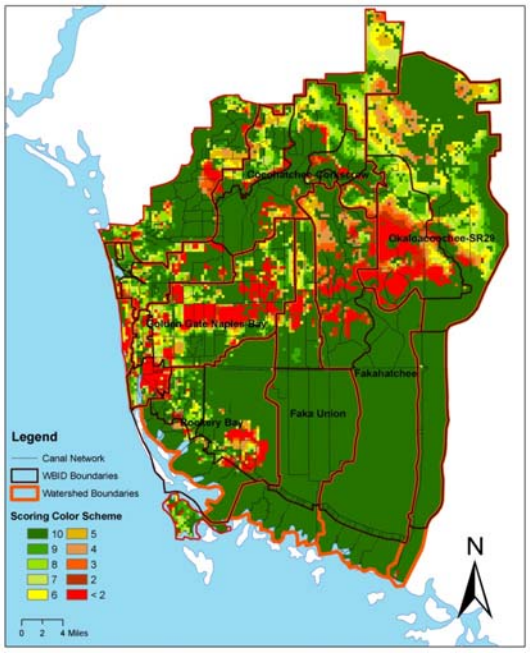


Figure 1-16. BOD-5 Pollution Load Scores

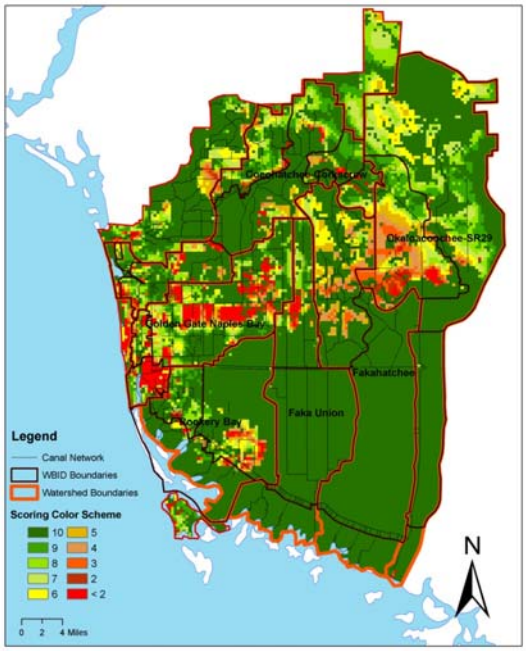


Figure 1-17. Copper (Cu) Pollution Load Scores

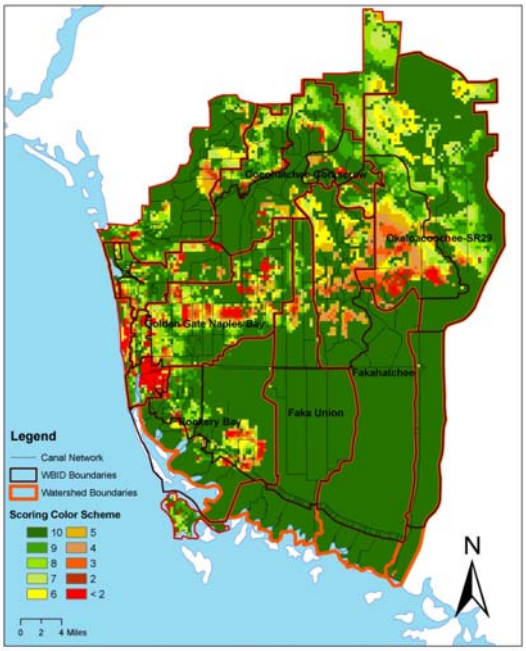


Figure 1-19. Zinc (Zn) Pollution Load Scores

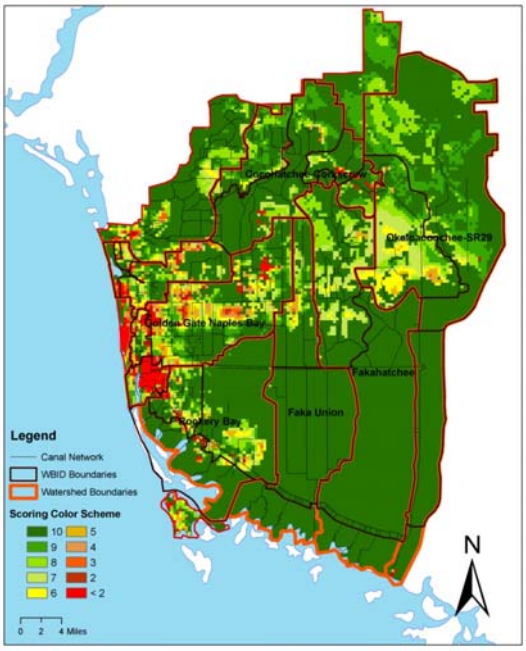


Figure 1-18. Lead (Pb) Pollution Load Scores

1.2: Groundwater

Groundwater analyses were completed using the Collier County MIKE SHE/MIKE11 Existing Conditions Model (ECM) to develop groundwater budgets for aquifers and watersheds. Annual and seasonal groundwater levels were examined to evaluate potential groundwater drawdowns in aquifers with respect to minimum aquifer levels.

1.2.1: Hydrogeology

Groundwater budgets and annual and seasonal groundwater levels for current conditions in Collier County watersheds were developed using the ECM. This groundwater assessment provides a means of identifying potential locations for future water supply withdrawals that also minimize impacts to natural systems such as wetlands.

Introduction

The groundwater resource in Collier County is essential to agricultural and urban, as well as natural systems, environments, and quantifying the components of this resource is important to the success of any WMP. A conceptual groundwater budget (below) illustrates inflows (primarily precipitation and agricultural irrigation runoff), outflows (discharge to canals, overland flow, etc.), and storage (water budgets related to surface water runoff and base flow are presented in later sections). Water that infiltrates into the soils may be assimilated by vegetation or percolate into the upper portion (water table) of the surficial aquifer. The water can be removed from the surficial aquifer by vegetation, lateral flows, water supply withdrawals, or percolation to deeper aquifers and water may move between aquifers. Any residual water is stored in the aquifer (s). Here, the focus is on interactions within and among the aquifers. The three primary aquifer systems in Collier County and Southwest Florida are the surficial (SAS), intermediate (IAS), and Floridan (FAS) aquifer systems.

Methods

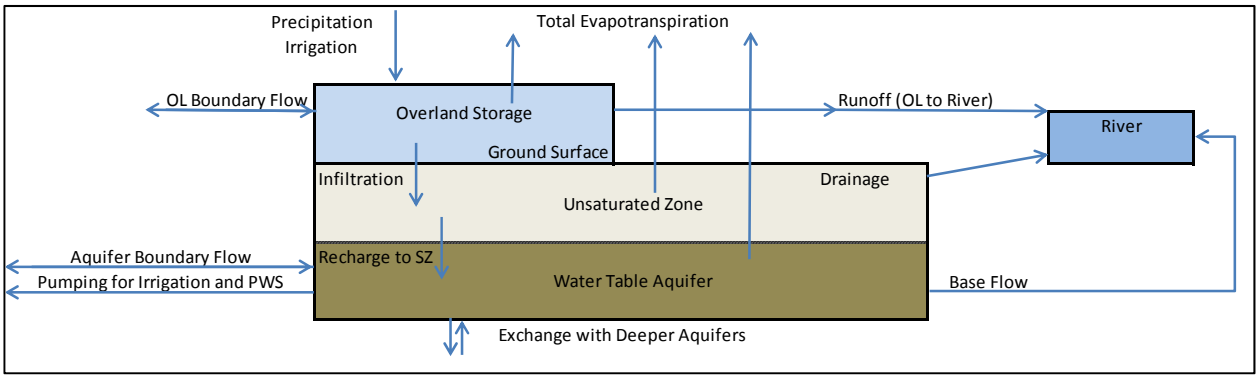
Groundwater budgets were developed for each aquifer and for the primary (Cocohatchee-Corkscrew, Golden Gate Naples Bay, Rookery Bay) and eastern (combined Faka Union, Okaloacoochee / SR 29, Fakahatchee) watersheds. Average annual and seasonal (wet and dry) groundwater budgets were developed for each watershed and each aquifer. Average annual and seasonal groundwater elevations and annual fluctuations were calculated and mapped for the watersheds and indicate areas where pumping and subsequent aquifer drawdown may be an issue. The analysis also considers the difference in the seasonal elevations to identify areas of extreme drawdown.

The ECM was used to simulate the hydrodynamics of the SAS (consisting of the water table and lower Tamiami aquifers and the semi-confining marl between them) and the IAS (sandstone and mid-Hawthorn aquifers and the confining units between them). Municipal water supplies are included in the ECM. Water budgets were developed to evaluate the lateral flow of water across and within model basin boundaries, and the vertical flow of water between aquifers. Annual and seasonal aquifer specific water budgets were generated for the model simulation period of January 1, 2002, through October 31, 2007.

Results for Groundwater Budgets

Surficial aquifer. Approximately 93 percent of the water percolating from the unsaturated zone (from land surface to the water table) of the water table aquifer downward into the aquifer(s) is lost due to evaporation, base flow, or withdrawals. The average annual water movement is greater downward and into (approximately 8.5 inches) than upward and from (7.65 inches) the lower Tamiami aquifer. The result is net recharge (approximately 0.85 inch) to the lower Tamiami aquifer. Seasonally, more water enters the lower Tamiami aquifer during the dry season than in the wet season due to aquifer and confining unit characteristics and there is an increase (1.92 inches) in storage in the aquifer during the wet season. During the dry season, the amount of water percolating down into the lower Tamiami aquifer exceeds the amount entering the upper water table aquifer from the overlying soils and, together with increased water withdrawals, results in an average net loss (2.19 inches) of aquifer storage. Annually, an average 0.44 inch of water is pumped from the water table aquifer, primarily during the dry season when demand is higher.

Figure 1-20. Conceptual Groundwater Budget



The Cocohatchee-Corkscrew watershed had the greatest proportion of annual average recharge to the lower Tamiami aquifer: more than 25 percent of the water entering the water table aquifer reached the lower Tamiami aquifer. Infiltration was lower in the Golden Gate Naples Bay (19 percent) and Rookery Bay watersheds (10 percent). In the eastern watersheds, there is net upward movement of water from the lower Tamiami aquifer into the water table aquifer that may be due to evapotranspiration from the extensive wetlands in the watersheds. The canal network also influences groundwater elevations and contributes to long term changes in the water table elevation.

The seasonal average groundwater surface elevation maps for the Water Table Aquifer and lower Tamiami aquifers indicate a shift in the isohyetal lines. This is most evident is near the coast in Naples and in the Rookery Bay and Faka Union watersheds where the 5- and 10-foot elevation contours shift as much as 3 miles further inland during the dry season. This shift is influence by increased groundwater pumping and may also be indicative of potential risks to water supply due to salt water intrusion.

Lower Tamiami aquifer. The average annual inflow to the lower Tamiami aquifer from the water table aquifer is 0.84 inch, in addition to net annual inflow from the lower sandstone Aquifer of 1.5 inches. The net inflow appears to be driven by the water withdrawals for potable water and irrigation. There is a net loss of water (1.9 inches) from the lower Tamiami to the sandstone aquifer in the Cocohatchee-Corkscrew watershed, suggesting that this watershed is a primary source of recharge to the sandstone aquifer system. There were net water gains to the lower Tamiami from the sandstone aquifer in the Golden Gate- Naples Bay (0.14 inch), Rookery Bay (0.78 inch) and the eastern (3.43 inches) watersheds. In the Golden Gate-Naples Bay and Rookery Bay watersheds, the net gain is likely the result of withdrawals for water supply. The net loss in the eastern watersheds is probably due to agricultural withdrawals.

Sandstone aquifer. No annual change is water storage was identified for the sandstone aquifer, indicating equal seasonal inflows and outflows. There is a net loss of 1.5 inches water from the sandstone aquifer to the overlying lower Tamiami aquifer, and a net gain of 0.3 inch in water from the underlying mid-Hawthorne. The estimated net annual loss of water is 0.76 inch and is due primarily due to dry season withdrawals for water supply. Boundary inflows account make up for the losses and results in no net change in storage.

In this aquifer system, the Cocohatchee-Corkscrew watershed has a net inflow of water from the Lower Tamiami aquifer of 1.93 inches annually, and a net loss to the mid-Hawthorne Aquifer of 0.05 inch annually. The other watersheds showed a net loss to the overlying lower Tamiami aquifer and a net gain from the underlying mid-Hawthorne Aquifer. The inflows from the mid-Hawthorne are less than 1 inch annually and indicate little interaction between the Sandstone and mid-Hawthorne aquifer systems

Mid-Hawthorne aquifer. The mid-Hawthorne has little interaction with the overlying aquifer systems. Less than 0.3 inch of water moves between the sandstone in mid-Hawthorne Aquifers across the study area. Withdrawals from this aquifer are limited, but occur during the dry season. Most of the pumping is in the Golden Gate – Naples Bay watershed at the Collier County wellfield. Smaller volumes are pumped from the Rookery Bay and Cocohatchee-Corkscrew watersheds. There is no net storage in the mid-Hawthorn aquifer as a result of equal inflows and withdrawals.

Results for Groundwater Levels

Average annual and seasonal fluctuations in groundwater surface levels (elevations) were predicted and mapped for each of the aquifer systems.

Surficial aquifer. The gradient of the average annual groundwater surface is approximately 0.8 foot/mile (0.016 percent) from the northeastern part of the county, north of Immokalee, to the southwest. The water surface gradient generally follows the topographic slope of approximately 1.0 foot per mile (0.020 percent). At a location north of Immokalee, the water table aquifer exceeds 30 feet in elevation, while groundwater elevations in the underlying lower Tamiami aquifer only reaches these levels during the wet season, suggesting a perched water table. Predicted annual fluctuation in the Surficial Aquifer illustrate the difference between the average annual maximum groundwater elevation and the average annual minimum groundwater elevation. Red areas indicate greater fluctuation in the groundwater surface. These large fluctuations are attributed to groundwater pumping to meet potable water supply and irrigation demand during the dry season. The extents of the areas of high demand are related to the horizontal conductivity of the aquifers and connectivity to other aquifers.

Lower Tamiami aquifer. The average annual groundwater surface elevations and annual fluctuation in groundwater head elevations are mapped in figures 1-23 and 1-24. Results indicate a high demand on this aquifer during the dry season in the Okaloacoochee/SR 29 and Fakahatchee watersheds, consistent with the agricultural and golf course withdrawals exceed 9 and 12 inches, respectively, from the lower Tamiami aquifer during the dry season.

Sandstone aquifer. Average annual groundwater surface elevations are mapped in Figure 1-25. Similar to the lower Tamiami aquifer, an area of higher groundwater elevations occurs north of Immokalee. Annual fluctuations in head elevations for the sandstone aquifer (Figure 1-26) indicate a high demand on this aquifer during the dry season. The Lee County wellfield draws from the sandstone aquifer and is the likely cause of the drawdown in the northern portion of the Cocohatchee-Corkscrew watershed. However, there is little pumping directly from the sandstone aquifer in the Faka Union and Okaloacoochee/SR 29 watersheds, indicating water is migrating from the sandstone aquifer into the lower Tamiami aquifer in response to withdrawals. In fact, more than 3 inches of groundwater migrates from the Sandstone to the lower Tamiami aquifer during the average dry season.

Mid-Hawthorne aquifer. The depression in the Mid Hawthorn Aquifer at the boundary between the Golden Gate – Naples Bay and Rookery Bay (Figure 1-27) is likely due to the is associated with the wellfield located there that pumps water from the mid-Hawthorne Aquifer. This pattern of drawdown was not observed in the sandstone aquifer; indicating that there is little interaction between the mid-Hawthorne Aquifer and the overlying sandstone aquifer.

Conclusions

The groundwater system of Collier County is an integral part of the highly integrated hydrologic system of southwest Florida. The large amount of precipitation in the County goes to evapotranspiration, runoff, drainage, and groundwater storage. The groundwater system acts as a regional reservoir and exhibits seasonal variations in water storage.

- The water budget analysis indicates that current wet season recharge rates within each aquifer tend to correspond to the current dry season withdrawals. However, additional groundwater withdrawals may lead to an annual loss of stored water within each aquifer.
- Changes in structural operations in the Golden Gate Canal network will help mitigate groundwater losses and increase water availability.
- Reducing water demand to meet irrigation requirements will increase the volume of water available for potable water supply and habitat protection.

