
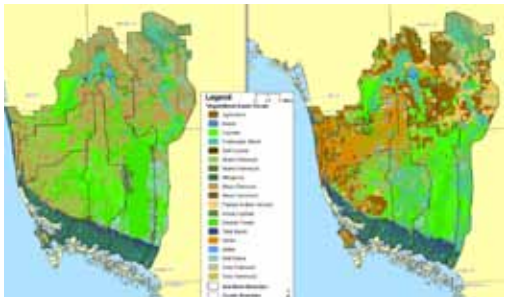

Collier County watershed management plan

Final Report Volume 1:

Executive Summary

Assessment of Existing Conditions and Performance Measures

01022-12

Collier County

Prepared by: ATKINS

NOVEMBER 2011

Document No. 110082
Job No. 100013237

FINAL REPORT

COLLIER COUNTY WATERSHED MANAGEMENT PLAN COLLIER COUNTY, FLORIDA

VOLUME 1: EXECUTIVE SUMMARY, SUMMARY ASSESSMENT OF EXISTING CONDITIONS, AND DEVELOPMENT OF PERFORMANCE MEASURES

Prepared for:

Collier County, Florida
3301 East Tamiami Trail
Naples, Florida 34112

Prepared by:

Atkins North America
4030 Boy Scout Boulevard
Suite 700
Tampa, Florida 33607

November 2011

Contents of Volume 1

Figures

Figures, cont'd.

Figures, cont'd.

Tables

Acronyms and Abbreviations

ACSC	Area of Critical State Concern
ACSC-ST	Area of Critical State Concern – Special Treatment
BCB	Big Cypress Basin
BCC	Board of County Commissioners
BCE	Black, Crow, and Eidsness
BCNP	Big Cypress National Preserve
BMAP	Basin Management Action Plan
BMP	Best Management Practices
BOD-5	5-Day Biochemical Oxygen Demand
CC	Cocohatchee-Corkscrew Watershed
CCME	Conservation Coastal Management Element
CCPC	Collier County Planning Commission
CCWMP	Collier County Watershed Management Plan
CDU	Community Development Unit
CERP	Comprehensive Everglades Restoration Plan
cfs	Cubic feet per second
CN	Curve Number
Cu	Copper
DCIA	Directly Connected Impervious Area
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EAC	Environmental Advisory Council
ECM	Existing Conditions Model
EDDMapS	Early Detection and Distribution Mapping System
EMC	Event Mean Concentration
ENP	Everglades National Park
EPA	Environmental Protection Agency
ERD	Environmental Research and Design
ERP	Environmental Resource Permit
ERU	Equivalent Residential Unit
ET	Evapotranspiration
F.A.C.	Florida Administrative Code
FAS	Floridan Aquifer System
FCM	Future Conditions Model
FDEP	Florida Department of Environmental Protection

FDoH	Florida Department of Health
Fe	Iron
FLInv	Florida Invasive Plants Geodatabase
FLUCCS	Florida Land Use, Land Cover Classification System
FLUE	Future Land Use Element
FLUM	Future Land Use Map
FNAI	Florida Natural Areas Inventory
FPLOS	Flood Protection Level of Service
FRESP	Florida Ranchlands Environmental Services Project
FUFHOK	Faka Union, Fakahatchee, and Okaloacoochee-SR29 Watersheds
FWRI	Fish and Wildlife Research Institute
GGAMP	Golden Gate Area Master Plan
GGNB	Golden Gate-Naples Bay Watershed
GIS	Geographic Information Systems
GMP	Growth Management Plan
H&H	Hydraulic and Hydrologic
HOA	Homeowners Association
IAS	Intermediate Aquifer System
IWR	Impaired Waters Rule
JEI	Janicki Environmental Inc.
LASIP	Lely Area Stormwater Improvement Plan
LDC	Land Development Code
LID	Low Impact Development
LSI	Landscape Suitability Index
MAL	Minimum Aquifer Level
mg/l	milligrams/liter
MPN	Most Probable Number
MSL	Mean Sea Level
MSTU	Municipal Services Taxing Unit
NAVD	North American Vertical Datum
NEXRAD	High Resolution Radar
NGGE	Northern Golden Gates Estates
NGGEFRA	North Golden Gate Estates Flowway Restoration Area
NGGEFRP	North Golden Gate Estates Flowway Restoration Program
NGVD	National Geodetic Vertical Datum
NOx	Nitrate + Nitrite
NSG	Natural Systems Group

NSM	Natural Systems Model
OFW	Outstanding Florida Water
OL	Overland
Pb	Lead
PBS&J	Post Buckley Schuh and Jernigan
PCU	Platinum Cobalt Units
PDVM	Pre-Development Vegetation Map
PIR	Project Implementation Report
PSRP	Picayune Strand Restoration Project
PUD	Planned Unit Development
RB	Rookery Bay Watershed
RFMU	Rural Fringe Mixed Use
RIDS	Regional Irrigation Distribution System
RLSA	Rural Lands Stewardship Area
ROMA	Regional Offsite Mitigation Area
RSF	Residential Single Family
RWCA	Recyclable Water Containment Areas
SAS	Surficial Aquifer System
SCS	Soil Conservation Service
SFWMD	South Florida Water Management District
SGGE	Southern Golden Gate Estates
SOW	Scope of Work
S.R.	State Road
ST	Special Treatment
SWFFS	Southwest Florida Feasibility Study
SWIM	Surface Water Improvement and Management
SZ	Saturated Zone
TDR	Transfer of Development Rights
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TKN	Total Kjeldahl Nitrogen
TM	Technical Memorandum
TP	Total Phosphorus
TSS	Total Suspended Solids
TTI	Ten Thousand Islands
ug/l	micrograms/liter
UMAM	Uniform Mitigation Assessment Method

URF	Urban Residential Fringe
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geologic Survey
UZ	Unsaturated Zone
WBID	Water body Identification Number
WMD	Water Management District
WMPs	Watershed Management Plans
Zn	Zinc

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. In addition, goals of the CCWMP are to help meet levels of service for flood protection, as well as sustainability of future water supplies for the citizens of Collier County.

Background and Purpose

Under pre-development conditions, surface waters flowed through wetlands in Collier County and into the receiving estuaries Rookery Bay, Ten Thousand Island, Naples Bay and Wiggins Pass. Originally most of the land drained towards Ten Thousand Island and Rookery Bay. However, intense development that has occurred in Collier County over the past 70 years, including the extensive canal construction that began in south Florida in the 1940s, has substantially changed the drainage patterns. For example, the Golden Gate Canal network that was constructed in the 1960s more than doubled the size of the Naples Bay watershed and reduced by that same amount the drainage area to Rookery Bay.

Growth in Collier County has continued in recent years. According to the 2010 Census data, population increased by about 27 percent between 2000 and 2009. As development continues, the risk of impacting the natural system will increase. In addition, external factors such as sea level rise will result in further environmental pressures.

Drainage canals and urbanization have 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. Therefore, 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 environmental needs.

Development of the CCWMP started with an evaluation of the current conditions in the study area in terms of surface and groundwater quantity and quality, as well as the natural system. These conditions were then compared to pre-development by way of performance measures. The performance measures were also used to later evaluate proposed recommendations for 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

Collier County encompasses an area of approximately 2,000 square miles. The CCWMP was developed to address watershed and estuarine conditions in the approximately 1,400 square mile area that has been subject to historical impacts due to human activity. That area is located west of the Big Cypress Preserve (Figure ES-1) and includes: three high priority watersheds: Cocohatchee-Corkscrew, Golden Gate, and Rookery Bay. The eastern watersheds, Faka Union, Okaloacoochee / State Road (SR) 29, and Fakahatchee watersheds were evaluated as a single unit due to their less intensive land development and restoration activities currently underway in those watersheds. The estuaries in the study area are Wiggins Pass, Naples Bay, Rookery Bay, and the Ten Thousand Islands estuaries.

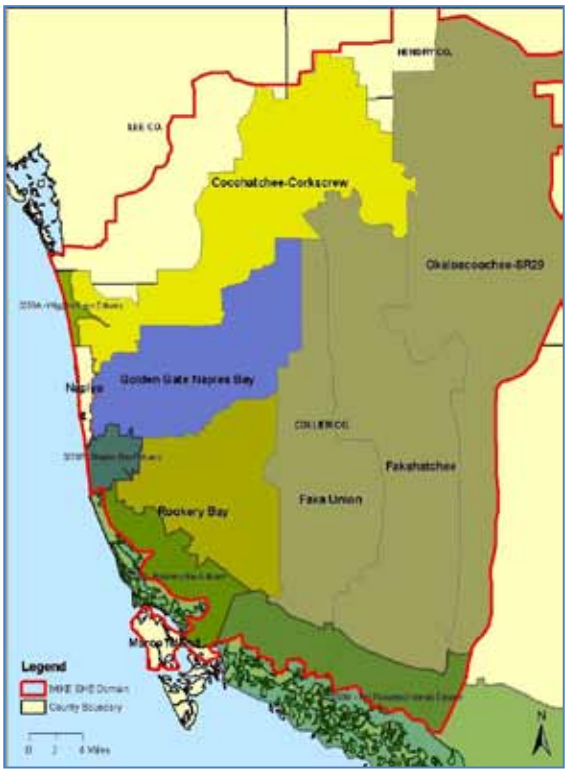

Figure ES-1. Collier County Watersheds and Estuaries

Approach

Relevant data were compiled from numerous sources, including State and local agencies, the Florida STORET data base, and the extensive literature available on relevant topics. Two primary hydrologic/hydraulic computer modeling tools were used to compare pre-development with current conditions in the study area: a) a MIKE-SHE natural systems, or pre-development, model (NSM) developed for the Southwest Florida Feasibility Study (SWFFS) area (SDI, 2007), and b) a MIKE-SHE existing conditions model (ECM) developed as part of this project.

The NSM model domain includes the BCB as well as the Caloosahatchee and Estero River Basins. The ECM is an integrated surface and groundwater model based on the previous SFWMD Big Cypress basin (BCB) model. The model was setup to analyze the watershed processes using a grid approach. Each cell in the grid is 1,500 x 1,500 ft long. This indicates the extensive level of detail applied in the analysis.

Existing conditions were assessed for surface and groundwater quantity and quality, as well as the characteristics of the natural system. A major conclusion of the analysis was that the study area is an integrated system where water moves between watershed boundaries depending on local and regional hydrologic characteristics. Therefore, the CCWMP does not focus on individual watersheds that were artificially created by land development activities, particularly construction of roads and drainage canals, but on the system as a whole.

Differences between pre- and post- development conditions were used as the basis to develop performance measures. In this manner it was possible to quantify existing watershed and estuary conditions and also quantify the improvement anticipated as a result of implementing proposed management actions.

Performance measures were developed to quantify conditions in terms of seasonal water levels in natural systems, freshwater discharges to estuaries, surface water pollutant loads, and groundwater aquifer conditions.

A number of potential capital improvement projects were 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 in the system due to proposed projects. A benefit/cost analysis was also completed, for which benefit=improvement and cost=construction cost. Priority project are recommended and described for each watershed.

A major finding of the analysis was that the proposed structural projects will provide improvements from existing conditions, but will not be enough to reach restoration goals. They must be complemented by non-structural/ policy actions. A total of thirteen non-structural initiatives are recommended for implementation. They are primarily incentive-based and cost neutral. They range from suggested changes to the land development code to establishment of a watershed-specific mitigation bank. These actions are summarized later in this document and described in detail as part of the WMP recommendations.

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

A detailed water budget analysis (Figure ES-2) showed that stormwater runoff volumes are strongly influenced by precipitation; therefore, small changes in rainfall can result in large runoff changes. Increases in baseflow are a major impact to the natural conditions because they represent groundwater contributions to surface water flows due to the drainage canals cutting into the Water Table aquifer. In this sense, the Collier County drainage canals act as an extensive source or sink of groundwater to and from the Water Table aquifer system.

The Big Cypress Basin and Collier County, respectively, maintain the primary and secondary canal system through a rigorous water control operation schedule, with virtually no surface water discharges to the estuaries for at least five months of an average year. In spite of such rigid operation, the canals derive baseflow from the Water Table aquifer system and incur losses to evaporation. It is recommended that the County and the District further evaluate the operation of the canal structures in response to groundwater levels to help manage freshwater discharges to estuaries. Maintenance of minimum flows and levels is necessary to protect in-stream fish and wildlife.

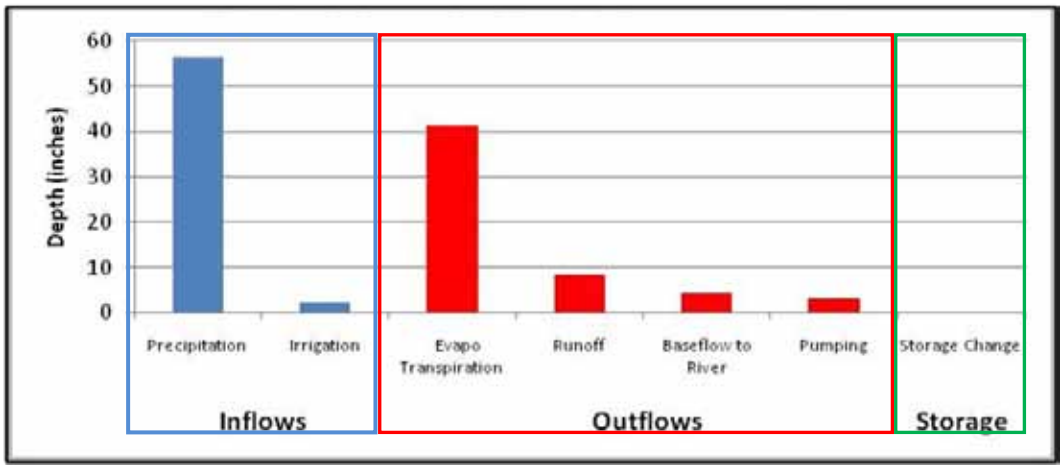

Figure ES-2. Surface Water Budget

The surface water quantity analysis also showed that the drainage system capacity is limited. In some cases, the drainage canals are unable to accommodate the flow associated with large storm events (return periods of 10 years or more). Lowering the water surface in the canal network prior to large storm events can provide storage and mitigate some of the flood risks.

In-stream 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's FDEP verified list of impaired waters. Multiple impairments were documented. Each of the six watersheds have identified dissolved oxygen impairments, The Golden Gate watershed is also impaired for iron. Two watersheds had fecal coliform impairments and one was impaired for nutrients. The dissolved oxygen and iron impairments may be caused by pollution from human activities as organic material and nutrients discharged from urban areas affect dissolved oxygen concentrations. Sources of high iron concentrations may include mine drainage, sewage treatment plan outfalls and landfill leachate from industrial scarp yards. It is also possible that the impaired dissolved oxygen and iron conditions may be the result of baseflow (groundwater) in the canals. Groundwater concentrations of dissolved oxygen and iron do not meet surface water quality standards (Collier County Groundwater Database, 2010) and the water budget conducted for each watershed as part of this project showed that baseflow represents up to 70 percent of the surface water in the canals during the dry season and 55 percent during the wet season.

Watershed pollutant loads

Watershed pollutant loads reflect man-made pollution. Areas with larger pollutant loads, particularly nutrients, corresponded to older urban areas without stormwater runoff treatment facilities. Nutrient loads are also higher in agricultural areas, although further verification and definition of discharge characteristics from these areas is recommended. Higher 5-day biological oxygen demand (BOD-5) and heavy metals loads corresponded with low/medium residential land uses and commercial areas, respectively.

Watershed hydrogeology and water uses

Hydrogeology. The groundwater system in Collier County is a regional reservoir and varies in response to seasonal precipitation. 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-Hawthorn aquifers. The combined Water Table and Lower Tamiami aquifer system is often referred to as the Surficial aquifer system.

The pattern of drawdown was similar among the Water Table, Lower Tamiami, and Sandstone aquifers (Figure ES-3). The Mid-Hawthorn aquifer is relatively isolated from these three and exhibits a somewhat different pattern due to limited withdrawals. Aquifer conditions are generally acceptable, except in the areas of influence of the existing wellfields, which produce significant groundwater drawdowns.

Changes in the operation of the existing surface water control structures in the Golden Gate Canal may provide opportunities to reduce groundwater losses and increase water availability. Reducing groundwater withdrawals for agricultural irrigation would also increase the water available for potable supply and habitat protection.

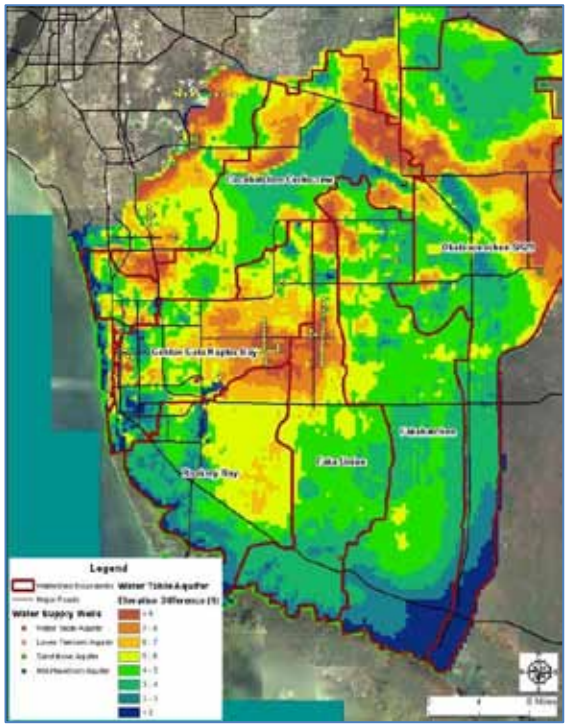

Figure ES-3. Water Table Aquifer Average Annual Groundwater Fluctuation

Water uses. Changes in groundwater levels due to withdrawals were examined with respect to minimum aquifer levels established by the SFWMD. Predicted additional declines in aquifer levels exceeded 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 from the existing wellfields (Figure ES-4). Predicted impacts are greater under prolonged dry season conditions. That is an indication that new water supply sources must be identified to meet expected future demands.

Groundwater quality and pollutant loads

Dissolved oxygen concentrations in groundwater are less than 1.5 mg/L in most of the County, compared to the State of Florida surface water standard of 5 mg/L. Because the Collier County Existing Conditions model results indicated that for the study area, baseflow (groundwater) represents 36 percent of the total annual flow in the canals and as much as 56 percent during the dry season, groundwater is a potential cause of the dissolved oxygen impairments in the canals However, it should be noted that the discharge of organic material and nutrients into surface waters resulting from human activities may also be the cause of the lower dissolved oxygen levels.

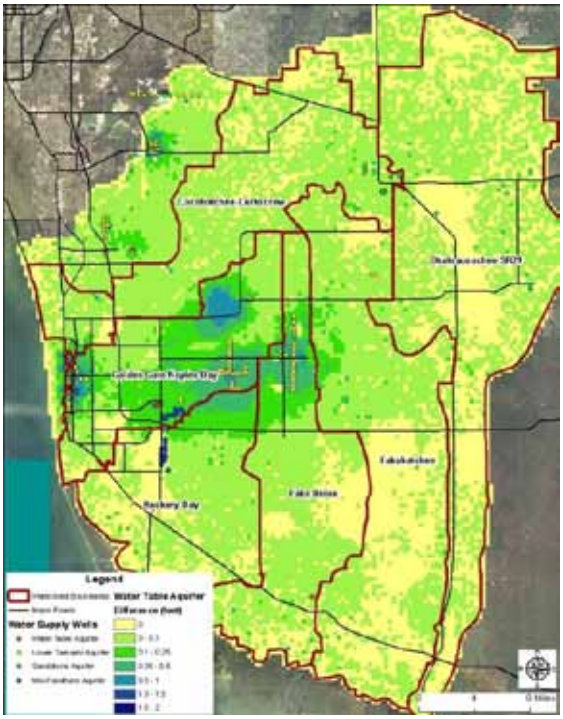

Figure ES-4. Water Table Aquifer (Prolonged Dry Season) Drawdown with 10 percent Increase in Withdrawals

Similarly, groundwater concentrations of total nitrogen in most of the County and phosphorus concentrations in the North County and coastal areas also exceed corresponding Florida surface water criteria and because baseflow represents a large percent of the total annual flow in the canals, it is possible that groundwater is a source of the reported Rookery Bay nutrient impairment. No correlation was found between septic tank density and nutrient concentrations in the watersheds, but further study is required.

Iron concentrations may also be affected by baseflow. Groundwater concentrations are often five times larger than the State's surface water standard. Given the amount of baseflow in the surface water system, it is possible that the reported surface water iron impairment is affected by groundwater, although, as described previously, sources of high iron concentrations may include mine drainage, sewage treatment plan outfalls and landfill leachate from industrial scarp yards.

High copper concentrations in surface waters, on the other hand, are likely the result of human activities. No groundwater impacts were identified in close proximity to surface water copper exceedances.

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. Measures used in the assessment included landscape suitability index (LSI), vegetation, and hydrology. Figure ES-5 shows the results of the hydrology assessment. In general, the combined Faka Union, Okaloacoochee/ SR29, and Fakahatchee watersheds exhibited the highest functional values (the least change from pre-development) when compared with the other watersheds. Measured functional values were lower in the Rookery Bay and Cocohatchee-Corkscrew watersheds, and least in the Golden Gate-Naples watershed. These scores were also used as performance measures for evaluating potential improvement projects.

The functional assessment analysis also provided a means of identifying resource protective lands that are not currently included in the County's or the SFWMD's preserved lands and supportive agricultural lands programs. Those resource protective lands were identified via consideration of LSI and vegetation scores.

Element 2, Existing Conditions – Estuaries

Volume and timing of freshwater flows

Figures ES-6 and ES-7 (red bars) show the fresh water surplus /deficit entering the estuaries during the wet and dry seasons compared to the natural system based on ECM and NSM comparisons. 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. For the Rookery Bay Estuary, the primary issue appears to be the timing of flow to the estuary and is due to fresh water surplus during the wet season and deficit during the dry season. The ECM and NSM comparisons were further verified by developing a model based on measured salinity at the estuaries. Salinity model results (green bars) are consistent with differences measured by comparing pre- and post- development conditions.

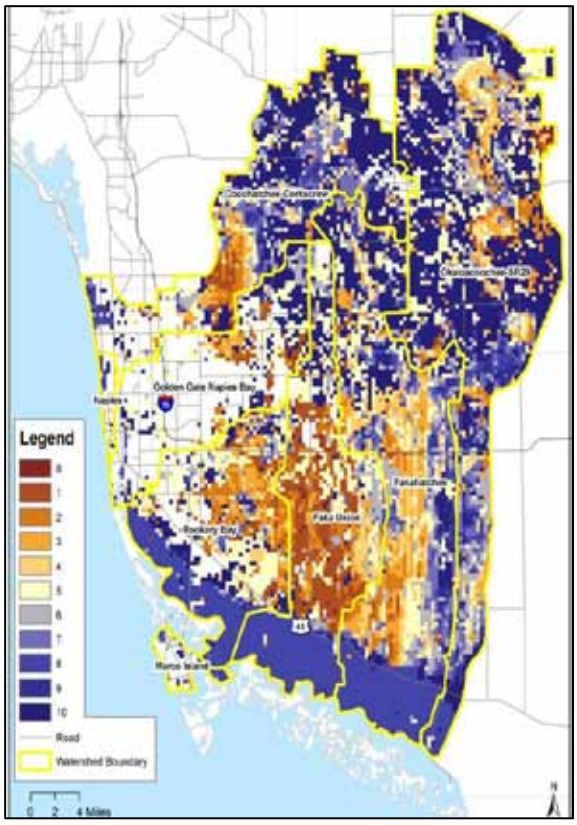

Figure ES-5. Hydrology Assessment (pre-development vs. existing conditions)

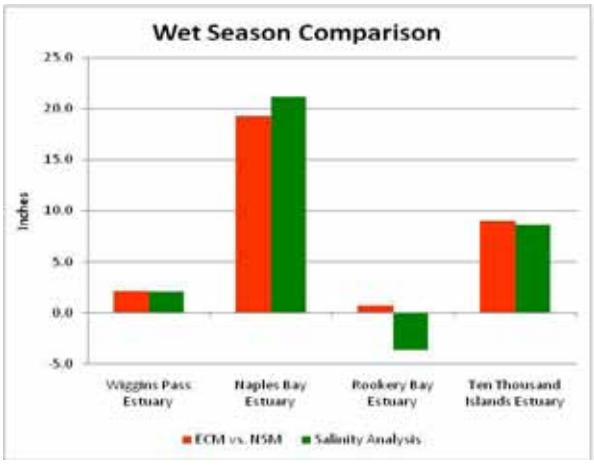

Figure ES-6. Wet season fresh water surplus/deficit (inches) in Collier County estuaries

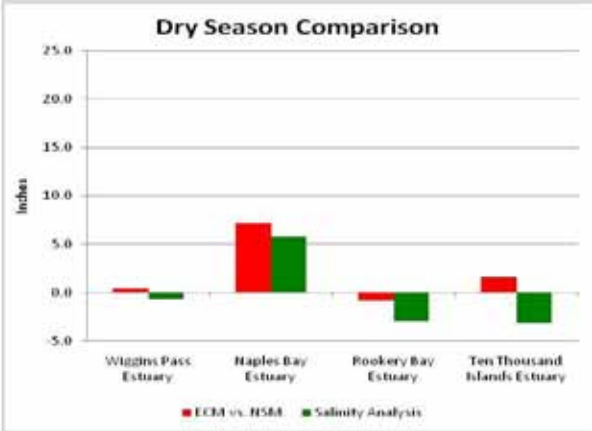

Figure ES-7. Dry season fresh water surplus/deficit (inches) in Collier County estuaries

Water quality of fresh water discharges

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. The causes of the impairments are not yet clearly defined and require further analyses. It could be attributed to nutrient discharges due to human activity, groundwater influence, or impacts of discharges from wetland systems. However, it is noted that concentrations of dissolved oxygen and fecal coliform bacteria in the discharges to the estuaries do not meet water quality criteria. Therefore, it can be concluded that watershed conditions are likely impacting the receiving estuaries.

