SOUTH DISTRICT • CHARLOTTE HARBOR BASIN

DRAFT
Nutrient TMDLs for Sanibel Slough (WBIDs 2092F1 and 2092F2)

and Documentation in Support of the Development of Site-Specific Numeric Interpretations of the Narrative Nutrient Criterion

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Executive Summary

Sanibel Slough is located on Sanibel Island, Lee County, Florida. The waterbody was identified as impaired for nutrients based on elevated annual average Trophic State Index and was added to the 303(d) list by Secretarial Order on May 27, 2004, as the segment with **w**ater**b**ody **id**entification (WBID) number 2092F. Subsequently, Sanibel Slough was reclassified as an estuarine system and then subdivided into two basins, Sanibel Slough West (WBID 2092F1) and Sanibel Slough East (2092F2). Individual total maximum daily loads (TMDLs) for total nitrogen (TN) and total phosphorus (TP) have been developed, and supporting information for the TMDLs is listed below in **Table EX-1**. These TMDLs were developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by the U.S. Environmental Protection Agency.

Table EX-1: Summary of TMDL supporting information for Sanibel Slough

Type of Information	Description
Waterbody name/ WBID number	Sanibel Slough West/WBID 2092F1 Sanibel Slough East/WBID 2092F2
Hydrologic Unit Code (HUC) 8	03100103
Use classification/ Waterbody designation	Class III/Marine
Targeted beneficial uses	Fish consumption; recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife
303(d) listing status	Verified List of Impaired Waters for the Group 2 basins (Charlotte Harbor) adopted via Secretarial Order dated May 27, 2004.
TMDL pollutants	TN and TP
TMDL and Site Specific Interpretations of Narrative Nutrient Criteria	**WBID 2092F1:** **Chlorophyll *a*:** 11 micrograms per liter (µg/L), expressed as an annual geometric mean (AGM) concentration not to be exceeded more than once in any consecutive 3-year period. **TN:** 966 kilograms per year (kg/yr), expressed as a rolling 3-year annual average load not to be exceeded. **TP:** 176 kg/yr, expressed as a rolling 3-year annual average load not to be exceeded. **WBID 2092F2:** **Chlorophyll *a*:** 11 µg/L, expressed as an AGM concentration not to be exceeded more than once in any consecutive 3-year period. **TN:** 1,644 kg/yr, expressed as a rolling 3-year annual average load not to be exceeded. **TP:** 143 kg/yr, expressed as a rolling 3-year annual average load not to be exceeded.
Load reductions required to meet TMDL	**WBID 2092F1**: 18 % TN reduction and 27 % TP reduction to achieve a chlorophyll *a* target of 11 µg/L. **WBID 2092F2**: 31 % TN reduction and 74 % TP reduction to achieve a chlorophyll *a* target of 11 µg/L.

Acknowledgments

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Websites

Florida Department of Environmental Protection

TMDL Program

Identification of Impaired Surface Waters Rule

Florida STORET Program

2016 Integrated Report

Criteria for Surface Water Quality Classifications

Surface Water Quality Standards

Basin Management Action Plans

U.S. Environmental Protection Agency

Region 4: TMDLs in Florida

National STORET Program

Chapter 1: Introduction

1.1 Purpose of Report

This report presents the total maximum daily loads (TMDLs) developed to address the nutrient impairment of Sanibel Slough, located in the Charlotte Harbor Basin. The TMDLs will also constitute the site-specific numeric interpretation of the narrative nutrient criterion set forth in Paragraph 62-302.530(47)(b), Florida Administrative Code (F.A.C.), that will replace the otherwise applicable numeric nutrient criteria (NNC) in Subsection 62-302.531(2), F.A.C., for this particular waterbody, pursuant to Paragraph 62-302.531(2)(a), F.A.C. The waterbody was verified as impaired for nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR) (Chapter 62-303, F.A.C.), and was included on the Verified List of Impaired Waters for the Charlotte Harbor Basin that was adopted by Secretarial Order on May 27, 2004.

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and provides water quality targets needed to achieve compliance with applicable water quality criteria based on the relationship between pollution sources and water quality in the receiving waterbody. The TMDLs establish the allowable loadings to Sanibel Slough that would restore the waterbody so that it meets its applicable water quality criteria for nutrients.

1.2 Identification of Waterbody

For assessment purposes, the Florida Department of Environmental Protection (DEP) divided the Charlotte Harbor Basin (Hydrologic Unit Code [HUC] 03100103) into watershed assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or surface water segment. Sanibel Slough was originally assessed as the Sanibel River under WBID 2092F but was subsequently divided into two subbasins to acknowledge that the slough is comprised of two distinct systems separated by a water control structure. The Sanibel Slough West and Sanibel Slough East subbasins were assigned individual WBID numbers: 2092F1 and 2092F2, respectively.

In this report, discussions of the whole system will use the waterbody name Sanibel Slough. However, it will also be necessary to refer to the two subbasins individually, in which case they will be addressed as Sanibel Slough East (WBID 2092F2) and Sanibel Slough West (WBID 2092F1), or as the East and West Basins. **Figure 1.1** displays the location of the WBIDs in Lee County Florida, along with the major geopolitical and hydrologic features in the area.