Table 1-2. Annual Water Year and Seasonal Budgets

Water Table Aquifer	Inflows (inches)				Outflows (inches)					Change in Storage
	Infiltration from Unsaturated Zone	Recharge from Canal Network	From Lower Tamiami	Boundary Inflow	Evapo-transpiration	Baseflow	Percolation to Lower Tamiami	Pumping	Boundary Outflow	
Average Water Year	14.93	0.35	7.65	0.31	9.92	3.90	8.50	0.44	0.68	-0.16
Average Wet Season	8.72	0.05	3.02	0.10	4.07	2.26	3.35	0.05	0.26	1.92
Average Dry Season	5.86	0.30	4.53	0.20	5.76	1.52	4.99	0.39	0.41	-2.19
Lower Tamiami Aquifer	**Inflows (inches)**				**Outflows (inches)**					**Change in Storage**
	Percolation from Surficial	Recharge from Canal Network	From Sandstone	Boundary Inflow	Baseflow	To Surficial	Percolation To Sandstone	Pumping	Boundary Outflow	
Average Water Year	8.50	0.08	2.81	2.65	0.80	7.65	1.31	2.13	2.13	-0.01
Average Wet Season	3.35	0.02	0.98	0.83	0.37	3.02	0.30	0.38	0.92	0.18
Average Dry Season	4.99	0.05	1.82	1.80	0.41	4.53	1.00	1.77	1.15	-0.19
Sandstone Aquifer	**Inflows (inches)**				**Outflow (inches)**					**Change in Storage**
	Percolation from Lower Tamiami		From Mid-Hawthorne	Boundary Inflow		To Lower Tamiami	Percolation to Mid-Hawthorne	Pumping	Boundary Outflow	
Average Water Year	1.31		0.39	2.20		2.81	0.09	0.76	0.24	0.00
Wet Season Average	0.30		0.10	0.74		0.98	0.04	0.07	0.05	0.00
Dry Season Average	1.00		0.27	1.47		1.82	0.06	0.69	0.17	0.00
Mid-Hawthorne Aquifer	**Inflows (inches)**				**Outflows (inches)**					**Change in Storage**
	Percolation From Sandstone			Boundary Inflow		To Sandstone		Pumping	Boundary Outflow	
Average Water Year	0.09			0.43		0.39		0.09	0.03	0.00
Wet Season Average	0.04			0.12		0.10		0.02	0.00	0.00
Dry Season Average	0.06			0.29		0.27		0.07	0.00	0.00

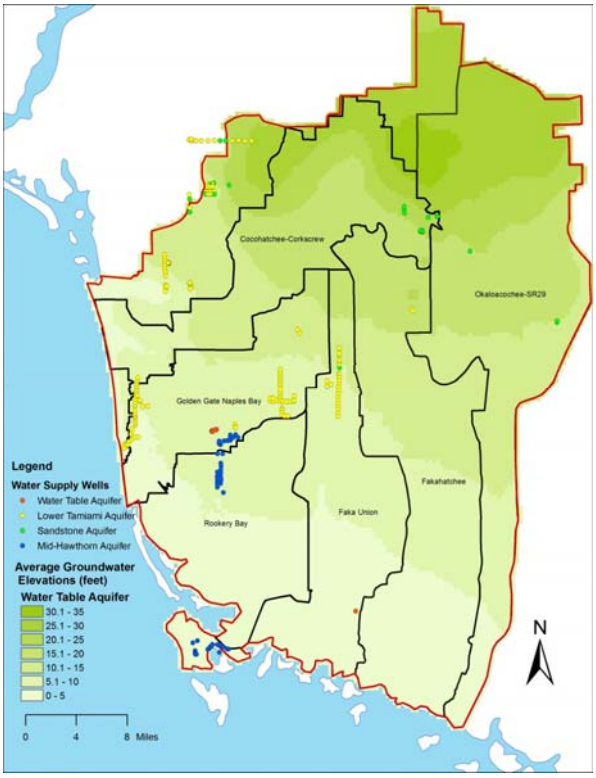


Figure 1-21. Surficial Aquifer Average Annual Elevation

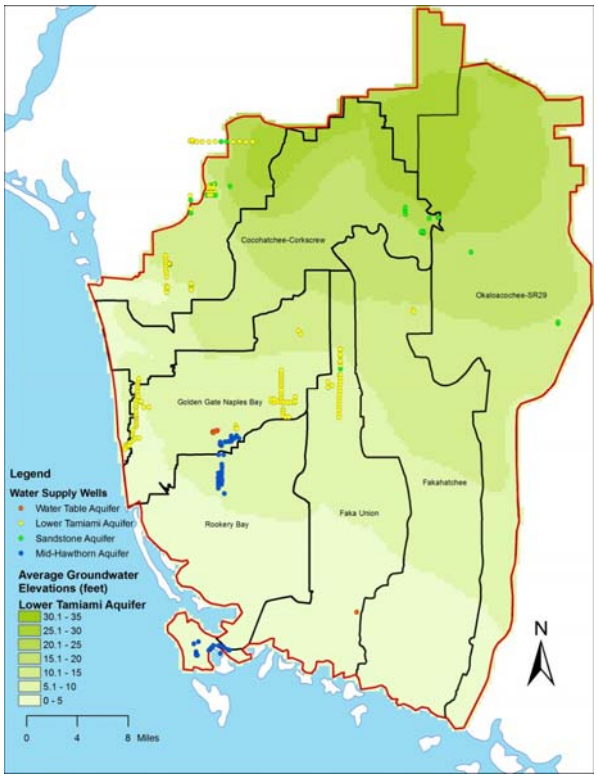


Figure 1-23. Lower Tamiami Aquifer Average Annual Elevation

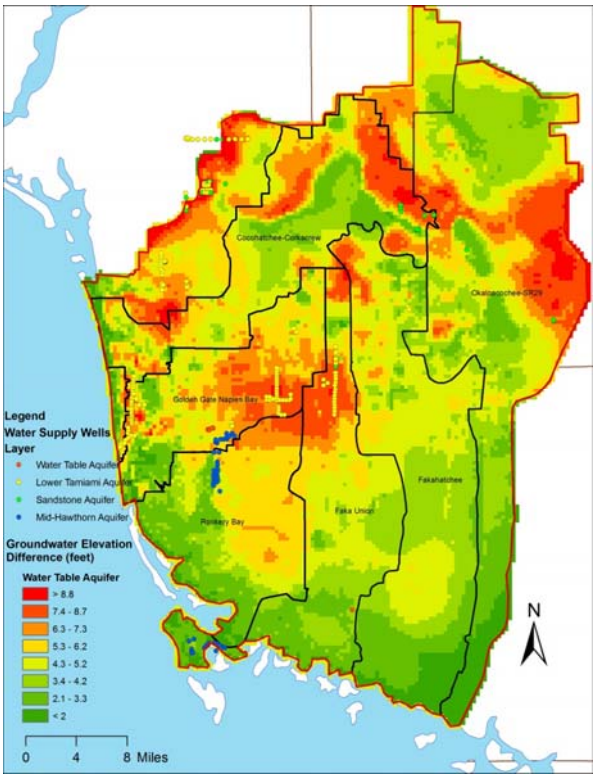


Figure 1-22. Surficial Aquifer Average Annual Groundwater Fluctuation

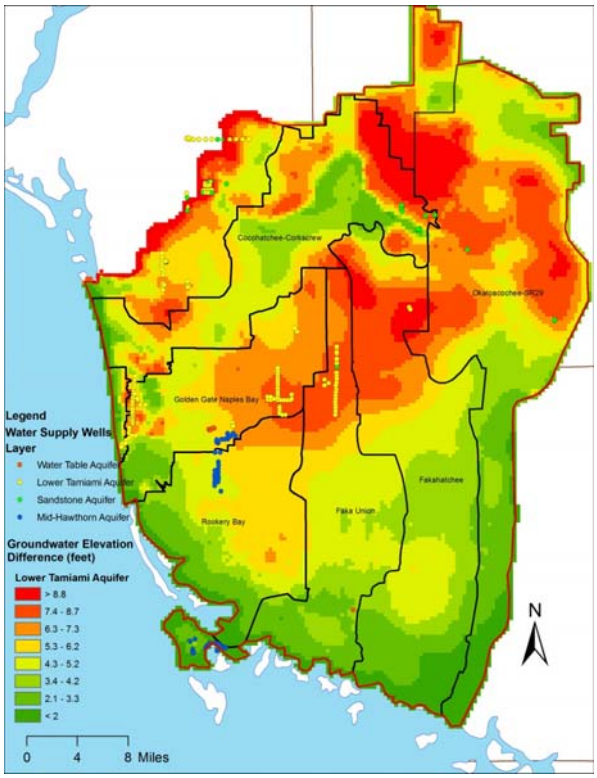


Figure 1-24. Lower Tamiami Aquifer Average Annual Groundwater Fluctuation

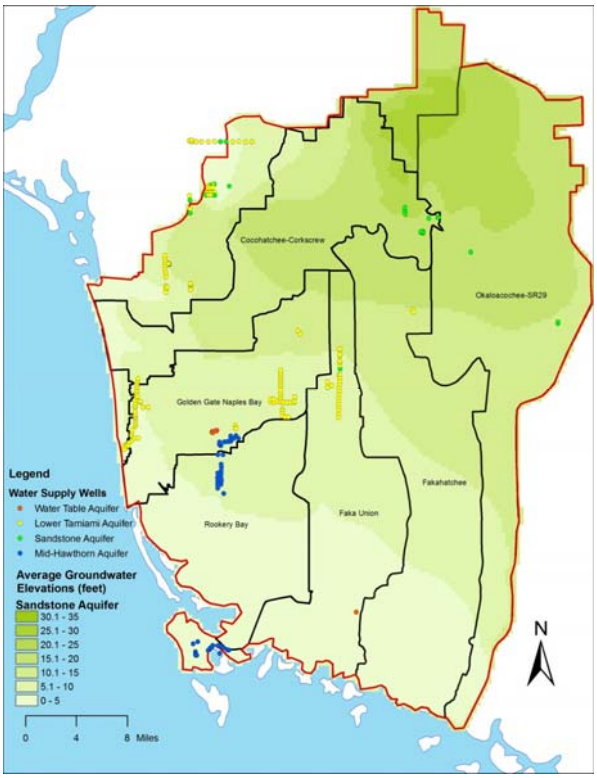


Figure 1-25. Sandstone Aquifer Average Annual Elevation

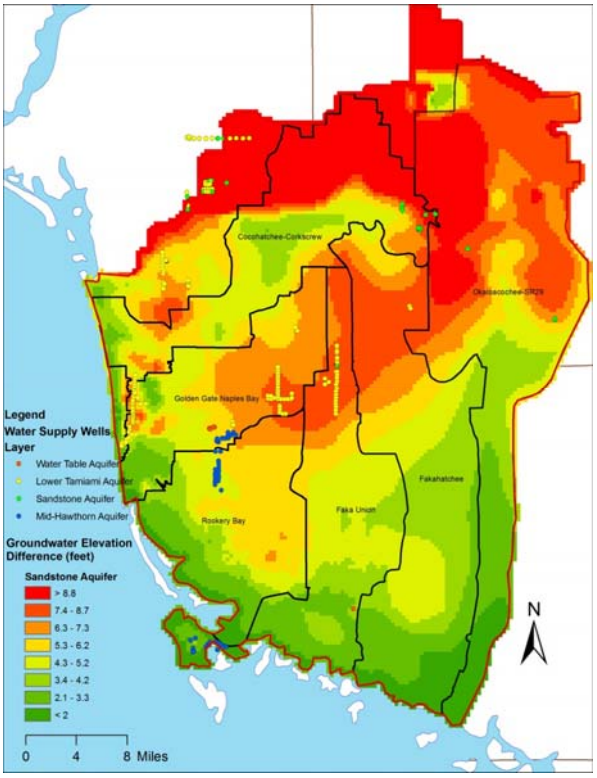


Figure 1-26. Sandstone Aquifer Average Groundwater Fluctuation

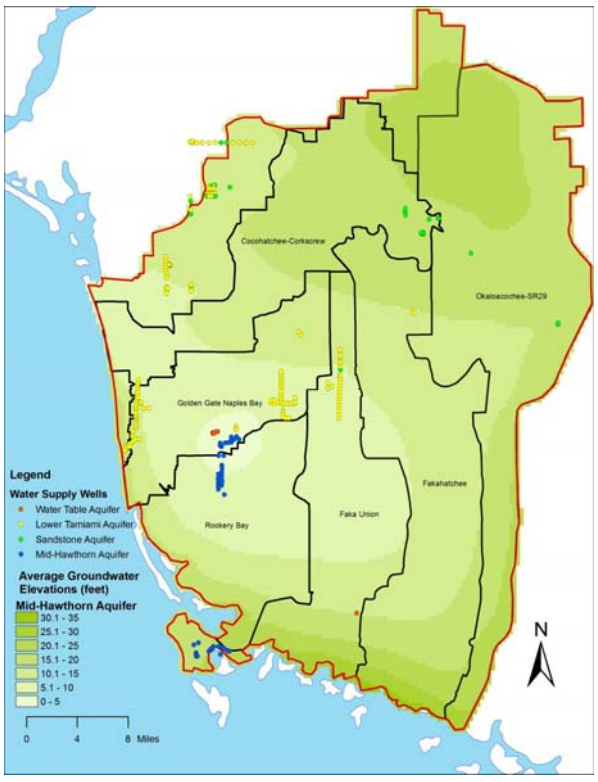


Figure 1-27. Mid-Hawthorn Aquifer Average Groundwater Fluctuation

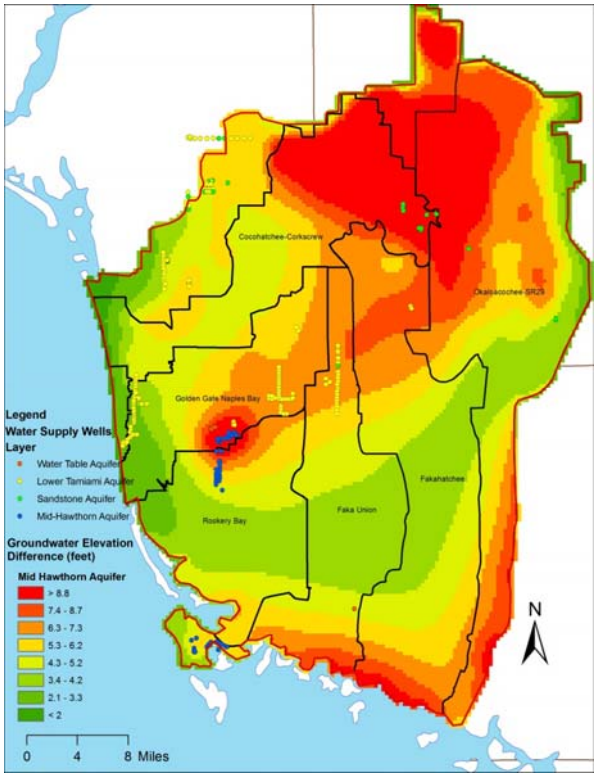


Figure 1-28. Mid-Hawthorn Aquifer Average Annual Groundwater Fluctuation

1.2.2: Water Uses

A water supply analysis was completed for Collier County to assess the change from pre-development to existing conditions and the effects of increased urban and agricultural water supply demands with respect to minimum aquifer levels. Results indicate groundwater level declines of more than 5 feet in some parts of the County and additional declines are anticipated if withdrawals are increased.

Introduction

Groundwater is important to urban, agricultural, and natural systems in the County. A water supply analysis was completed for Collier County to assess existing withdrawals from each aquifer with respect to pre-development conditions and to evaluate the use of the water for private or public supply or agriculture. The effects of increased withdrawals on the aquifers with respect to potential increases in water supply demand were also evaluated.

Methods

Groundwater withdrawals for public water supply are included as part of the Collier County MIKE SHE/MIKE 11 ECM and results of that analysis are the basis of the groundwater use assessment. The overall effect of groundwater withdrawals and subsequent groundwater level draw downs was estimated based on the difference between the average groundwater elevations simulated in the NSM (pre-development conditions) and the ECM (existing conditions) and results are mapped for the surficial, lower Tamiami, and sandstone aquifers. The NSM did not include the Mid Hawthorn Aquifer and so no comparison can be made to indicate the drawdown in the Mid Hawthorn Aquifer.

Private water supply wells throughout Collier County provide water for domestic consumption and landscape irrigation, although there is no available data base with documentation on these wells. Water supply wellfields in the County are mapped in Figure 1-29. The model makes an assumption that urban areas outside of water service areas use private wells. Water volumes applied to meet irrigation requirements in each watershed were also calculated.

Results

Pre-development vs. existing conditions. Based on a comparison of pre-development (NSM) and existing conditions (ECM) models, groundwater levels have declined in the surficial, lower Tamiami, and sandstone aquifers by more than 4 feet in portions of all six watersheds (Figure 1-30). The "head difference", or change in groundwater elevation of the surficial aquifer, in the wellhead protection zone in the Golden Gate-Naples Bay watershed, for example, experienced a decline of 4 to 4.9 feet. The Rookery Bay and Fakahatchee watersheds appear the least impacted, while the Golden Gate-Naples Bay, Faka Untion, and Okaloacoochee/SR 29 appear the most impacted. Patterns of decline were similar among the 3 aquifers and were also consistent with the location of wellfields and well head protection zones. Modeled drawdowns are somewhat greater in the lower Tamiami and sandstone aquifers, but the patterns are the same and larger drawdowns are associated with wellfields.

Private and public use. The majority of water supply wells are located in the Golden Gate-Naples Bay, Rookery Bay, and Faka Union watersheds (Figure 1-31). Most of the County's municipal water supply is pumped within the Golden Gate – Naples Bay watershed from the lower Tamiami aquifer. Analysis of private and public water use suggest that demand from private wells exceeds demand from municipal wells in the Cocohatchee – Corkscrew, Rookery Bay, and the eastern watersheds. In the Golden Gate – Naples Bay watershed, demand by municipal wells exceeds demand for domestic self supply

Agricultural and golf course irrigation use substantial amounts of water throughout Collier County. Urban water supply and distribution of irrigated agriculture and golf course lands in the County (figures 1-31 and 1-32) show the majority of the irrigated agricultural and pasture lands are in the northeastern part of the County in the Cocohatchee-Corkscrew, Faka Union, Fakahatchee, and Okaloacoochee/SR 29 watersheds.

Most golf courses are in urbanized coastal areas in the Golden Gate – Naples Bay watershed.

Conclusions

The results demonstrate that irrigation is applied primarily during the dry season. Agricultural production geared toward row crops is estimated to be the primary user of irrigation water throughout Collier County. In the Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds, golf courses are predicted to apply more water per acre; however, the golf course acreage is tiny when compared to the lands used for agricultural production. Golf course demand is fairly consistent at approximately 5 inches applied annually from wells in the Cocohatchee Corkscrew, Golden Gate, and Rookery Bay watersheds. Water to golf courses near the coast may also rely on reuse water that is not addressed here.

Effects of increased potable water supply on minimum aquifer levels. To evaluate the effects of an increase in potable water supply demand on the groundwater system, a model test was conducted that increased the pumping for public water supply by 10 percent. No change was made to irrigation or domestic self supply wells. The increase in groundwater production was

limited to the effect to minimum aquifer levels. This was accomplished by comparing the average annual minimum water level in each aquifer predicted by the ECM against the average annual minimum water level in each aquifer as predicted by the model with increased pumping. The change in drawdown resulting from the increased pumping is mapped in Figure 1-33 for the mid-Hawthorn aquifer under "driest dry season" conditions with a 10 percent increase in withdrawals and represents the increased withdrawal during a prolonged dry season. While the effects of the prolonged dry season results indicate even greater drawdown and larger cones of depression when compared with average conditions, like the pre-development vs. existing conditions drawdown maps, the patterns among aquifers are very similar.