Other parameters of impairment concern are iron and copper. The water budget analysis conducted based on the results of the existing conditions computer model developed for this project indicated that in the individual watersheds, up to 70 percent of the average dry season surface water flow in the canals is baseflow. Therefore, iron concentrations appear to be affected by the groundwater discharges to the canal network, although other sources related to human activity are possible. High copper concentrations may be the result of impacts of human activities 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 FDEP TMDL program were confirmed with a single exception: the Rookery Bay impairment for chlorophyll-*a.* This impairment was not confirmed and should be addressed through further analyses that include determination of actual causes.

The Wiggins Bay, Naples Bay, and Rookery Bay estuaries were found to be impaired for dissolved oxygen and fecal coliform. 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 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 and the associated changes in the hydrologic pattern of fresh water discharges. Habitat loss in Wiggins Pass and Naples Bay estuaries (Figures ES-8 and ES-9) is substantially greater when compared with the Ten Thousand Islands and Rookery Bay estuaries (Figures ES-10 and ES-11), 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.

Element 3, Performance Measures

Performance measures were developed as a baseline against which to measure the improvement due to implementation of proposed improvement projects. Performance measures

considered the natural system functional assessment results, freshwater discharges to estuaries, surface water pollutant loads, and aquifer conditions. Functional assessment values included vegetation, hydrology, and LSI. Water quality was not explicitly considered as a performance measure because it is a consequence of pollutant loading. Conditions were scored on a scale from 0 to 10, where ten represents the pre-development condition. Details of the methodology applied for establishing the Performance Measures are provided in Volume 4 of this report.

The expected benefits of proposed projects considered the increase in the performance measure score compared to existing conditions. More detailed descriptions of the evaluation of recommended projects are provided later in this Section.

Natural System Functional Assessment.

Functional assessment scores, or performance measures, are presented in Table ES-1. 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. Hydrologic restoration is defined as the attempt to replicate pre-development conditions.

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

Watershed	Non-Urban Area (acres)	Vegetation Score	Hydrology Score	LSI Score
Cocohatchee-Corkscrew	111,250	7	7	8
Golden Gate-Naples	36,630	5	6	6
Rookery Bay	83,100	8	6	9
Faka Union/ Okaloacoochee SR 29/ Fakahatchee	431,410	9	6	9

Freshwater discharges 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. Average annual and seasonal scores for existing conditions are shown in Table ES-2.

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

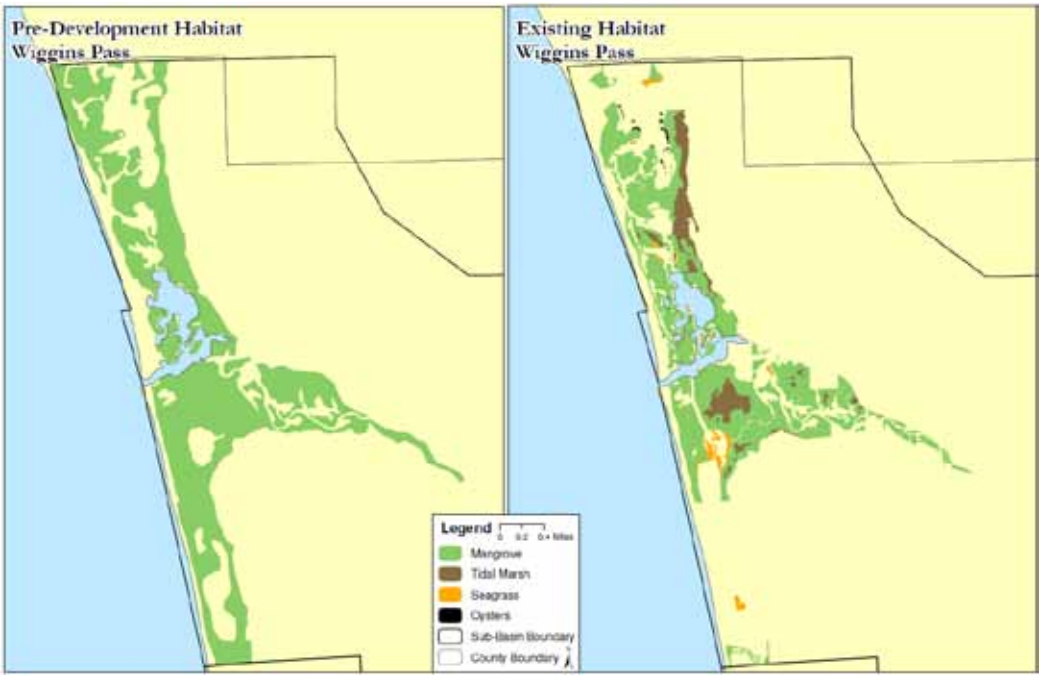

Figure ES-8. Wiggins Pass Habitat

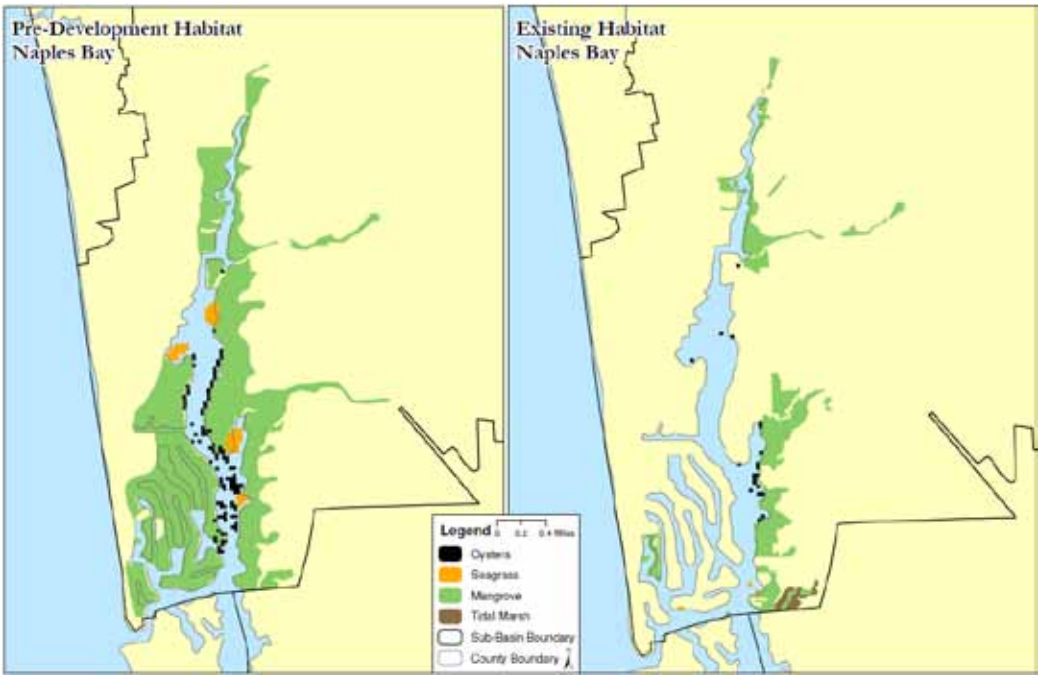

Figure ES-9. Naples Bay Habitat

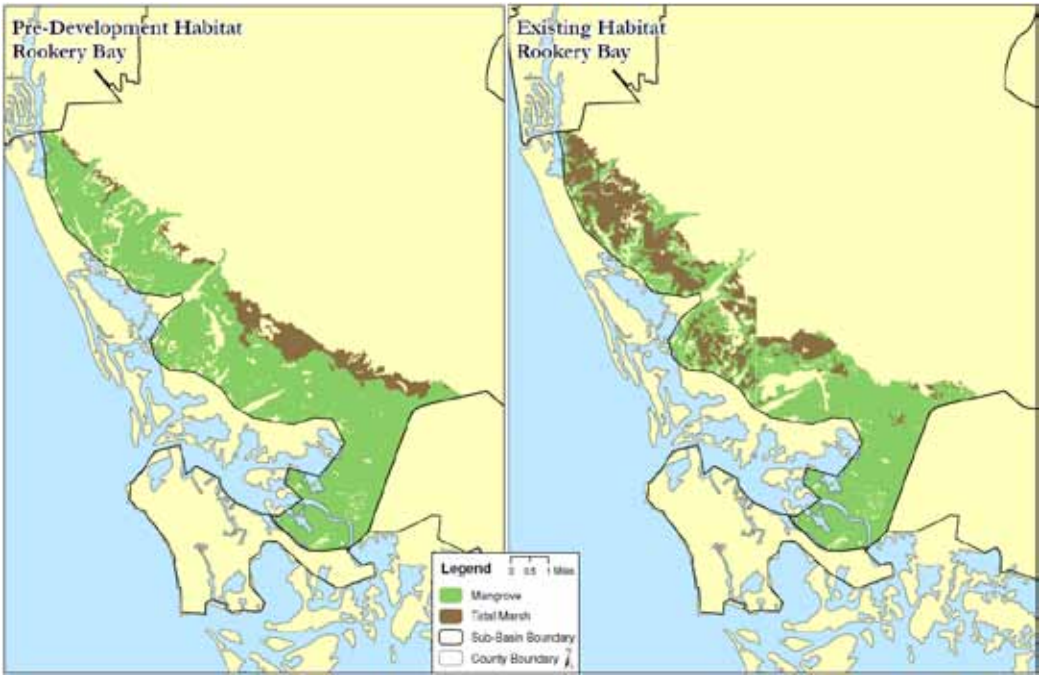

Figure ES-10. Rookery Bay Habitat

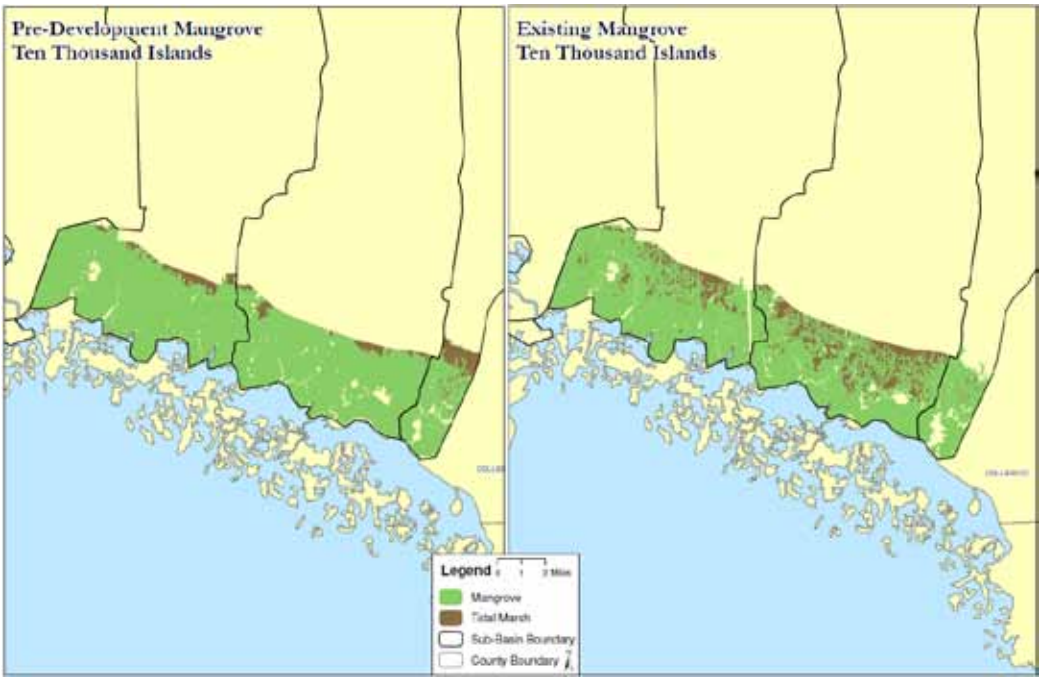

Figure ES-11. Ten Thousand Islands Mangrove

Higher scores indicate greater similarity to pre-development conditions. The Golden Gate – Naples Bay watershed has the lowest annual score of 1.6; this is due to 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. During the wet season the problem is a freshwater surplus likely due to stormwater runoff from the Lely area and from the agricultural lands in the southeastern watershed.

Scores for the Cocohatchee-Corkscrew, and eastern watersheds suggest that the operational controls used to manage dry season flows are reasonably effective at reducing baseflow and therefore provide some control over potential impacts. 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 each individual cell in the ECM grid. The loads were then aggregated by FDEP water body identification numbers (WBIDs) and for each watershed. Scores (Table ES-3) were calculated as a function of pollutant loads relative to the land use and the extent of runoff treatment existing with each cell. Natural areas received a score of 10, whereas areas of high pollution potential received scores lower than 3. Current scores indicate that the WBIDs of most concern in terms of nutrient 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 pollutant loading scores for total suspended solids, biochemical oxygen demand and heavy metals because of the presence of areas of urban development with no treatment. The Lake Trafford WBID includes only the lake itself and received a score of zero for nutrient loads (area of high nutrient load) due to the high measured concentrations of nitrogen and phosphorus. The scores do not reflect conditions after the recent large-scale restoration projects.

Table ES-3. Nutrient Pollution Load Performance Scores

Watershed	Total Nitrogen	Total Phosphorus
Golden Gate-Naples Bay	1.0	3.0
Cocohatchee-Corkscrew	6.0	9.0
Rookery Bay	8.0	7.0
Faka Union, Okaloacoochee / SR 29, and Fakahatchee	5.0	4.0

Groundwater aquifer conditions

Weighted average performance scores were determined for each cell in the study area by comparing average existing conditions dry season water levels with respect to pre-development (NSM) conditions. Those scores were then aggregated to reflect average watershed conditions. Low performance scores within each watershed were typically associated with locations of public water supply wellfields and areas of heavy agricultural irrigation. Figure ES-12 shows mapped scores for the water table aquifer.

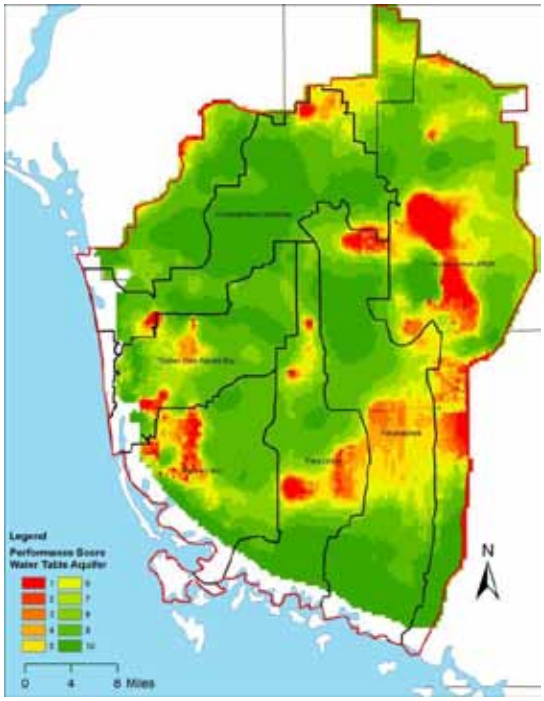

Figure ES-12: Mapped scores for the water table aquifer

High scores (10) indicate relatively a small change in dry season aquifer level condition when compared with the NSM. Low scores (1) indicate areas where aquifer levels are lower relative to historic conditions because of the presence of facilities that help meet agricultural and potable water supply needs. Areas that score poorly correspond generally to the locations of the public water supply wellfields.

Table ES-4 shows average scores by watershed. Those average scores do not adequately represent problem areas at specific locations within each watershed.

Table ES-4. Aquifer Conditions Performance Scores

Watershed	Water Table	Lower Tamiami	Sandstone
Golden Gate-Naples Bay	9.4	9.5	9.6
Cocohatchee-Corkscrew	8.9	9.3	9.8
Rookery Bay	8.7	9.3	9.9
Faka Union, Okaloacoochee / SR 29, and Fakahatchee	8.2	8.5	9.3

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.

Recommended Structural Improvements

The methodology to identify structural recommendations included: a) an initial identification of potential projects from the review of previous studies including the Southwest Florida Feasibility Study (SWFFS), or projects identified as part of this study, b) a preliminary screening of those projects based on permitting and constructability issues, c) a more detailed evaluation of the projects that passed the initial screening based on a further assessment of potential benefits, and d) final selection of recommended projects.

A total of 105 projects were initially identified and were subject to initial permitting and constructability screening. A total of 27 were selected for the more detailed evaluation that included environmental benefits and preliminary implementation costs. This final evaluation reduced the number of feasible projects to 18. Of those 18 projects, 10 were found feasible for implementation through capital improvements by the County or other agencies such as SFWMD. The other eight (8) projects are located on private property within Stewardship Sending Areas or Flowway Stewardship Areas in the Fakahatchee and Okaloacoochee- SR29 watersheds and should be implemented through existing incentive programs.

The 10 recommended capital projects were evaluated against the four performance criteria (seasonal water levels for natural systems, freshwater discharges to estuaries, surface water pollutant loads, and groundwater aquifer conditions). Project benefits were measured by the "lift," or the improvement in performance criteria anticipated as a result of the proposed project. Weighting factors were integrated into the calculation process to address both individual watershed characteristics (e.g. watershed size) and the relative importance of the watershed issues (e.g. extent of development). The performance "lifts" were then normalized to a 0 to 10 scale and summed for each of the criteria to represent the expected project benefit.

The evaluation process also allowed for the calculation of a benefit/cost (B/C) ratio associated with each project by dividing the benefit score by the estimated project construction cost. The B/C ratio was used to prioritize project implementation. Table ES-5 shows normalized project benefit scores for each performance criteria, estimated project construction costs, and B/C ratios.

The final 10 projects, in order of B/C ratio, range in cost from $96,000 to approximately $7 million

(Table ES-6). 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 improvement 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-5. 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 ($ millions)	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 Construction	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 Reservoir	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-6. 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

Recommended non-structural (policy) initiatives

An important finding of the existing conditions analysis was that the recommended structural watershed projects will provide only partial restoration of the currently affected environment. Fourteen non-structural initiatives or Best Management Practices (BMPs) are recommended to complement the structural improvements. The non-structural initiatives focus on preserving and protecting natural features of the landscape and attempt to manage stormwater at its source. The purpose was to formulate recommendations that allow for the implementation of an environmentally sustainable management program that includes modifications to the applicable regulatory framework such that they can be used to guide land development into the future. The recommended initiatives are listed in Table ES-7 and briefly described below.

Low Impact Development Program (LID). This initiative encompasses implementation of an LID program that would apply to all new development in Collier. LID aims at reducing pollutant loads using micro-controls that either reduce the volume of runoff or treat the runoff at the source (i.e. pervious pavement, rain gardens, or created wetlands). It is proposed that new development include LID techniques to remove **the nutrient load associated with 50 percent of the basic ERP State requirement**. Based on input from local stakeholders, LID treatment would be in addition to the current County 150% treatment requirement. It should be noted that the local requirement is the same as the current SFWMD requirement for impaired water bodies.

Table ES-7. Recommended Non-Structural Initiatives

Low Impact Development (LID) Program
Stormwater Retrofit Program
Fee-Based Stormwater Utility Incentive Program
Allowable Maximum Site Discharges
Stormwater Runoff Volume Control
Verification of No Floodplain Impact
Flood Protection Levels of Service Criteria
Golden Gate Estates Transfer of Development Rights Program
Golden Gate Estates Watershed Mitigation Program
Modified Operations of Water Control Structures
Expanded Water Quality Monitoring Program
Additional Watershed Protection Programs
Stormwater Facilities Maintenance and Certification Program
Establish a Fertilizer Ordinance

The implementation of the proposed LID program is expected to be cost neutral for the development community. However, to promote program

implementation, various incentives are proposed through changes in the Land Development Code (LDC).

Stormwater Retrofit Program. Protection of the existing natural system will require establishment of a retrofit program for existing developments. The proposed initiative will focus on: a) retrofit of public facilities, including parking lots in public buildings such as the Government Center and public schools, b) installation of local treatment facilities in areas that lack runoff treatment and where land acquisition makes traditional approaches cost prohibited, and c) retrofit private facilities by working with Municipal Services Taxing Units (MSTUs). It is recommended that the County establish a program dedicated to funding of stormwater retrofits. The program would be funded using current stormwater utility revenues and complemented by funds from available state and federal grants. The projects to be funded would be selected from a prioritized list to be developed by County staff.

Fee-Based Stormwater Utility Incentive Program. The existing stormwater utility funds the stormwater program based on ad-valorem property tax revenues. It is recommended that the financing of the utility be changed to a fee-based system that in turn is based on the volume of runoff discharged from each property. All properties within the County would be assessed. However, the estimates of runoff discharges would concentrate on large parcels that could substantially benefit from a reduced fee. The goal would be to maintain the same County revenue, but using a different fee structure. The advantage of the proposed fee structure is that it can be used to provide incentives for both more environmentally-friendly new development design and retrofit of private property. An economic feasibility study must be conducted to establish a cost neutral fee schedule. To minimize any initial economic impact on existing properties that discharge large amounts of stormwater runoff, a credit system that incentivizes retrofitting should be considered.

Allowable Maximum Site Discharges. Specific maximum allowable discharges have been established in the GMP for five of the identified 28 stormwater basins in the County. The rest are subject to a default value of 0.15 cfs/acre. Computer model results indicated that many of the drainage canal segments lack the conveyance capacity to accommodate large storm events. To reduce the risk of flooding, basin-specific maximum discharges less than the default value are recommended for 14 additional basins. The recommended maximum allowable discharges by basin are listed in Table 3-3 in the WMP Volume 3 report. The proposed maximum discharges should apply to new development as part of the development permit. This initiative is simply a re-visiting of current requirements using the available computer modeling tools.

Stormwater Runoff Volume Control. Changes in discharge timing due to new development may impact flood elevations downstream for large storm events. In addition to the established maximum allowable discharges, it is recommended that the land development regulations be updated to require post-development volume mitigation not to exceed pre-development conditions for the 25-year/24-hour design storm event conditions. Analyses conducted as part of the watershed management plan development process have shown that this recommendation would have basically no impact on new development because the limiting condition in terms of required site storage capacity is the allowable maximum discharge limit. The volume control requirement will be a

double check on potential impacts in the areas downstream from a proposed development.

Verification of No Floodplain Impact. It is critical that future development discharges do not impact the extent of the FEMA regulatory floodplain at any point along the canal network. It is recommended that the County implement the requirement that impacts resulting from large development permits (e.g. 160 acres or larger) be verified by using one of the currently available regional computer models, such as the Tomasello model developed by the County for floodplain management purposes, or a version of the MIKE-SHE model developed using a smaller grid size, i.e. 500 ft. Application of this initiative will require changes to LDC Section 3.07.02 referencing affected properties

Flood Protection Levels of Service (FPLOS) Criteria. The existing FPLOS criteria are based on the results of a single design storm event (return period = 25-years and duration = 72-hours) and do not allow county staff to prioritize drainage improvement projects based on the type of road. It is recommended that new criteria be establish that consider both the type of road and the return period of the storm. Some flooding would be acceptable on minor roads during large events as long as health and safety are not compromised. Evacuation Routes would have the highest priority and no flooding would be acceptable even for the 100-year return period event.