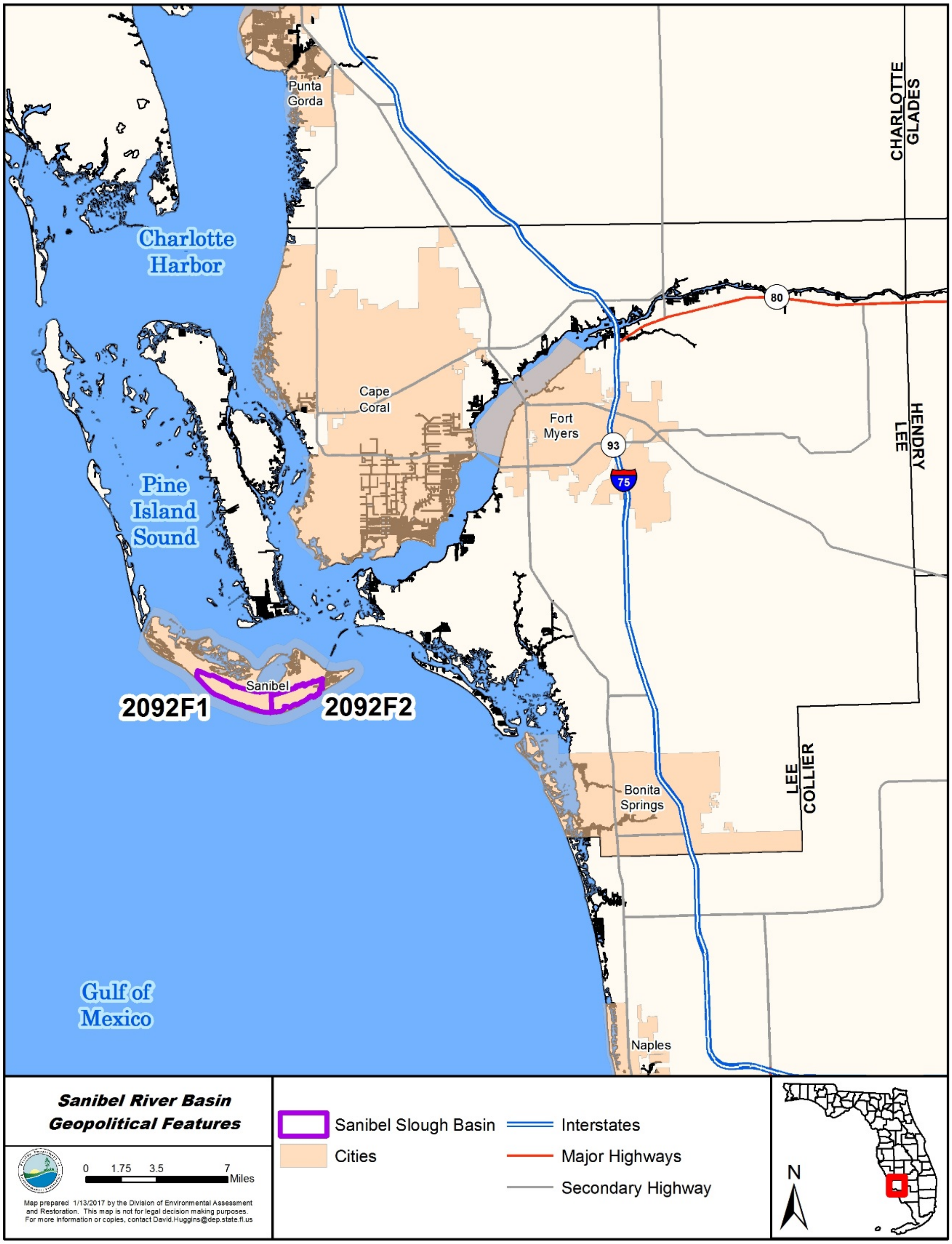

Figure 1.1. Location of Sanibel Slough (WBIDs 2092F1 and 2092F2) in Lee County and major hydrologic and geopolitical features in the area

1.3 Site-Specific Information

1.3.1 Population and Geopolitical Settings

Although the waterbody is known as the Sanibel River, per the Sanibel-Captiva Conservation Foundation (SCCF) the waterbody resembles a slough and will therefore be renamed by DEP and referred to as Sanibel Slough (Thompson and Milbrandt 2013). Sanibel Slough is located on Sanibel Island within the city limits of the City of Sanibel in Lee County, Florida.

Sanibel and the adjacent island of Captiva are barrier islands separated from the mainland by San Carlos Bay and Pine Island Sound. The primary link to the mainland is a three-part causeway and high-span bridge. The population of Sanibel Island was 6,469 according to the 2010 U.S. Census. The population density at the time was estimated at 400 individuals per square mile. The eastern portion of Sanibel Slough is more urbanized, and the western portion is in a somewhat less developed area adjacent to J.N. "Ding" Darling National Wildlife Refuge. Multiple tracts of preserved lands, primarily located near the western portion of Sanibel Slough, provide the slough a vegetative buffer from developed land. Sanibel Island is also the home to the nonprofit research and conservation facility of the SCCF, and the organization has worked in partnership with the City of Sanibel on conservation issues on the island.

1.3.2 Topography

Sanibel Island is a long, low island with very little relief. The average elevation is slightly less than one meter above sea level, and elevation changes are gradual. **Figure 1.2** provides a light detection and ranging (LiDAR) topographic map of Sanibel Island showing a high-resolution elevation model for the island based on LiDAR data collected in 2007 by the Florida Division of Emergency Management. In general, the eastern end of the island, which has experienced the most development and fill, is slightly higher than the western portion. Sanibel Slough runs in a lower east–west basin predominantly less than 3 meters above sea level through the center of the island, and this interior basin is largely confined by higher elevations to the north, south, east, and west.