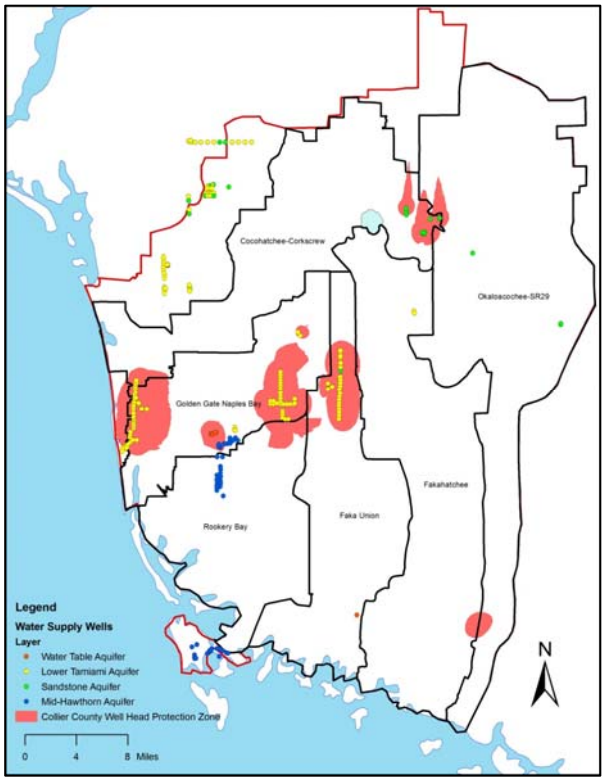


Figure 1-29. Well Head Protection Zones and Public Supply Wells

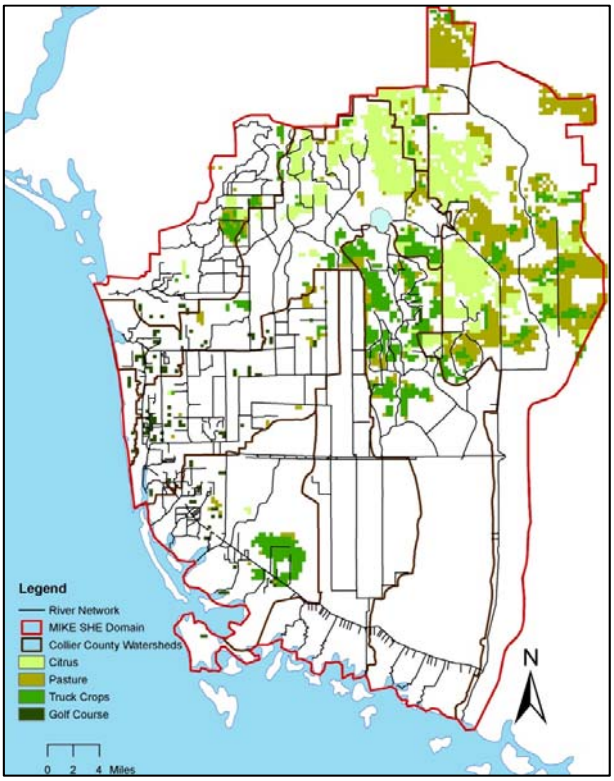


Figure 1-31. Agricultural and Golf Course Irrigated Areas

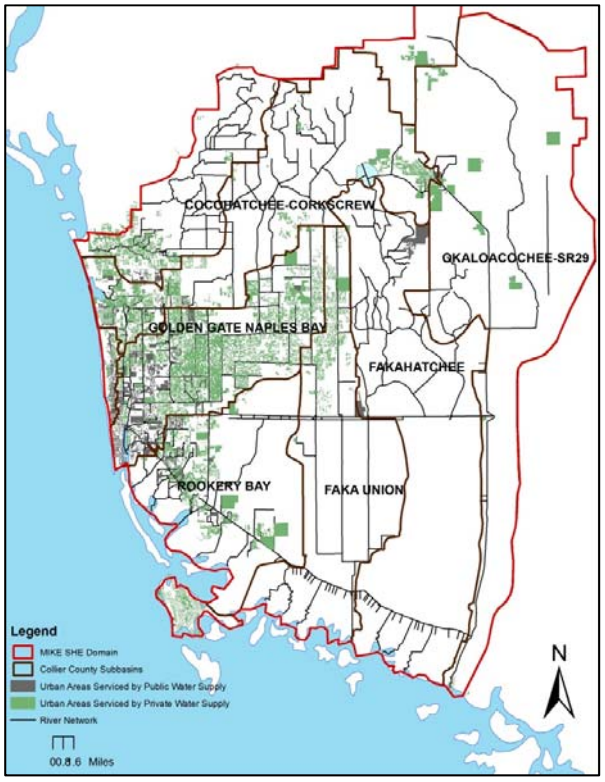


Figure 1-30. Urban Water Supply Distribution

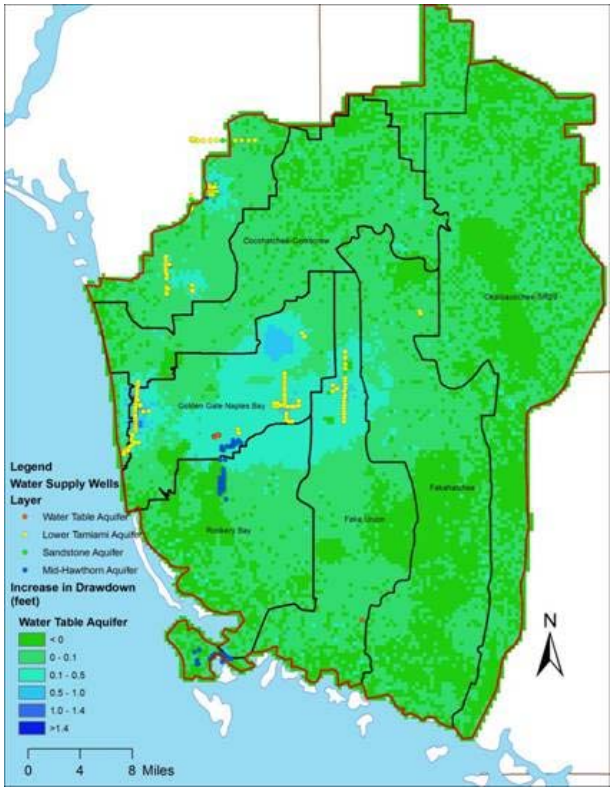


Figure 1-32. Water Table Aquifer Driest Dry Season Increase in Drawdown With 10% Increase in Groundwater Withdrawal

1.2.3: Groundwater Quality and Pollutant Loads

Groundwater quality was characterized and pollutant loads to canals were estimated for Collier County watersheds. The contribution of groundwater inflows to dissolved oxygen impairments in the watersheds was documented. Total nitrogen and phosphorus concentrations in groundwater exceed corresponding surface water criteria and may be a source of nutrient impairment to Rookery Bay. Iron in surface waters, but not copper, may be attributable to groundwater sources. No correlation was found between septic tank density and nutrients in the watersheds.

Introduction

Groundwater quality in the Cocohatchee-Corkscrew, Golden Gate-Naples Bay, Rookery Bay, and the combined Faka Union, Okaloacoochee/SR 29, Fakahatchee watersheds was characterized and the groundwater pollutant loads to the canals in the watersheds were estimated. Pollutants identified for analyses were dissolved oxygen, total nitrogen and phosphorus, copper, and iron, based on National Pollutant Discharge Elimination System (NPDES) pollutant list. In addition, a preliminary study of the potential impacts of septic tanks on groundwater quality in the watersheds was completed. This effort focused on the groundwater quality in the surficial and lower Tamiami aquifer systems. The other aquifers are confined and are not known to interact with the surface water drainage system.

Methods

Concentrations of the water quality parameters in the groundwater in Collier County and estimates of pollutant loads from the local aquifers into the surface water hydrologic network that eventually reaches the receiving estuaries were calculated.

Because groundwater systems are more regional in nature when compared with surface water systems, a Kriging interpolation method was applied to create regional groundwater concentration maps for each water quality constituent. For each well with available data, median concentrations were calculated for each water quality parameter of interest and groundwater concentrations were predicted for each cell in the hydrologic/hydraulic model domain. Consequently, the groundwater quality analysis was consistent with the surface water modeling approach.

Results

Dissolved Oxygen

Dissolved oxygen concentrations are not typically monitored in groundwater. Therefore the data available for analysis are limited and most are from wells associated with the Gordon River and the Picayune Strand. No groundwater quality data are available for the Cocohatchee-Corkscrew, Faka Union, and Okaloacoochee/SR 29 watersheds, or the eastern portion of the Golden Gate watershed. Nevertheless, given that dissolved oxygen concentrations do not vary significantly across the study area, the data available are considered appropriate to assess groundwater quality in the watersheds. Low dissolved oxygen concentrations in the groundwater and substantial base flows in the primary canals are probably contributing to low dissolved oxygen concentrations in the canals.

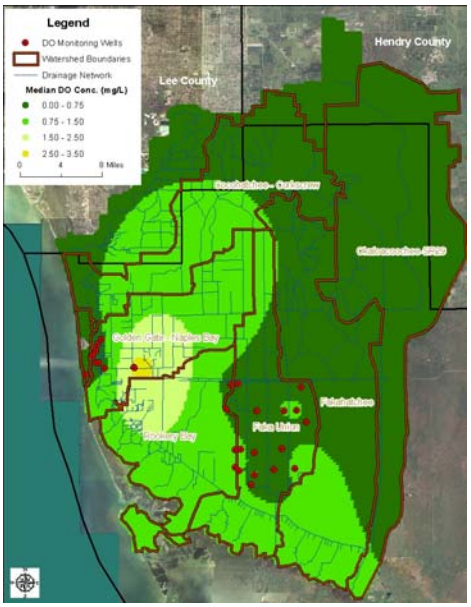


Figure 1-33. Dissolved Oxygen Concentration Interpolation

Total Nitrogen

Total nitrogen data were available at 94 wells in the study area. Because 38 of 47 wells along the coast from the Cocohatchee canal to Henderson Creek are associated with the County's reuse monitoring program, a comparison of total nitrogen concentrations at the reuse wells with other wells was made. Results indicated no significant difference in total nitrogen among the wells, with the exception of three monitoring wells. Wells for which water exceeded the criteria (75th percentile) were located primarily in the western portion of the County. While none of the basins in which the wells were located were identified as impaired for nutrients, they may be considered at risk due to groundwater discharges.

Groundwater total nitrogen concentrations exceeded Florida Department of Environmental Protection (FDEP) screening criteria for streams (1.6 mg/L) in the Golden Gate-Naples Bay and Rookery Bay watersheds as well. Total nitrogen concentrations did not exceed state criteria in the combined watershed. The average predicted concentration of total nitrogen in the Faka Union, Okaloacoochee/SR 29, and Fakahatchee watershed is less than the in stream water quality screening level in most of the watershed.

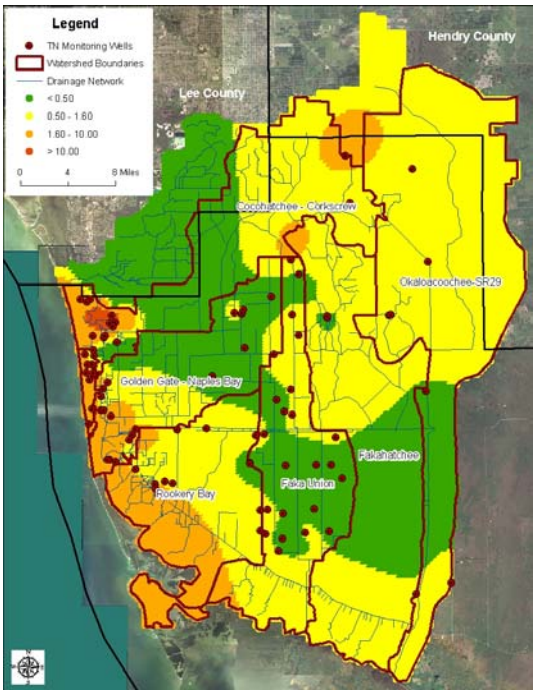


Figure 1-34. Total Nitrogen Concentration Interpolation

Total Phosphorus

Total phosphorus concentration data are available at 117 wells located throughout the study area. Similar to the total nitrogen analysis, the interpolated values for total phosphorus were compared to the FDEP screening criteria for streams (0.22 mg/L). Comparisons of total phosphorus between reuse and non-reuse wells indicated no significant difference in concentrations among wells.

A summary of the results indicates that the relatively high groundwater total phosphorus concentrations are not currently determining surface water quality conditions in terms of nutrients because only one WBID (3278U – Rookery Bay Coastal Segment) has been identified as impaired for nutrients. However, the relatively high groundwater total phosphorus concentrations in the groundwater at some of the reuse wells may indicate a risk of groundwater pollution loads. Results indicate that areas in which predicted concentrations exceed the in stream water quality criteria are located along the coast and along the northeastern portion of the study area.

In the Cocohatchee-Corkscrew and Golden Gate – Naples Bay watersheds, the high total phosphorus concentrations along the coast appear to be the result of interpolation of the high concentrations at some of the reuse wells.

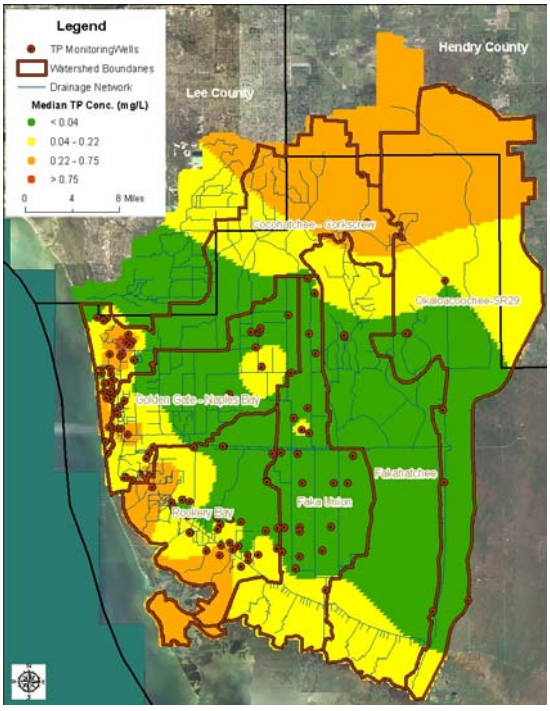


Figure 1-35. Total Phosphorus Concentration Interpolation

Copper

Well C-00495 is used to monitor the Lower Tamiami aquifer system in the watershed and is located near the SR 29 canal. Median copper concentration in the well exceeds 90 µg/L. For comparison, the instream standard for copper in WBID 3261C is 22.69 µg/L. Collier County is investigating potential sources of metals in the area around this well. There is no known activity in the area that would contribute to elevated copper concentrations.

Iron

The results of the Kriging interpolation for iron concentrations in groundwater predict that the groundwater concentration of iron in most of the study area exceeds the instream water quality standard of 1,000 µg/L. These results suggest that surface water impairments for iron may be attributed to groundwater inflows. In the Cocohatchee-Corkscrew watershed, all but one of the WBIDs exceed the screening criterion was exceeded in all but one of the basins (based on Water Body Identification numbers, or WBIDs). Concentrations in two of the three WBIDs exceeded the State water quality standard. Groundwater iron concentrations exceeded the water quality criterion for iron in the Rookery Bay watershed as well.

Groundwater Pollutant Loading to the Surface Water Network

Pollutant loads associated with groundwater discharges from the surficial and Lower Tamiami aquifers to the surface water system were estimated based on flows obtained for each model cell in the hydrologic/hydraulic model simulation domain and pollutant concentrations from the Kriging analysis. Pollutant loads were calculated for total nitrogen, total phosphorus and copper.

The largest predicted total nitrogen groundwater load was identified in Northern Golden Gate. Base flow discharging into canals contributes to the dissolved oxygen impairment in the Naples Bay estuary, although nutrients entering the estuary via canal flows may also be a factor.

Results also indicate that 74 and 88 percent of the total nitrogen and phosphorus, respectively, entering the estuaries is from surface water sources. Rookery Bay is the only watershed for which predicted total nitrogen loads from groundwater is the same and the surface water load. Total nitrogen and phosphorus from groundwater make up about 30 and 40 percent, respectively, of the load in other estuaries.

Copper loads appear to originate in the surface water system, although groundwater is a source of iron inputs into the estuaries.

Assessment of Pollution Loads from Septic Tanks

Septic tanks are common in parts of Collier County that are not served by sewer. They are also potential sources of nutrient discharges into the receiving water bodies by way of percolation into the water table aquifer. The objective of this analysis was to evaluate the potential effect of septic tanks on the groundwater concentrations of total nitrogen and total phosphorus. This was done by first estimating the number of septic tanks in each cell within the model domain and subsequently conducting a correlation analysis between septic tank density and constituent concentration in the groundwater.

Conclusions

- Kriging interpolation indicated that dissolved oxygen concentrations in groundwater are less than 1.5 mg/L throughout most of Collier County and likely contribute to dissolved oxygen impairments in the canal network.
- Differences in total nitrogen and total phosphorus concentrations between reuse and non-reuse wells were not significant in most cases and these data were considered appropriate for subsequent analyses.
- Total nitrogen concentrations in groundwater exceed the corresponding screening criteria for surface water in a large portion of the study area. Total phosphorus concentrations exceed the criteria along the coast and in the northern portion of the study area.
- Copper concentrations in groundwater are typically very low throughout the County, suggesting that copper impairments in the canal network can be attributed to surface runoff.
- Iron concentrations in groundwater were elevated relative to the Class 3 surface water standard in several areas that correspond with identified impairment locations in the canal network. Groundwater appears to be a source of iron to the surface water system.

- Pollution load estimates indicate that groundwater is a potential contributor to the nutrient impairment in the Rookery Bay watershed.
- There is little correlation between total nitrogen and total phosphorus and septic tank density, suggesting that septic tanks are not a water quality issue in Collier County.

1.3: Natural Systems

The conversion of natural wetlands and uplands represent a loss of nearly 273,000 acres (426 square miles) of wildlife habitat, natural water storage, filtration, and open recreational space in these 6 watersheds.

1.3.1: Reference Period Comparison

Pre-development and current conditions were compared to estimate the loss of native vegetation over the past 50–60 years in the Cocohatchee-Corkscrew, Golden Gate-Naples Bay, Rookery Bay, and combined Faka Union, Okaloacoochee/SR 29, Fakahatchee watersheds. Losses of native vegetation total nearly 273,000 acres. Losses were due to primarily urban development and were most conspicuous in the Golden Gate-Naples watershed.