Golden Gate Estates Transfer of Development Rights (TDR) Program It is recommended that the County evaluates the feasibility of establishing a TDR program in the North Golden Gate Estates Flowway Restoration Area (NGGEFRA) located between the Faka Union and Golden Gate Canals. The program would be designed to provide sufficient market attraction to not only accomplish resource protection goals, but also to provide enhanced incentives to promote development of the Rural Villages in all or some of the established Rural Fringe Mixed Use (RFMU) Receiving lands. The TDR program would provide for the voluntary severing of residential development rights from the identified Sending lands and allow the transfer of such rights to targeted Receiving lands, which may be those currently identified in the existing RFMU program. It is recommended that programs be implemented to encourage aggregation of smaller parcels into a larger development tract. An oversight committee should be established to develop the specifics of the program. The purpose of the oversight committee will be to define the relationship between the various County programs and to ensure that the proposed TDR program in the NGGE complements and enhances the existing programs. The oversight committee may elect to modify those existing programs to address known deficiencies.

Golden Gate Estates Watershed Mitigation Program. Regulations allow wetland impacts to be mitigated either on-site, at a permitted mitigation bank or at an authorized "regional offsite mitigation area" (ROMA). There is no ROMA within the Golden Gate – Naples Bay watershed. However, ROMAs do exist within the Cocohatchee – Corkscrew, Rookery Bay, and Okaloacoochee – SR29 watersheds. It is recommended that the County develop a mitigation area within the Golden Gate – Naples Bay and Faka Union watersheds to offset wetland losses within the watershed. The lands required for the establishment of the mitigation bank would be located within the area considered for the Golden Gate Estates TDR program to provide another mechanism to finance the proposed North Golden Gate Estates Flowway Restoration Plan.

Improved Operations of Water Control Structures. The Big Cypress Basin and Collier County respectively maintain the primary and secondary canal system through a rigorous water control operation schedule that limits the amount of baseflow entering the canals. In spite of such rigid operation, the canals will continue to derive baseflow from the Water Table aquifers and incur losses to evaporation.

Results of the existing conditions model (ECM) developed as part of this study indicate that baseflow (groundwater) discharges entering the drainage canal system contribute approximately 58 percent of the annual flow from the Golden Gate Main Canal to Naples Bay. During the dry season, as much as 70 percent of the discharge to

the estuary is predicted to come from groundwater. It is recommended that Collier County and the South Florida Water Management District (SFWMD) work together to fully evaluate opportunities to improve structure operations within the physical limitations of the existing structures to maintain the water surface in the canals at an elevation that more closely matches the water table elevation such that baseflow is reduced.

Water Quality Monitoring Program. Multiple agencies collect water quality data from surface water and groundwater sampling locations. The various agencies should coordinate their activities so that the collected data are consistent for all stations and can be applied for multiple purposes. It would be beneficial if one agency were responsible for collecting all data and sharing the analytical results with the other agencies. Implementation of a one-time wet weather sampling program is also recommended to better define pollutant loading contributions from specific land uses, particularly agriculture.

Additional Watershed Protection Programs. Several watershed protection programs are recommended for implementation in various areas identified as being valuable for resource protection: a) land acquisition along the State Road 29 corridor from I-75 to US 41, b) expansion of the incentive-based Recyclable Water Containment Area Programs by partnering with the SFWMD to include agricultural lands in the Rookery Bay watershed and those areas in Lee and Hendry counties that flow into Collier County watersheds, c) evaluation of the rural fringe neutral lands programs to reclassify some areas as Rural Fringe Sending Lands based on the vegetative communities and preservation standards required for Red Cockaded Woodpecker protection, d) coordination with property owners to ensure that resource protective lands within the Rural Lands Stewardship Area (RLSA) are added to the existing Stewardship Sending, or Flowway Stewardship Areas.

Stormwater Facilities Maintenance and Certification Program. Proper operation of existing stormwater system, including the runoff treatment facilities, is critical to safeguard water quality. It is recommended that a certification program be implemented to make sure that the stormwater facilities continue to operate as originally permitted. The objective is to be able to implement remedial actions before water quality in the receiving water bodies is impacted.

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

Simulation results of the existing conditions model (ECM) developed as part of this management plan and the SWFFS natural systems model (NSM) were used to evaluate historical changes and develop performance measures that were, in turn, used to quantify relative benefits anticipated from implementing proposed structural projects.

Several structural projects are recommended for implementation. Projects were ranked based on various criteria, including a detailed cost versus benefit analysis. The top four 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

Thirteen nonstructural policy initiatives that will provide long term, sustainable ecosystem benefits are also recommended for implementation. These non-structural measures promote an integrated approach to managing water resources in Collier County and include programs such as low impact development (LID), transferrable development rights, better management and/or improvements of existing control structures, and water quality monitoring. The implementation of these initiatives will require significant input from stakeholders, including the land development community, environmental groups, and the general public.

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. Intense development has occurred in Collier County over the past 50 years. 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). Growth has continued to recent years. According to the 2010 Census data, population increased by about 27 percent between 2000 and 2009.

Water control projects, particularly canal systems, have severely impacted small- and large- scale processes throughout the County. Canals drain surface waters and groundwater and subsequently alter freshwater discharges to estuaries. 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 Naples Bay.

The drainage system in the study area has been statutorily administered through the SFWMD Big Cypress Basin Board since 1977. The Big Cypress Basin and Collier County maintain the primary and secondary canal system in the study area, respectively, and through a rigorous water control operation schedule work to reduce the impacts of the existing infrastructure. In spite of such rigid operation, the canals continue to have significant impacts on the area's natural resources.

In terms of the natural system, 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 altered salinity regimes in the estuaries, degraded water quality, reduced water supply availability, and fish and wildlife habitat losses in many areas throughout the County. Altered salinity regimes may in turn impact the ecology and productivity of an estuary. Reduced flows and subsequently increased salinities can shift seagrass species composition and location, reduce oyster populations due to increased parasitism and species competition, reduce primary productivity, and alter the life cycles of fish. The ecological effects of increased flows due to increased groundwater discharges include algal bloom initiation and eutrophication as a result of nutrient inputs, as well as contamination due to metals.

Specific impacts of altered flows include increased 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. Variation in freshwater flow can result in increased loading and transport of materials and organisms, dilution or mobilization of contaminants, a shift or compression of the salinity gradient, increase in stratification, and decreased water residence time. Freshwater flow accounts for the primary physical variability in estuaries and can be an issue where a substantial fraction of the fresh water has been diverted (Kimmerer 2002).

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. Intense development has occurred in Collier County in recent years. According to the 2010 Census data, population increased by about 27 percent between 2000 and 2009. As development continues, the risk of impacting the natural system will increase. In addition, external factors such as sea level rise will result in further environmental pressures.

The CCWMP is intended to evaluate these issues with respect to pre-development conditions and develop recommendations for water management actions that will help restore surface water quality and freshwater flows, groundwater quality and recharge, and the condition of natural systems in the County.

Collier County encompasses an area of approximately 2,000 square miles. The CCWMP was developed to address conditions in the approximately 1,400-square-mile area of historical anthropogenic impacts located west of the Big Cypress Preserve. The study area includes three highest priority watersheds: Cocohatchee-Corkscrew, Golden Gate, and Rookery Bay (Figure 1.1). In addition, the plan included an assessment of the Faka Union, Fakahatchee, and Okaloacoochee / 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 — Wiggins Pass, Naples Bay, Rookery Bay, and the Ten Thousand Islands.

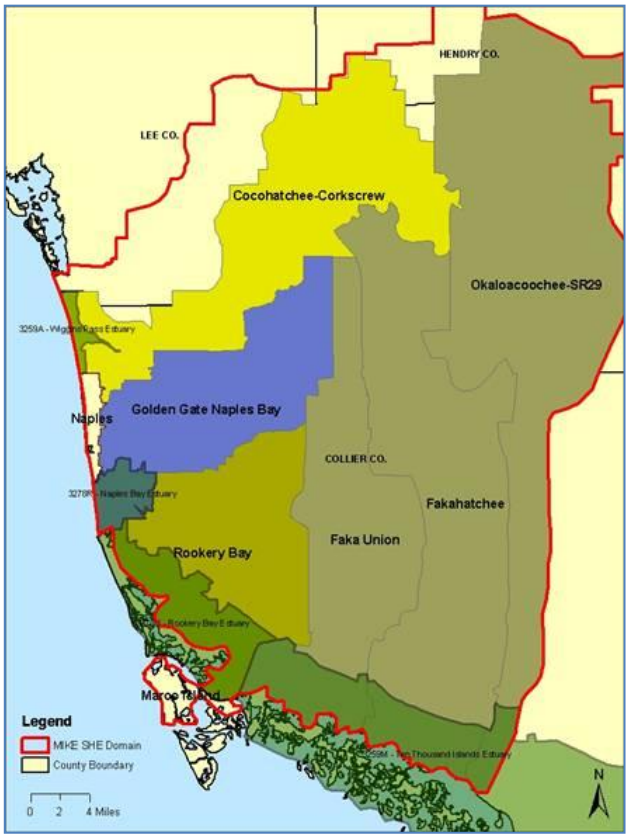

Figure 1-1. Collier County Watersheds and Estuaries

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:

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

In addition to the goals stated in the GMP, the CCWMP also addressed issues of flood protection levels of service.

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 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. 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

Watershed 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 organized by Elements for consistency with the work elements outlined in the County's Scope of Work and then grouped into four volumes. The first three volumes provide a description of the analysis, conclusions, and recommendations of the CCWMP. Volume 4 provides technical details of the assessments that support the plan's conclusions and recommendations. Further details of the report contents are provided below.

Volume 1

Volume 1 presents a summary of existing conditions in the watersheds and estuaries and the performance measures developed for evaluating potential projects. Volume 1 addresses Elements 1 through 3 of the CCWMP scope of services. Because of the extent of the analyses completed for the CCWMP, the detailed analyses are presented in technical memos in Volume 4 of this report.

Introduction. This introduction presents an overview of the purpose and development of the CCWMP, as well as the organization.

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 conditions in the watersheds.

Element 2, Assessment of Existing Conditions – Estuaries. Similarly, existing 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 quantitatively assessing watershed and estuary conditions and providing a measure of improvement anticipated as a result of implementing proposed management actions. Performance measures were developed for surface water quantity, surface water pollutant loads associated with human activity, aquifer/hydrogeology conditions, and conditions of the natural system.

Volume 2

Volume 2 is a stand-alone report that describes the structural best management practices (BMPs) recommended for implementation. Volume 2 describes the identification, screening, evaluation, and ranking of recommendations for addressing water resource issues in the County. Project implementation rankings are based on the anticipated improvements in the system due to proposed projects. Priority improvements are recommended and described for each watershed.

Volume 3

Volume 3 was prepared as a stand-alone document to describe the non-structural (policy) initiatives recommended for implementation as part of the watershed management plan. The non-structural, initiatives are designed to help bridge the gap between the benefits expected from structural projects and the long-term approaches needed to address water quantity, water quality, and resource protection in Collier County as land development continues.

Volume 4

Volume 4 is a compilation as separate sections, of the individual technical memoranda completed to address existing conditions in the County's watersheds and estuaries. Volume 4 presents detailed descriptions of the analyses conducted, with supplemental appendices as appropriate, of the applied methodologies and corresponding results of the work conducted as part of the development of the CCWMP. Volume 4 also includes a complete list of project references. Volumes 1 through 3 include separate sections on the cited literature.

SUMMARY ASSESSMENT OF EXISTING CONDITIONS – WATERSHED

1.1: Surface Water Quantity

Stormwater runoff and base flow account for about 15 and 8 percent, respectively, of the 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.

Introduction

Surface water budgets, based on results from the Collier County MIKE SHE/MIKE11 Existing Conditions Model (ECM) 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 in Figure 1-2 illustrates that 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 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 shown in Figure 1-3 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.

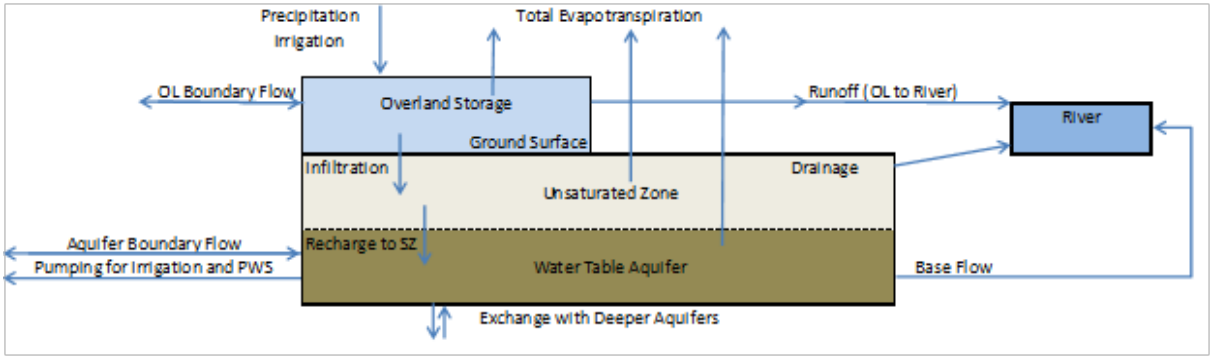

Figure 1-2. Surface Water Flow Schematic

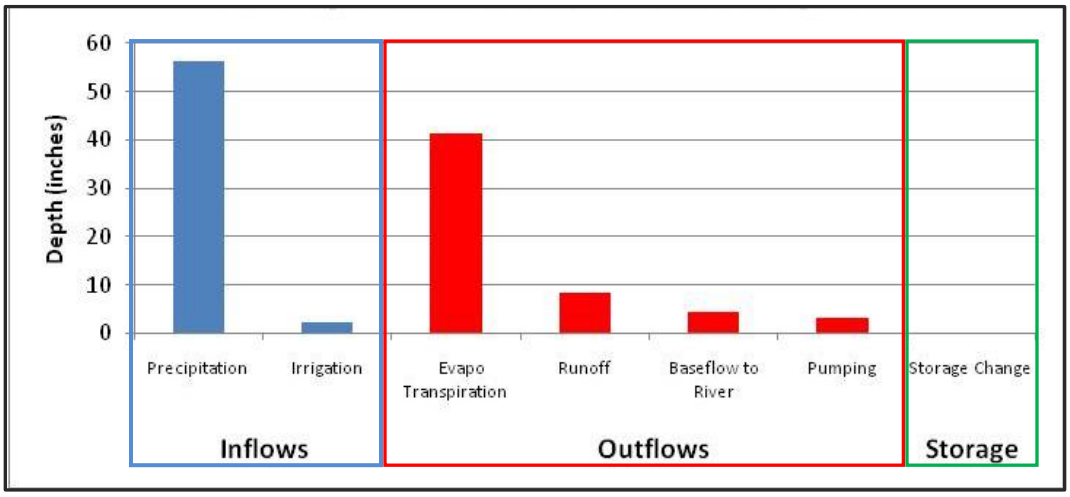

Figure 1-3. Average Water Year (2003–2007) Water Budget

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. Dry season irrigation accounts for 85 percent of the annual irrigation demand.

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 baseflow are critical to reducing the volume of water discharged to the estuaries. During the dry season, reduced baseflow to the canal network appears to be of primary importance.

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 shown in Figure 1-4.

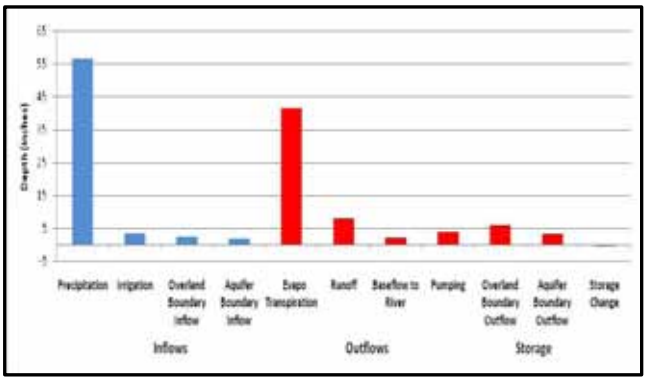

Figure 1-4. Average Water Year Budget – Cocohatchee-Corkscrew Watershed

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 in Figure 1-5.

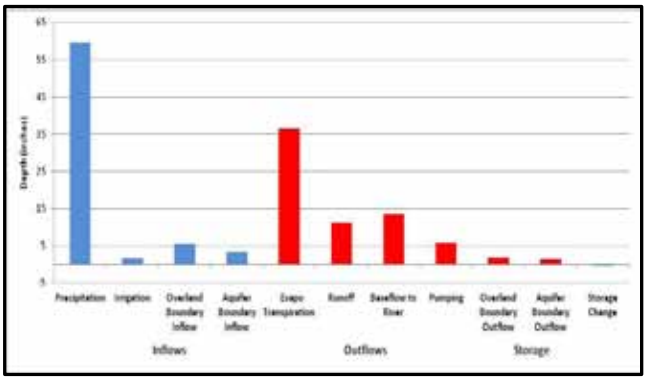

Figure 1-5. Average Water Year Budget – Golden Gate-Naples Bay Watershed

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 Water Table aquifer and directs water to the estuary.

Rookery Bay Watershed. 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. Water budget results are in Figure 1-6.

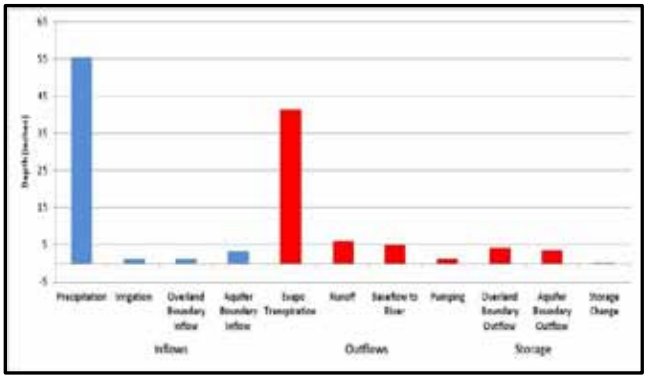

Figure 1-6. Average Annual Water Budget – Rookery Bay Watershed

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 shown in Figure 1-7.

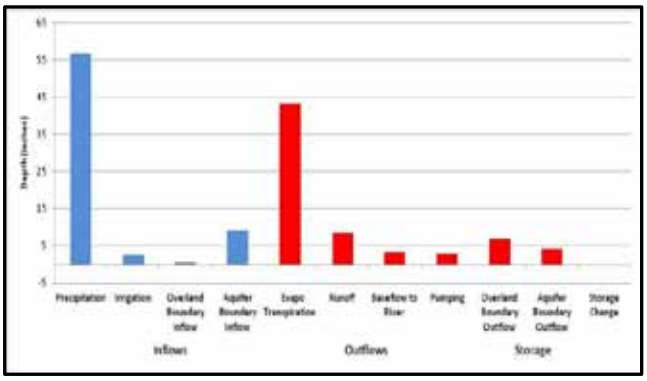

Figure 1-7. Average Water Year Budget – Faka Union, Okaloacoochee/SR 29, and Fakahatchee Watersheds

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 7.5 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. This is possibly the result of high base flow contributions to the canal network in the Faka Union watershed or groundwater pumping for potable water supply and agricultural irrigation in the northern parts of the study area. Further site specific analyses would be required to quantity actual causes of the storage loss.

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 (Figure 1-8), 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.

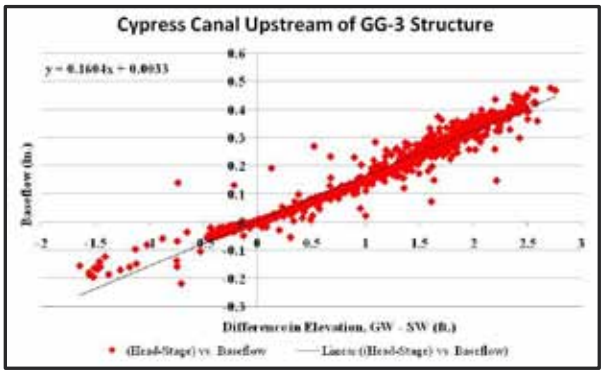

Figure 1-8. Relationship of Baseflow and (Head – Stage) Elevation Difference

- 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 Water Table 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.

1.2: In-Stream Surface Water Quality

In-stream water quality was evaluated in the context of the Total Maximum Daily Load (TMDL) impairment process. Results are consistent with FDEP's findings. Detailed site specific analyses are necessary to establish cause-effect relationships for the potential impairments.

Introduction

In-stream water quality in the study area was characterized based on comparisons to the State's water quality standards per FDEP's TMDL impairment analysis. Screening criteria were used for parameters that do not have a numerical standard. Analyses included: 1) review of relevant reports from local, state, and regional agencies, 2) review of relevant water quality data, 3) identification of water quality concerns that may require source verification or restoration measures., 4) identification of factor(s) that may affect conclusions related to TMDL impairment, and 5) an overview of factor(s) that strongly influence water quality in Collier County's watersheds.

Methods

In-stream water quality was 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

Per the data analysis, the fourteen FDEP identified water body identification (WBID) basins previously verified as impaired by FDEP were confirmed to be impaired. An additional 16 WBIDs were identified as potentially impaired, or "basins of concern" by FDEP standards. Impairments relate primarily to low dissolved oxygen concentrations (Figure 1-9). The potential new impairments, which will have to be verified by FDEP, may be due to the use of additional data available for this study, compared to the FDEP databases, as well as differences in the timeframe used in the analysis. The data analysis indicated also that with the exception of Lake Trafford (Figure 1-10), watersheds are not characterized by high levels of total nitrogen or total phosphorus. Chlorophyll-*total* phosphorus, and total suspended solids concentrations were within the range of the regulatory standards and screening levels for all six watersheds. Therefore, further study to be conducted as part of the TMDL program is necessary prior to the County committing to implement water quality improvement projects.

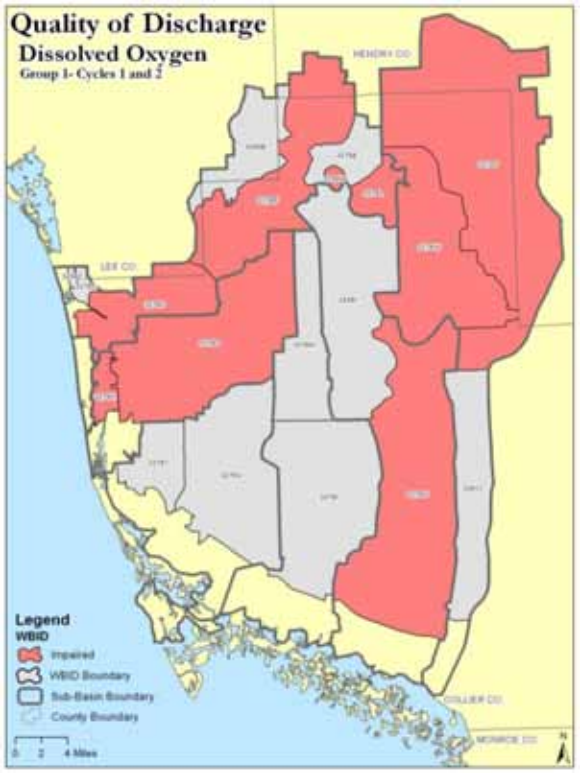

Figure 1-9. WBIDs Impaired for Dissolved Oxygen

Another impairment parameter is fecal coliforms. Before any action is taken to address this issue, the County should wait for further guidance by FDEP. The agency is looking into this issue on a statewide basis.

Cocohatchee-Corkscrew Watershed

Water quality assessments conducted as part of this project indicated three potential parameters of concern: color, dissolved oxygen, and fecal coliform bacteria. Statistical data analyses were conducted to identify the most likely cause of the low dissolved oxygen levels in the watershed. Those analyses indicated that color resulting from discharges from wetland systems may be the primary causative factor. This finding applies primarily to the Corkscrew marsh and potentially the area downstream from the marsh. Nutrient loading from urban runoff may also contribute to low dissolved oxygen levels in the western portion of the watershed. The area around Immokalee is likely impacted by urban and agricultural runoff.