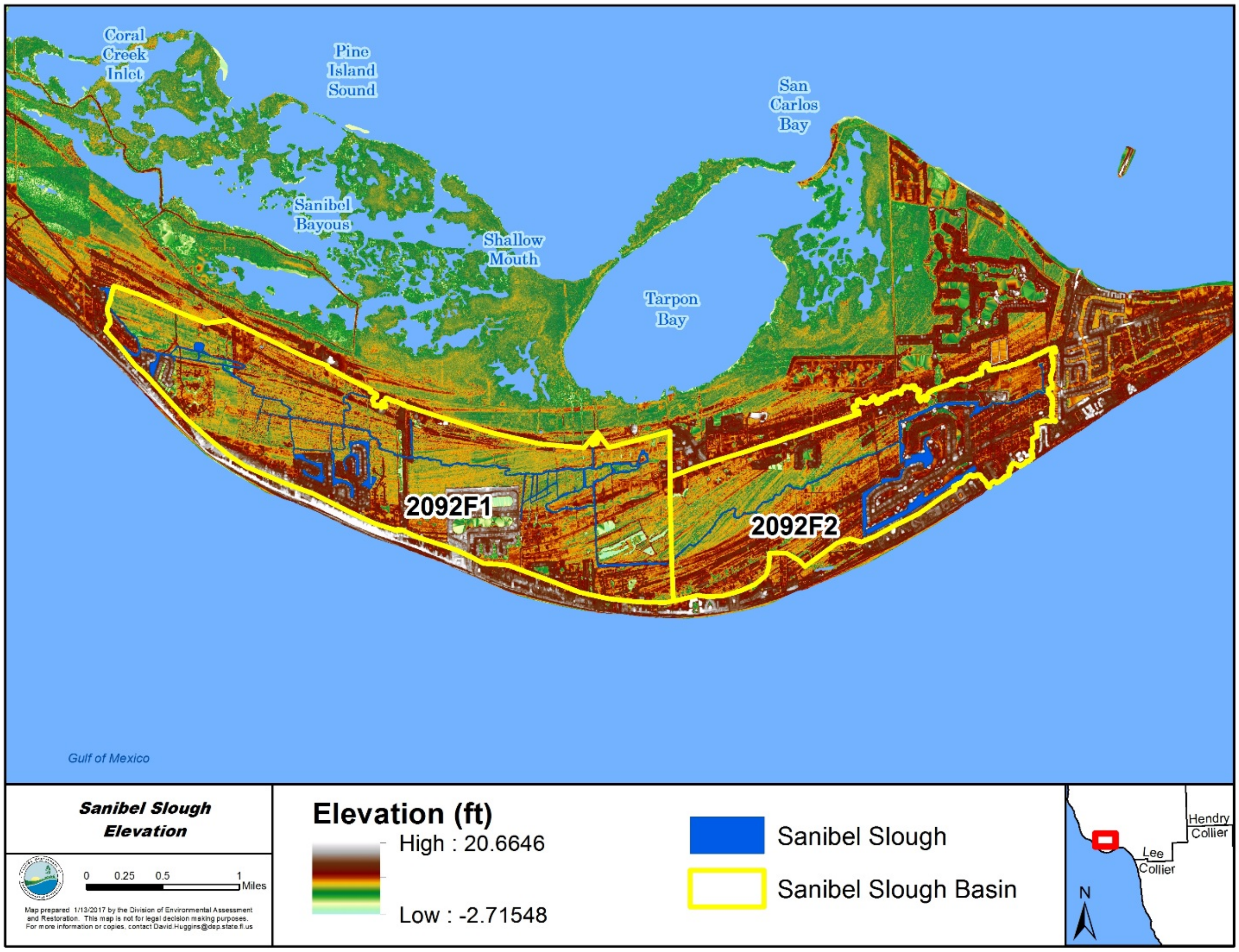

Figure 1.2. Topographic map of Sanibel Island using LIDAR-based elevation model

1.3.3 Hydrogeological Setting

The hydrogeological context of Sanibel Slough includes the topography discussed in the preceding section, along with soil geology, aquifer/groundwater interactions with surface water, and climate. Each of these factors helps to define the inflows and outflows that characterize the Sanibel Slough system.

The primary soils, based on the National Cooperative Soil Survey, belong in the Hydrologic Soil Groups C, B/D, and D. Group C soils are associated with urban land use as a result of the application of fill material. These moderately fine textured soils have low infiltration rates and impede the downward movement of water. Group D soils, found throughout the island, have a particularly low rate of water transmission and high runoff potential when thoroughly wet. The remaining Group B/D soils are better drained than the other soils on the island and have a moderate rate of water transmission. Groundwater interactions are through a surficial aquifer consisting of an upper sequence of unconsolidated, unconfined sediments comprising a sand/shell composite substrate (Missimer and O'Donnell, 1976). The mean thickness of the surficial aquifer is approximately 3.6 meters (Missimer and O'Donnell 1976).

The aquifer level varies by season (being higher in the wet season) and can discharge directly into the Gulf and Sound ecosystems at high water levels.

The island's climate is humid subtropical with daily high temperatures ranging from approximately 24° to 32° C. The rainy season is from July to early October with a long dry season from mid-October through June (Thompson and Milbrandt 2014). The island is subject to the periodic influence of tropical cyclones. In the model period two tropical storms (Fay in 2008 and Bonnie in 2010) passed nearby Sanibel. Although the island was not on the direct path of either storm system, both tropical storms impacted Southwest Florida.

In the 1940s, Sanibel Slough was created by dredging channels between the interior wetlands of the island to serve as a mosquito control and drainage structure. The early stages of slough formation are seen in archived aerial photos of Sanibel Island collected by the U.S. Department of Agriculture in 1944 (**Figure 1.3**).