Introduction

Vegetation changes were quantified as the change in the number of acres for each vegetation community in each watershed, and further analyzed to determine losses as a result of conversion to specific types of development. The pre-development data served as the reference period or an index against which to evaluate current vegetation conditions in evaluating ecological function. Changes in areal extent of natural vegetation communities and the causes of those changes are reported here.

Methods

Vegetation changes were quantified as the change in number of acres in each vegetation community for each watershed, and further examined to determine losses due to conversion to specific types of development (i.e., change analysis). Changes were quantified from a simple comparison of pre-development and current vegetation data. Land use conversions were quantified using a GIS digital overlay process that generates a matrix of "from/to" changes in land use and cover (e.g. cypress swamp to urban). Vegetation classes from MIKE SHE, Florida Land Use and Cover and Forms Classification System (FLUCCS), and the Southwest Florida Feasibility Study (SWFFS) were developed as part of a "crosswalk" so that comparisons between pre-development and 2007 vegetation maps could be made.

Results

Cocohatchee-Corkscrew Watershed

The Cocohatchee-Corkscrew Watershed had a nearly 85 percent reduction in acres of pre-development uplands and a loss of more than 30 percent of pre-development freshwater wetlands. Native uplands were replaced by primarily agricultural land uses, while urban development accounted for the greatest loss of wetlands. In 2007, the watershed included 8,300 acres of undeveloped uplands (16 percent of the pre-development acres) and 51,000 acres of freshwater wetlands (71 percent of the pre-development acres).

Golden Gate-Naples Bay Watershed

The Golden Gate-Naples Bay watershed had the greatest loss of pre-development vegetation communities when compared with the other watersheds, with a loss of almost 70 percent of wetland acres and over 80 percent loss of native uplands. Unlike the Cocohatchee-Corkscrew watershed, the largest conversion of lands in the Golden Gate-Naples Bay watershed occurred due to urban development. In 2007, there were just over 17,000 acres of wetlands (31 percent of the pre-development amount) and 25,000 acres of undeveloped uplands (17 percent of the pre-development amount) in the watershed.

Rookery Bay Watershed

The Rookery Bay Watershed had the smallest loss of pre-development vegetation communities of the three primary watersheds, with a loss of approximately 30 percent of wetland acreage and less than 50 percent of native uplands. The Rookery Bay watershed still included approximately 42,000 acres of wetlands (70 percent of the pre-development amount), 8,500 acres of undeveloped uplands (52 percent of the pre-development amount), and 16,000 acres of tidal systems (87 percent of the pre-development amount).

Faka Union, Okaloacoochee/SR 29, and Fakahatchee Watersheds

These three watersheds were combined for analysis because they were assigned lower priority relative to the previously described three watersheds. As an example, existing acres of wetlands make up 85 percent of the pre-development acres freshwater wetlands and 87 percent of the former tidal wetlands. However, only 30 percent of the pre-development native uplands remain. The largest conversion of lands in this set of watersheds occurred due to agriculture.

Conclusions

The conversion of natural wetlands and uplands represent a loss of nearly 273,000 acres (426 square miles) of wildlife habitat, natural water storage, filtration, and open recreational space in these 6 watersheds. Of the three primary watersheds, the greatest percentage loss occurred due to urban development in the Golden Gate-Naples Bay watershed, with almost 60 percent of the watershed now categorized as urban. In contrast, just 23 percent of the lands within Rookery Bay watershed are categorized as any type of development. Of the 273,000 acres of natural lands converted to other land uses throughout these six basins, agriculture accounts for approximately 97,000 acres (12 percent of the combined watershed area).

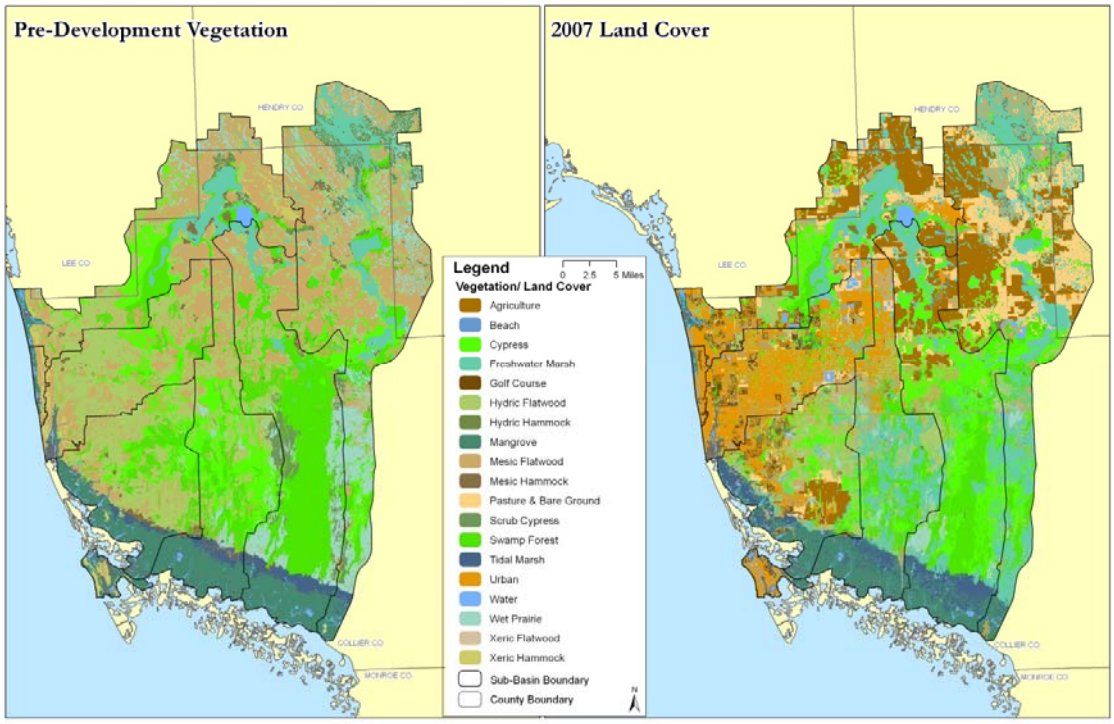


Figure 1-36. Model-Wide Overview, Land Use and Land Cover Changes from Pre-Development to 2007

1.3.2: Functional Assessment

A method was developed to assess and compare systems functions of existing and pre-development conditions in the Collier County watershed and to quantify the loss of natural system functions. The assessment will be used to develop performance measures against which restoration project success can be measured under a later task (performance measures are addressed in Chapter 3).

Introduction

A landscape-level functional assessment method was developed and used to assess, and assign value to, existing natural systems conditions in the Cocohatchee-Corkscrew, Golden Gate-Naples Bay, Rookery Bay, and the combined Faka Union, Okaloacoochee/SR 29, Fakahatchee watersheds in Collier County. The same method was developed for use as ecological-based performance measures for the evaluation of proposed restoration projects (described in Chapter 3).

Methods

The Uniform Mitigation Assessment Method (UMAM, Chapter 62-345 Florida Administrative Code) provided the template from which to design the functional assessment method for this project. Modifications from UMAM were made to implement the functional assessment at the watershed level, rather than the site-specific level for which UMAM was designed

Similar to UMAM, the optimal condition for the functional assessment addresses landscape position, vegetation, and hydrology of the ecological community of a targeted reference condition. Scores are assigned on a scale of 1 to 10, based on the degree of ecological change from the reference (in this case pre-development), to the existing condition. A score of 10 for existing conditions is appropriate where a site retains optimal value (100 percent of the value compared to the reference condition), 7 for moderate value (70 percent of the value compared to the reference condition), 4 for minimal value (40 percent of the value compared to the reference condition), 0 for no value, and other whole-number scores between 1 and 9 as appropriate.

The functional assessment method relies exclusively on available GIS data due to the watershed-scale analysis required here and the resolution available for the analyses and mapping is a grid cell size of 1500 X 1500 feet. Three independent scores, or indices, were developed to evaluate the current condition with respect to the appropriate referenced condition:

- Vegetation Score
- Hydrology Score
- Landscape Suitability Index (LSI)

Vegetation scores represent the ecological function, or value, of the landscape (cells) based on the degree to which the pre-development vegetation persists under existing conditions. For example, dramatic conversions from pre-development wet prairie vegetation to a developed urban land use, for example, would be assigned low scores, while little or no change in vegetation cover (i.e., no change from pre-development, or shift to another natural vegetation classification) would be scored higher. The vegetation score also reflects the value of certain developed land uses for local sensitive wildlife species (e.g., relatively high score for pasture due to use by Florida panther, burrowing owl, gopher tortoise, and Audubon's crested caracara), as well as hydrologic conditions. Examples of the approach are listed below and are based on conversion between Florida Land Use Cover and Forms Classification System (FLUCCS) designations and the previously developed Pre-Development Vegetation Map (PDVM) (as polygons in GIS).

- Score=10. Polygons indicate the same natural water system in existing and pre-development conditions.

- Score=10. Polygons that retained the same dominant stratum and ecosystem type (freshwater forested wetland to freshwater forested wetland).
- Score=8. Polygons that shifted in vegetation but retained the same ecosystem type (forested freshwater wetland to herbaceous freshwater wetland).
- Score=6. Natural system that converted to an artificial water body.
- Score=4. Natural system converted to agriculture.
- Score=0. A natural system converted to a developed land use such as urban high density urban or bare ground.

The hydrology score is a measure of the ecological effects of depth and duration (hydroperiod) of inundation and represents the functional value of a cell based on the degree to which the cell retains the hydrological characteristics of the pre-development conditions. Pre-development hydrological conditions are estimated based on the typical range of depth and duration (hydroperiod) of inundation of the vegetation community present on the PDVM. Like the vegetation scores, no change from pre-development is scored 10, while total loss of hydrology (e.g., a cell dominated by a pre-development wetland or open water body but now experiences no inundation) would result in a score of 0.

The LSI is an index of the effects of adjacent lands on the target site and represents the degree to which adjacent lands provide or inhibit ecological connectivity, buffers, and corridors. Higher scores indicate adjacent natural lands or lands conducive to wildlife passage, while lower LSI scores are surrounded by land uses that act as barriers. Even a natural preserve area would score low if surrounded by commercial land uses, while a parcel with otherwise poor ecological conditions would score high if surrounded by pasture or natural areas. Cells were first assigned LSIs by FLUCCS codes, e.g., natural systems and open water = 10, pine plantation=9.4, crops=6.07, industrial=1.87, etc. An LSI score for a cell was then calculated as the average of the 8 surrounding cells.

Results

In general, the combined Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds exhibited the highest functional value (the least change from pre-development), when compared with the other watersheds. Measured functional value was less in the Rookery Bay and Cocohatchee-Corkscrew watersheds, and least in the Golden Gate-Naples watershed (see table below).

Table 1-3. Average Functional Values of Non-Urban Lands, by Watershed

Watershed	Non-Urban Acres	Average Vegetation Score	Average Hydro-logic Score	Average LSI Score
Cocohatchee-Corkscrew	111,250	7	7	8
Golden Gate-Naples	36,627	5	6	6
Rookery Bay	83,105	8	6	9
FakaUnion/ Okaloacoochee SR 29/ Fakahatchee	431,414	9	6	9

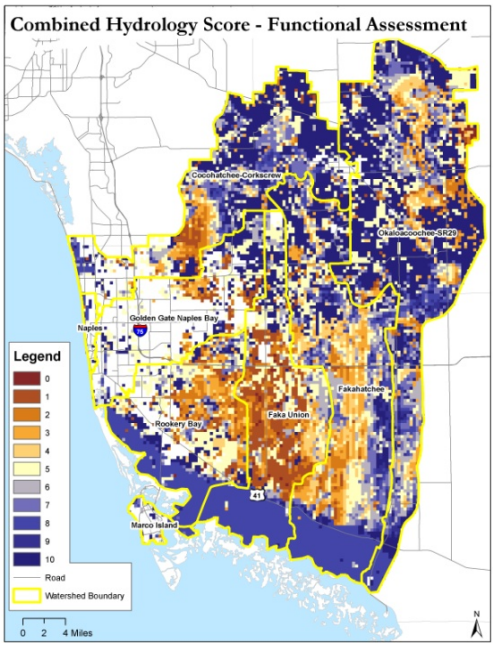


Figure 1-37. Combined Hydrology Score, Functional Assessment

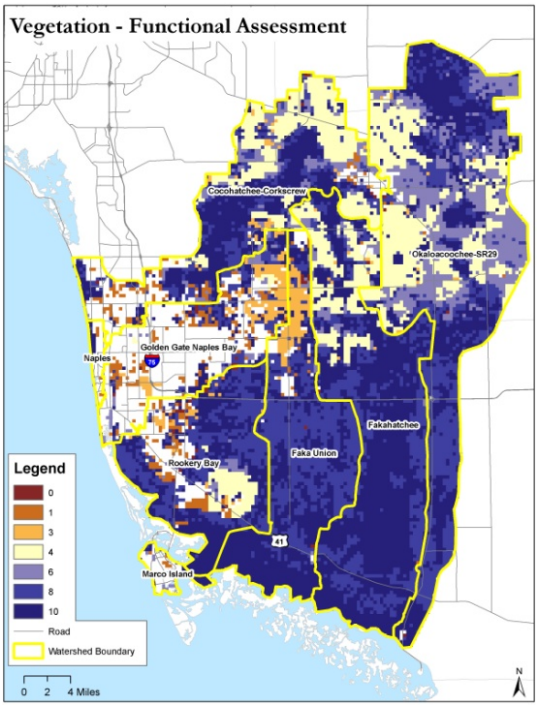


Figure 1-38. Vegetation, Functional Assessment

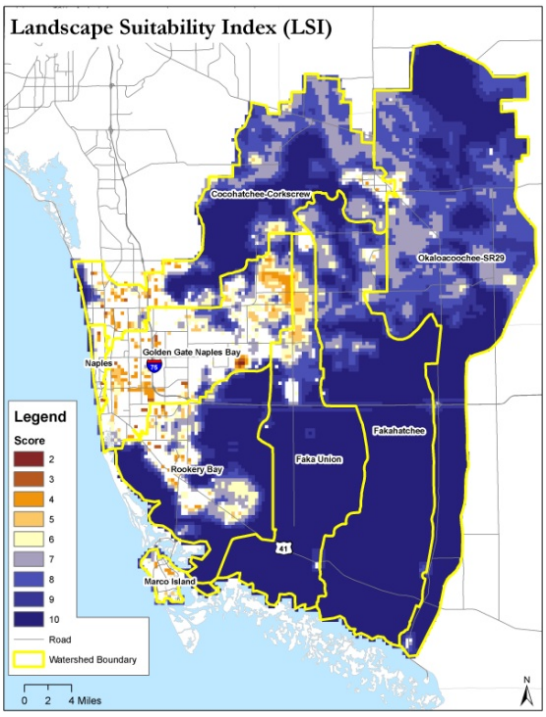


Figure 1-39. Landscape Suitability Index (LSI)

Cocohatchee-Corkscrew Watershed

The functional assessment of the non-urban portions of the Cocohatchee-Corkscrew indicates that the central part of the watershed just east of Corkscrew Swamp system maintains a high functional value, as measured by all 3 parameters, while the northern and eastern portions have relatively high hydrology and LSI scores and moderate vegetation scores due to non-pasture agricultural lands. The LSI is high (7 or greater) throughout the non-urban portion of the watershed due to natural and agricultural land uses. Vegetation and hydrology scores are somewhat lower due to conversion to agricultural uses.

Golden Gate-Naples Bay Watershed

Nearly 60 percent (over 50,000 acres) of the Golden Gate-Naples Bay watershed is urban land not suitable for ecological restoration. The analysis of current conditions and restoration projects is focused on the remaining non-urban portion of this watershed. Overall, even the non-urban areas have relatively low ecological value, with an average vegetation score of 5 and hydrology and LSI scores of 6. Overall, this watershed presents relatively few opportunities for large-scale improvement in ecological value. Urban and suburban development throughout the watershed limits the degree to which restoration projects would improve functional values beyond the footprint of the project itself.

Rookery Bay Watershed

The functional assessment in this watershed reflects the low proportion (30 percent) of the watershed that has been converted to urban or agricultural uses. Scores are low in the vicinity of Belle Meade and Tamiami Trail, but relatively higher in the remainder of the watershed. Overall, functional values are higher than in Golden Gate-Naples and Cocohatchee-Corkscrew watersheds, with a watershed-wide average LSI score of 9 and average vegetation score of 8.

The large extent of undeveloped and agricultural lands in this watershed provides opportunities for ecological restoration, while the functional values indicate opportunities for improvements via hydrological restoration throughout these lands.

Faka Union, Okaloacoochee/SR 29, and Fakahatchee Watersheds

These watersheds, individually and as a whole, retain relatively high functional value, with average

vegetation and LSI scores of 9, and hydrological score average of 6. The mapped scores indicate higher vegetation and LSI scores south of I-75 than north, and higher hydrology scores in the north than in the south.

Ecologically Valuable Lands

Results of this analysis were also used to identify ecologically valuable lands, such that comparisons can be made with areas currently included in the County's or the South Florida Water Management District's (SFWMD) preserved lands and supportive agricultural lands programs. Much of the currently preserved lands with high-value ecological functions and extensive areas within and adjacent to the preserves are consistent with the natural land uses. Therefore, continued or improved management of these areas' passive land uses provide opportunities for additional ecological improvement.

Conclusions

Vegetation, hydrology, and landscape scores were developed to assess ecological functional value and indicated that hydrologic restoration may provide the greatest opportunity for measurable improvement in functional value in Collier County.

The functional values presented here provide performance measures for later evaluation of proposed projects.