Figure 1-10. Collier County Nutrient Impairment

Groundwater is also a potential contributor to low dissolved oxygen levels as baseflow represents about 23 percent of the average annual flow and 36 percent of the dry season flow. Baseflow occurs primarily in the areas near the coast and into the Cocohatchee Canal adjacent to Immokalee Road.

A review of water quality data completed during this project indicated that concentrations of chlorophyll-*a* and nutrients have been below FDEP's screening criteria, including those in the Lake Trafford basin. The results for Lake Trafford are most likely due to the sediment removal projects being conducted in the lake. Continued coordination with FDEP is necessary to confirm this finding and define the next courses of action in the TMDL process.

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 baseflow contributions, and runoff from forested areas may all influence dissolved oxygen concentrations in the watershed. Groundwater, which is low in dissolved oxygen concentration, represents 58 percent of the annual flow and 70 percent of the dry season flow from the Golden Gate – Naples Bay watershed However, as potential man-made impacts cannot be disregarded, further site-specific analyses in coordination with FDEP are required to verify the dissolved oxygen impairments and to identify the causes of the impairment. In terms of the iron impairment, results from a computerized water quality model of the watershed, discussed in Volume 4, have indicated that it may be the result of groundwater contributions to the canal network, although human activities may also be sources of high iron concentrations. Iron concerns and recommended courses of action will need to be defined during the next FDEP TMDL assessment cycle.

Rookery Bay Watershed

None of the WBIDs that comprise the Rookery Bay watershed were identified by FDEP as impaired for dissolved oxygen. However, based on the evaluation of the long term water quality data, dissolved oxygen was identified as being of "potential concern". Statistical relationships conducted as part of this project, which are described in Volume 4, suggest that total phosphorus may be indirectly responsible for the low dissolved oxygen by stimulating algae growth that in turn may deplete waters of oxygen. However, the statistical relationship is weak. In addition, chlorophyll-*a* and nutrient values were found to be consistently below FDEP's screening criteria. Pollutant loads from developed land uses, significant baseflow contributions, and runoff from forested areas may all influence dissolved oxygen concentrations in the watershed. Further analyses are needed to identify the actual cause of the low dissolved oxygen concentrations.

Faka Union, Fakahatchee, and Okaloacoochee/SR 29 Watersheds

Some of the WBIDs in these watersheds have been found impaired for dissolved oxygen, fecal coliform, and iron. The evaluation of the long term water quality data from this watershed confirmed the impairments.

Regression analyses conducted as part of this project (see Volume 4) suggest that low dissolved oxygen concentrations in discharge waters in the watershed may be due to color. That is consistent with the characteristics of these watersheds, as 86 percent of the area is comprised of natural areas. High color is typical of water discharged from forested areas.

Other factors that can affect dissolved oxygen concentrations are baseflow contributions and the discharge of pollutants from areas impacted by human activity. More detailed studies are necessary to define the actual cause of the impairment.

In terms of iron concentrations, similar to the conditions in the Golden Gate- Naples Bay watershed, baseflow is a likely source of the elevated concentrations, although human activity sources should also be considered and evaluated. 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 impairment.

Conclusions

The FDEP has identified multiple impairments of individual WBIDs for several water quality parameters in Collier County. The data analyses for individual WBIDS conducted as part of this project, which use all the FDEP data plus new data collected specifically for this project, are consistent with the FDEP findings. Additional potential water quality impairments were also identified. Impairments for parameters such as dissolved oxygen and iron could be attributed to several causes including pollutant loading from developed areas, water color from natural landscape discharges, and groundwater contributions (baseflow) to the surface water flows.

The data analyses conducted by either FDEP as part of the TMDL implementation process or as part of this study are not sufficient to determine impairment. Establishment of a cause versus effect relationship through more detailed analysis is necessary. Those efforts should be coordinated with FDEP. Ideally conclusions are reached as part of the work necessary prior to the TMDL development stage of the TMDL program.

1.3: Surface Water Pollutant Loading

Net surface water pollutant loads were quantified for priority watersheds in Collier County. 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., pollutants that are discharged into the primary and secondary drainage network, were calculated for the entire study area. The pollutant loads provide a means of examining the relative contribution o f land use types to total pollutant loads as well as a baseline against which to measure the effects of improvement projects. The calculation of pollution loads addressed strictly those resulting from human activities in the watershed given the CCWMP focus on mitigation of those impacts.

Methods

Pollutant loads to the receiving waters were estimated using a Pollutant Loading and Removal Model based on the U.S. Environmental Protection Agency Method. By this method, average annual pollutant loads are calculated by the product of average annual stormwater runoff volume times an event mean concentration (EMC). The EMC represents the estimated concentration of a pollutant in the discharge from a particular land use.

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. The MIKE SHE / MIKE 11 hydrologic and hydraulic (H&H) existing conditions model (ECM) was used to estimate runoff volumes. For consistency with the SWFFS, the EMCs were also assumed to be the same as those used in that study. However, they were checked with other data available from the literature. No significant differences were noted. A recommendation from the analysis is that additional data be collected through wet weather sampling monitoring to better define the EMCs associated with agricultural discharges given the variations in runoff pollution control practices.

Gross pollutant loads, defined as loads generated in a watershed, were calculated 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, which are typical treatment systems. The net loads are those that enter the drainage network, and therefore discharge into the estuary systems.

Results

Table 1-1 provides a summary of predicted nutrient pollutant loads by watershed, which are critical for TMDL impairments analysis. The areas predicted to contribute the largest pollutant load are older developments, golf courses, and agriculture. Further details on areas of concern are provided later in this report and in Volume 4. The nutrient source may be related to excessive use of fertilizers. It must be noted that the largest EMC value for nutrients in the SWFFS analysis is for agricultural land uses. As indicated previously, further wet weather sampling is recommended to better define areas of agricultural nutrient concern.

Table 1-1. Predicted Surface Water Pollutant Loads

Watershed	Total Nitrogen		Total Phosphorus	
	Tons/year	lbs/acre/yr	Tons/year	lbs/acre/yr
Cocohatchee - Corkscrew	160	2.50	30	0.46
Golden Gate - Naples Bay	120	2.75	19	0.42
Rookery Bay	70	1.47	13	0.26
Faka Union, Fakahatchee, Okaloacoochee SR29	452	2.01	90	0.40

The magnitude of the tabulated loads can be assessed by comparing them to the loads from a single land use category. For example, using the same calculation methodology, the average loads per acre from a medium density residential area with no runoff treatment are 4.39 and 0.73 lbs/acre/year for TN and TP, respectively. Given that the loads represent only those from human activities but distributed over the entire watershed area, results indicate the presence of areas of critical concern.

1.4: Hydrogeology

Understanding the interaction of the surface water and the groundwater systems and the highly dynamic transfer of water between one system and the other is a critical aspect of the watershed management planning process

The groundwater resource in Collier County is essential to meet agricultural and urban needs, as well as to maintain the characteristics of the natural system. Therefore, understanding the interaction of the surface water and the groundwater systems and the highly dynamic transfer of water between one system and the other is a critical aspect of the watershed management planning process.

In the MIKE SHE Existing Conditions Model (ECM) developed as part of this project, the subsurface model includes the unsaturated and saturated zones. The unsaturated zone in South Florida is shallow and the soils are sandy and highly permeable, except in wetlands where a surface deposit of fine-grained sediment may be present. Soil porosities are typically high even compared to those for regular sandy soils. The ECM was based on the soil types and properties from the Southwest Florida Feasibility Study (SWFFS). In the SWFFS, soil types were classified into six different hydrologic response groups. Hydraulic parameters were defined for each soil profile.

The saturated zone has a complex stratigraphy. The primary aquifers that underlie Collier County in order of increasing depth: Water Table, Lower Tamiami, Sandstone unit of the Upper Hawthorn (Sandstone), and the Mid-Hawthorn. These hydrogeologic units are generally comprised of stratified layers of porous media having high transmissivities with relatively thin layers of silt and clay rich units that comprise the confining units.

In the ECM, each aquifer is represented as individual computational layers. Each computational layer is made up of an aquifer and overlying confining unit. Generally the upper aquifers exhibit significant interaction. Potentiometric elevation data from existing monitoring wells indicate variable amounts of communication between the Mid-Hawthorn and the overlying Sandstone Aquifer. In the northern parts of the study area, the potentiometric surface of the Mid-Hawthorn is similar to the overlying layers, indicating less confinement. However, the heads in the few wells screened in the Mid-Hawthorn in the southern part of Collier County indicate greater confinement. In the southern part of the County, the Mid Hawthorn is very thick and in the north it is relatively thin. The confinement is the result of reduced transmissivity, a function of the vertical conductivity and thickness of the unit. Since the vertical conductivity is uniform throughout the computational layer, the confinement is the result of the increased thickness of the aquifer layer.

The primary hydrogeologic parameters used in the ECM, horizontal and vertical hydraulic conductivities, leakance, and storage parameters were derived from the SWFFS and included revisions made during the calibration of subsequent modeling efforts, such as the Lee County DR/GR model. The hydrogeologic parameters are associated with each computational layer, which is made up of an aquifer and overlying confining unit. Therefore the hydrogeologic parameters are composites of parameters representing the combined parameter estimates of the geologic units that make up each computational layer. 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.

1.5: Groundwater Quantity

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

The Collier County Existing Conditions Model (CC ECM) was used to simulate the hydrodynamics of the Collier County aquifer systems. Groundwater budgets were developed to assess aquifer conditions including the lateral flow of water across and within model basin boundaries, and the 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. Atkins believes that the model is adequate to assess the conditions in Collier County; however, it is recognized that the groundwater calibration, primarily in the deeper aquifers, may be improved with additional effort. A detailed discussion of model limitations is presented in the Model Calibration Report

A conceptual groundwater budget (Figure 1-11) illustrates inflows (primarily percolation to underlying layers), outflows (discharge to canals, pumping, etc.), and storage. Water that infiltrates into the soils may be assimilated by vegetation or percolate into the upper portion of the Water Table aquifer. The water can be removed from the Water Table aquifer by vegetation, lateral flows, water supply withdrawals, or percolation to adjacent aquifers. Any residual water is stored in the aquifer(s).

Average annual and seasonal (wet and dry) groundwater budgets were developed for each aquifer system. The budget included both the natural processes and groundwater demands. Average annual groundwater elevations, as well as annual fluctuations were also calculated and mapped. The analysis considered differences in seasonal elevations to identify areas of extreme drawdown.

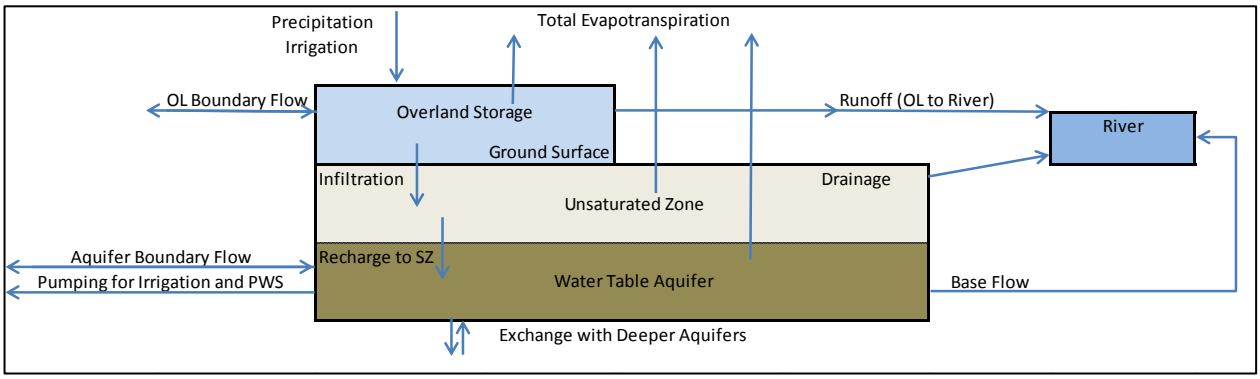

Figure 1-11. Conceptual Groundwater Budget

Groundwater Demands

An important component of the groundwater budget is water demands, which include public supply, private domestic consumption, and irrigation for agriculture and golf courses. The average annual public water demand over the ECM simulation period was about 46 mgd. In the CC ECM, pumping rates were defined by time series of reported monthly pumping for each well. The majority of potable water supply wells are located in the Golden Gate-Naples Bay, Rookery Bay, and Faka Union watersheds (Figure 1-12), but most water supply withdrawals are from the Lower Tamiami aquifer from wells located in the Golden Gate watershed.

The domestic groundwater demand from private wells (Figure 1-13) amounts to about 7.5 mgd and represents approximately 16 percent of the public supply demand.

Agricultural and golf course irrigation (Figure 1-14) use substantial amounts of water throughout Collier County. In the CC ECM, irrigated agricultural areas were defined from water use permits issued by the SFWMD. Model results indicated that irrigation for agriculture is on the same order of magnitude as public supply. 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. The golf course irrigation demand is about 2.5 mgd. Golf courses are located in the urbanized coastal areas in the Golden Gate – Naples Bay watershed.

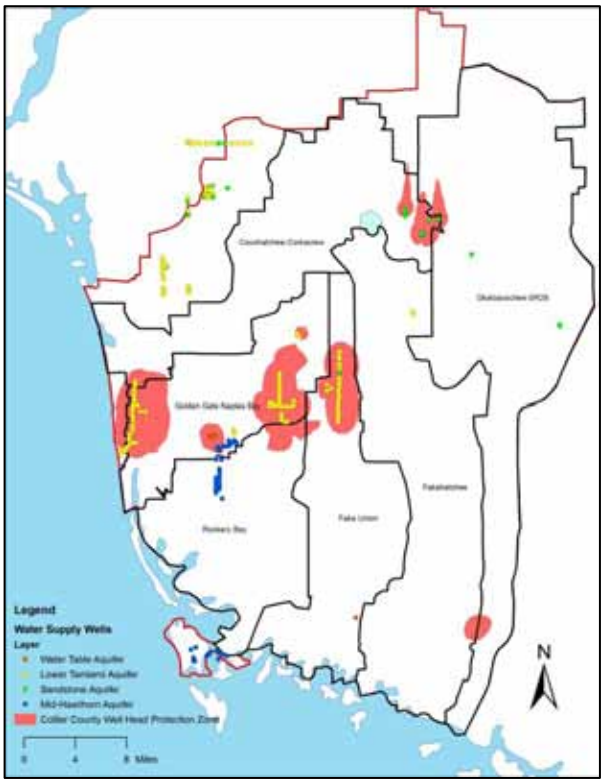

Figure 1-12. Well Head Protection Zones and Public Supply Wells

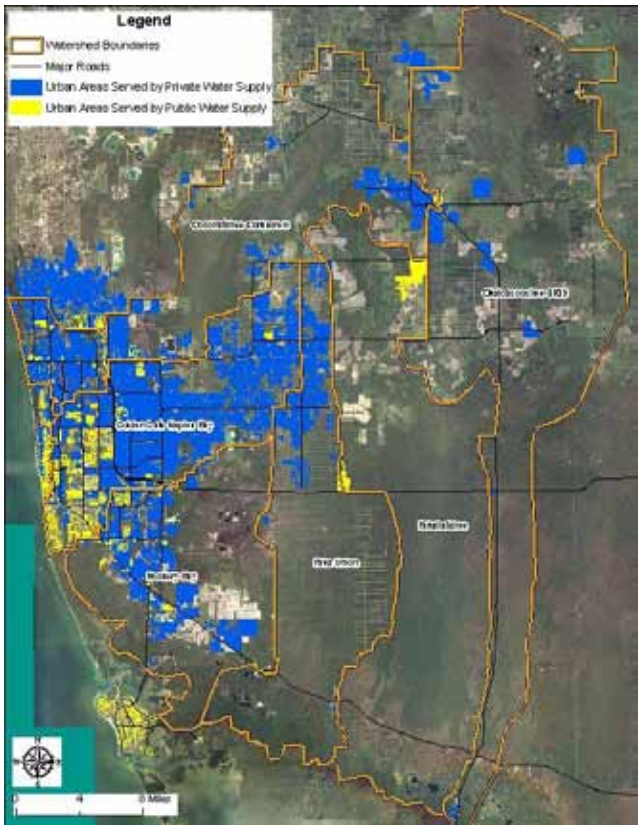

Figure 1-13. Urban Water Supply Distribution

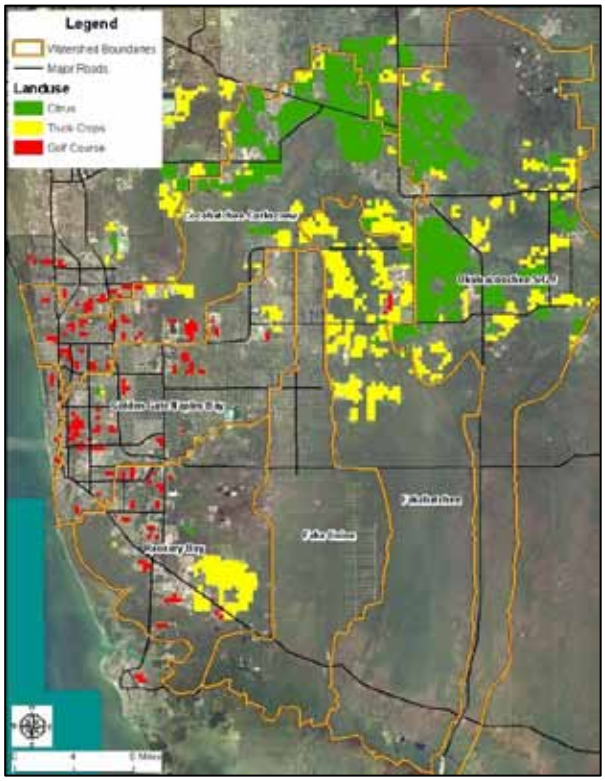

Figure 1-14. Agricultural and Golf Course Irrigated Areas

Groundwater Budget Results

Budgets were developed for each aquifer system and included recharge, transfer of water to adjacent aquifers, losses to baseflow, and pumping. As indicated previously, groundwater flows in the Water Table aquifer are influenced by the operations of the control structures. The Big Cypress Basin and Collier County, respectively, maintain the primary and secondary canal system through a rigorous water control operation schedule to limit groundwater inflows into the surface water system. Table 1-2 provides a summary of the groundwater budget results. Following are descriptions of conditions by aquifer.

Water Table aquifer

It is estimated that about 15 inches of water infiltrates from the unsaturated zone into the Water Table aquifer. An important result of the assessment is that approximately 26 percent is lost as baseflow to the drainage canal system. The average annual water transfer to the Lower Tamiami aquifer is approximately 8.5 inches, but almost the same amount (7.65 inches) flows back to the water table, depending on pumping conditions. During the dry season, the amount of water percolating down into the Lower Tamiami aquifer exceeds the amount entering the 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. Most of that is recovered during the wet season. Annually, an average 0.44 inch of water is pumped from the Water Table aquifer. Close to 90 percent of the pumping occurs during the dry season when demand is higher.

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 due to the difference in head elevation resulting from 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.

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 due to the difference in head elevation resulting from 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

As indicated above, the average annual inflow to the Lower Tamiami aquifer from the water table aquifer is 0.85 inches. In addition, there is a net annual inflow from the underlying Sandstone Aquifer of 1.5 inches. The net inflow appears to be driven by water withdrawals for potable water and irrigation that create a hydraulic gradient. 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 are net water inflows 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 pumping to meet irrigation needs. Although not as drastic as in the Water Table aquifer, the Lower Tamiami also loses about six (6) percent of the inflow as drainage canal baseflow.

Sandstone aquifer

No annual change in water storage was identified for the Sandstone aquifer, indicating equal seasonal inflows and outflows. There is a net loss of 1.5 inches of water from the Sandstone aquifer to the overlying Lower Tamiami aquifer, and a net gain of 0.3 inches from the underlying Mid-Hawthorn. 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-Hawthorn 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-Hawthorn Aquifer. The inflows from the Mid-Hawthorn are less than 1 inch annually and indicate little interaction between the Sandstone and Mid-Hawthorn aquifer systems

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

Mid-Hawthorn aquifer

The Mid-Hawthorn has little interaction with the overlying aquifer systems. Less than 0.3 inch of water moves between the Sandstone in Mid-Hawthorn 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 change in the Mid-Hawthorn aquifer as a result of inflows and withdrawals.

Groundwater Aquifer Levels

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

Water Table aquifer

The gradient of the average annual groundwater surface (Figure 1-15) 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 Water Table aquifer (Figure 1-16) illustrates 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 1-17 and 1-18. 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 1-19. 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 1-20) 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-Hawthorn aquifer

The depression in the Mid Hawthorn Aquifer at the boundary between the Golden Gate – Naples Bay and Rookery Bay (Figures 1-21 and 1-22) is likely associated with operations of the Mid-Hawthorn wellfield. This pattern of drawdown was not observed in the Sandstone aquifer; indicating that there is little interaction between the Mid-Hawthorn Aquifer and the overlying Sandstone aquifer.