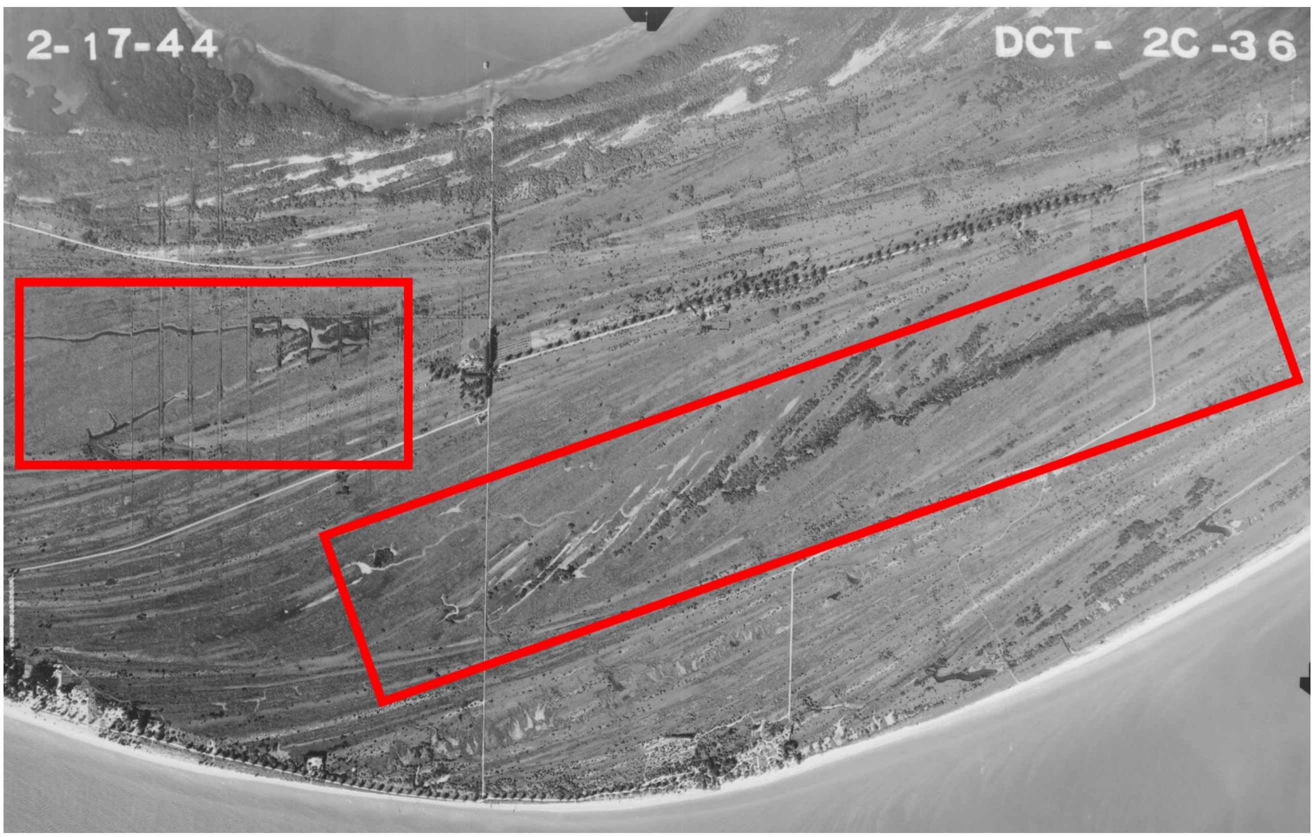

Figure 1.3. Aerial photographs of Lee County – U.S. Department of Agriculture Flight 2C-36 (1944) with red rectangles indicating dredging channels

The slough is severed from the surrounding estuarine areas of the Gulf of Mexico and San Carlos Bay by control weirs at Sanibel-Captiva Road (West Basin) and Beach Road (East Basin). The slough itself is further divided into eastern and western segments by another control weir located at Tarpon Bay Road. This divide is the basis for the division of the slough into the East and West Basins, because water does not normally pass from one basin into the other, and because water quality, land use, and development in the two basins differ. **Figure 1.4** shows the location of these outflow weirs, as well as the weir separating the East Basin from the West Basin.