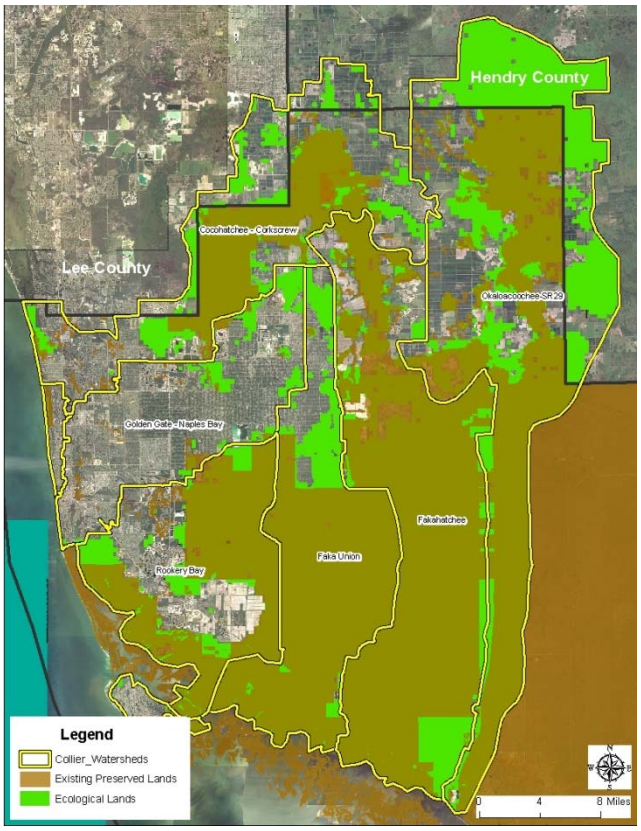


Figure 1-40. Ecologically Valuable Lands

Element 2: Assessment of Existing Conditions – Estuaries

2.1: Volume and Timing of Freshwater Inflows

The volume and timing of freshwater inflows to the Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Islands estuaries were compared for existing and pre-development conditions as a means to define water surplus and deficit targets for potential restoration projects in Collier County. The issue in Rookery Bay is the timing of flows to the estuary: it receives too much water in the wet season and too little in the dry season. The primary challenge with the three other estuaries is excess surface water runoff in the wet season.

Introduction

Historical fresh water flow patterns in Collier County have changed over the years due to increased development. The consequences have been increased freshwater flows into the estuaries and changes to the estuarine systems resulting from reduced salinity and increased deliveries of organic sediments. Quantifying these changes is important to developing any restoration projects. Therefore, the changes in freshwater flows were assessed by comparing existing conditions with natural (or pre-development) conditions through the use of hydrology/hydraulic models. The results provide a means with which to determine the monthly water surplus or deficit targets for restoration.

Methods

Existing freshwater discharges from the watershed into the estuaries were characterized based on results of the MIKE SHE/ MIKE 11 Existing Conditions model (ECM), which represents 2007 land use conditions in Collier County and was calibrated against surface water stage and flow and groundwater elevation data. The Natural Systems Model (NSM 1989) was developed in 1989 based on the South Florida Water Management Model (SFWMM) to represent land use and conveyance systems under pre-development conditions. The NSM presents pre-development conditions by "removing" water control structures from the landscape and modeling overland flows as if water control structures are absent.

The results of the ECM and NSM results were validated against previously completed salinity:flow analysis. Based on available salinity and flow data, the salinity:flow relationships representing conditions for Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Islands were completed. Flow deficits or surpluses required at each of the monitoring stations to reach the salinity target were estimated and compared with the ECM/NSM results.

Results

Wiggins Pass Estuary

Analyses results indicate that the total freshwater discharges into Wiggins Pass have increased since pre-development conditions, particularly in the wet season, and that flow increases begin earlier in the year and continue longer than in the pre-development period. There was an unexpectedly large increase in June that suggests a change in timing of flows to the estuary, or may be due to differences in June rainfall volumes between the models. Surplus flows in November and December are likely associated with groundwater recharge to the canal system and delayed runoff following above average rainfall in 2003 and 2005.

Naples Bay Estuary

Results indicate a year-round increase in the magnitude of water volume released to the estuary. The results do not indicate a significant change in the timing of discharges. These results were consistent with previous studies (Black, Crow, and Eidsness, 1974; SFWMD, 2007). The increased discharges are attributed to construction of the Golden Gate Main Canal that effectively increased the extent of the watershed drainage area from approximately 50 to approximately 135 square miles.

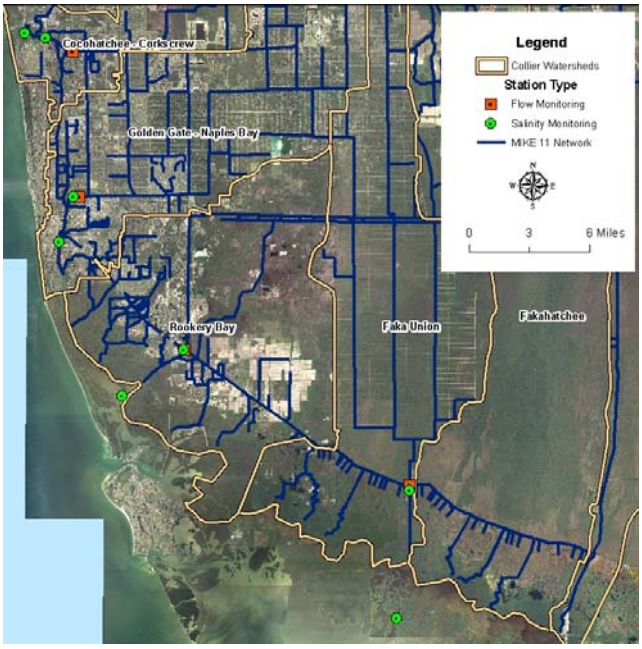


Figure 2-1. Flow and Salinity Monitoring Stations in Collier County

Rookery Bay Estuary

Model results indicate a flow deficit during the dry season (October through May) and a flow surplus during the wet season (June through September). The total volume discharged to the estuary is very similar for both models indicating that the timing of flows is the challenge in this system. The results of the salinity:flow analysis show a deficit during the wet season. The difference is due to the fact that the salinity analysis considers flow from only the Henderson Creek Canal, which drains approximately 40 percent of the watershed, whereas the ECM vs. NSM analysis considers the entire watershed.

Ten Thousand Islands Estuary

The Ten Thousand Islands Estuary receives freshwater discharges from the Faka Union, Okaloacoochee / SR 29, and Fakahatchee watersheds. Control structures manage the discharge from the Faka Union and SR 29 canals into the estuary. Model results indicate that excess freshwater is discharge to the estuary primarily during the wet season. Like Wiggins Pass and Naples Bay, excess flows during November and December are likely due to delayed runoff resulting from above-average rainfall during 2003 and 2005.

Comparison of Model Results with Salinity Analysis

Results of the ECM and NSM comparison with the salinity analysis are presented in the following figures for each of the estuaries and for the wet and dry seasons. The similarity of the ECM vs. NSM results (for wet and dry seasons) suggest that the excess wet season flow to the Ten Thousand Islands estuary is dominated by discharges from the largely impacted Faka Union watershed and not from the Okaloacoochee/SR 29 and Fakahatchee watersheds, which have been impacted by development to a much small degree.

For the Rookery Bay estuary, the salinity analysis indicates a wet season deficit and a wet season surplus. The difference between the results of the salinity and model analyses is that the salinity analysis includes flows from the Henderson Creek Canal, which drains approximately 40 percent of the watershed. In contrast, the ECM vs. NSM analysis considers flows from the entire watershed and includes the urbanized Lely Area in the western portion of the watershed and the agricultural areas in the southeastern portion of the watershed.

During the dry season, there is a flow deficit from the primary canals to the Wiggins Pass, Rookery Bay, and Ten Thousand Islands estuaries. This is not unexpected, given the most downstream control structures in the Cocohatchee, Henderson Creek, and Faka Union Canals often prevent flows during the dry season. In the ECM vs. NSM results, a flow surplus, or a smaller flow deficit, can be attributed to the flow contributions from the secondary and uncontrolled releases to the estuary systems.

In the Naples Bay Estuary, the dry season results indicate a surplus using both calculation methods. This indicates that the Golden Gate Main Canal remains the primary source of discharge to the estuary; however, it is likely that flows from the smaller tributaries make up a larger percentage of the total flow to the estuary during the dry season.

Wet season flows to the estuary are dominated by discharge from the Cocohatchee and Golden Gate Main Canals to the Wiggins Pass and Naples Bay estuaries; respectively. The similarity of the ECM vs. NSM results suggest that the excess wet season flow to the Ten

Thousand Islands estuary is dominated by discharges from the largely impacted Faka Union watershed and not from the Okaloacoochee/SR 29 and Fakahatchee watersheds, which have been impacted by development to a much smaller degree.

Conclusions

Results of the ECM and NSM models were used to characterize the freshwater discharges into Collier County estuaries. Model results are comparable and validate the use of the ECM to evaluate potential restoration projects. Compared with pre-development conditions, discharges to Wiggins Pass, Naples Bay, and Ten Thousand Islands estuaries are excessive during the wet season.

In the Rookery Bay estuary, the difference in timing flows to the estuary appears more important: the system receives too much water during the wet season and too little water during the dry season.

The pre-development flow estimates generated from the NSM offer a baseline against which surplus or deficit flow targets for restoration projects can be measured (performance measures are specifically addressed as part of Element 3, in Chapter 3).

2.2: Quality of Discharge

Water quality of freshwater flows entering the Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Islands estuaries is characterized here. Annual pollutant loads were calculated for each watershed and for basins (designated with water body identification numbers, "WBIDs") in the watersheds.

Introduction

Water quality was characterized for 6 watersheds that discharge fresh water to these 4 estuaries. The Wiggins Pass estuary receives runoff from the Cocohatchee-Corkscrew watershed. The Golden Gate-Naples Bay and Rookery Bay watersheds discharge into Naples Bay and Rookery Bay estuaries, respectively. Three watersheds comprise the drainage area to the Ten Thousand Islands estuary: Faka Union, Okaloacoochee/SR 29, and Fakahatchee.

Methods

Water quality data used in this analysis were acquired from the Impaired Waters Rule (IWR) Run 39 data (provided by FDEP), Florida STORET data warehouse, Collier County, City of Naples, and the Rookery Bay National Estuarine Research Reserve. Data were screened through a quality assurance and control procedure and data from the most downstream monitoring stations were included for the analysis. Percent exceedances were calculated for dissolved oxygen, total phosphorus, total nitrogen, and fecal coliform bacteria concentrations with respect to screening criteria for the Total Maximum Daily Loads (TMDL) planning and verification periods. Data were compared with state water quality criteria.

Results

Wiggins Pass

Wiggins Pass is the receiving water for the Cocohatchee-Corkscrew watershed. Available data indicate that the dissolved oxygen concentration in the watershed discharge falls below the 4 mg/L standard for the estuary. Low oxygen levels could be attributed to excessive nutrient concentrations (that subsequently stimulate plant growth, which in turn may deplete oxygen from the water, or may result from the influence of groundwater from canals), however, total nitrogen and total phosphorus concentrations exceed the Hendry Creek TMDL target, but generally not Florida stream criteria.

Based on results from one of the two samples available for the analysis time period, fecal coliform bacteria in discharge waters are a possibility. However, bacteria source evaluations are necessary to confirm the condition. Although not been confirmed, groundwater discharges via canals is an important source of elevated iron levels. Other activities, such as mine drainage, wastewater treatment facility outfalls, and/or landfill leachate from industrial scrap areas (e.g., junkyards for cars) are also potential sources of iron, although not likely the main source of fecal coliform bacteria.

Naples Bay Estuary

Naples Bay is presently listed as impaired for 4 parameters: dissolved oxygen, fecal coliform bacteria, copper, and iron. Naples Bay receives water from the Golden Gate- Naples Bay watershed and Gordon River Extension. Analyses of data available from two stations and analyzed for the TMDL planning period, and the four stations with data available for the verified period, indicate that dissolved oxygen concentrations in the discharges do not meet the estuary water quality standard. Like Wiggins Pass, low dissolved oxygen may be attributable to excessive nutrient concentrations but neither total nitrogen nor total phosphorus concentrations in the discharges exceed the Florida stream criteria standards. Therefore, it is unclear if total nitrogen and total phosphorus in discharges from the watershed are causing the lower dissolved oxygen levels. Again, groundwater influence may be another factor affecting low dissolved oxygen concentrations.

Fecal coliform bacteria concentrations exceeded the state standard at most discharge locations. Therefore, there is a possibility that the estuary is affected by watershed discharges of fecal coliform bacteria.

Bacteria source evaluations are necessary to confirm this condition.

Similar to the discussion for Wiggins Pass, it is possible that groundwater discharges through the canal system are a source of elevated iron levels. Mine drainage, wastewater treatment facility outfalls, and landfill leachate from industrial scrap areas are also potential sources of fecal coliform bacteria, although not likely the main source of the elevated iron levels.

The source of copper in the estuary could be anthropogenic, such as algaecides used to prevent algae growth. High copper concentrations could also occur due to site-specific sources such as leachate from boardwalks and pilings that are constructed from pressure-treated lumber.

Rookery Bay Estuary

Rookery Bay is the receiving water for the Rookery Bay watershed and is presently listed as impaired for dissolved oxygen and fecal coliforms. This estuary is also listed impaired for nutrients, which are potential causes of low dissolved oxygen concentrations.

Data available at the two stations analyzed for planning period conditions and the four stations with data available for the verified period analysis indicate that the dissolved oxygen concentration in the discharges do not meet the estuary water quality standard. Low dissolved oxygen concentrations could be attributed to excessive nutrient concentrations, as well as groundwater inflows.

The estuarine water quality criterion for fecal coliform bacteria is exceeded between approximately 60 and 75 percent of the time at the watershed discharge point. It is therefore likely that the estuary is affected by watershed discharges. Additional bacteria source evaluations are necessary to verify or refute that the estuary is affected by fecal coliform bacteria.

Ten Thousand Islands Estuary

The Ten Thousand Islands is the receiving water for the Faka-Union, Okaloacoochee/SR 29, and Fakahatchee watersheds. The watersheds remain relatively undeveloped in comparison with the three priority watersheds.

No detailed water quality evaluations of the discharge characteristics were conducted for this watershed. However, dissolved oxygen concentrations in the watershed discharges were below the threshold concentration for 24 to 85 percent of the time during the planning and verified periods. Low dissolved oxygen concentrations in the watershed are likely the result of discharges from the forested wetland systems in the watersheds (and associated increases in water color), coupled with groundwater contributions to the total flow in the canals. Total phosphorus and total nitrogen concentrations are below the screening criteria for Florida streams and fecal coliform data show values above the estuarine criterion around 60 percent of the time.

Conclusions

Collier County estuaries are typically impaired (with respect to state water quality criteria) for dissolved oxygen and fecal coliform bacteria. Rookery Bay is also impaired for nutrients. Discharges to the estuaries also have concentrations of dissolved oxygen and fecal coliform bacteria that exceed water quality criteria. Consequently, the watershed conditions are likely impacting the receiving estuaries. While causes of low dissolved oxygen are often attributed to nutrients, groundwater influence, and water color, the causes in these estuaries are not clear and would require further study.

Fecal coliform bacteria are indicators of pathogenic organisms and are used to identify potential health threats. However, fecal coliform bacteria may not be an appropriate indicator for pathogenic diseases in sub-tropical climates. Further source identification efforts are warranted.

Other parameters of impairment concern are iron and copper. Iron appears to result from the groundwater discharges throughout the canal network, although other sources are possible. High copper concentrations may be the result of anthropogenic impacts such as the use of copper sulfate as an algaecide to prevent algae growth in ponds or leaching from boardwalks and pilings that are constructed from pressure-treated lumber.

2.3: Quality of Receiving Waters

Water quality in Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Island estuaries was characterized with respect to Total Maximum Daily Load (TMDL) criteria per the Florida Department of Environmental Protection's (FDEP) verified list of impaired waters. The primary water quality concerns were dissolved oxygen, fecal coliform bacteria, and iron. Further studies are necessary to identify the causes of the impairments.

Introduction

Water quality in Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Islands estuaries was characterized in the context of the Total Maximum Daily Load (TMDL) impairment conditions per the Florida Department of Environmental Protection's (FDEP) verified list of impaired waters. The Wiggins Pass estuary is the receiving water of the Cocohatchee-Corkscrew watershed. The Naples Bay estuary is the receiving water of the Golden Gate-Naples Bay watershed and Gordon River extension. The Rookery Bay estuary is the receiving water of the Rookery Bay watershed. The Ten Thousand Islands estuary is the receiving water of the Faka Union, Okaloacoochee / SR 29, and Fakahatchee watersheds combined. The analysis included a review of FDEP's TMDL reports and other water quality data, and the identification of factors that are likely responsible for impairments, and the identification of factors that require additional study.

Methods

The estuaries were evaluated for potential impairments by analyzing data collected during the 10-year period of 2000 – 2009. Water quality parameters reviewed included dissolved oxygen, fecal coliform bacteria, chlorophyll-*a*, iron, copper, color, transparency, total suspended solids, total nitrogen, and total phosphorus.

Results

Water quality impairments previously identified by FDEP were generally confirmed by the analyses completed, with only 1 discrepancy detected. FDEP listed Rookery Bay as impaired for chlorophyll-*a*, although further analyses by Atkins did not support the impairment. Water quality impairments verified by FDEP in Wiggins Pass and Naples Bay were confirmed. FDEP had no listed impairments for the Ten Thousand Islands estuary.

Figure 2-2. Collier County Estuaries and Major Features

Wiggins Pass Estuary

Based on analysis of available water quality data, impairments for dissolved oxygen, fecal coliform, and iron in Wiggins Bay estuary previously identified by FDEP was confirmed. The dissolved oxygen impairment could be attributed to the decomposition of organic material from the adjacent mangroves and upstream landscapes, or possibly to the presence of high concentrations of total nitrogen and total phosphorus. Source identification studies are suggested to determine whether the cause of the elevated fecal coliform levels result from anthropogenic causes. Due to the shellfish industry in Collier County estuaries presence of bacteria is an important public health concern. Iron from groundwater inputs to Wiggins Pass could be the source of elevated iron in the estuary, although source-identification studies are recommended to evaluate the influence of groundwater and anthropogenic sources..

Naples Bay Estuary

An analysis of available water quality data confirmed the dissolved oxygen, fecal coliform, iron, and copper impairments identified previously by FDEP for the Naples Bay estuary. The dissolved oxygen impairment could be attributed to total nitrogen and total phosphorus inputs, although this is unlikely. Other

potential causes of the dissolved oxygen impairment include elevated total suspended solids loads if sufficient organic material is available for decomposition, and the stratification caused by stormwater discharges. Additional studies are needed to identify the actual causes of the dissolved oxygen impairment. Elevated bacterial concentrations in Naples Bay have historically been attributed to the Naples sewage treatment facility effluent, although data do not support this contention. Bacterial loads from the watershed could be a source of contamination, but none of the water bodies in the watershed have been declared impaired for fecal coliforms. Because the source of the fecal coliform impairment is uncertain, source identification studies are recommended.