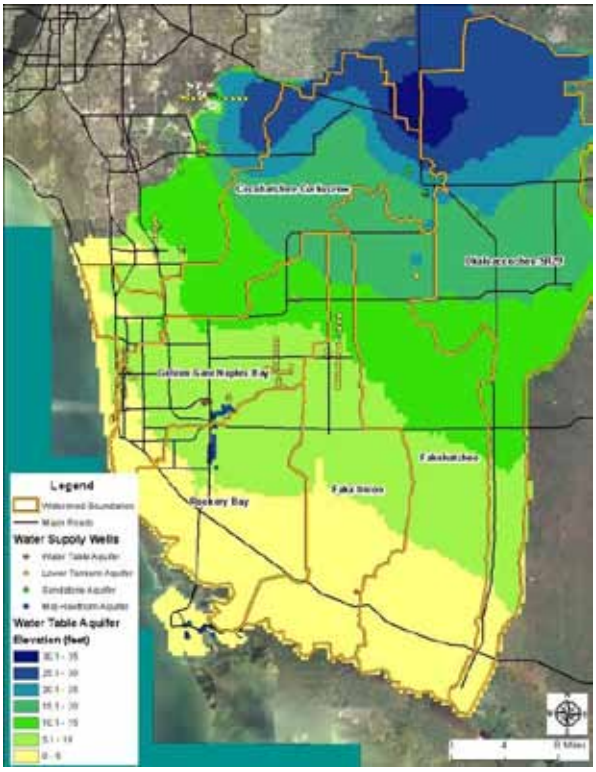

Figure 1-15. Water Table Aquifer Average Annual Groundwater Head Elevation

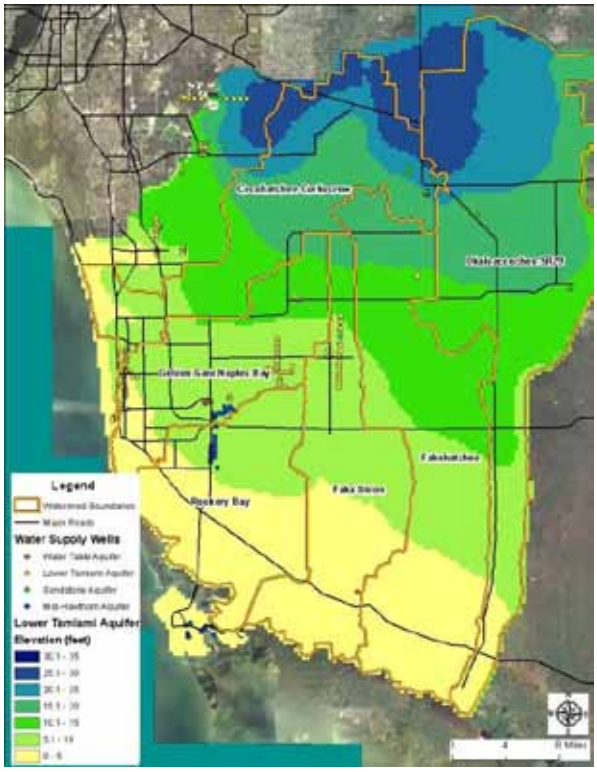

Figure 1-17. Lower Tamiami Aquifer Average Annual Groundwater Head Elevation

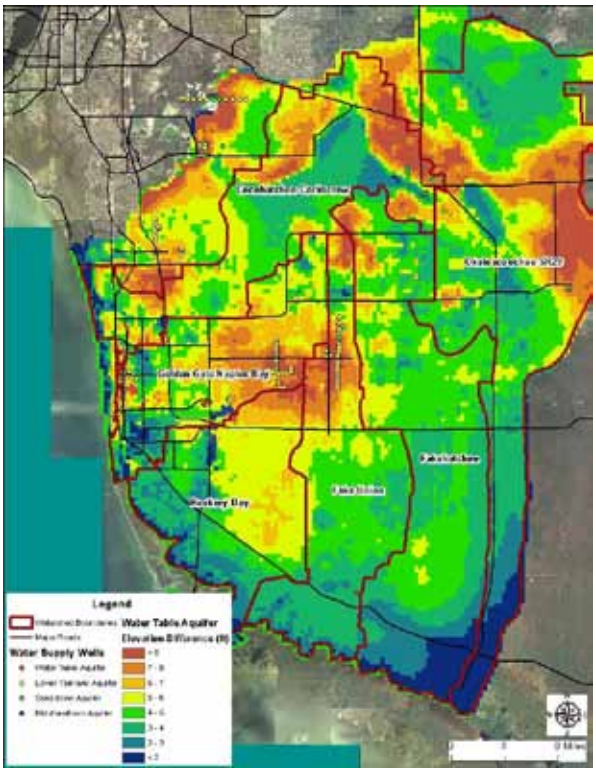

Figure 1-16. Water Table Aquifer Average Annual Groundwater Fluctuation

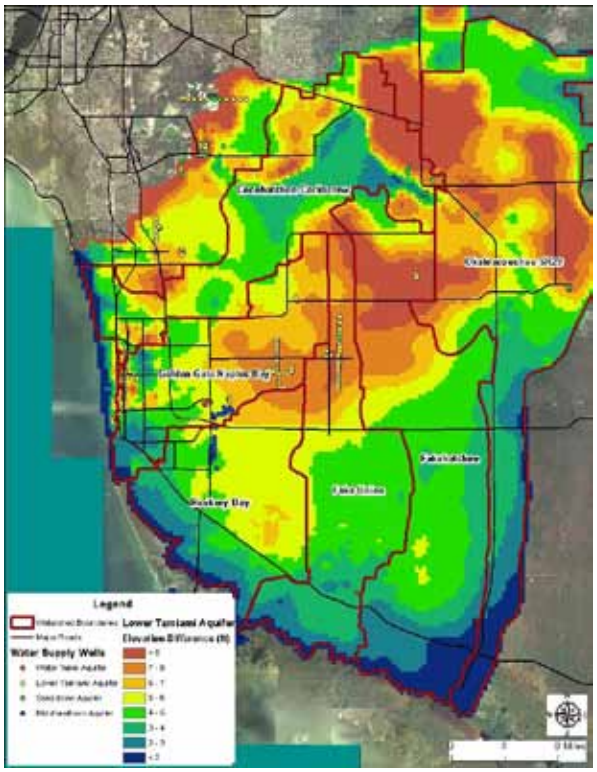

Figure 1-18. Lower Tamiami Aquifer Average Annual Groundwater Fluctuation

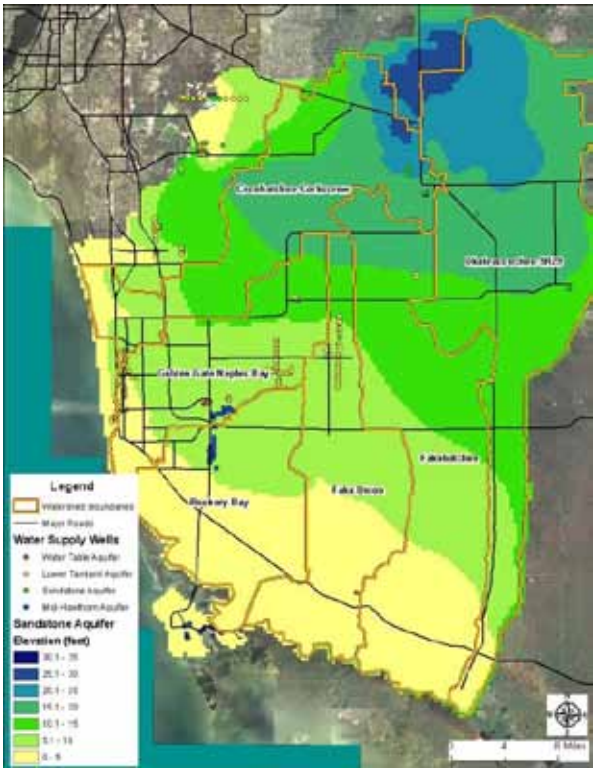

Figure 1-19. Sandstone Aquifer Average Annual Groundwater Head Elevation

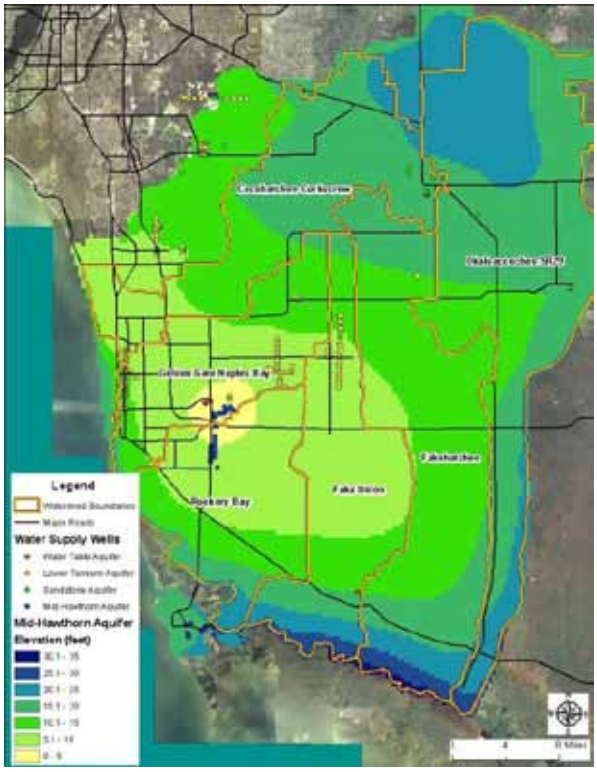

Figure 1-21. Mid-Hawthorn Aquifer Average Annual Groundwater Head Elevation

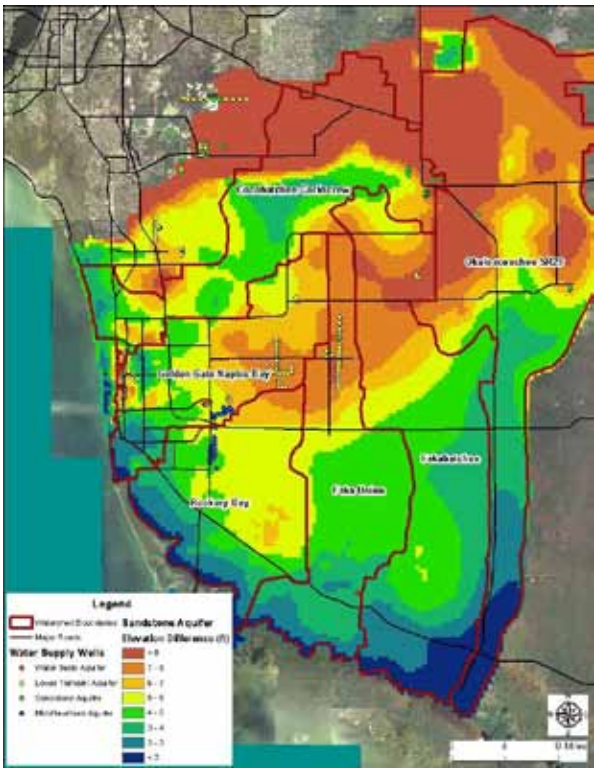

Figure 1-20. Sandstone Aquifer Average Annual Groundwater Fluctuation

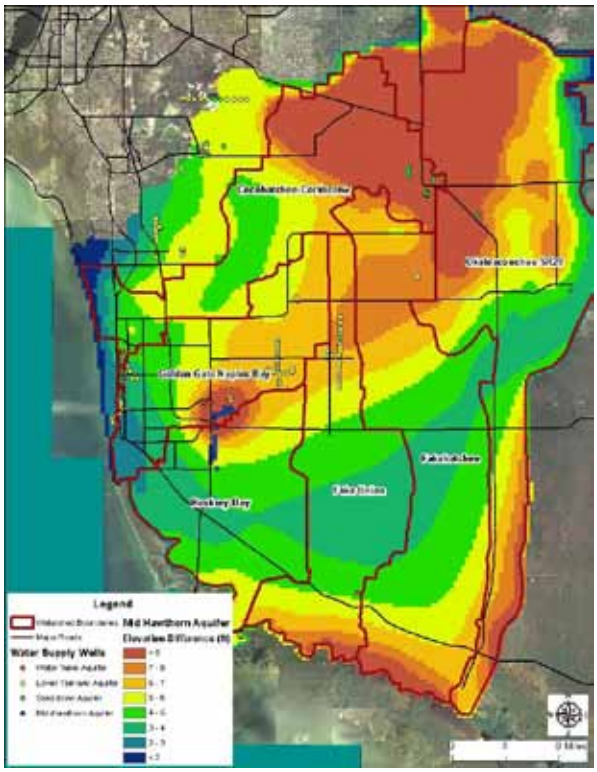

Figure 1-22. Mid-Hawthorn Aquifer Average Annual Groundwater Fluctuation

Comparison to Pre-Development Conditions

The overall effect of groundwater withdrawals was assessed by comparing groundwater head elevations for existing and pre-development conditions. The process consisted of comparing the average groundwater elevation water surface elevation or potentiometric head) simulated in the NSM (pre-development conditions) and the ECM (existing conditions). Results were mapped for the Water Table, Lower Tamiami, and Sandstone aquifers. The NSM did not include the Mid Hawthorn Aquifer and so no direct comparison was possible to assess drawdown impacts in the Mid Hawthorn Aquifer. In the Mid Hawthorn Aquifer, head elevations during periods of pumping were compared to head elevations during periods with no pumping.

Results indicated that groundwater levels have declined in the Water Table, Lower Tamiami, and Sandstone aquifers by more than 4 feet in portions of all six watersheds (Figure 1-23). For example, the "head difference", or change in groundwater elevation of the Water Table aquifer in the wellhead protection zone in the Golden Gate-Naples Bay watershed experienced a decline of 4 to 4.9 feet. Watershed most impacted by the declining groundwater levels are the Golden Gate-Naples Bay, Faka Union, and Okaloacoochee/SR 29. Impacts are less severe in the Rookery Bay and Fakahatchee watersheds because of the location of the existing wellfields.

Patterns of decline were similar among the aquifers and coincide with the location of the public supply wellfields and well head protection zones. Modeled drawdowns are somewhat greater in the Lower Tamiami and Sandstone aquifers (Figures 1-24 and 1-25). As with the other aquifers, the greatest drawdown in the Mid Hawthorn Aquifer was observed in the Mid Hawthorn well field in the southern portion of the Golden Gate-Naples Bay watershed.

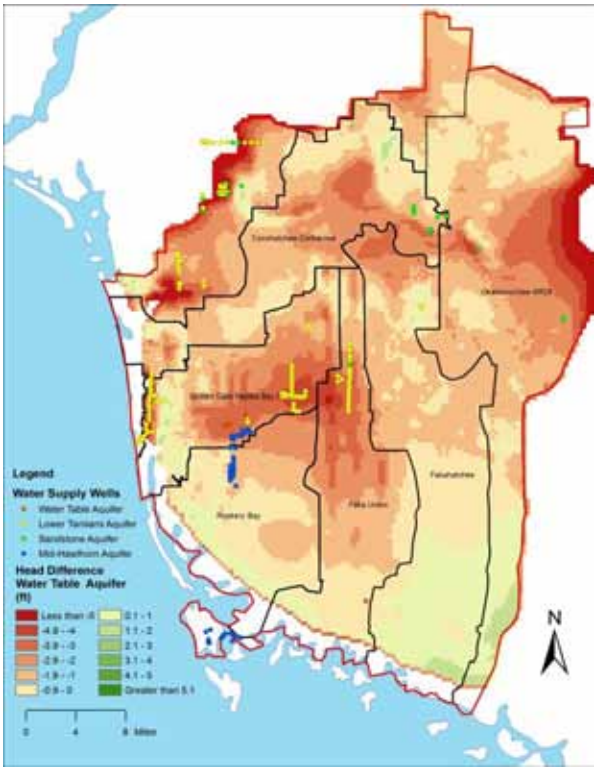

Figure 1-23. Water Table Aquifer Average Annual Groundwater Head Elevation Difference (ECM-NSM)

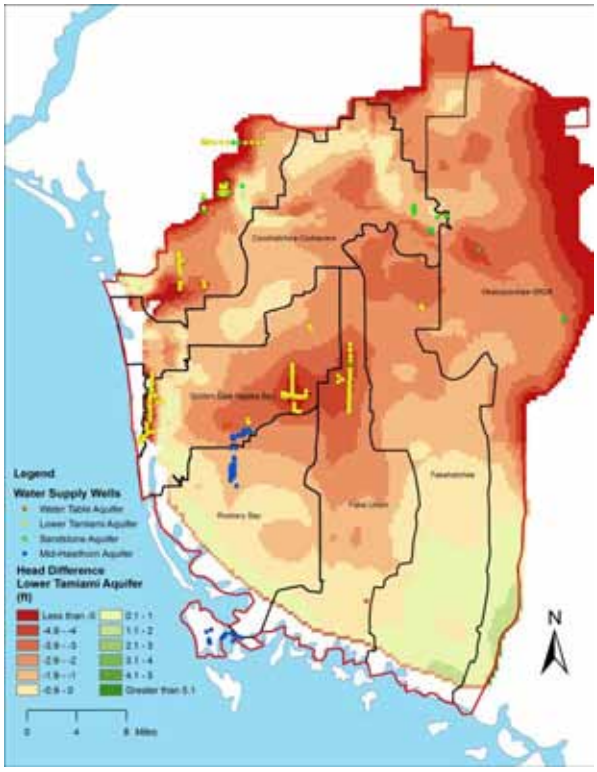

Figure 1-24. Lower Tamiami Aquifer Average Annual Groundwater Head Elevation Difference (ECM-NSM)

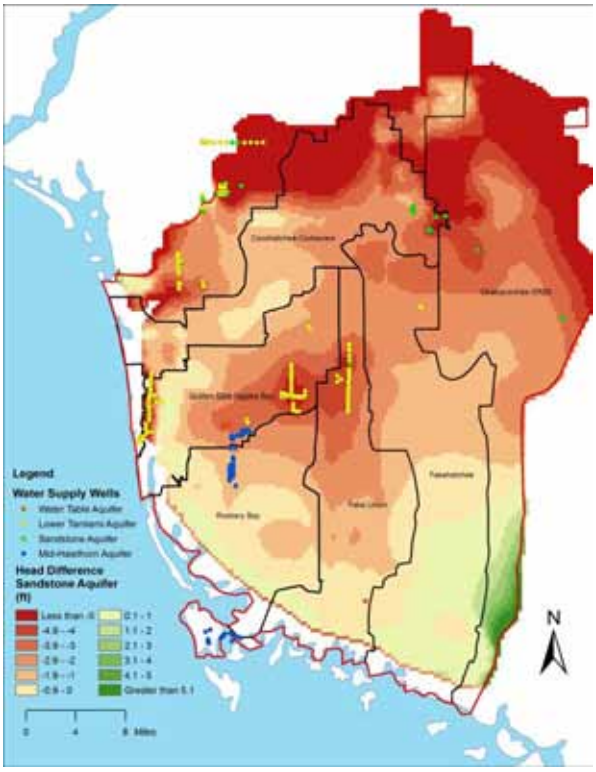

Figure 1-25. Sandstone Aquifer Average Annual Groundwater Head Elevation Difference (ECM-NSM)

Effects of Increased Wellfield Pumping Rates

A computer model sensitivity run was conducted to evaluate the effects of increasing pumping rates from the existing wellfields. Although water demands in Collier County are expected to increase by 50 percent in the next 20 years, it was considered that an assumed 10 percent increase from the existing wellfields would provide meaningful results to assess potential impacts. For this sensitivity analysis, it was also assumed no changes on irrigation or domestic self supply demands.

The initial sensitivity test consisted of comparing the average annual minimum head elevation in each aquifer predicted by the ECM against the average annual head elevation in each aquifer as predicted by the model with increased pumping. The results are shown in maps that define the change in drawdown resulting from the increased pumping in each aquifer. Figures 1-26 – 1-29 show the increased drawdown in each aquifer.

A second sensitivity test considered the effect of increased pumping during a prolonged dry season. The dry season of 2007 which began on November 1, 2006 and continued through June 2007 followed a wet season with little rainfall. This average groundwater elevation calculated for the dry season 2007 was used to evaluate the effect of increased pumping during prolonged drought conditions. Figures 1-30 – 1-33 show the extent of the increased drawdown during the extended dry period.

In each of the aquifer systems, the extent of the predicted areas influenced by pumping increases as a result of increased pumping. The results show that during periods of extended drought, the area of influence extends from the City of Naples wellfield into the northern portions of the Fakahatchee watershed and that individual areas of influence have merged into a single area of influence that encompasses almost the entire area of the Golden Gate – Naples Bay watershed.

The results indicate that the availability of groundwater is limited to meet long-term water supply needs for Collier County. Increased pumping is predicted to increase the risk of salt water intrusion and potentially affect availability of water for domestic self supply from the Water Table and Lower Tamiami aquifer systems.

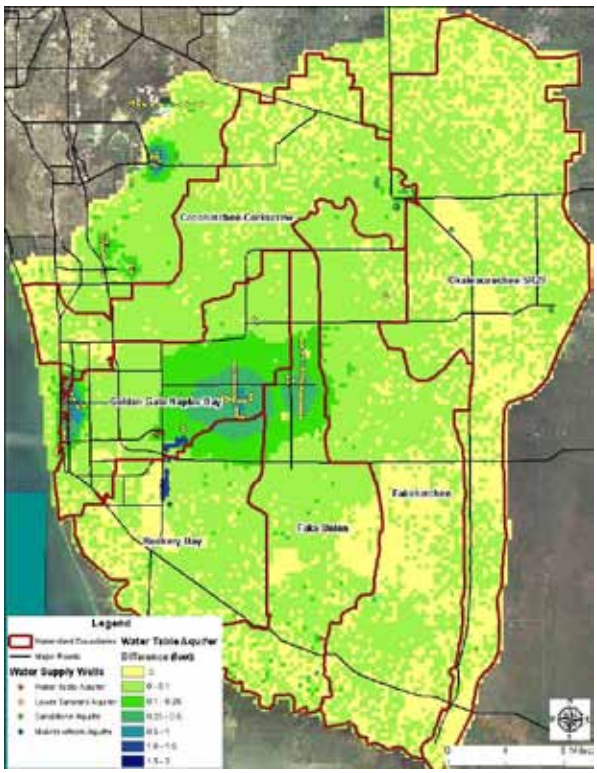

Figure 1-26. Water Table Aquifer Average Increase in Drawdown with 10% Increase in Groundwater Withdrawal

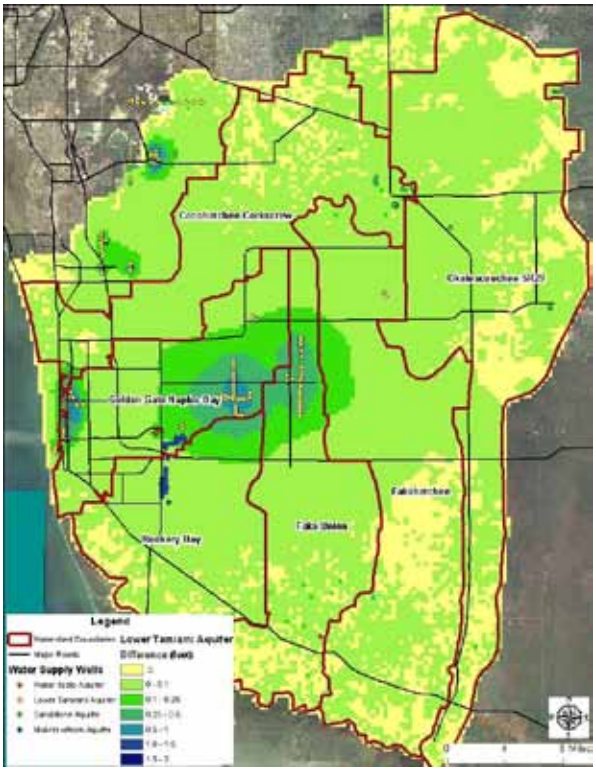

Figure 1-27. Lower Tamiami Aquifer Average Increase in Drawdown with 10% Increase in Groundwater Withdrawal

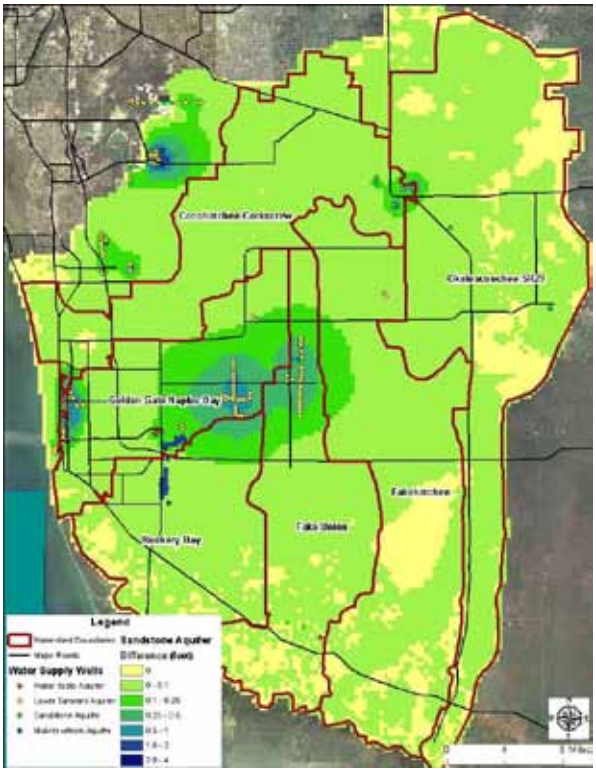

Figure 1-28. Sandstone Aquifer Average Increase in Drawdown with 10% Increase in Groundwater Withdrawal

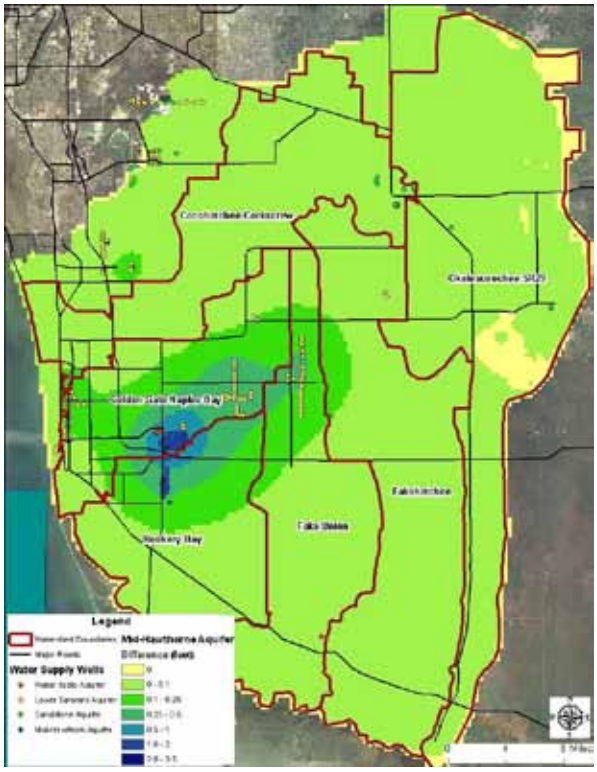

Figure 1-29. Mid-Hawthorn Aquifer Average Increase in Drawdown with 10% Increase in Groundwater Withdrawal