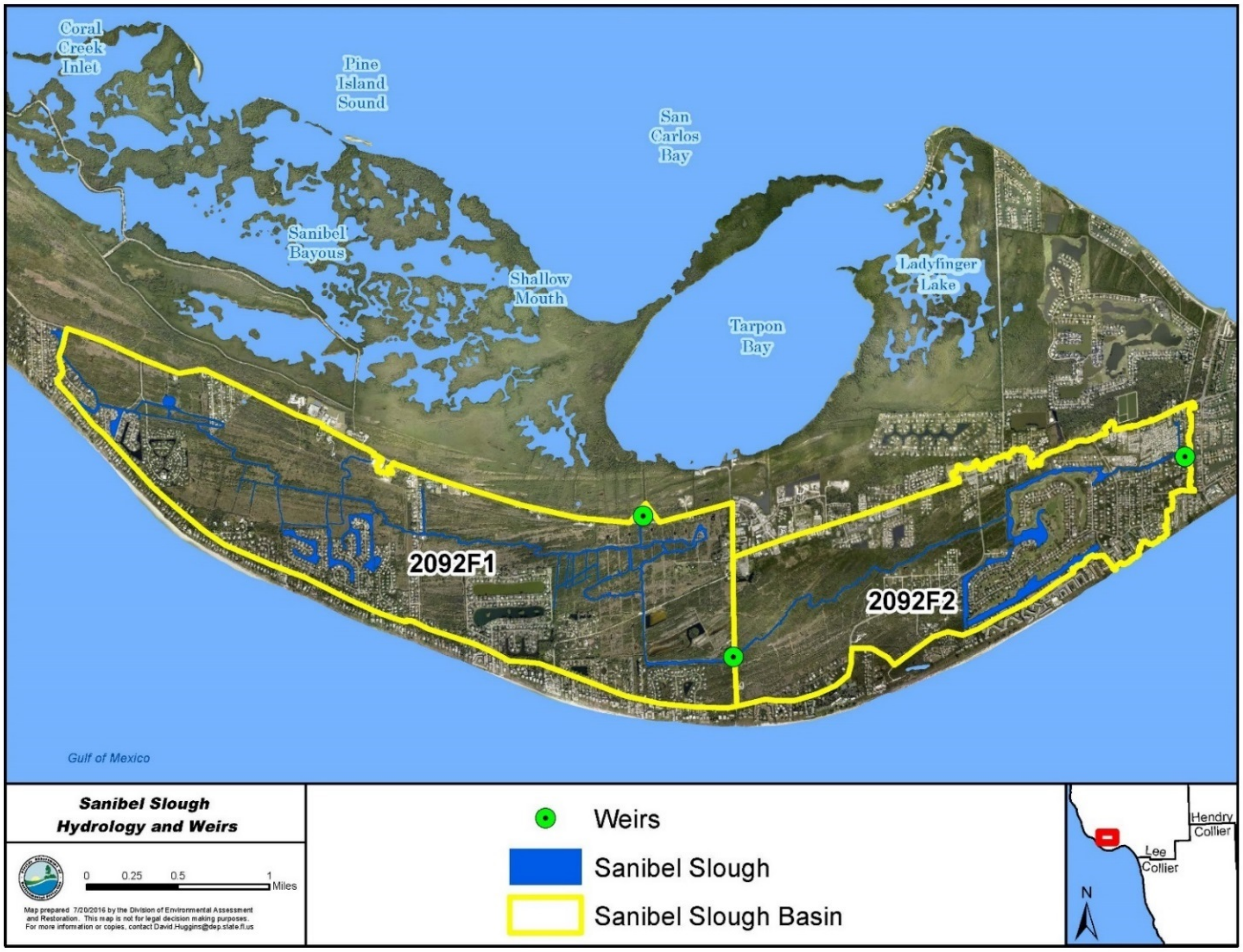

Figure 1.4. East and West Basins and locations of the control weirs

The slough level is managed to maintain flooded interior wetlands so long as water levels do not adversely impact developed areas (Evans and Williams 2016). This strategy results in minimal discharges from the control weirs except in extreme storm events and has the added benefit of helping to prevent the spread of encroaching invasive hardwoods, especially Brazilian pepper (*Schinus terebinthifolius*). **Figure 1.5** shows the number of days with recorded flows over the control weirs for the years 2007-2013.

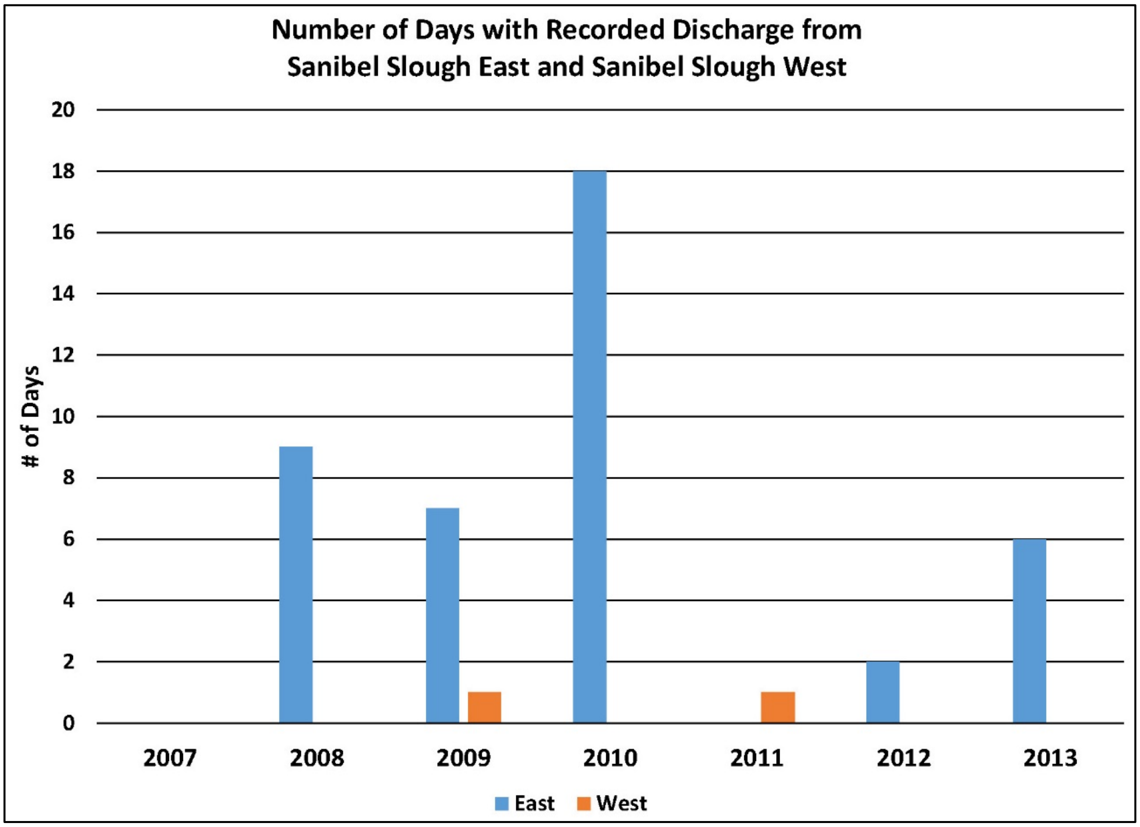

Figure 1.5. Number of days with recorded discharge from Sanibel Slough

1.4 Pollutant Sources and Waterbody Stressors

1.4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of the pollutant of concern in the target watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point sources or nonpoint sources. Historically, the term "point sources" has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from failing septic systems; and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act (CWA) redefined certain nonpoint sources of pollution as point sources subject to regulation under the U.S. Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Program. These nonpoint sources included certain urban stormwater discharges, such as those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with CWA definitions, the term "point source" is used to describe traditional point sources (such as domestic and industrial wastewater discharges) **and** stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (**see Section 4.1** on **Expression and Allocation of the TMDL**). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

1.4.2 Point Sources

1.4.2.1 Wastewater Point Sources

There are two permitted wastewater treatment facilities located in the Sanibel Slough Watershed. The Island Water Association Inc. (IWA) (NPDES FL0025593) is an existing 1.33-million-gallon-per-day (mgd) industrial wastewater facility that serves a reverse osmosis drinking water treatment plant. The IWA is permitted to discharge to an underground injection well, U-001, and has a permitted surface water discharge outfall to the Gulf of Mexico, D-001. The IWA has no direct surface water discharge to Sanibel Slough.