High contributions of groundwater to the bay may be a source of iron, but the source may also be anthropogenic. Sources of copper may also be anthropogenic, or a result from site-specific characteristics of the sampling locations such as boardwalks and pilings constructed from pressure-treated lumber. Further source identification studies are needed to determine the causes of the iron and copper impairments.

Rookery Bay Estuary

Based on analysis of available water quality data, Atkins confirmed FDEP's Rookery Bay impairments for dissolved oxygen and fecal coliform. FDEP's assessment that the estuary is impaired for chlorophyll-*a* was not confirmed. The dissolved oxygen impairment is not likely due to total nitrogen and total phosphorus. Another potential cause of the high dissolved oxygen levels is the stratification caused by stormwater discharges. Additional studies are needed to identify the causes of the dissolved oxygen impairment. Bacterial loads from the watershed may be a source of the elevated levels of fecal coliforms, but impairment for fecal coliforms may not be the result of anthropogenic causes. Source identification studies are warranted.

Ten Thousand Islands Estuary

Based on analysis of available water quality data, FDEP has determined that the Ten Thousand Islands estuary is not impaired for any water quality parameter.

Conclusions

The Wiggins Bay, Naples Bay, and Rookery Bay estuaries were found to be impaired for dissolved oxygen and fecal coliforms. Wiggins Bay was also found to be impaired for iron, and Naples Bay was found to be impaired for iron and copper. The Ten thousand Islands estuary was not found to be impaired for any water quality parameter. It is recommended that Collier County work with the FDEP to determine the sources for the identified impairments in Wiggins, Naples, and Rookery Bay estuaries.

2.4: Coastal Habitats

The reduction in areal extents of oyster bars, seagrass beds, mangrove forests and salt marshes for the estuaries of Wiggins Pass, Naples Bay, Rookery Bay, and the Ten Thousand Islands is attributable to direct physical loss associated with coastal development. Habitat loss in Wiggins Pass and Naples Bay estuaries has been substantially greater when compared with the Ten Thousand Islands and Rookery Bay estuaries, due to greater urbanization in Wiggins Pass and Naples Bay estuaries.

Introduction

Estuaries provide many ecosystem functions, including shoreline stabilization, nutrient recycling, and habitat for a diverse assemblage of plants and animals. Within Collier County, dredge-and-fill became the established method to meet the post-World War II demand for housing. Canals served to create waterfront property, increase access for boating, and provide fill material needed for the creation of buildable lots. Coastal development has also led to increased extent of impermeable surfaces and a subsequent increase in freshwater inputs from the watershed. The timing and volume of freshwater discharges to the estuaries have been dramatically altered when compared with historical conditions as a result of too much fresh water delivered to the estuaries during the wet season and too little during the dry season. As a result, the historical areal extents of oyster bars and seagrass beds have been reduced by salinity changes in response to altered freshwater inputs, shading due to increased water turbidity, and smothering due to increased sedimentation. The tidal mangrove habitat has also been affected by coastal development and the altered salinity regime.

Methods

To quantify changes, if any, in the spatial extent of oyster bars, seagrass beds, mangrove forests, and salt marshes, a variety of GIS databases were queried, and results compared and contrasted.

Results

Wiggins Pass

Wiggins Pass was first officially dredged in 1952, and dredging has continued in the inlet and along the inland waterway south of Bonita Beach and north of Naples Park. Development of the coastal area surrounding Wiggins Pass began in the early 1950s resulting in the creation of residential canals which have altered natural sheet flow of water. The area adjacent to Wiggins pass has shifted from a mangrove dominated system to a one of both tidal marsh and mangroves. In addition, there has been an overall decrease in the extent of the mangrove community associated with direct physical alterations of the shoreline due to coastal development.

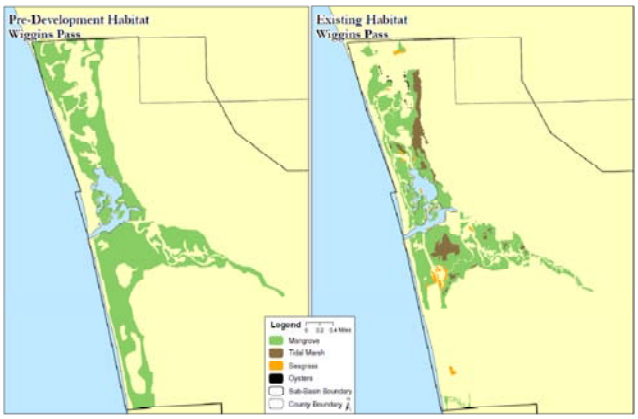


Figure 2-3. Wiggins Pass Habitat

Naples Bay

Historical maps and records indicate that Naples Bay was a shallow estuarine system with mangrove islands surrounded by oyster and seagrass beds. Dredging to create the residential development along artificially created canals altered the tidal flushing patterns and the overall function of the bay as a shallow estuarine system. The length of shoreline along Naples Bay increased by nearly 50 percent between 1927 and 1965, followed by an additional increase of 11 percent between 1965 and 1978. The increase in shoreline length is due to the construction of residential canals. In addition, a 91 percent loss in seagrass habitat and 82 percent loss in oyster habitat since the 1950s were documented.

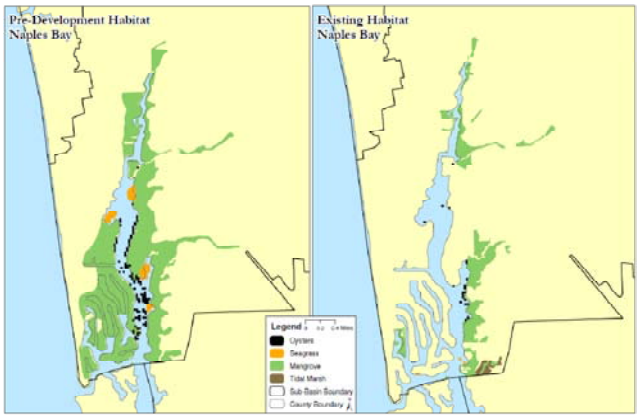


Figure 2-4. Naples Bay Habitat

Rookery Bay

The Rookery Bay watershed has been dramatically altered by channel construction and current estuarine salinity regimes are more strongly influenced by canal management than by tides or rainfall.

Based on assessments of the rates of vertical accretion in the mangrove forests within Rookery Bay, elevations of the mangrove forest have kept pace with sea level rise over approximately the past 70 years. This finding supports the importance of mangroves as a stabilizing influence on shorelines and preventing erosion in coastal regions. Rookery Bay has experienced an overall decrease in the combined mangrove and salt marsh habitat within its estuary boundaries.

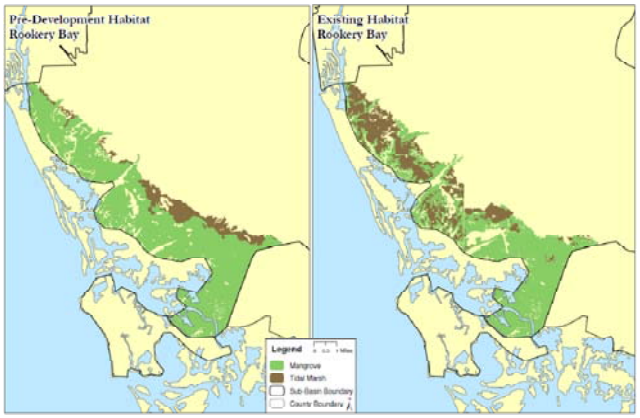


Figure 2-5. Rookery Bay Habitat

Ten Thousand Islands

Within the Ten Thousand Islands estuary, the natural spatial and temporal variation in salinities has been substantially and adversely affected by upstream water management. The Ten Thousand Islands estuary is a complex community of mangrove islands, oyster beds and shallow lagoons. The Ten Thousand Islands mangrove system appears to have declined slightly in areal extent, but has also apparently transitioned into tidal marsh.

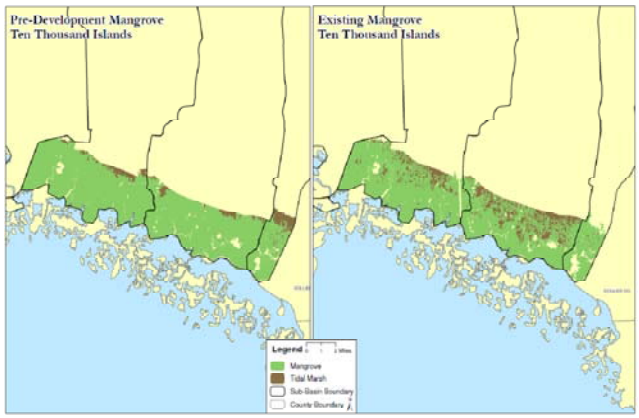


Figure 2-6. Ten Thousand Islands Mangrove

Conclusions

The loss of coastal habitats in Collier County's estuaries is due primarily to direct physical loss associated with coastal development. However, habitat loss in the Wiggins Pass and Naples Bay estuaries has been substantially greater when compared with the Ten Thousand Islands and Rookery Bay estuaries. In the Wiggins Pass estuary, the combined acreage of salt marsh and mangroves has declined by 29 percent over pre-development conditions. Acres of salt marsh and mangrove have declined by approximately 76 percent over time in Naples Bay. In contrast, the less-impacted estuaries of Rookery Bay and the Ten Thousand Islands have experienced salt marsh and mangrove declines of 12 and 5 percent, respectively.

For Wiggins Pass and Naples Bay, the amount of loss of salt marsh and mangrove reflects the greater degree of development pressures. Less development in the coastal reaches of the Rookery Bay estuary reflects the protection this area has received through various land acquisition activities (e.g. the 110,000-acre Rookery Bay National Estuarine Research Reserve). Direct loss of salt marsh and mangrove habitat is even less in the Ten Thousand Islands; however the remaining estuarine habitats have been adversely affected by alterations in the timing and quantity of freshwater inflows.

In addition to the reduced ecosystem functioning of estuarine ecosystems due to alterations in the timing and quantity of freshwater inflow, Collier County's

more urbanized estuaries (e.g., Wiggins Pass and Naples Bay) have also experienced large-scale habitat losses due to direct physical alterations of the shoreline. For Wiggins Pass and Naples Bay, re-creating a more natural hydrologic inflow pattern might not be sufficient for restoring past estuarine functions, since the physical features of oyster reefs and seagrass meadows have been lost over time. In contrast, the majority of tidal marsh and mangroves is still intact in Rookery Bay and the Ten Thousand Islands. What remains to be accomplished in Rookery Bay and Ten Thousand Islands appears to be restoration of a more natural pattern of freshwater inflow for these less-developed estuaries, a feasible option that will be fully developed as part of this project.

Element 3: Development of Performance Measures

Performance measures were developed for freshwater discharge to estuaries, pollutant loads, aquifer recharge, and natural systems using the same approach of comparing pre-development with existing conditions to establish a performance score against which to evaluate the success of proposed projects.

Performance measures are tools based on a set of indicators used in project planning to predict (or evaluate) the degree to which proposed alternative plans are likely to meet restoration objectives and to assess the success of implemented plans in meeting restoration objectives (CERP 2006). Most performance measures for the Everglades restoration projects were developed through conceptual ecological models that identified key stressors and attributes of the natural system. Attributes are biological and ecological indicators in the natural system that respond to effects of stressors. Performance measures for other water-related needs of the system, such as water supply and flood control to meet urban and agricultural needs, are derived from state and federal laws.

The intent of the performance measures developed for the CCWMP was to maintain consistency with this concept, as developed by the CERP program. Therefore, performance measures for freshwater discharge to the estuaries, aquifer recharge/yield, and natural systems were developed based on the concepts outlined below.

- The performance measure must address indicators that represent attributes or stressors of natural or human systems that (the proposed project or management action) is expected to affect.
- The performance targets, e.g. improved water quality, must reflect the desired restoration condition, which is the maximum level of restoration possible given the existing development conditions.
- The performance measure must provide an understanding of system-wide responses relative to how project implementation will meet improvement and/or restoration goals, while not being so unwieldy and costly that system-wide modeling and monitoring programs cannot be sustained over many years.

The approach to developing the performance measures was based on "restoring" the system as close as possible to the original condition, within the constraints of existing development, and given the constraints of funding.

The maximum level of restoration, then, would be pre-development conditions. The NSM was used to provide the pre-development, or baseline condition. The County's ECM was used to characterize existing conditions. The difference between the two gives the total restoration possible, without restraints of existing development and cost and provides a means of evaluating the improvement, or "lift" anticipated as a result of implementing a project.

Performance measures for each of the components examined, i.e. freshwater discharge, aquifer recharge, pollutant load, and natural systems, were developed using this approach. Development of individual performance measures are presented in the following sections.

3.1: Natural Systems

Functional assessment scores, or performance measures, were calculated for the watersheds in Collier County. Average scores are lower for the Golden Gate-Naples Bay watershed due to extensive canals systems and development and suggest that hydrologic restoration may provide the greatest opportunity for measurable improvement in functional value in the County.

Introduction

As described previously (Element 1, Task 3), performance measure development the natural systems component of the CCWMP was accomplished as part of the *Functional Assessment*. Under this task, pre-development and current conditions were compared and losses and conversions of native plant communities in Collier County watersheds over the past 50-60 years were estimated via a change analysis of land use cover data. The 1942 Collier County soils map provided additional data to characterize pre-development characteristics in the watersheds. The vegetation and soils data are reported and analyzed for the first three watersheds individually and the other three watersheds collectively.

Methods

Results of an analysis of changes in areal extent of natural communities and the causes of those changes are reported here and used to evaluate current watershed functions for Element 1 Task 3.2 (Functional Assessment). The pre-development data serve as the reference period, or baseline index against which to evaluate current vegetation data in determining ecological function. Performance measures were established prior to the development of proposed project alternatives and will be used to:

- Evaluate how well proposed alternatives meet specific project objectives.
- Examine the applicability and feasibility of specific alternative analyses.
- Address the issues identified in the assessment of existing conditions, including surface water, groundwater, and natural systems.

Similar to performance measures developed for freshwater discharges and groundwater, performance scores were calculated that provide a baseline conditions against which the success of proposed projects can be measured.

Vegetation scores represent the ecological function, or value, of the landscape based on the degree to which the pre-development vegetation persists under existing conditions. The difference in scores between pre-development and existing provides the baseline against which to evaluate the result of a project, such as removing a control structure or filling a canal. If the anticipated improvement, or "lift" score from the proposed project is greater than the performance score, one can conclude that the project will have a net benefit on the system. Hydrology and landscape (LSI) scores are developed similarly.

Dramatic conversions from pre-development wet prairie vegetation to a developed urban land use, for example, would be assigned low scores, while little or no change in vegetation cover (i.e., no change from pre-development, or shift to another natural vegetation classification) would be scored higher.

Results

Performance measures developed for this CCWMP are simply the hydrology and LSI scores developed for the functional assessment. The LSI and hydrology scores were developed as a means of characterizing existing baseline data (in numerical form) for natural conditions and, therefore, provide the conditions against which proposed projects can be measured. The vegetation score is not as applicable for evaluating the results of hydrological restoration projects because proposed projects will not focus on active vegetation management (although shifts in vegetation are expected to occur over time, commensurate with changes in hydrology).

The performance measures developed, i.e., the LSI and hydrology scores (refer to Element 1, Task 3 for further detail on development of scores), are suitable for small-scale site-level assessments (i.e., for projects that have little or no affect on the score of a 1500-X-1500-foot cell) or as modeled performance measures for larger-scale projects. The functional value of proposed

projects will be assessed using the UMAM functional value calculation below:

Functional Value = [(Anticipated Score- Existing Score)/Maximum Score] x Number of Acres

where:

Performance Measure = Functional Value

Anticipated Score = anticipated hydrology index or LSI

Existing Score = Hydrology score OR LSI based on existing conditions

Maximum Score = 10

Number of Acres = Acres of site being evaluated

As an example, consider a 500-acre proposed project area with a current hydrology score of 6. Rehydration of the site by filling a drainage ditch to the elevation of the surrounding area is reasonably expected to increase the hydrology score to 8. The hydrologic functional value of this proposed project would be 100 ((8-6)/10) X 500 acres). Likewise, LSI functional values would improve within, and adjacent to, projects that include restoration to more-natural conditions, conservation easements, transfers of development rights, or other similar means of improving the degree of ecological support to adjacent areas.

Conclusions

Functional assessment scores, or performance measures, are presented below for the watersheds in Collier County. Average scores are lower in the Golden Gate-Naples Bay watershed due to extensive canals systems and development and indicate that hydrologic restoration may provide the greatest opportunity for measurable improvement in functional value in Collier County.

Table 3-1. Average Functional Values of Non-Urban Lands, by Watershed

Watershed	Non-Urban Acres	Average Vegetation Score	Average Hydro Score	Average LSI Score
Cocohatchee-Corkscrew	111,250	7	7	8
Golden Gate-Naples	36,627	5	6	6
Rookery Bay	83,105	8	6	9
FakaUnion/ Okaloacoochee SR 29/ Fakahatchee	431,414	9	6	9

3.2: Freshwater Discharge to Estuaries

A performance measure was developed for freshwater discharges from Collier County watersheds and provides a baseline against which to measure the improvement, or "lift" due to implementation of a proposed project. The Golden Gate – Naples Bay watershed had the lowest performance score among the watersheds. The low score represents the year round flow surplus discharging into Naples Bay.

Introduction

A "Discharge to Estuary" performance score was developed for the Cocohatchee-Corkscrew, Golden Gate-Naples Bay, Rookery Bay, and Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds. The score was based on a comparison of existing and pre-development discharge conditions and provides a baseline against which to measure the improvement, or "lift" due to implementation of a proposed project. As indicated previously, the method is defined as the Performance Measure and is used to assign a score to the characteristics of the system under existing conditions against which the success of proposed projects can be measured. It will also be used to identify benefits of alternative improvement projects that are being proposed for each watershed.