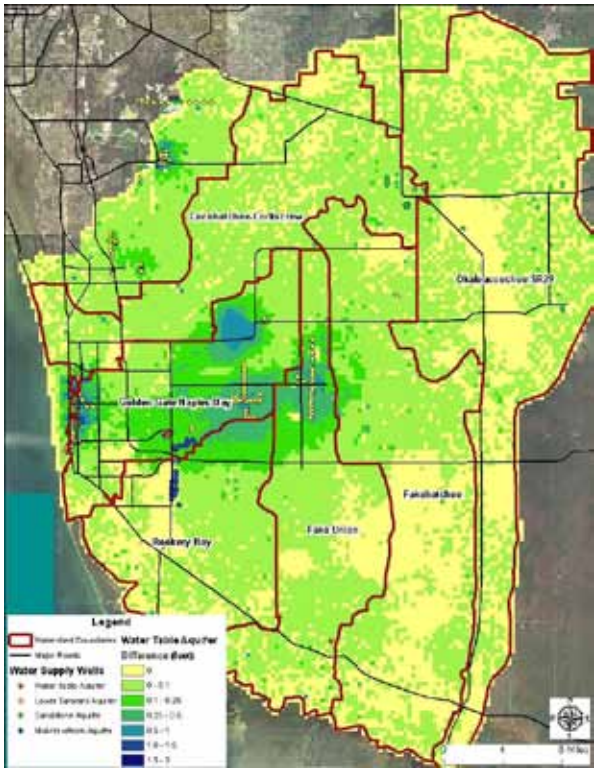

Figure 1-30. Water Table Aquifer Average Driest Dry Season Increase in Drawdown with 10% Increase in Groundwater Withdrawal

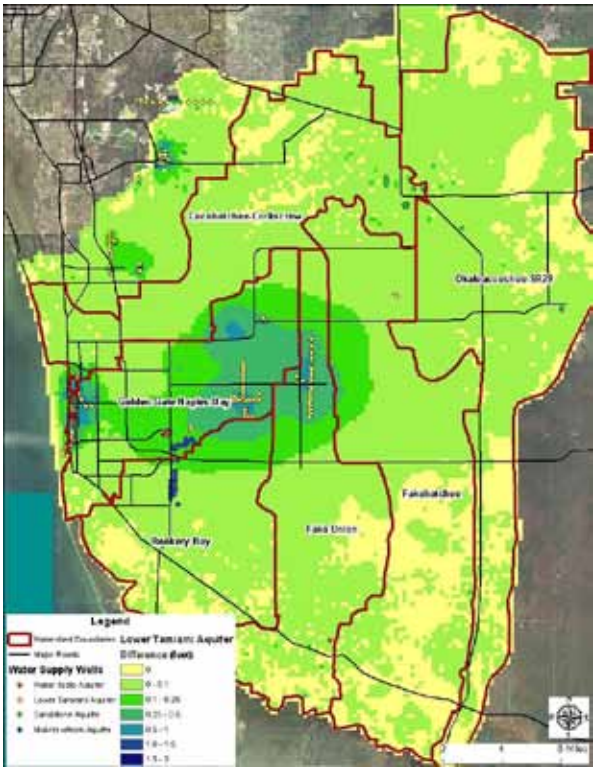

Figure 1-31. Lower Tamiami Aquifer Average Driest Dry Season Increase in Drawdown with 10% Increase in Groundwater Withdrawal

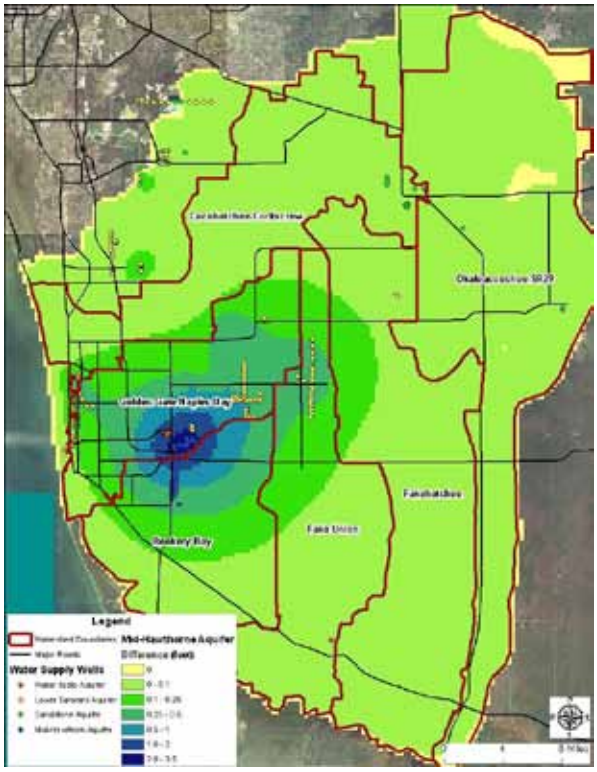

Figure 1-33. Mid Hawthorn Aquifer Average Driest Dry Season Increase in Drawdown with 10% Increase in Groundwater Withdrawal

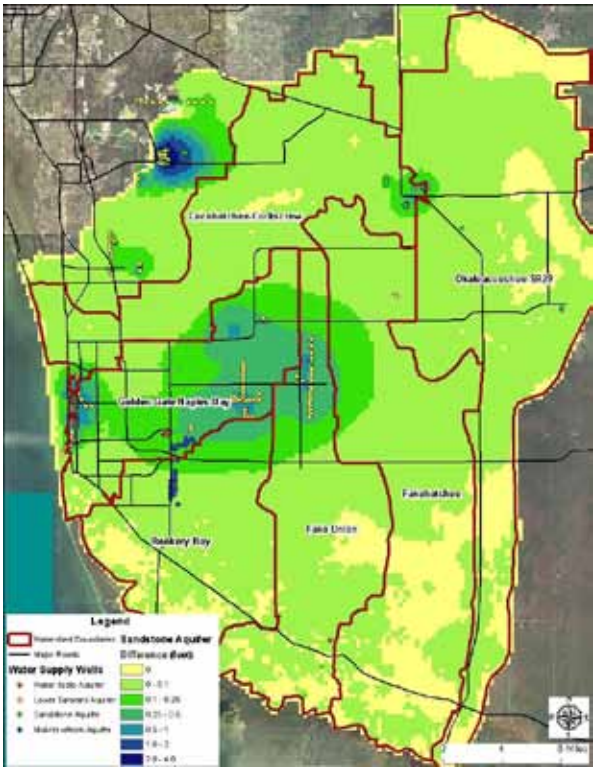

Figure 1-32. Sandstone Aquifer Average Driest Dry Season Increase in Drawdown with 10% Increase in Groundwater Withdrawal

1.6: Groundwater Quality and Groundwater Pollutant Loads

Groundwater quality was characterized and pollutant loads to canals were estimated for Collier County watersheds. Data indicated that dissolved oxygen concentration in groundwater is significantly lower than the surface water standard, whereas total nitrogen and phosphorus concentrations exceed corresponding surface water criteria. Iron concentrations also exceed the surface water standard.

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 the National Pollutant Discharge Elimination System (NPDES) pollutant list. In addition, the analyses included a preliminary regional assessment of the potential impacts of septic tanks on groundwater quality in the watersheds. This effort focused on the groundwater quality in the Water Table 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.

Pollutant loads associated with groundwater discharges from the Water Table and Lower Tamiami aquifers to the surface water system were determined based on the calculated baseflow to the drainage network and the predicted average concentrations of each parameter in groundwater.

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, Fakahatchee, and Okaloacoochee/SR 29 watersheds, or the eastern portion of the Golden Gate watershed (Figure 1-34).

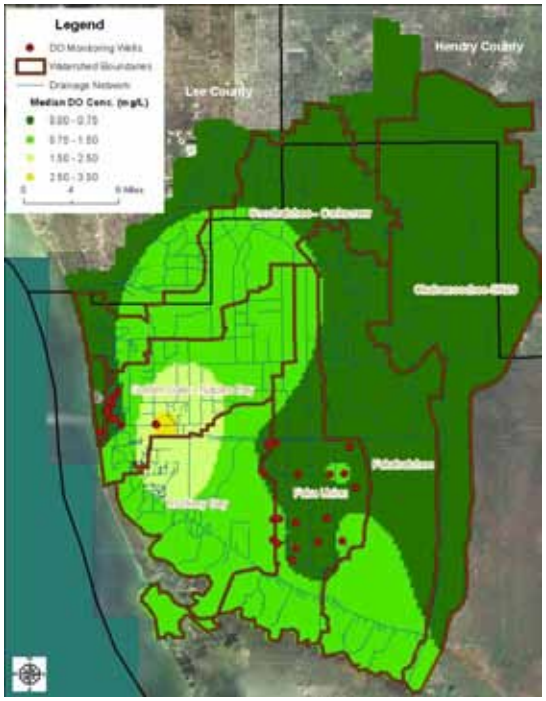

Figure 1-34. Dissolved Oxygen Concentration Interpolation

The data evaluation predicts that dissolved oxygen concentrations do not vary significantly across the study area and are less than 3.5 mg/L. Adamski (2001) states that dissolved-oxygen concentrations in ground

water generally decrease over time as the oxygen in the water reacts with minerals and organic material; therefore, it is assumed that the predicted results are appropriate to provide a preliminary assessment of groundwater quality in the watersheds. It is recommended that additional groundwater monitoring for dissolved oxygen be completed to verify this assumption.

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 from the water quality analyses completed during this project indicated no significant difference in total nitrogen among the wells, except for a few identified areas. Other than at those locations, it was considered that the analysis provided adequate results. Wells for which water exceeded the screening criteria for nitrogen are 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 (Table 1-3).

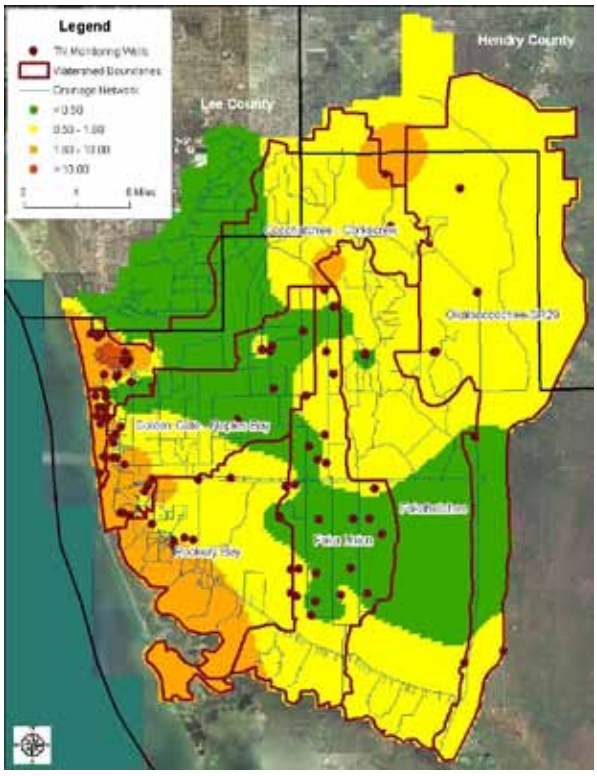

Figure 1-35. Groundwater Total Nitrogen Concentration

Groundwater total nitrogen concentrations (Figure 1-35) exceeded FDEP screening criteria for streams (1.6 mg/L) in the Golden Gate-Naples Bay and Rookery Bay watersheds as well. 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.

Table 1-3. Predicted Groundwater Pollutant Loads

Watershed	Groundwater Pollutant Load			
	TN	TP	Cu	Fe
	tons/yr	tons/yr	tons/yr	tons/yr
Cocohatchee - Corkscrew	53	4	0.06	53
Golden Gate - Naples Bay	76	4	0.17	212
Rookery Bay	74	8	0.05	104
Faka Union/ Fakahatchee/ Okaloacoochee -SR29	89	5	0.27	124
	Groundwater Pollutant Load			
	TN	TP	Cu	Fe
	lbs/ac/yr	lbs/ac/yr	lbs/ac/yr	lbs/ac/yr
Cocohatchee - Corkscrew	0.831	0.067	0.001	0.82
Golden Gate - Naples Bay	1.729	0.094	0.004	4.83
Rookery Bay	1.518	0.167	0.001	2.14
Faka Union/ Fakahatchee/ Okaloacoochee -SR29	0.4	0.023	0.001	0.56

The largest total predicted TN groundwater load in lbs acre/ year was found in the Golden Gate – Naples Bay watershed. Naples Bay is listed as impaired for DO with the likely cause identified as nutrients. The water budget analysis indicated that baseflow makes up more than 50 percent of discharge from the watershed annually and more than 70 percent of discharge during the dry season. It is likely that baseflow contributes to the low DO concentrations in the estuary; however nutrients entering the groundwater system and discharging to the canal network may also contribute to the impairment.

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). Results indicated 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.

Given that only one WBID (3278U – Rookery Bay Coastal Segment) in the study area has been identified as impaired for nutrients, it appears that high groundwater total nitrogen and total phosphorus (Figures 1-35 and 1-36) concentrations are not currently determining surface water quality conditions. However, the relatively high groundwater concentrations in the groundwater at some of the reuse monitoring wells may indicate a risk of groundwater pollution loads (Table 1-3).

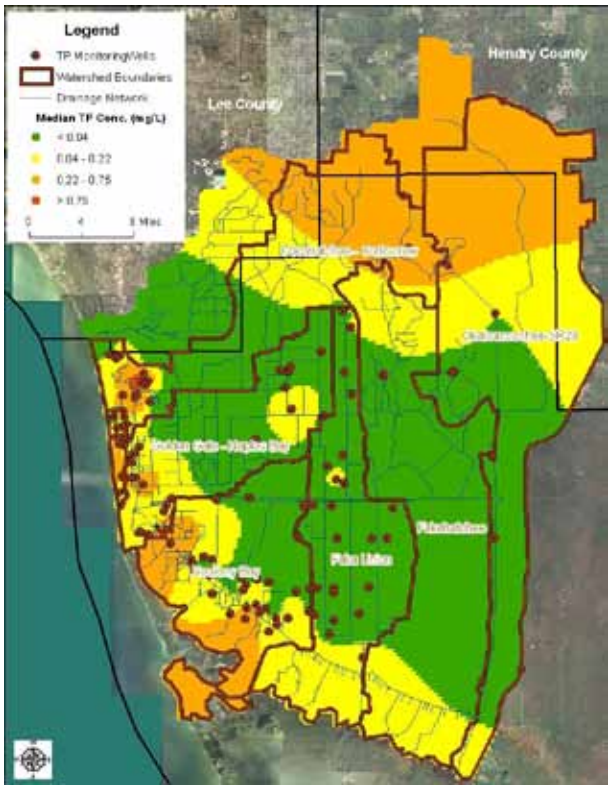

Figure 1-36. Groundwater Total Phosphorus Concentration

Also similar to nitrogen, a potential identified problem with the analysis was that many of the wells along the coast are associated with the County's reuse monitoring program. Unfortunately, as opposed to the TN analysis, the reuse wells showing higher TP concentrations do not define specific problem areas, but are present at various locations along the coast. Therefore some of the phosphorus hot spots, particularly along the coast in the Cocohatchee-Corkscrew and Golden Gate – Naples Bay watersheds may be associated with having information only from reuse wells. Better data is needed to better define the groundwater concentration of total phosphorus in the study area. In any case it was considered that the analysis provided meaningful results.

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 in stream 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 indicate that the groundwater concentration of iron in most of the study area exceeds the in stream water quality standard of 1,000 µg/L. These results suggest that groundwater entering the surface water system as baseflow (Table 1-3) is a potential cause of the identified iron surface water impairment. As indicated previously, more detailed source identification efforts are necessary to define the cause of the reported iron impairments. A special case is with the Rookery Bay watershed where no iron impairments have been identified, although groundwater concentrations are predicted to be elevated in a portion of the watershed. A close examination of the data revealed that the highest rates of baseflow occur in areas where the predicted iron concentration in groundwater is below the state standard. As human activities may also be sources of iron, Collier County should collaborate with FDEP to complete further source evaluation studies.

Groundwater Pollutant Loading to the Surface Water Network

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

Results of the analysis conducted as part of this project indicated that the majority of the area-wide pollution load originates in the surface water system. About 26 and 12 percent of the total nitrogen and total phosphorus load into the estuaries, respectively, are from groundwater sources, whereas the groundwater load of copper represents about 25 percent of the total. It is to be noted, however, that Rookery Bay is the only watershed for which the predicted total nitrogen load from groundwater is approximately the same as the surface water load. That can be attributed to the estimated higher groundwater nitrogen concentrations along the coast.

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 provide a preliminary and region-wide assessment of 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. Results of the analysis indicated that, on a region-wide basis, there is little correlation between total and nitrogen and total phosphorus and septic tank density. It should be kept in mind that this is a regional analysis that does not reflect localized problems.

Conclusions

- Kriging interpolation indicated that dissolved oxygen concentrations in groundwater are less than 1.5 mg/L throughout most of Collier County, compared to the surface water standard of 5 mg/L. Given the significant amount of baseflow entering the system, it is likely that baseflow contributes to the low dissolved oxygen levels in the canal network, However, human activities are also factors that can contribute to reduced dissolved oxygen concentrations.
- 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.
- Pollution load estimates indicate that groundwater is a potential contributor to the nutrient impairment in the Rookery Bay watershed.
- Copper concentrations in groundwater are typically 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 potential source of iron to the surface water system.
- A preliminary assessment indicated 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. However, as this is a regional analysis, site specific studies in problem areas may be appropriate to fully define the nutrient contributions from septic tanks.
- It was suspected that the use of data from wells in the County's reuse program may have introduced bias in the analysis. A data review completed as part of this project indicated that the results are adequate.

1.7: Natural Systems: Reference Period Comparison

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.

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 the natural system 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. Figure 1-37 shows a comparison of pre-development and 2007 vegetation maps.

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).

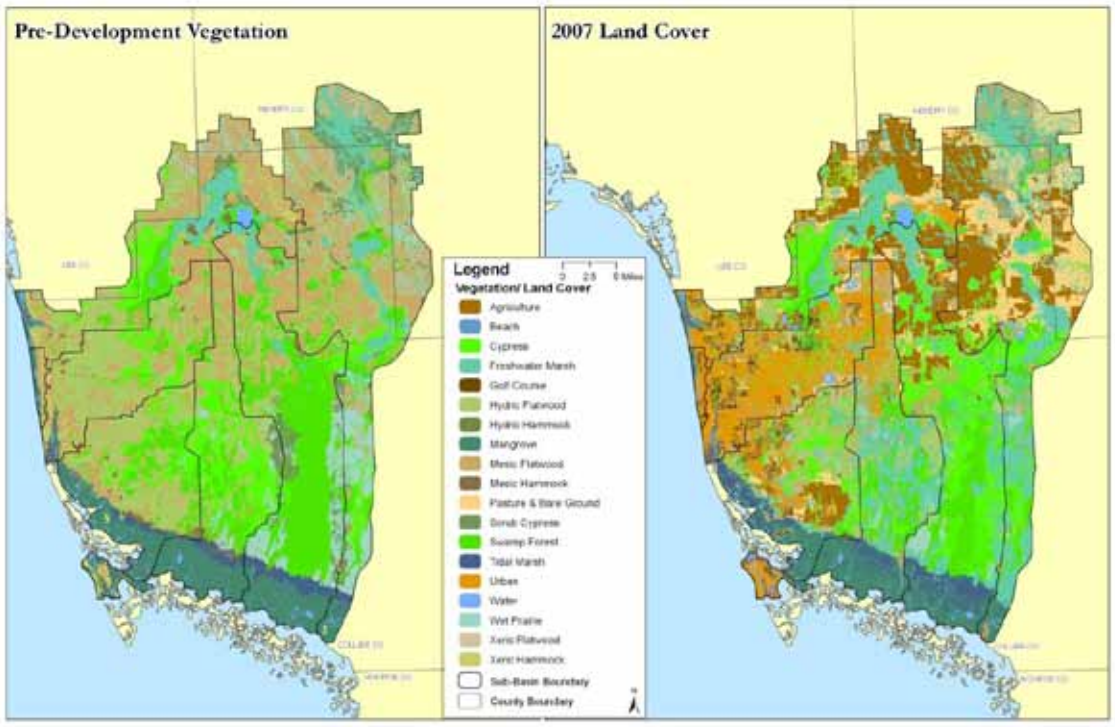

Figure 1-37. Model-Wide Overview, Land Use and Land Cover Changes from Pre-Development to 2007

1.8: Natural Systems: 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 2).

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 resource protection-based performance measures for the evaluation of proposed restoration projects (described in Chapter 2).

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 condition of a natural system for the functional assessment addresses landscape position, vegetation, and hydrology. Scores are assigned on a scale of 1 to 10, based on the degree of change compared to a reference (in this case pre-development). A score of 10 is appropriate where a site has retained 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. Whole-number scores between 1 and 9 are used as appropriate to represent interpolated conditions.

The functional assessment method applied herein relied 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. As indicated previously, 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 (Figure 1-38) represent the 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 scores for agriculture and other developed areas reflect the degree of support for wetland resources. Scores are assigned to each community based on the information listed below and are based on conversion between FLUCCS designations and the previously developed Pre-Development Vegetation Map (PDVM). No other values were assigned during this evaluation.

- Score=10. Natural water systems that are present in both existing and pre-development conditions and areas that retained the same dominant stratum and ecosystem type (freshwater forested wetland to freshwater forested wetland).
- Score=8. Areas where the vegetation has shifted, but has retained the same ecosystem type (forested freshwater wetland to herbaceous freshwater wetland).
- Score=6. Natural systems that have been converted to an artificial water body.

- Score=4. Natural systems that have been converted to agriculture.
- Score=0. Natural systems that have been converted to a developed land use such as high density urban or bare ground.

The hydrology score (Figure 1-39) is a measure of the 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 connectivity, buffers, and corridors. Higher scores (Figure 1-40) 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 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 values (the least change from pre-development), when compared with the other watersheds. The measured functional values were less in the Rookery Bay and Cocohatchee-Corkscrew watersheds, and least in the Golden Gate-Naples Bay watershed (see Table 1-4).

Table 1-4. Average Functional Values of Non-Urban Lands, by Watershed

Watershed	Non-Urban Acres	Average Vegetation Score	Average Hydrologic 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
Faka Union/ Okaloacoochee SR 29/ Fakahatchee	431,414	9	6	9

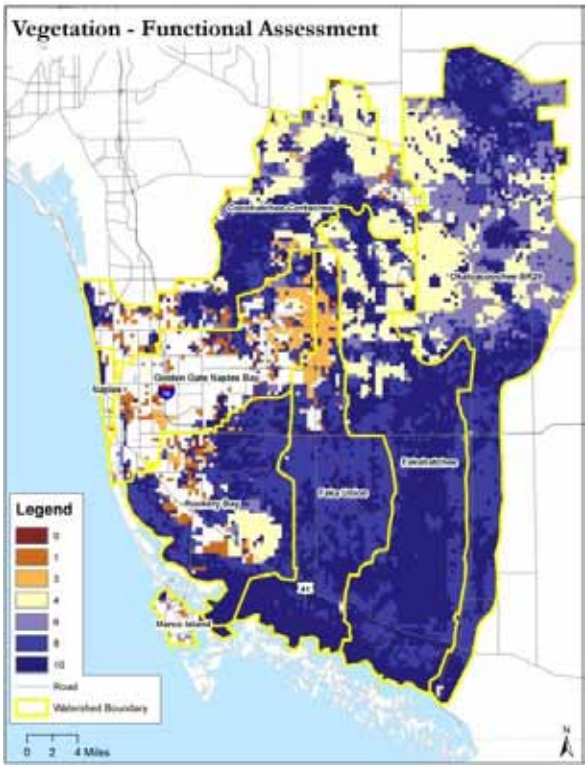

Figure 1-38. Vegetation, Functional Assessment

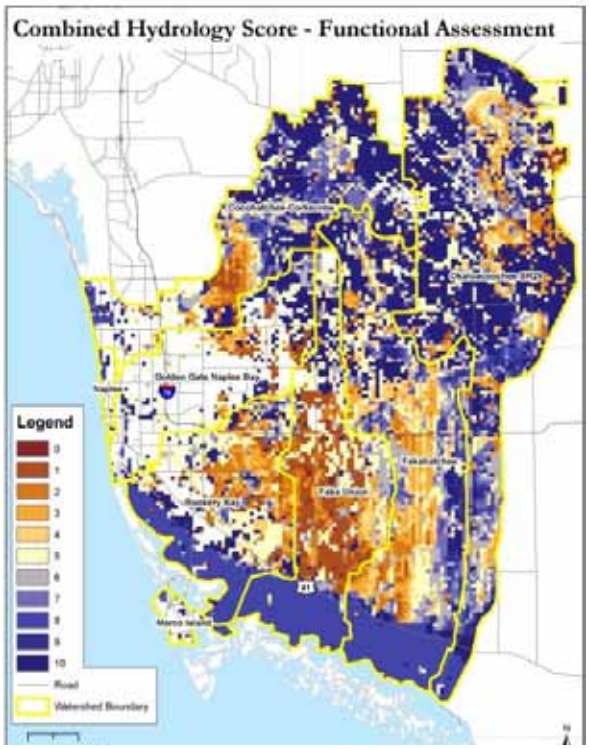

Figure 1-39. Combined Hydrology Score, Functional Assessment

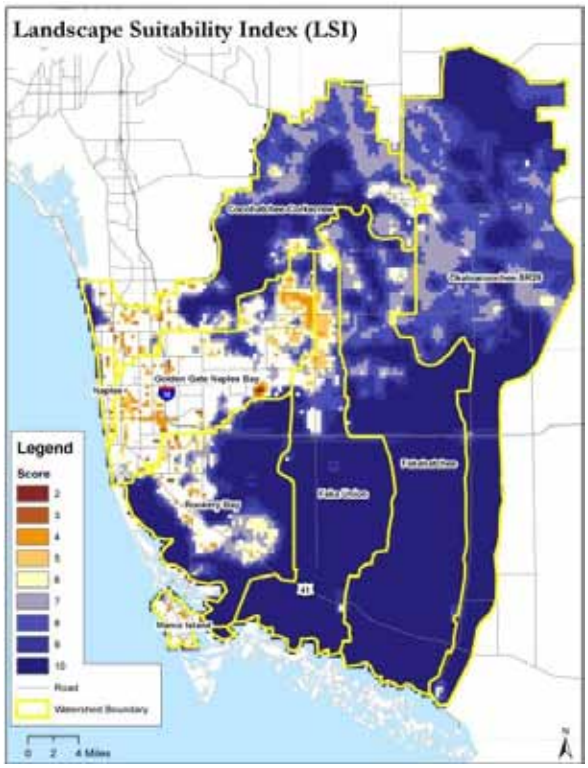

Figure 1-40. Landscape Suitability Index (LSI)

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 large ecological restoration projects. Even the non-urban areas have relatively low ecological value, with an average vegetation score of 5 and hydrology and LSI scores of 6. However, this present opportunities for both restoration of natural areas, and improved urban landscape through policy changes regarding new development.