The Donax Water Reclamation Facility (WRF) (FLA014430) is an existing 2.375 mgd maximum monthly average daily flow (MMADF) domestic wastewater treatment plant that does not have a direct surface water discharge to Sanibel Slough. The City of Sanibel Service Area is identified as a Regional Reuse Service Area, which incorporates the entire island of Sanibel, for Part III public access reuse. The permitted reuse capacity of this facility is 2.375 mgd MMADF. The permitted reuse consists of the irrigation of grass at golf courses, athletic complexes and parks, other landscape irrigation areas, and residential areas.

Water from the IWA and Donax facilities is used for irrigation in the Sanibel Slough Watershed. The City of Sanibel determined that 0.044 pounds (lbs) of nitrogen and 0.018 lbs of phosphorus are applied to the land surface for every 1,000 gallons of reclaimed water used (Thompson and Milbrandt 2014). The use of reclaimed water for irrigation is suspected to be a major source of nutrient loading in the East and West Basins, and percolation from irrigation water could be a potential source of nutrient loads to the groundwater (Thompson and Milbrandt 2016). **Figure 1.6** shows the location of the wastewater facilities in the Sanibel Slough Watersheds.

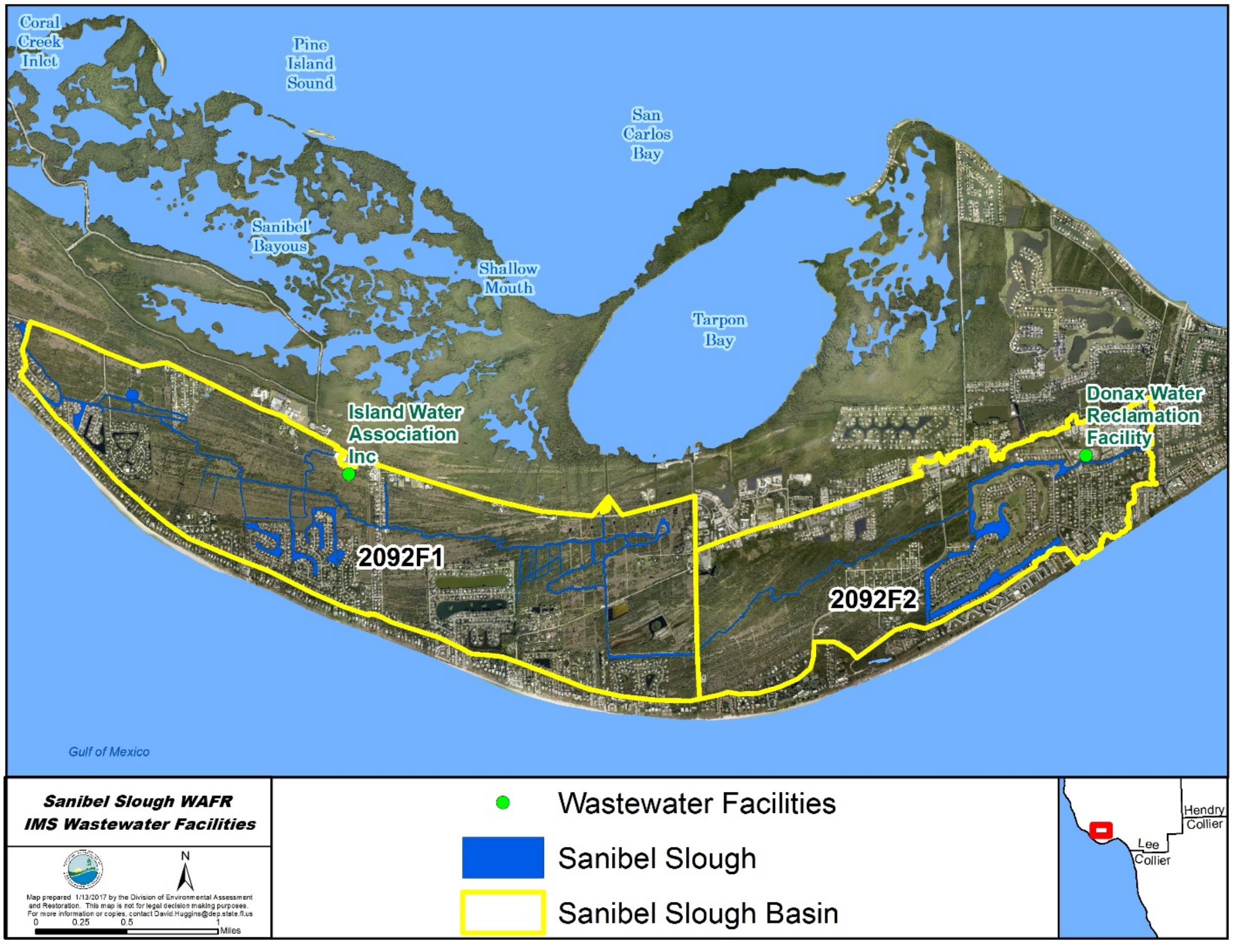

Figure 1.6. Wastewater facilities in the Sanibel Slough Watershed

1.4.2.2 Municipal Separate Storm Sewer System (MS4) Permittees

MS4s may also discharge pollutants to waterbodies in response to storm events. To address stormwater discharges, the EPA developed the NPDES stormwater permitting program in two phases. Phase I, promulgated in 1990, addresses large and medium-size MS4s located in incorporated areas and counties with populations of 100,000 or more. Phase 2 permitting began in 2003. Regulated Phase II MS4s are defined in Rule 62-624.800, F.A.C., and typically cover urbanized areas serving jurisdictions with a population of at least 1,000 or discharging into Class I or Class II waters, or into Outstanding Florida Waters (OFWs). The stormwater collection systems in the Sanibel Slough Watershed, which are owned and operated by Lee County and Co- Permittees (Florida Department of Transportation [FDOT] District 1 and the City of Sanibel), are covered by an NPDES Phase I MS4 permit (FLS000035). The MS4 permit covers the entire extent of Sanibel Island.