Methods

Scoring is based on results of the timing and volume of discharges to estuaries from the NSM and ECM for the watersheds. As described previously, average monthly discharge volumes from the NSM and ECM models were used to define the baseline distribution and total volume of flow from each watershed. The methods are outlined below.

- The monthly discharge from each watershed in the NSM model is considered the baseline condition and assigned a performance score = 10.
- Monthly discharge from the ECM is assigned a score from one (1) to 10.
- The monthly score is (NSM volume/ECM volume) X 10. If the NSM volume is larger than the ECM volume, score = (ECM volume/NSM volume) X 10.
- The average of the monthly scores determines the watershed score relative to the NSM.

Results

The scoring matrix below lists wet and dry season and annual scores for each of the other watersheds. Of the four watersheds, the Golden Gate – Naples Bay watershed received the lowest annual score of 1.6. The score is indicative of the year round flow surplus discharging into Naples Bay. The scores for the Rookery Bay watershed indicate that the primary impairment occurs during the dry season due to freshwater deficits. This is likely due to the reduced size of the watershed caused by construction of the Golden Gate Main Canal. The observed wet season surplus is likely due to stormwater runoff from the Lely area and from the agricultural lands in the southeast portion of the watershed.

In the Cocohatchee-Corkscrew, and Eastern (Faka Union, Fakahatchee, and Okalocoochee/SR 29) watersheds, the scoring results indicate that the operational controls that are used to manage dry season flows are reasonably effective at matching pre-development flow conditions. This contributes to the higher monthly scores observed during the dry season. However, the wet season scores are low for all watersheds. This provides an indication of the effect of development on the natural drainage system.

Table 3-2. Discharge to Estuary Performance Scores

Watershed	Annual Score	Dry Season Score	Wet Season Score
Golden Gate-Naples Bay	1.6	1.9	1.0
Cocohatchee-Corkscrew	5.4	6.9	2.5
Rookery Bay	4.3	3.1	6.8
Faka Union, Okaloacoochee / SR 29, and Fakahatchee	5.6	7.4	2.0

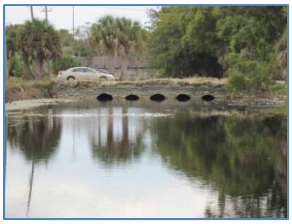
Conclusions

To evaluate the alternative scenarios, a similar scoring methodology will be used. The calculated monthly flows for each scenario will be compared to the NSM calculated monthly flows. For instance, for a project implemented in the Golden Gate Naples Bay watershed that leads to a reduction in flow to the estuary, the calculated monthly flow for September might be 5.0 inches. In the ECM, the score for September is one (1), but for the alterative, the score would be two (2):

$$(0.78/5.0) \times 10 = 2, \text{ where:}$$

0.78 = the NSM monthly flow for September, and

5.0 = the Alternative monthly flow for September



3.3: Surface Water Pollutant Loads

Performance measures for pollutant loads were calculated as a function of pollutant loads and medium density residential reference loads. Current scores indicate that the WBIDs of most concern in terms of nutrient pollution loads are in the Cocohatchee – Corkscrew and the Golden Gate – Naples Bay watersheds, particularly the coastal segment of Naples Bay and the Gordon River Extension.

Introduction

Pollutant loads were characterized for existing conditions as part of Element 1: Assessment of Existing Conditions- Watersheds. Performance scores were calculated as part of that characterization and provide performance measures for measuring the improvement, or "lift" in water quality due to reduced pollutant loads anticipated as a result of implementing proposed projects. The means by which the performance scores were calculated are detailed in Element 1, section 1.1.3, of this report.

Pollution scores, or performance scores for pollutant loadings, were calculated for each watershed and will be used as performance measures to evaluate proposed watershed improvement projects. Anthropogenic pollution load reductions will be used to evaluate potential benefits. An important criterion for assessing project feasibility will be the estimated cost per pound of pollution load removed.

Methods

As described previously (Element 1, Task 1), the performance score for watersheds is a function of the pollutant loads for each model cell and a reference standard, which for this analysis was assumed to be the average pollutant load in the County from a medium density residential development not including treatment facilities. That standard was developed by averaging the annual runoff of medium density residential land use (8.3 inches), and multiplying it by the corresponding EMC associated with a chemical parameter.

Therefore, the ratios of total load from a model cell to the standard were scored as shown in the table below. A score of 10 indicates no anthropogenic pollution, whereas a score less than 2 indicates areas (urban or agriculture) that exhibit pollutant loads equal or larger than those from a typical residential development with no stormwater runoff treatment.

Table 3-3. Pollution Load Scores and Ratios

Score	Ratio of Net Load to Standard Load
10	< 10% of standard
9	10% < standard < 20%
8	20% < standard < 30%
7	30% < standard < 40%
6	40% < standard < 50%
5	50% < standard < 60%
4	60% < standard < 70%
3	70% < standard < 80%
2	80% < standard < 90%
Less than 2	> 90% of standard

Conclusions

The estimated annual pollutant loads by cell were aggregated to reflect loads by WBID and watershed. Average performance scores for each pollutant constituent examined are presented in the following table, by watershed and by WBID. Scores indicate that the WBIDs of most concern in terms of nutrient pollution loads are in the Cocohatchee – Corkscrew and the Golden Gate – Naples Bay watersheds, particularly the coastal segment of Naples Bay and the Gordon River Extension. The Golden Gate – Naples Bay watershed received the lowest average scores for the other pollutants because of the presence of areas of urban development with no treatment. It should be noted that the Lake Trafford WBID shows a pollution load of zero (0). That is because the WBID includes only the lake itself. The drainage area contributing to Lake Trafford includes WBIDs 3278E, Cow Slough, and 3278L, the Immokalee Basin.

Table 3-4. Pollutant Load Performance Measures, by WBID and Watershed

Watershed	WBID	WBID Name	BOD-5	TP	TN	TSS	Zinc	Copper	Lead
Cocohatchee-Corkscrew	3259A	COCOHATCHEE RIVER	8	8	7	8	8	8	8
	3259B	DRAINAGE TO CORKSCREW	7	0	2	9	8	9	8
	3259W	LAKE TRAFFORD	10	10	10	10	10	10	10
	3259Z	LITTLE HICKORY BAY	6	5	5	7	7	7	7
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	8	7	5	7	8	6	8
	3278D	COCOHATCHEE (INLAND SEGMENT)	8	4	4	9	8	8	8
	3278E	COW SLOUGH	8	4	4	9	9	9	9
	3278F	CORKSCREW MARSH	9	5	6	10	9	10	9
	3278L	IMMOKALEE BASIN	7	1	2	8	8	8	8
Average			8.2	3.8	4.5	9.3	8.5	9.1	8.5
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	5	2	1	6	6	5	6
	3278R	NAPLES BAY (COASTAL SEGMENT)	0	0	0	0	1	0	0
	3278S	NORTH GOLDEN GATE	6	6	5	8	8	8	7
Average			5.3	5.1	4.2	7.0	7.1	7.0	6.2
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	10	8	9	10	10	10	10
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	9	6	7	10	10	10	9
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	9	7	6	9	9	8	9
Average			9.3	6.7	7.4	9.8	9.8	9.7	9.3
Faka Union Okaloacoochee / SR29 Fakahatchee	3278H	FAKA UNION (NORTH SEGMENT)	8	8	8	10	9	10	9
	3278I	FAKA UNION (SOUTH SEGMENT)	10	10	10	10	10	10	10
	3259I	CAMP KEAIS	7	0	1	9	8	9	8
	3278G	FAKAHATCHEE STRAND	10	10	10	10	10	10	10
	3261C	BARRON RIVER CANAL	10	10	10	10	10	10	10
	3278T	OKALOACOOCHEE SLOUGH	9	4	5	10	9	10	9
	3278W	SILVER STRAND	5	0	0	8	7	8	7
Average			8.6	5.8	6.2	9.6	9.0	9.6	9.0

3.4: Aquifer Recharge/Yield

Introduction

The potential groundwater quantity available from the surficial, lower Tamiami, and sandstone aquifers in the Cocohatchee-Corkscrew, Golden Gate- Naples Bay, Rookery Bay, and the combined Faka Union, Okaloacoochee / SR 29, Fakahatchee watersheds was evaluated against pre-development conditions using the NSM. A performance measure was developed to assess the difference in the potentiometric surface elevation (or level to which water in a confined aquifer rises) of each aquifer between pre-development and existing conditions.

Groundwater levels in Collier County fluctuate seasonally in response to withdrawals, as described previously. Rainfall and recharge during the wet season typically maintain aquifer yields. However, during the dry season, reduced rainfall leads to additional groundwater pumping to meet seasonal population and irrigation needs.

Methods

The pre-development hydrologic condition of watersheds was characterized with the NSM and compared to existing conditions represented by the ECM. The NSM is considered to represent the highest potential aquifer yield. The SFWMD has defined the minimum aquifer level for confined aquifers to be the structural top of each aquifer. The lower limit of the performance measure was therefore designated as the physical upper limit of the aquifer unit. The upper limit of the aquifer is defined by the simulated NSM results.

A performance score (0 to 10) of the ECM was defined for each aquifer as the ratio of the estimated amount of water in each aquifer as predicted by the ECM (current potentiometric surface) compared to the estimated amount of water in each aquifer as predicted by the NSM. The performance score was calculated for each WBID using the following equation:

$$\text{Performance Score} = 10 - (10 \times [\text{NSM-ECM}] / [\text{NSM-TOA}])$$

where ECM = current potentiometric surface elevation

TOA = elevation of structural top of aquifer

NSM = elevation of potentiometric surface under pre-development conditions

The average dry season water levels from the ECM and NSM were assigned to corresponding WBIDs and the difference in elevations between minimum aquifer level and each aquifer average water level provided the relative potential yield for each aquifer. The potential yield provides a scoring mechanism to evaluate the amount water level reduction or drawdown that has occurred in each WBID. The NSM does not include the Mid Hawthorn Aquifer so no performance score has been calculated for the Mid Hawthorn. An aquifer with a performance score of approximately 4.5 is represented by the conceptual diagram below.

Results

Weighted average performance scores for each WBID in each watershed are listed below. These scores are based on the average dry season water level for the ECM and the NSM.

The relatively high performance scores among the WBIDs do not have adequate scale to evaluate local effects of groundwater drawdown. However, mapped performance scores illustrate a clear pattern (Figures 3-2 through 3-4). For example, high (i.e., 10) scores (green) indicate high performance or relatively little change in dry season condition when compared with the NSM. Red areas represent low scores (i.e., 1) and are indicative of areas where water demand to meet agricultural and potable water supply needs reduce the performance scores relative to historic groundwater levels against which they are measured. Areas that score poorly tend to correspond to wellfield locations

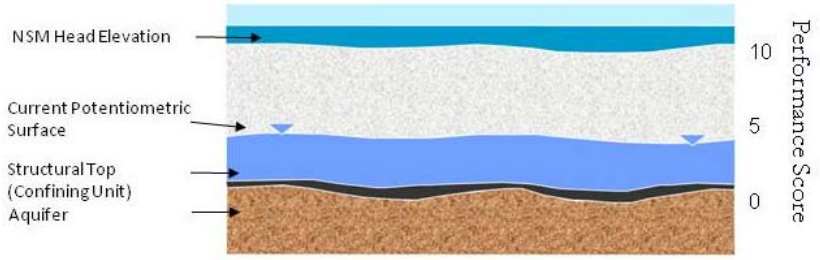


Figure 3-1. Conceptual Aquifer with Performance Score = 4.5

Table 3-5. Performance scores for each aquifer by WBID

Watershed	WBID	WBID Name	Water Table Aquifer	Lower Tamiami Aquifer	Sandstone Aquifer
Cocohatchee-Corkscrew	3278D	COCOHATCHEE (INLAND SEGMENT)	9.3	9.6	9.9
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	9.1	9.6	9.7
	3278F	CORKSCREW MARSH	9.4	9.4	9.6
	3278E	COW SLOUGH	9.5	9.4	9.5
	3259B	DRAINAGE TO CORKSCREW	9.5	9.6	9.5
	3278L	IMMOKALEE BASIN	9.1	9.2	9.5
	3259W	LAKE TRAFFORD	9.4	9.4	9.7
	3259Z	LITTLE HICKORY BAY	8.9	9.6	9.7
	Weighted Average		9.4	9.5	9.6
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	9.3	9.5	9.8
	3278R	NAPLES BAY (COASTAL SEGMENT)	9.6	9.6	10.0
	3278S	NORTH GOLDEN GATE	8.9	9.3	9.8
	Weighted Average		9.0	9.3	9.8
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	9.6	9.8	10.0
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	9.0	9.2	9.9
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	7.2	9.1	9.9
	Weighted Average		8.7	9.3	9.9
Fakaunion	3278H	FAKA UNION (NORTH SEGMENT)	8.5	8.8	9.7
	3278I	FAKA UNION (SOUTH SEGMENT)	8.4	8.9	9.8
	Weighted Average		8.5	8.9	9.8
Fakahatchee	3259I	CAMP KEAIS	9.3	9.2	9.8
	3278G	FAKAHATCHEE STRAND	8.7	9.0	9.9
	Weighted Average		7.7	7.8	8.5
Okaloacochee-SR29	3261C	BARRON RIVER CANAL	8.4	8.8	10.0
	3278T	OKALOACOOCHEE SLOUGH	8.5	8.9	9.3
	3278W	SILVER STRAND	8.4	8.6	9.5
	Weighted Average		8.4	8.8	9.5

such as the Rookery Bay and Golden Gate watersheds and the northern portion of the Faka Union watershed. A low scoring area in the Okaloacoochee / SR 29 watershed corresponds with agricultural areas with significant irrigation demands. The southern Faka Union watershed was also scored poorly as a likely result of the canal network that has effectively drained the historical wetlands. Results are similar in a portion of the Golden Gate – Naples Bay watershed. These canals also influence the groundwater elevations and contribute to lower water table elevations and changes in structure operations could have a positive influence on groundwater elevation and availability in the watershed.

The results for the lower Tamiami aquifer indicate the same pattern of performance scores exhibited by the surficial aquifer. These similarities can be attributed to water movement between the aquifer systems and to high demand in these areas. Low scoring (red) areas along the watershed boundaries for the surficial and lower Tamiami aquifers indicate that differences in defined boundary conditions between the ECM and NSM contribute to the poor performance scores rather than a result of water demand or other factors.

Results

Low performance scores were typically associated with wellfield locations, agricultural irrigation concentrations, and canal networks in the Collier County watersheds.

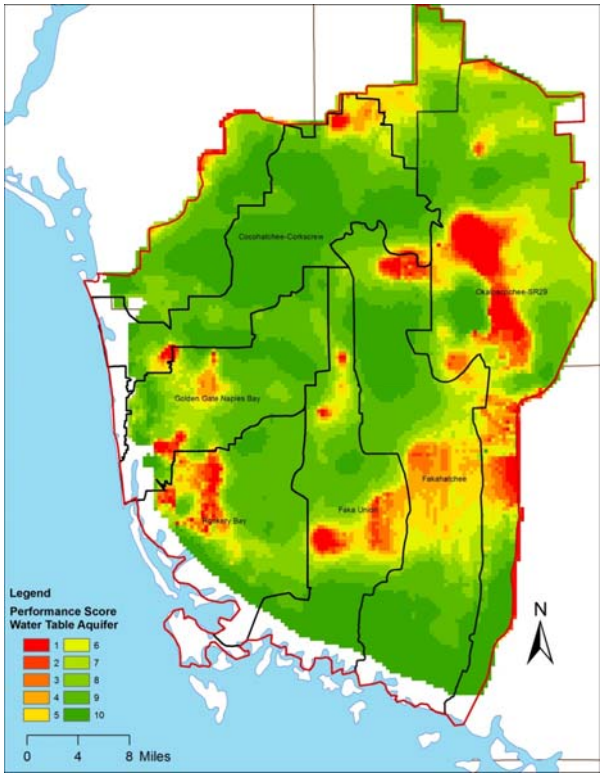


Figure 3-2. Surficial Aquifer Average Dry Season Performance Score

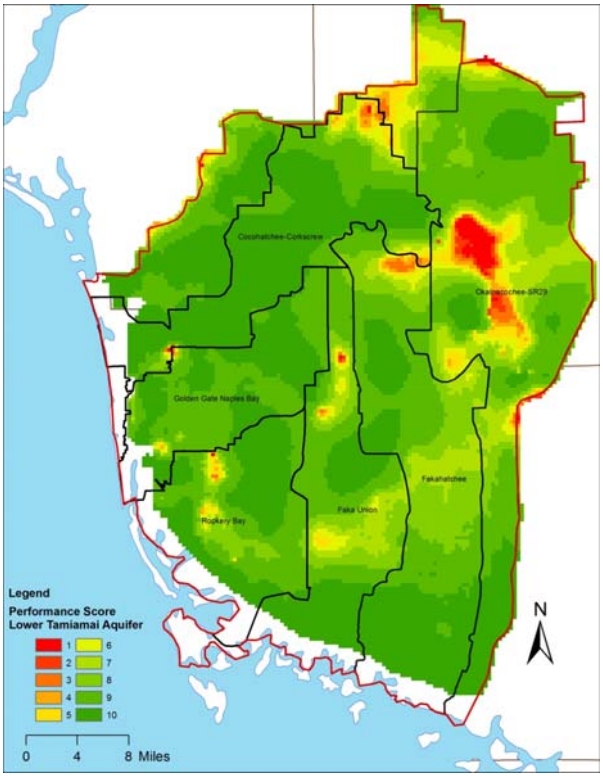


Figure 3-3. Lower Tamiami Aquifer Average Dry Season Performance Score

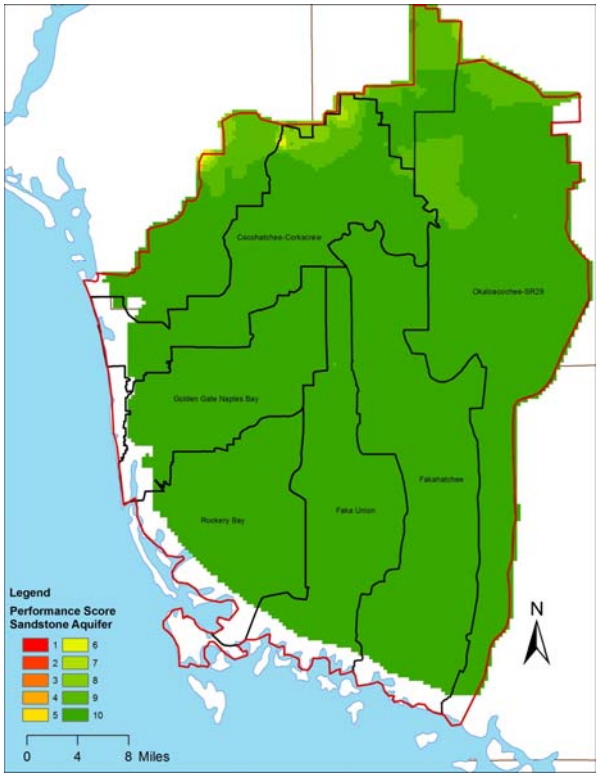


Figure 3-4. Sandstone Aquifer Average Dry Season Performance Score

3.5: Flood Risk

The primary objective of this document is to review the process of developing and applying the 5-, 10-, 25- and 100-year, 72-hour storm event to the Collier County Existing Conditions MIKE SHE/MIKE11 Model (ECM). The ECM was used to simulate the period from January 1, 2002, through October 30, 2010. The results of the storm event simulations were then used to evaluate the Level of Service for roads in Collier County.