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 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.

Resource Protective Areas

The natural system functional assessment methodology is described in detail in Volume 4, Section 2.8. Results of the analysis were also used to identify resource protective lands that are not included in any of the existing land conservation or land protection programs such that recommendations about protection measures can be assessed as part of the CCWMP. The procedure consisted of comparing the total extent of resource protective lands identified in this study with the extent of the areas included in the existing land conservation and protection programs. Results shown in Figure 1-41indicate that much of the identified resource-protective lands are currently included in the existing protection programs. Recommendations regarding protection for the areas not currently protected are described in Volume 3 of the WMP.

Conclusions

Vegetation, hydrology, and landscape scores were developed to assess functional values of the natural system. These scores can be used as indicators of hydrologic restoration and will provide opportunities for quantifying the impact of future natural resources restoration programs in Collier County. As expected, the areas most impacted by human activities, particularly in the Golden Gate – Naples Bay and Rookery Bay watersheds, received the lowest scores, whereas the Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds, individually and as a whole, have retained relatively high functional values,

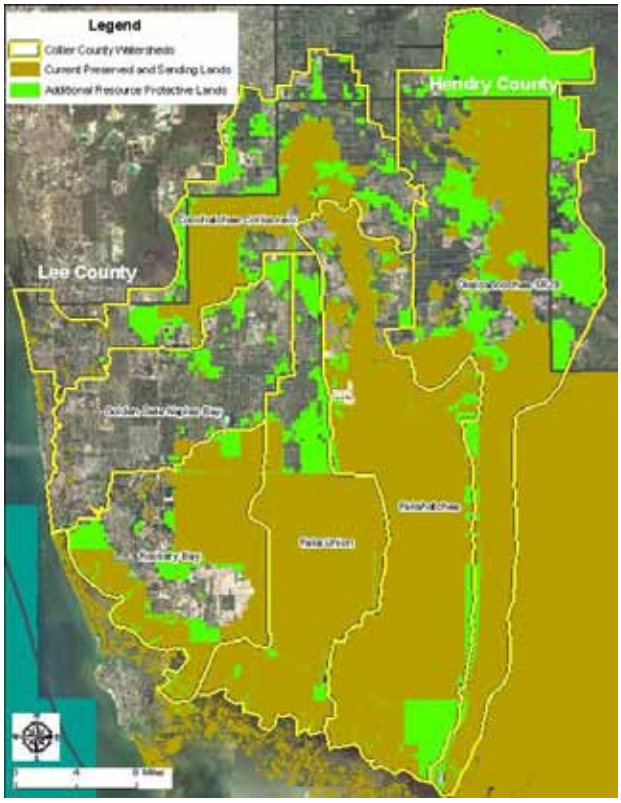

Figure 1-41. Resource Protective Lands not Currently Protected

1.9: 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.

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.

Methods

The changes in freshwater flows (surplus and deficits) into the estuaries 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.

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.

Predevelopment conditions were characterized using the results of the Natural Systems Model (NSM), which was developed for the Southwest Florida Feasibility Study (SWFFS) area. The NSM represents land use and conveyance systems under pre-development conditions. Also, it assumes the absence of the existing water control structures. A full description of the model can be found in the report titled "Final Report, Natural Systems Model (NSM) Scenario Southwest Florida Feasibility Study" (SDI, 2007). The model domain includes the BCB as well as the Caloosahatchee and Estero River Basins.

The results of the ECM and NSM comparisons were validated against salinity:flow analysis conducted using available salinity and flow data to create salinity:flow relationships. Flow deficits or surpluses required to reach historical salinity targets were calculated at each of the monitoring stations shown in Figure 1-42. These results were then compared with those from the ECM and NSM analysis.

Results

The analysis included average annual, seasonal, and monthly assessments of flow comparisons. Figures 1-43 and 1-44 (red bars) depict the average surplus and/or deficit of fresh water inflows to each of the estuaries during the wet and dry seasons, respectively, based on the ECM to NSM comparison. More detailed discussions are included in Volume 4 of this report. Following are summaries of finding for each estuary.

Wiggins Pass Estuary

Analyses results indicate that Wiggins Pass is experiencing a surplus of approximately two inches of freshwater inflows compared to pre-development conditions during the wet season. This is likely due to new development in the western portion of the watershed, particularly along the Cocohatchee canal. The monthly flow analysis indicates that flow increases begin earlier in the year and continue longer than in the pre-development period.

Naples Bay Estuary

The magnitude of development experienced by this watershed, coupled with the extensive network of drainage canals and the substantial disruption of drainage patterns (the Golden Gate Main Canal effectively increased the extent of the watershed drainage area from approximately 50 to approximately 135 square miles), has created an average freshwater

surplus of close to 20 inches during the wet season. A surplus of close to seven inches has also been estimated for the dry season. The dry season surplus occurred in June, November, and December. The excess flows during November and December shown by the monthly analysis are likely due to delayed runoff resulting from above-average rainfall during 2003 and 2005. The results do not indicate a significant change in the timing of discharges. These results are consistent with previous studies (Black, Crow, and Eidsness, 1974; SFWMD, 2007).

Figure 1-42. Flow and Salinity Monitoring Stations in Collier County

Rookery Bay Estuary

The main impact of human activities in terms of freshwater discharges from the watershed have related to timing. The ECM vs. NSM results indicate a small flow deficit during the dry season (October through May) and a flow surplus during the wet season (June through September). Results of the ECM and the NSM indicate that the total average annual volume discharged to the estuary is similar. During the dry season, the flow surplus can be attributed to the flow contributions from the secondary and uncontrolled releases to the estuary systems.

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 a freshwater surplus is discharged to the estuary primarily during the wet season. The excess wet season flow 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.

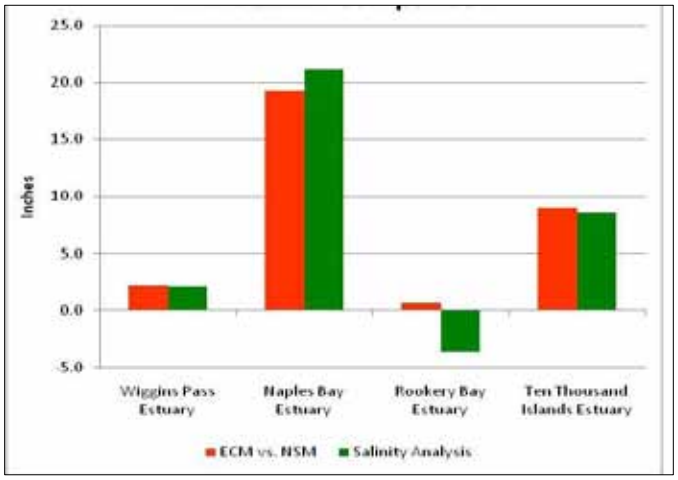

Figure 1-43. Average Wet Season Freshwater Surplus/Deficit in Collier County Estuaries

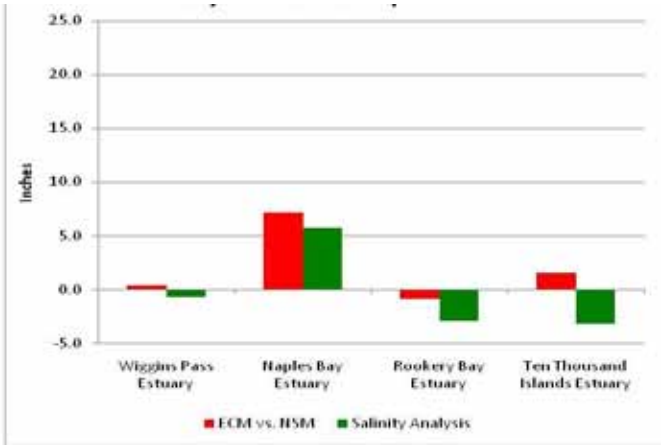

Figure 1-44. Average Dry Season Freshwater Surplus/Deficit in Collier County Estuaries

Salinity Analysis

The ECM and NSM results were further verified by conducting a salinity analysis that consisted of analyzing measured salinities at the discharge points and comparing them to a location that has been subject to minimum historical development impacts. The estuarine surplus or deficit of freshwater discharges was then estimated based on calculated salinity vs. flow

relationships. Results are also shown in Figures 1-43 and 1-44 (green bars).

The similarity of the ECM vs. NSM results to those from the salinity analysis (for wet and dry seasons) provides confidence in the results of the overall analysis.

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.

The salinity analysis also shows that 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.

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 discussed in Chapter 2).

1.10: Quality of Freshwater Inflows

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. No TMDL-related data were available from the Collier County Health Department. 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 the state water quality standards. As no numeric State standards exist for nutrients, data were compared to FDEP's screening criteria for streams. In addition, at the direction of the County, data were compared to FDEP's Hendry Creek TMDL concentrations because of the potential of those standards being used in the future for assessing fresh water outfalls in Collier County.

Results

Wiggins Pass

Wiggins Pass is the receiving water for the Cocohatchee-Corkscrew watershed. The estuary is presently listed as impaired for three water quality parameters; dissolved oxygen, fecal coliform and iron. Available data indicate that the dissolved oxygen concentration in the watershed discharge may be affecting the estuary because it generally falls below the 4 mg/L estuarine standard. Low oxygen levels may be attributed to high nutrient concentrations from runoff or other sources that subsequently stimulate plant growth, which in turn may deplete oxygen from the water. However, measured total nitrogen and total phosphorus concentrations do not exceed FDEP's screening criteria for streams, although they exceed the Hendry Creek TMDL target. Low dissolved oxygen concentrations may be caused by human activities, but it is also possible that the low measured values are the result of baseflow (groundwater) discharges from the watershed. Groundwater is low in dissolved oxygen concentration and baseflow represents up to 35 percent of the canal flow in the dry season, and over 23 percent as an annual average.

In terms of fecal coliform bacteria, because the data available show some exceedences of the estuarine standard, there is the possibility that the estuary is affected by watershed discharges. However, bacteria source evaluations are necessary to confirm the condition.

No data for iron is available at the sampling stations considered for data analysis. However, there is data from groundwater samples that indicates groundwater iron concentrations are high enough to account for the surface water concentrations. The water quality model developed for the Golden Gate watershed also suggested groundwater discharges may be a potential source of iron. Other activities such as mine drainage, sewage treatment plant outfalls, or landfill leachate from industrial scrap yards (e.g., junkyards for cars) are also potential sources that should be investigated.

Naples Bay Estuary

Naples Bay is presently listed as impaired for four 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. Low dissolved oxygen concentration 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. Like Wiggins Pass, low dissolved oxygen concentrations in the estuary may be impacted by baseflow discharges from the drainage canals. Groundwater is predicted to be low in dissolved oxygen concentration and baseflow in the watershed represents as much as 70 percent of the canal flow in the dry season and about 58 percent as an annual average. Additional monitoring should be conducted to evaluate the effect of any nutrient loading that may occur as a result of human activities.

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 concentrations. In fact, the water quality model developed for the Golden Gate watershed (discussed in Volume 4) predicts high concentration of iron in canal discharge during dry periods.

The source of copper in the estuary could be due to human activity, such as algaecide applications used to prevent algae growth. Sources of high copper concentrations could also include 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 coliform. 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 in the drainage canals 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 the sources of fecal coliform in the estuary.

Ten Thousand Islands Estuary

The Ten Thousand Islands is the receiving water for the Faka-Union, Okaloacoochee/SR 29, and Fakahatchee watersheds and is presently not listed as impaired for any parameter. The watersheds remain relatively undeveloped in comparison with the three priority watersheds. Therefore, the estuary has not been subject to significant impacts from human activity.

Conclusions

Wiggins Pass, Naples Bay, and Rookery Bay have been found impaired for dissolved oxygen and fecal coliform bacteria. Rookery Bay is also impaired for nutrients. The discharges to the estuaries have concentrations of dissolved oxygen and fecal coliform bacteria that may affect the estuarine water quality. The causes of low dissolved oxygen concentration may include high nutrients concentrations, baseflow (groundwater) discharges, and potentially water color. Additional monitoring is needed to determine if low dissolved oxygen concentrations are due to natural processes or due to human activity.

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

1.11: Quality of Receiving Waters

Water quality in Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Island estuaries was characterized with respect to 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

The estuaries in Collier County are designated as Class II – Shellfish Propagation or Harvesting, and FDEP established water quality criteria to protect recreation and the propagation of a healthy, well-balanced population of fish and wildlife. The water quality assessment completed in Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Islands estuaries (Figure 1-45) was characterized in the context of the TMDL impairment conditions per the Florida Department of Environmental Protection's (FDEP) verified list of impaired waters. The full evaluation criteria and results of the analysis are described in Volume 4. 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.

Methods

The estuaries were evaluated for potential impairments by analyzing data collected during the 10-year period of 2000 – 2009. FDEP data was supplemented with data from Florida STORET, Collier County, the City of Naples, and the Rookery Bay National Estuarine Research Reserve (RBNERR) to create a comprehensive water quality database. 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

The data analysis confirmed most of the water quality impairments previously identified by FDEP for Wiggins Pass, Naples Bay and Rookery Bay. The results of the analysis completed for this project indicated that the Rookery Bay chlorophyll-*a* impairment is not supported by the available data. Rookery Bay may be re-assessed in the next FDEP listing cycle. FDEP has no listed impairments for the Ten Thousand Islands estuary. Following is a more detailed description of the findings by estuary system.

Figure 1-45. Collier County Estuaries and Major Features

Wiggins Pass Estuary

The estuary is presently listed as impaired for dissolved oxygen, fecal coliform and iron. Based on analysis of available water quality data, impairments for dissolved oxygen, fecal coliform, and iron in Wiggins Bay estuary previously identified by FDEP were confirmed. Per the State's Impaired Waters Rule 62-303.710 FAC, the cause of the dissolved oxygen impairment must be identified. The data analysis completed for this project indicated that one potential cause is the decomposition of organic material from the adjacent mangroves and upstream landscapes. Low dissolved oxygen concentrations due to high levels of color (aka. tannins) occurring in wetland systems is a factor of importance in the watershed that is mostly comprised of natural areas. Another potential cause is baseflow (groundwater) discharged into the estuary as it represents between 20 and 40 percent of the total annual surface water flow. Nutrient runoff from agricultural and urban areas in the watershed may also

be a contributing factor; however, measured concentrations of total nitrogen and total phosphorus are below FDPE's screening criteria. Source identification studies are recommended to further determine the cause of the impairment.

Atkins confirmed the listed impairment for fecal coliforms. Source identification studies are recommended to determine whether anthropogenic factors are the source of the elevated bacteria concentrations. Currently, the FDEP is evaluating the application of the State standard (Bartlett, 2010) and the County should continue to work with the agency to address the issue.

In terms of iron concentrations, the sources may be the result of human activity or the sources may be due to groundwater contributions. As indicated above, baseflow represents between 20 and 40 percent of the total annual surface water flow in the Cocohatchee watershed. In addition, the results of a water quality computer model developed for the Golden Gate watershed have shown that iron concentrations remain high in the drainage canals during dry periods when the flow consists primarily or baseflow. Source identification assessments are necessary to identify the source of impairment.

Naples Bay Estuary

An analysis of available water quality data completed as part of this project confirmed the dissolved oxygen, fecal coliform, iron, and copper impairments identified previously by FDEP for the Naples Bay estuary. The dissolved oxygen impairment may be attributed to nutrient inputs, however measured nutrient concentrations are less than 15 percent of FDEP's screening criteria. Low dissolved oxygen concentrations may also be the result of baseflow discharges, since it represents 58 percent of the average annual flow into the estuary, and is as high at 73 percent during the dry season. 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. Further study is needed to identify the actual causes of the dissolved oxygen impairment.

In addition to dissolved oxygen, the Naples Bay Estuary was found to be impaired for fecal coliform. Elevated fecal coliform bacteria concentrations in Naples Bay may be caused by discharges from the watershed; however, none of the water bodies in the watershed have been declared impaired for this parameter. As in Wiggins Pass, source identification studies are recommended to determine whether anthropogenic factors are the source of the elevated bacteria concentrations.

Similar to the Wiggins Pass Estuary, the iron impairment may be a result of human activity or may be due to groundwater influence. The Golden Gate watershed computer model (discussed in Volume 4) has shown that iron concentrations remain high in the drainage canals during dry periods because the flow is primarily baseflow. Source identification assessments are necessary to further verify the cause of the impairment.

Sources of copper appear to be due to human activity. The source of copper in the estuary could be due to human activity, such as algaecide applications used to prevent algae growth. Sources of high copper concentrations could also include leachate from boardwalks and pilings that are constructed from pressure-treated lumber. It is possible that the siting of the sampling stations near boardwalks and pilings contributed to the overall determination of copper impairment. The City of Naples and FDEP are completing additional copper sampling to try and identify the sources of this impairment.

Rookery Bay Estuary

Based on analysis of available water quality data, Atkins confirmed FDEP's Rookery Bay impairments for dissolved oxygen and fecal coliform. However, FDEP's assessment that the estuary is impaired for chlorophyll-*a* was not confirmed. The designated impairment for chlorophyll-*a* may be re-assessed by FDEP as part of the next impairment cycle.

Similar to the other estuaries, the dissolved oxygen impairment may be attributed to nutrient loading from runoff; however, the measured concentrations of total nitrogen and total phosphorus are approximately 10 percent of the FDEP's screening criteria. The dissolved oxygen impairment may also be attributed to the decomposition of organic material from the adjacent wetlands and upstream landscapes (McCormick, 1997), or from baseflow discharges that represent 63 percent of the total annual flow and 71 percent of the dry season flow in the drainage canals. Source identification studies are recommended to further determine the cause of the impairment.

The Rookery Bay Estuary was also found to be impaired for fecal coliform. Elevated fecal coliform bacteria concentrations may be caused by discharges from the watershed; however, as in the Naples Bay Estuary, none of the water bodies in the watershed have been declared impaired for this parameter. Source identification studies are also recommended for this estuary system.

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.

1.12: Coastal Habitats

The reduction in areal extents of oyster bars, sea grass 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 sea grass 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, sea grass 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 (Figure 1-46) 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.

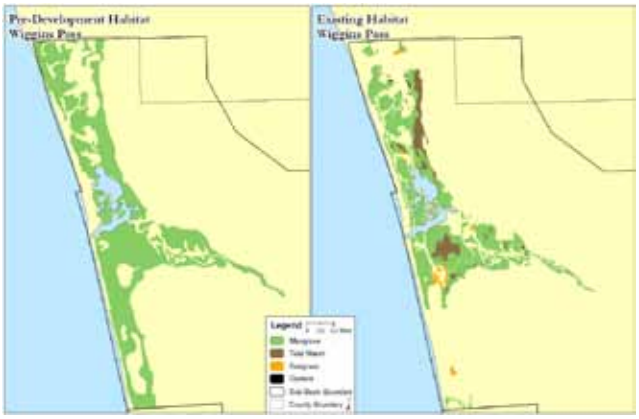

Figure 1-46. Wiggins Pass Habitat

Naples Bay

Historical maps and records indicate that Naples Bay was a shallow estuarine system with mangrove islands surrounded by oyster and sea grass 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 (Figure 1-47) 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 sea grass habitat and 82 percent loss in oyster habitat since the 1950s were documented.

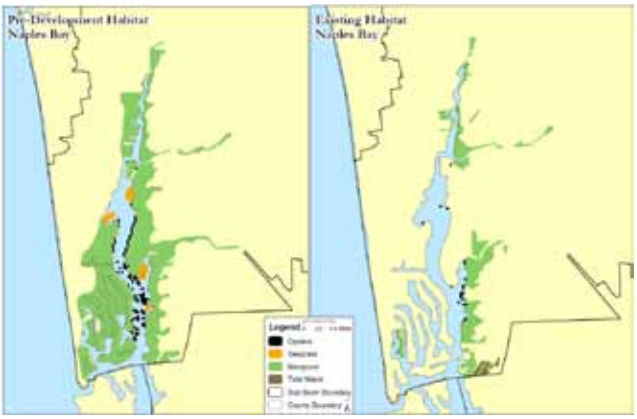

Figure 1-47. Naples Bay Habitat

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 (Figure 1-48), 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.

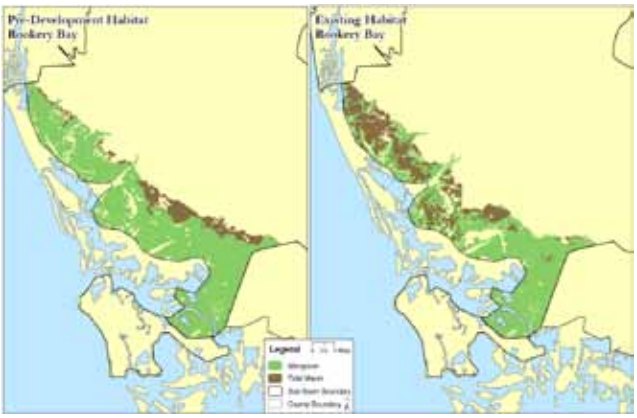

Figure 1-48. Rookery Bay Habitat

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 (Figure 1-49) appears to have declined slightly in areal extent, but has also apparently transitioned into tidal marsh.

Figure 1-49. 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 many of the physical features formed by oyster reefs and sea grass meadows have been lost over time. In contrast, the majority of tidal marsh and mangrove systems are 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.

SUMMARY 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 2007). For example, most performance measures for the Everglades restoration projects were developed through conceptual 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 watershed processes are based on estimates of potential impacts to the natural system.

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 natural systems, freshwater discharge to the estuaries, pollutant loads, and aquifer characteristics 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., reduced pollutant loads, 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

The approach to developing the performance measures was based on "restoring" the system as close as possible to the original condition, while being cognizant of the limitations imposed by existing land use conditions and economic constraints.

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. The process applied to the development of individual performance measures is described in the following sections.

2.1: 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

Performance measure development for 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 (described in Volume 4) were used to evaluate current watershed functions (Functional Assessment). The pre-development data serve as the reference period, or baseline index against which to evaluate current land cover data. The modified UMAM scoring provided a landscape scale functional assessment adequate to identify resource protection areas. Performance measures were established prior to the development of proposed project alternatives and were 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.

Resource protection scores represent the function, or value, of the landscape based on the degree to which the existing conditions are the same as pre-development. The difference in scores between pre-development and existing conditions 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 Volume 4 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:

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

where:

Performance Measure = Resource Protection 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 resource protection to adjacent areas.