1.4.3 Nonpoint Sources

1.4.3.1 Land Use and Land Use Practices

Land use classification for the Sanibel Slough Basin was identified using the 2008–09 South Florida Water Management District (SFWMD) land use geographic information system (GIS) coverage. A combination of Florida Land Use, Cover and Forms Classification System (FLUCCS) Level 1/Level 3 land use categories, summarized in **Table 1.1** and **Figure 1.7**, was used to classify the contributing area. Wetlands covered 40 % of the East Basin and 55 % of the West Basin. The East Basin had slightly more residential development, with a total of 34 % low, medium and high-density residential compared with approximately 29 % in the West Basin. Medium density made up most of the residential land types in the East Basin, while low density was the primary residential type in the West Basin. The East Basin also had more commercial development, with a total of 103 acres in the East compared with 1 acre in the West.

Table 1.1. 2008–09 land use in the Sanibel Slough Watershed

Land Use	East Basin (acres)	East Basin % of Contributing Area	West Basin (acres)	West Basin % of Contributing Area
Low-Density Residential	113	9	347	18
Medium-Density Residential	235	19	214	11
High-Density Residential	79	6	2	0
Commercial	103	8	16	1
Institutional	2	0	12	1
Recreational	100	8	0	0
Rangeland	30	2	150	8
Forest/Rural Open	25	2	45	2
Water	56	4	104	5
Wetlands	503	40	1,081	55
Communication and Transportation	8	1	7	0
TOTAL	**1,255**	**100**	**1,978**	**100**

Nutrient loading from urban areas is most often attributed to multiple sources, including stormwater runoff, leaks and overflows from sanitary sewer systems, illicit discharges of sanitary waste, runoff from the improper disposal of waste materials, leaking septic systems, and domestic animals. The largest anthropogenic land use in the Sanibel Slough Watershed consists of residential areas. These areas, as well as golf courses, which are classified under "Recreational" land use, can contribute nutrients from fertilizer application. The City of Sanibel proactively implemented a fertilizer ordinance (Sanibel, 2007) on the island in 2007 to reduce the potential runoff contribution to Sanibel Slough (Thompson and Milbrandt 2014).

The largest land use category in the Sanibel Slough watershed consists of wetlands. A majority of the total island, 51 %, is held in conservation through the SCCF, the J.N. "Ding" Darling National Wildlife Refuge, or various city parks. Approximately 46 % of the West Basin and 26 % of the East Basin are preserved lands (**Figure 1.8**). The refuge is home to over 245 species of birds and provides feeding, nesting, and roosting areas for migratory birds (J.N. "Ding" Darling National Wildlife Refuge website 2014).

In addition to the nutrient sources associated with anthropogenic activities, birds and other wildlife can also contribute considerable amounts of nutrients to waterbodies through their feces, particularly in areas with bird rookeries. While detailed source information is not always available for accurately quantifying the loadings from wildlife sources, land use information can be used to help identify areas with the potential for wildlife to congregate. It is not DEP's intent to mitigate natural conditions, but it is necessary to understand the various potential sources in the watershed.