Introduction

This section describes the methods used to develop and run the design storms and describe how the data derived from the design storm simulations were used to evaluate flood inundation and the Level of Service (LOS) for roads in Collier County.

Methods

The 72-hour design storms used for the CCMP were based on data from South Florida Water Management District (SFWMD) guidelines published in Environmental Resource Permit Information Manual Volume IV. The Environmental Resource Permit (ERP) manual provided isohytal maps of various storm events in south Florida. Isohytal maps showing the total rainfall of the 10-, 25-, and 100-year, 72-hour storm events were taken directly from the ERP manual. Kriging interpolation was conducted to define rainfall depth between the isohytes.

Gridded rainfall map data for each storm event were converted into time varying model input files combined with a 72-hour rainfall distribution time series.

The initial condition from the ECM model results represented a period between storm events where there is little storage available in the unsaturated zone or in the wetland and slough systems in Collier County. Review of the ECM model results indicated that the initial condition should represent the hydrologic conditions from September 4, 2004. This is a few days after Hurricane Charlie and prior to Hurricane Francis. The map below shows the level of inundation across the study area on this date and indicates that there is little storage available throughout the study areas.

To ensure model stability for short-term design storm evaluations, the time steps used in the model were reduced by 50 to 75 percent. The model was run first for the largest rainfall event (100-yr/72-hour) to verify the numerical stability of the storm simulation. After this simulation completed successfully, with no indications of numerical instability, the other design storms were completed.

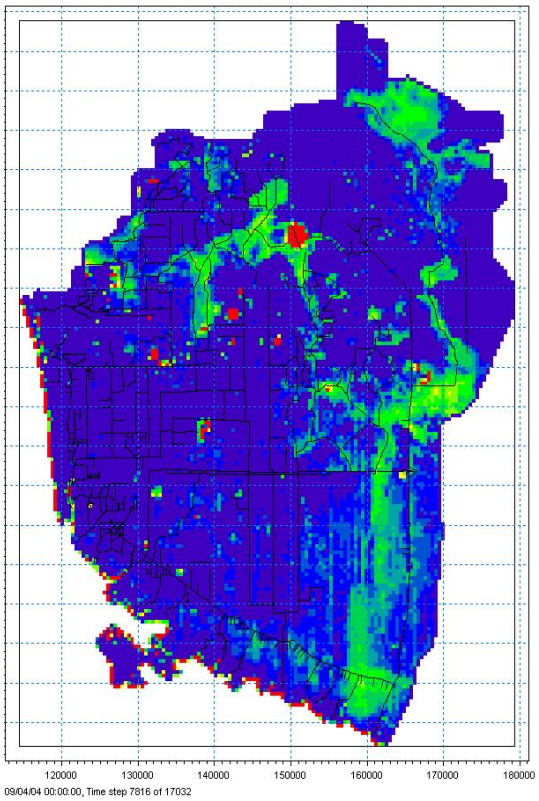


Figure 3-5. Initial Conditions Inundation Map for 9/4/04

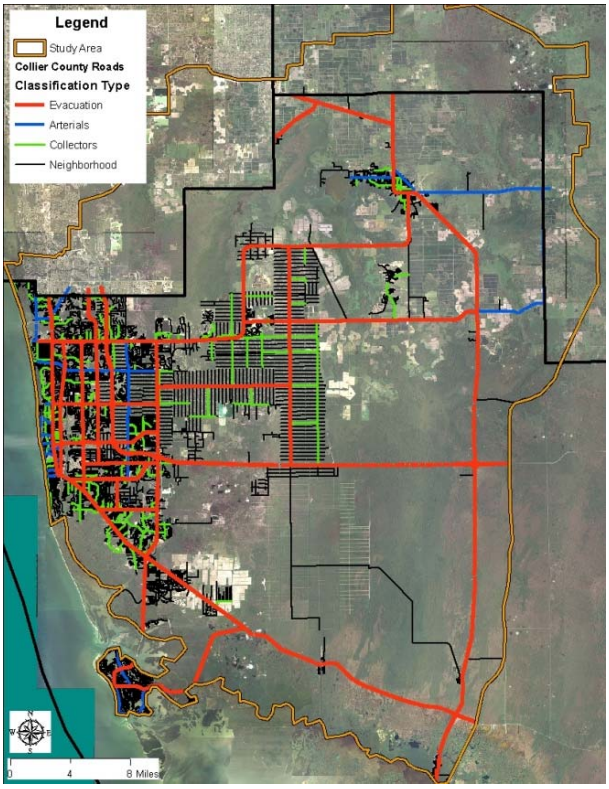


Figure 3-6. Road Classifications in Collier County

Results of Level of Service Analysis

Under the existing Level of Service (LOS) requirements (Ordinance 90-10), designs for roads and parking lot travelways shall provide drainage and flood protection during the 25-year, 3-day storm event.

The evaluation of the proposed LOS was completed by classifying roads within Collier County as Evacuation Routes, Arterials, Collectors, or Neighborhood.

- Evacuation Routes – These are roads identified as evacuation routes by Collier County regardless of CFCC designation.
- Arterial Roads – These are high capacity urban roads that connect developed areas to freeways and evacuation routes.
- Collectors – These are low to moderate traffic roads that link local streets to arterial roads. These also provide access to the residential areas.
- Neighborhood – These are local roads within neighborhoods or other developed areas.

Conclusions

The results of comparing the existing and proposed LOS criteria have several implications for Collier County.

- Currently, roads within the county are considered as either evacuation routes or other surface streets. There is no distinction between arterial, collector, or neighborhood roads. The existing LOS analysis indicates that most of the evacuation routes meet the 25-year; 72-hour storm event criteria; however, most of the surface streets fail. There is no effective means for the county to prioritize projects to address flooding.
- The proposed LOS analysis indicates that several segments of road along the evacuation routes should be evaluated more thoroughly to ensure that that there is no flooding and that the route remains open during all large storm events. This should be the first priority for Collier County.
- Existing arterial, collector, and neighborhood roads should be more rigorously evaluated based on the proposed LOS for the 10-year design storm. The proposed LOS analysis suggests that road segments that meet the 10-year LOS, will also meet the LOS criteria for the 25- and 100-year storm events.

Element 4: Analysis of Alternatives and Recommendations

4.1: Identification of Potential Projects, Future Watershed Stressors, and Policies

Structural and non-structural projects were identified as potential solutions to existing and anticipated water resource and natural systems issues in Collier County based on analyses completed as part of this study, as well as previously completed studies. A total of 27 projects were identified for further evaluation (presented in section 4.2, under Element 4, Task 2).

4.1.1: Identification of Non-Structural/Policy Actions

[to be provided]

4.1.2: Identification and Initial Screening of Potential Structural Improvement Projects

Introduction

The population of Collier County is expected to reach 950,000 people at full build-out (see figures below). The consequences of this growth and the subsequent development on water supply and environmental issues (after SFWMD 2006) are outlined below and provide the framework for policies and projects to address watershed issues considered as part of the CCWMP.

- Saltwater intrusion, wetland protection, and interference with existing water uses may affect existing ground and surface water supplies.
- Increased freshwater discharges from altered surface water systems that adversely impact coastal resources and estuaries may provide an alternative water supply and benefit the environment.
- Additional water storage is needed to better use reclaimed water and seasonal surface water resources and meet urban irrigation needs.

Information relevant to existing watershed problems, watershed problems anticipated as a result of future development, and potential solutions to these issues was compiled to develop a list of structural and non-structural projects intended to address watershed issues in the Cocohatchee-Corkscrew, Golden Gate-Naples Bay, Rookery Bay, and the combined Faka-Union, Okaloacoochee / SR 29, and Fakahatchee watersheds. Project feasibility and comparison with performance measures for success are addressed under Task 2 of this Element.

Methods

Potential projects were identified based on information compiled from projects identified for previous studies and an analysis of existing conditions (chapters 1 and 2). The list of potential projects includes refinement of projects previously completed or presently underway as well as new improvement projects. Factors considered in developing the list of proposed projects included freshwater surpluses and deficits, changes in hydrology, future roadway improvements, and property ownership. During the initial screening process, more than 150 potential projects were identified. Projects that do not support the water quantity and water quality goals of the WMPs were eliminated from further consideration and include:

- Wildlife road crossings
- Exotic species removal
- Local flood control projects
- Projects with designated Rural Fringe Receiving Areas
- Berm removal projects that cannot be adequately represented at the regional scale
- Urban BMPs designed to provide water quality treatment.
- Projects recommended for implementation or scheduled for construction, including projects with active permits.

Results

Twenty-seven projects (listed below) were identified for further evaluation:

- One project in the Cocohatchee-Corkscrew watershed
- Ten projects in the Golden Gate-Naples Bay watershed
- Six projects in the Rookery Bay watershed
- Ten projects in the Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds

Conclusions

These 27 projects were subsequently evaluated further with respect to water quality, discharge, aquifer recharge, and natural systems in the following section.

4.2: Alternatives Analysis and Recommended Watershed Management Actions

A total of 27 structural improvement projects were evaluated with respect to permitting, constructability, environmental benefits, and costs in the Collier County watersheds. Ten projects were subsequently recommended for the priority watershed, ranging in cost from $96,000 to $24.3 million.

Introduction

The 27 potential structural improvement projects were evaluated with respect to permitting, constructability, and performance criteria, including water quality, pollutant load reductions, improved hydrology, and groundwater recharge. The improvement, or "lift" in the watershed due to the project was projected and used to assess project benefits. Projects were subsequently ranked and recommended based on expected benefits and costs.

Methods

The 27 potential projects identified previously (Element 4, Task 1.1) were first evaluated for permitting constraints based on project location and ownership, technical limitations such as infiltration capacity, operation and management issues, public acceptance, and other factors. Seven of the 27 projects were subsequently eliminated from further evaluation and 2 projects were combined with other projects.

The remaining 18 projects were evaluated for project benefit based on comparisons with corresponding performance measures (presented previously under Element 3). Project “lift,” or the anticipated improvement, resulting from a project, was calculated for the 4 performance criteria (freshwater discharge, water quality, wetland hydrology/habitat, and groundwater recharge). Weighting factors that considered both individual watershed characteristics and the relative importance of the watershed issues were also part of the ranking. Costs for implementation in the calculation of the benefit/cost (B/C) ratio were based on cost of construction, given that operation and maintenance costs are typically proportional to the size of the project and would therefore have equal weight.

The cost item in the calculation of the B/C ratio was cost of construction. It is recognized that project implementation also includes operation and management (O&M) costs. Therefore, it is not necessary to include O&M costs for project prioritization purposes.

Two additional weighting factors were applied to further assess project benefits. A watershed-based factor was used to account for differences among watersheds with respect to the effect of watershed size on flows, water quality, hydrology, and groundwater in the watershed. Once the "lift" was modified by the weighting factors, they were normalized using a 0 to 10 scale so that all scores were measured using the same scale. Combined, normalized project scores with respect to performance criteria, cost, and B/C ratio are listed in Table 4-1.

Similarly, the issue-based weighting factor provided a means of accounting for the relative importance of the various watershed issues. For example, the primary anthropogenic impact in Collier County is the altered freshwater discharge pattern. Therefore, a weighting factor was applied to assign greater priority to projects that focus on restoring freshwater discharge patterns.

Combined, normalized projects scores for performance measures and (B/C) ratios for all 10 publicly funded projects considered feasible are listed in Table 4-2 in order of recommended implementation.

Results

- The Corkscrew Regional Ecosystem Watershed restoration is expected to provide greatest benefit for the dollars spent due to the low cost. However, the anticipated lift in wetland hydrology is localized and does not address the more important issues facing the county. Consequently, the project was assigned a lower priority for implementation.
- The first project recommended for implementation is the Northern Golden Gate Estates Flowway Restoration. Although it ranks second for B/C, it ranks first on benefits. This project provides a lift for each of the 4 performance criteria used to evaluate the projects. The project provides minimal lift in the discharge to estuary criteria, but provides the most lift for each of the other evaluation criteria.
- The second project recommended for implementation is the North Belle Meade Spreader Swale. The project provides lift to each of the 4 performance criteria. The primary benefit is a substantial lift in the discharge to estuary performance criterion in the Golden Gate and Rookery Bay watersheds due to a potential 10 percent reduction in flows to Naples Bay and increased flows to Rookery Bay. A moderate lift is anticipated for the other 3 performance measures.
- The Henderson Creek Diversion project is considered the third most important project to implement and ranks fourth in the B/C ratio. Similar to the North Belle Meade Spreader Swale, this project provides lift to estuary discharge for the Golden Gate and Rookery Bay watersheds. However, it provides no benefit for the other performance criteria.

Conclusions

The implementation of all proposed projects will require a very significant commitment by the County, SFWMD, and possibly the federal government and the overlap among projects may reduce implementation efficiency. For example, 2 projects are recommended that divert water from the Golden Gate Main Canal into the Rookery Bay watershed. Individually, each project may divert as much as 10 percent of the excess water discharging to Naples Bay. However, both projects may draw from the same segment of the Golden Gate Main Canal and consequently limit the total volume diverted. Implementing both projects may divert 15 percent of the excess water discharging to Naples Bay. Table 4-2 shows the combined benefits of the recommended publically funded projects in terms of a cumulative score lift achieved as projects are implemented.

Although the recommended projects are valuable steps towards protecting the ecological conditions in Collier County, watershed conditions cannot rely solely on construction of capital projects. Watershed management plans must also include a substantial regulatory-based, non-structural component and incentive programs to encourage better land management practices for new development and for the retrofit and modification of management practices on lands that are currently developed or used for agricultural purposes. These non-structural management strategies are presented in the following section.

Table 4-1. Combined Normalized Project Scores

Project Name	Discharge to Estuary Benefit	Water Quality Benefit	Wetland Hydrology/Habit	Groundwater Benefit	Total Normalized Project Score	ESTIMATED PROJECT COST	Benefit-to-Cost Ratio
	Normalized Score	Normalized Score	Normalized Score	Normalized Score		Cost (In Millions of Dollars)	
North Golden Gate Estates Flowway Restoration Project	0.0472	10.000	10.000	10.000	30.094	$2.368	**12.71**
North Belle Meade Spreader Swale[1]	8.5976	2.579	2.703	2.759	25.236	$7.026	**3.59**
Henderson Creek Diversion [1]	10.000	0.000	0.000	0.000	20.000	$5.708	**3.50**
South I-75 Canal Spreader Swale	0.1287	1.041	7.814	1.380	10.493	$3.131	**3.35**
Wolfe Road Wetland Treatment System	0.0000	0.112	0.000	3.341	3.453	$1.416	**2.44**
Corkscrew Regional Ecosystem Watershed	0.0000	0.000	2.011	0.000	2.011	$0.096	**20.95**
Upper Golden Gate Estates Canal Weir Constuction	0.0003	0.000	0.000	0.668	0.669	$0.552	**1.21**
Orange Tree Canal Control Structure Installation	0.0003	0.000	0.000	0.668	0.669	$0.552	**1.21**
Henderson Creek Off-Line Storage Reservior	1.0587	0.141	0.000	0.069	2.327	$2.929	**0.79**
Fakahatchee Wetland Restoration - Area 1	0.0000	0.182	0.004	0.000	0.186	$0.028	**6.64**
US HWY 41 Stormwater Treatment Area	0.0000	0.035	0.117	0.000	0.152	$0.544	**0.28**

Table 4-2. Cumulative Benefit and Cost of Project

Project Name	Cocohatchee-Corkscrew Cumulative Lift				Golden Gate - Naples Bay Cumulative Lift				Rookery Bay Cumulative Lift				Cumulative Cost (Millions of Dollars)
	Discharge to Estuary	Water Quality	Hydrology	Groundwater	Discharge to Estuary	Water Quality	Hydrology	Groundwater	Discharge to Estuary	Water Quality	Hydrology	Groundwater	
Corkscrew Regional Ecosystem Watershed	0.000	0.000	0.031	0.000									$0.096
North Golden Gate Estates Flowway Restoration Project					0.010	0.682	0.118	0.002					$2.464
North Belle Meade Spreader Swale[1]					0.900	0.682	0.118	0.002	1.250	0.435	0.036	0.200	$9.490
South I-75 Canal Spreader Swale									1.289	0.523	0.088	0.250	$12.621
Henderson Creek Diversion [1]					1.345	0.682	0.118	0.002	2.124				$18.329
Wolfe Road Wetland Treatment System					1.345	0.690	0.118	0.007					$19.745
Henderson Creek Off-Line Storage Reservior									2.282	0.547	0.088	0.255	$22.674
Upper Golden Gate Estates Canal Weir Constuction					1.345	0.690	0.118	0.008					$23.226
Orange Tree Canal Control Structure Installation					1.345	0.690	0.118	0.009					$23.778
US HWY 41 Stormwater Treatment Area									2.282	0.553	0.089	0.255	$24.322
Total Benefit or Cost	0.000	0.000	0.031	0.000	1.345	0.690	0.118	0.009	2.282	0.553	0.089	0.255	$24.322