Conclusions

Resource protection scores, or performance measures, are presented in Table 2-1 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 2-1. Existing Conditions Average Resource Protection Scores 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
Faka Union/ Fakahatchee/ Okaloacoochee - SR 29	431,414	9	6	9

2.2: 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 shown in Table 2-2 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 reflect the freshwater deficits occurring during the dry season and the surplus occurring during the wet season. The deficit is caused by the current reduced size of the watershed that resulted from construction of the Golden Gate Main Canal. The 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 Okaloacoochee/SR 29) watersheds, the dry season scoring results indicate that the operational controls that are used to manage dry season flows are reasonably effective at matching pre-development flow conditions. However, wet season scores are low for all watersheds, which is an indication of the effect of development on the existing canal drainage system.

Table 2-2. 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/ Fakahatchee/ Okaloacoochee- SR 29	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

2.3: Surface Water Pollutant Loads

Performance measures for pollutant loads were calculated as a function of pollutant 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. The pollution load calculations are based strictly on pollution resulting from human activities. Performance scores were developed as part of that characterization to provide a measurable means to assess pollutant loading conditions compared to the natural system. In addition, the scores were used as performance measures to assess the benefit of proposed watershed improvement projects. Post project conditions considered the improvement, or "lift" in water quality conditions due to reduced pollutant loads anticipated as a result of implementing proposed projects.

Pollution loads and pollution load scores were calculated for each cell in the computer model domain and then aggregated by watershed and water body identification number (FDEP basins for TMDL purposes). Further details on pollution loads calculations and scoring are provided in Volume 4.

Methods

The pollution load score is a function of the pollutant loads for each model cell based on land use and drainage characteristics. The first step in the calculation of pollutant load scores was to normalize the pollutant load estimate to allow for comparisons between cells, WBIDs, and watersheds on a common scale. A data normalization factor was used for that purpose. The normalization factor in this case was assumed to be the average pollutant load from a medium density residential development not including treatment facilities. That normalization factor has no other significance but to provide a way to compare loads from multiple land uses and flow characteristics. The natural system load cannot be used as the normalization factor because the associated load is zero.

Once the data were normalized, the pollution load scores were calculated based on the ratio of total load from a model cell to the normalization factor, as shown is Table 2-3.

Table 2-3. Pollutant Load Scores and Ratios

Score	Ratio of Net Load to the Normalization Factor
10	< 10% of Normalization Factor
9	10% < Normalization Factor < 20%
8	20% < Normalization Factor < 30%
7	30% < Normalization Factor < 40%
6	40% < Normalization Factor < 50%
5	50% < Normalization Factor < 60%
4	60% < Normalization Factor < 70%
3	70% < Normalization Factor < 80%
2	80% < Normalization Factor < 90%
1	90% < Normalization Factor < 100
0	> 100% of Normalization Factor

Results and Conclusions

The distribution of pollutant load scores in Collier County is shown in the maps below (Figures 2-1 through 2-7). A score of 10 indicates no pollution loading associated with human activity, while a score of less than 2 indicates areas (e.g., urban or agriculture) that exhibit pollutant loads equal to or greater than urban areas with no stormwater runoff treatment. The minimum value is consistent with the 90 percent removal rate identified by FDEP to meet State Water policy.

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. Nutrient loading scores (nitrogen and phosphorus) are lower in older developments, golf courses, and agriculture, most likely

a consequence of fertilizer application. Areas of concern for nutrient discharges are the Gordon River Extension, the Naples Bay and Wiggins Pass coastal area, and the agricultural areas along the eastern portion of the Cocohatchee-Corkscrew and Golden Gate-Naples Bay watersheds.

Lower heavy metal loading scores 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.

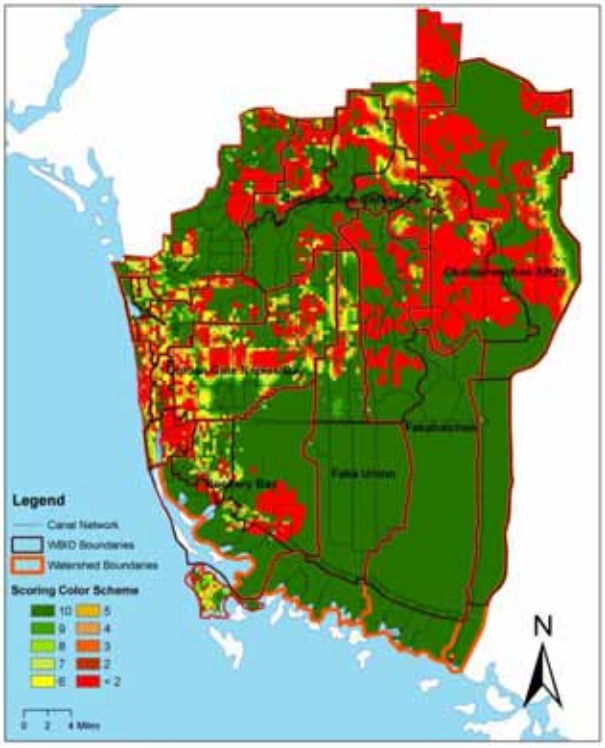

Figure 2-1. Total Nitrogen Pollutant Load Scores

Average performance scores for each pollutant constituent examined by watershed and by WBID are presented in the Table 2-4. 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.

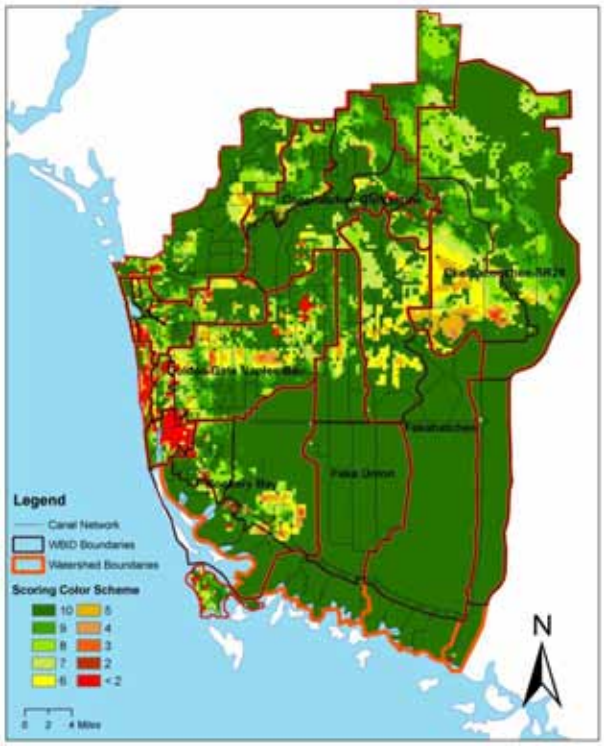

Figure 2-2. Total Suspended Solids Pollutant Load Scores

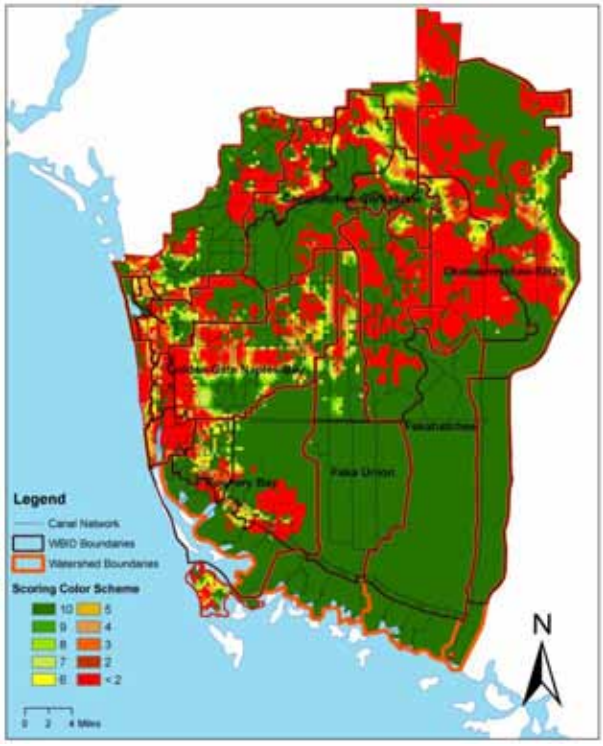

Figure 2-3. Total Phosphorus Pollutant Load Scores

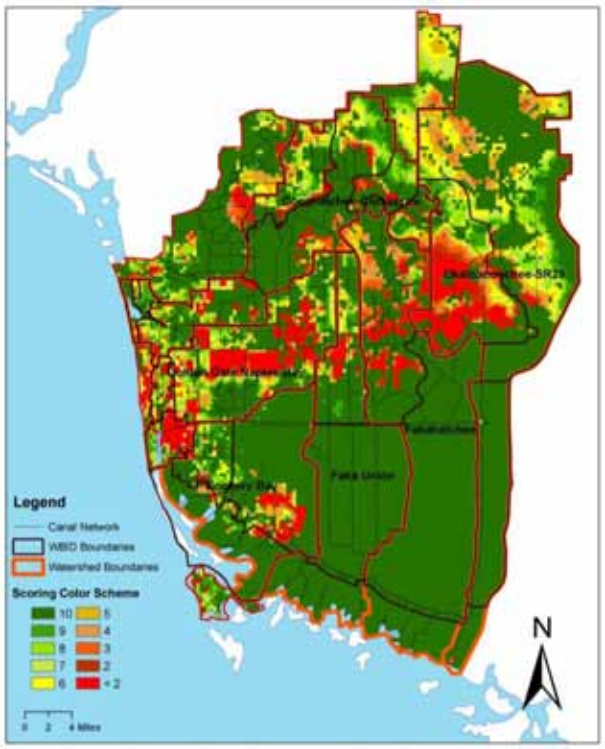

Figure 2-4. BOD-5 Pollutant Load Scores

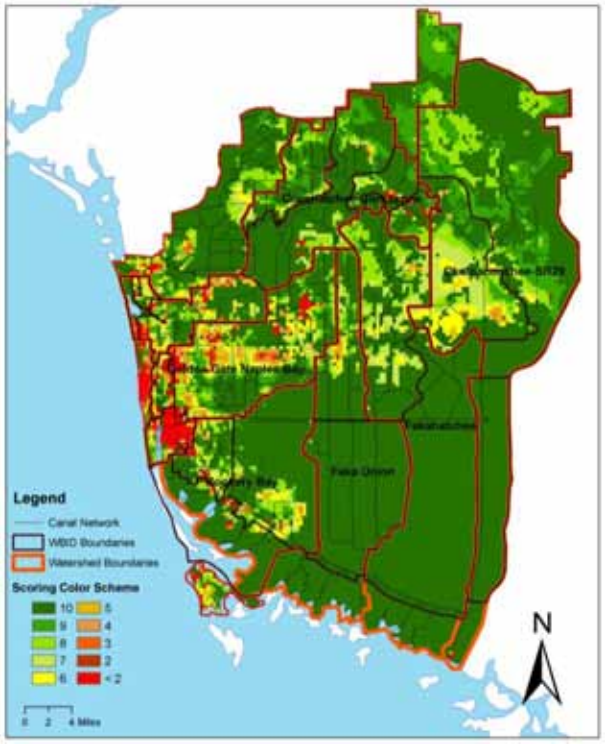

Figure 2-5. Copper (Cu) Pollutant Load Scores

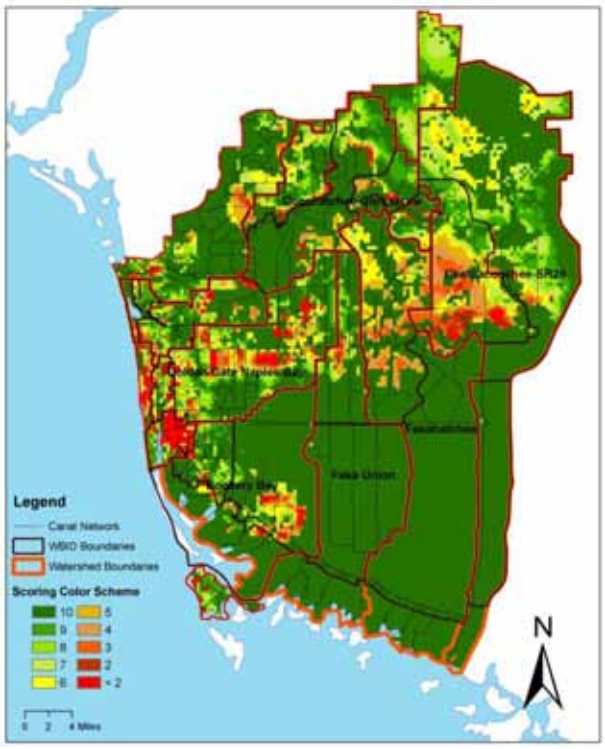

Figure 2-6. Lead (Pb) Pollutant Load Scores

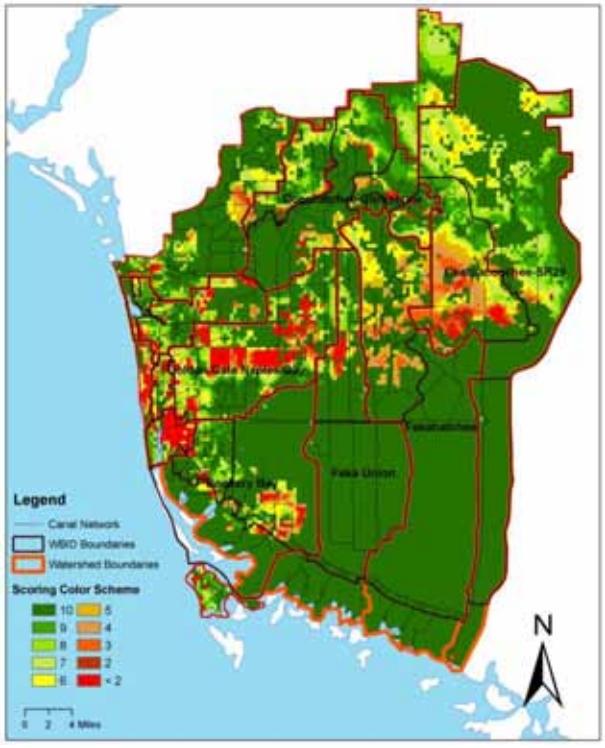

Figure 2-7. Zinc (Zn) Pollutant Load Scores

Table 2-4. 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/ Fakahatchee/ Okaloacoochee/ SR29	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

2.4: Aquifer Recharge/Yield

Areas in the Water Table aquifer that score poorly tend to correspond to wellfield locations such as the Rookery Bay and Golden Gate watersheds and the northern portion of the Faka Union watershed.

Introduction

Groundwater levels in Collier County fluctuate seasonally in response to withdrawals. The critical period for groundwater conditions is the dry season that coincides with the advent of seasonal population and when agricultural irrigation needs increase.

The impacts experienced by the Water Table, Lower Tamiami, and Sandstone aquifers systems in Collier County was assessed by comparing results of the NSM, which represents pre-development conditions, to those from the Existing Conditions Model ECM. A performance measure was developed to calculating the difference in potentiometric surface elevations for the confined aquifers, or the water level for the Water Table aquifer.

Methods

The NSM is considered to represent pre-development aquifer levels, which in turn represents the highest potential aquifer yield. A performance score of 10 was assigned to those pre-development aquifer levels. A performance score of zero was assigned to the lowest acceptable aquifer level. 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 lower limit of the Water Table aquifer was the bottom of the system, as defined by the location of the confining unit.

A performance score (0 to 10) for existing conditions was defined for each aquifer as the ratio of the ECM water level to the NSM water level 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

Figure 2-8 is a conceptual diagram representing an aquifer with a performance score of approximately 4.5. As the NSM does not include the Mid Hawthorn, no performance score has been calculated for that aquifer.

Results and Conclusions

Weighted average performance scores for each WBID in each watershed are shown in Table 2-5. These scores are based on the average dry season water level for the ECM and the NSM. Relatively high performance levels are the result of averaging scores over the WBID or watershed area. Mapped performance scores based on each cell in the ECM illustrate a clearer pattern (Figures 2-9 through 2-11). 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 reduces the performance scores relative to the historic groundwater levels against which they are measured.

Areas in the Water Table aquifer that score poorly tend to correspond to wellfield locations such as the Rookery Bay and Golden Gate watersheds and the northern portion of the Faka Union watershed. The results for the Lower Tamiami aquifer indicate the same pattern of performance scores exhibited by the Water Table aquifer. These similarities can be attributed to water movement between the aquifers.

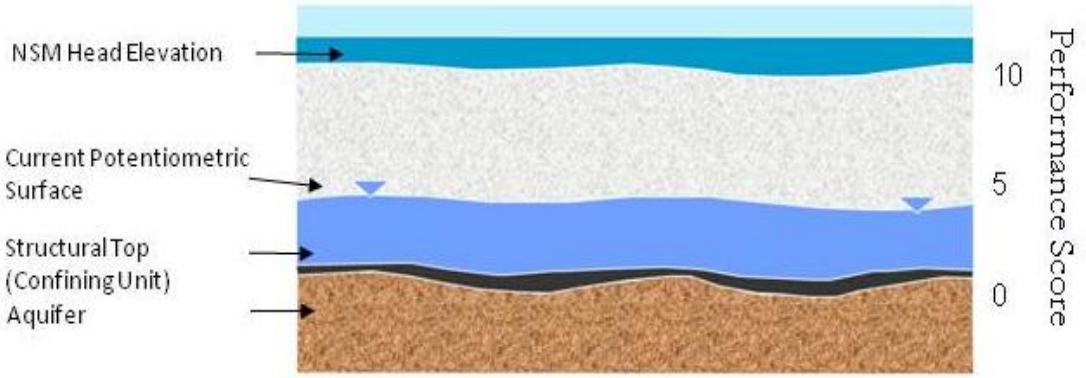

Figure 2-8. Conceptual Aquifer with Performance Score = 4.5

Table 2-5. 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		8.9	9.1	9.8
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

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. This result is likely due to the presence 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 head elevations in the Water Table aquifer. Changes in structure operations could have a positive influence on groundwater elevation and availability in the watershed.

Differences in defined boundary conditions between the ECM and NSM are the likely cause of the low scores along the watershed boundaries for the Water Table and Lower Tamiami aquifers.

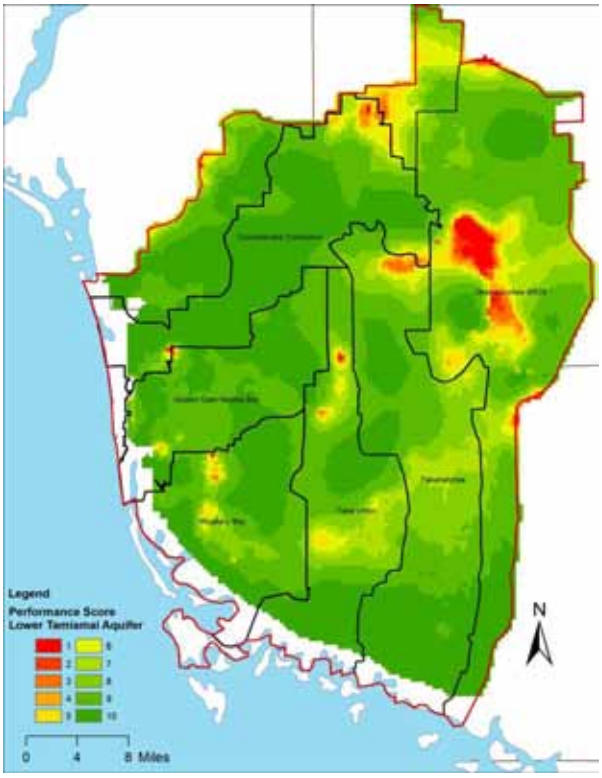

Figure 2-10. Lower Tamiami Aquifer Average Dry Season Performance Score

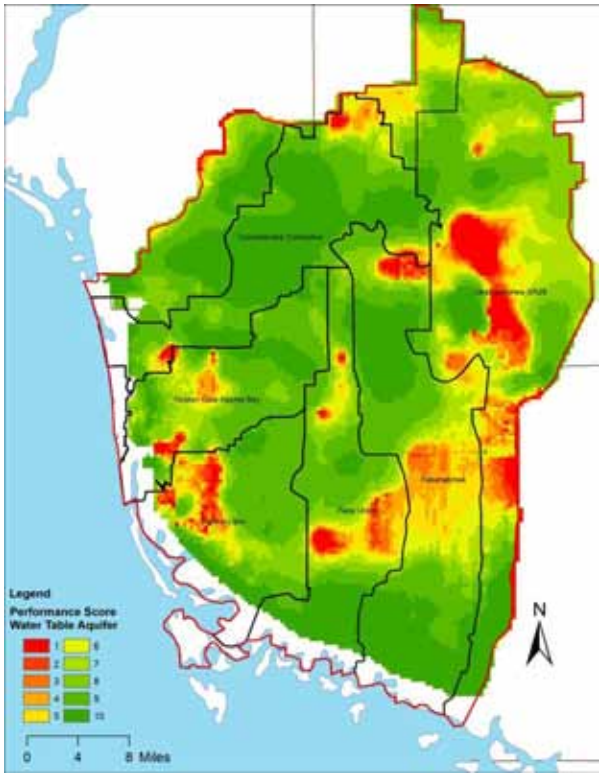

Figure 2-9. Water Table Aquifer Average Dry Season Performance Score

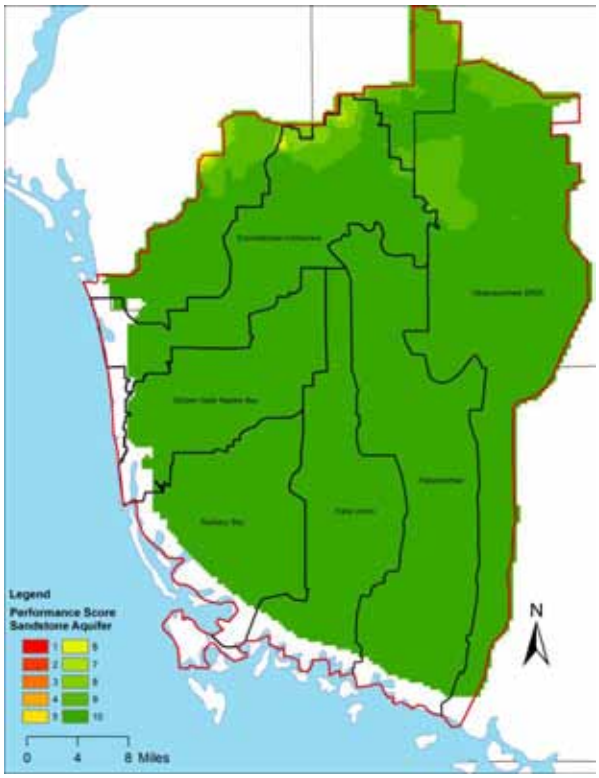

Figure 2-11. Sandstone Aquifer Average Dry Season Performance Score

LITERATURE CITED

Adamski, James C. and Leel Knowles, Jr. 2001. Ground-Water Quality of the Surficial Aquifer System and the Upper Floridan Aquifer, Ocala National Forest and Lake County, Florida, 1990 – 99. U.S. Department of the Interior, U.S. Geological Survey, Water-Resources Investigations Report 01-4008.

Bartlett, Drew, FDEP Director, Division of Environmental Assessment and Restoration, 2010, Personal Communication

Black, Crow, and Eidsness, Inc. 1974. Hydrologic Study of the G. A. C. Canal Network. Gainesville, FL. Project no. 449-73-53.

CERP. 2007. "Development and Application of Comprehensive Everglades Restoration Plan System-wide Performance Measures." Restoration Coordination and Verification, Comprehensive Everglades Restoration Plan, Central and Southern Florida Project

Grunwald, Michael. 2006. "The Swamp: Everglades, Florida and the Politics of Paradise." Simon and Schuster, New York, New York

Kimmerer, W. J. 2002. "Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary." Estuaries 25: 1275-1290.

McCormick, P.V., M.J. Chimney, and D.R. Swift. 1997. Diel oxygen profiles and water-column community metabolism in the Florida Everglades, U.S.A. Archive fhr Hydrobiologie 140:117-129.

SDI Environmental Services, Inc., BPC Group Inc. and DHI, Inc. 2007. "Final Report, Natural Systems Model (NSM) Scenario Southwest Florida Feasibility Study"

South Florida Water Management District. January 2007. Naples Bay Surface Water Improvement and Management Plan.

Collier County
Watershed Management Plan

Collier County

ATKINS