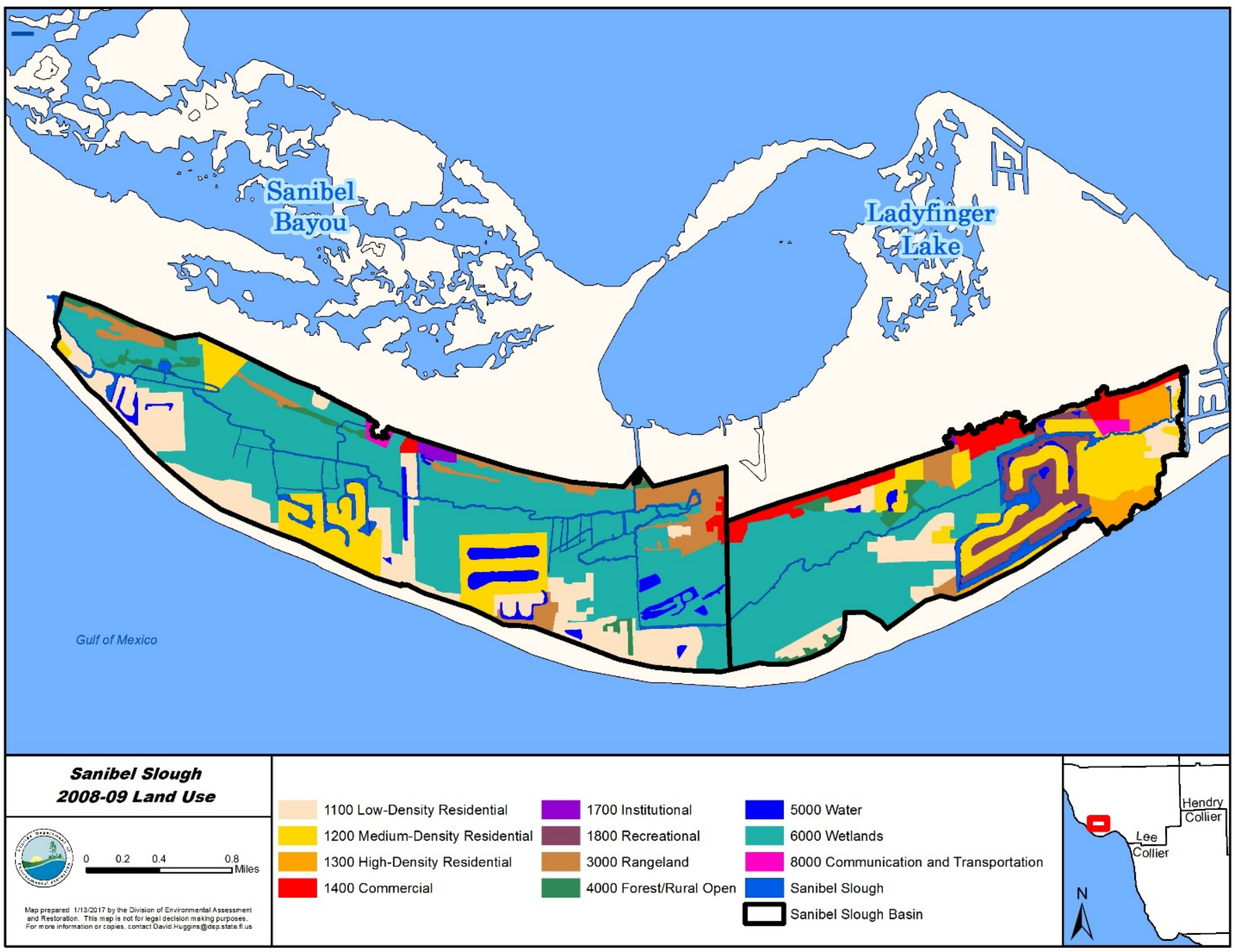

Figure 1.7. 2008–09 land use in the Sanibel Slough Watershed

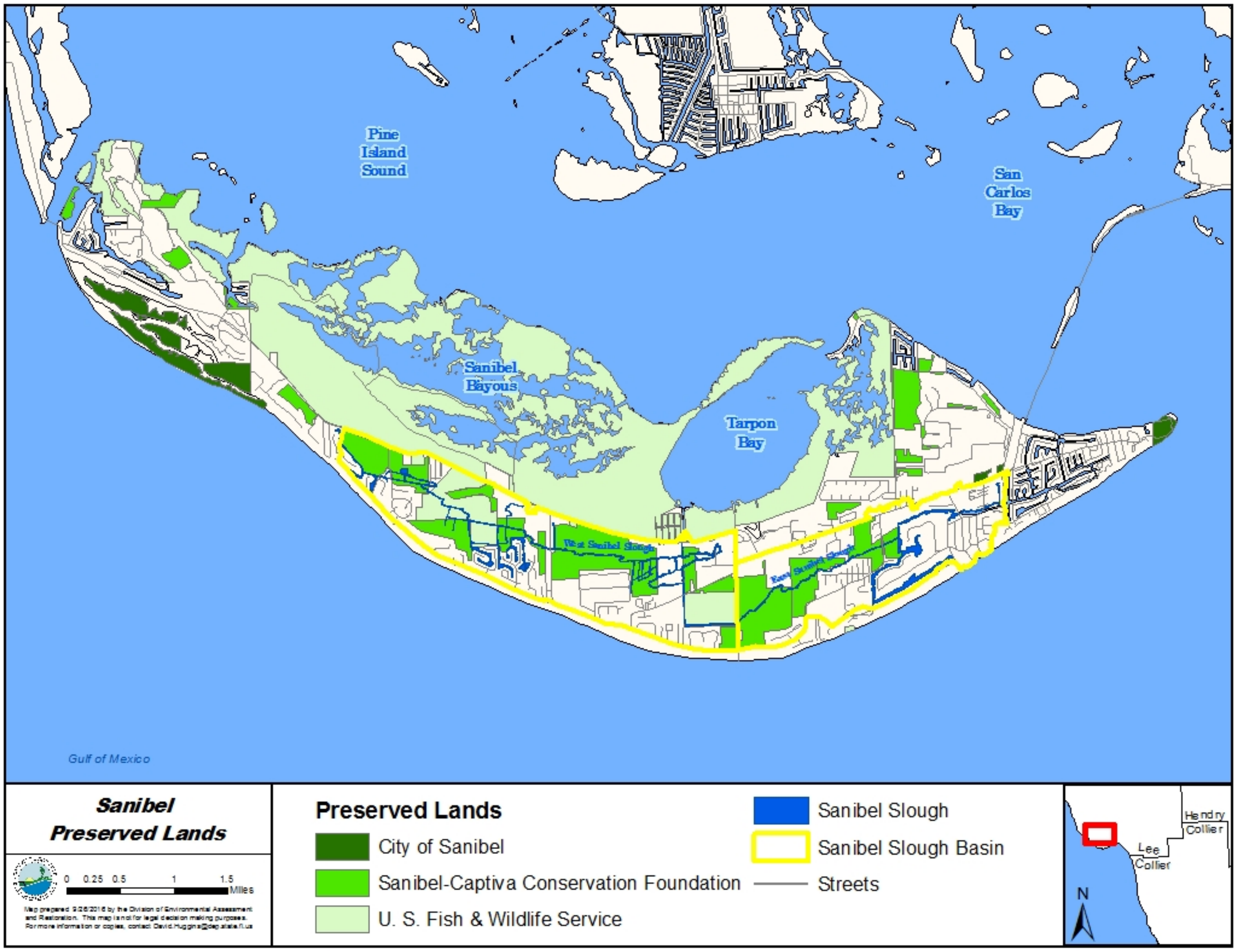

Figure 1.8. Preserved lands in the Sanibel Slough Watershed

1.4.3.2 On-Site Sewage Treatment and Disposal Systems (OSTDS)

OSTDS, including septic tanks, are commonly used where providing central sewer service is not cost-effective or practical. When properly sited, designed, constructed, maintained, and operated, OSTDS are a safe means of disposing of domestic waste. The effluent from a well-functioning OSTDS is comparable to secondarily treated wastewater from a sewage treatment plant. When not functioning properly, however, OSTDSs can be a source of nutrients (nitrogen and phosphorus), pathogens, and other pollutants to both groundwater and surface water.

The City of Sanibel has made great efforts to convert most of the island to the centralized sewer and treatment system. In total, there are only 69 OSTDS still in operation on the entire island, with only 30 left in the Sanibel Slough Watershed: 11 remaining OSTDS in the West Basin and 19 in the East Basin (**Figure 1.9**). Information on the location of septic systems was obtained from the City of Sanibel Utilities Department in September 2016. Nutrient loads from the remaining OSTDS in the Sanibel Slough Watershed are expected to be minimal due to the low number of systems, and any OSTDS loads, both from legacy contamination and from active sites, would be factored into the overall groundwater loading concentrations discussed in **Section 1.4.4**.

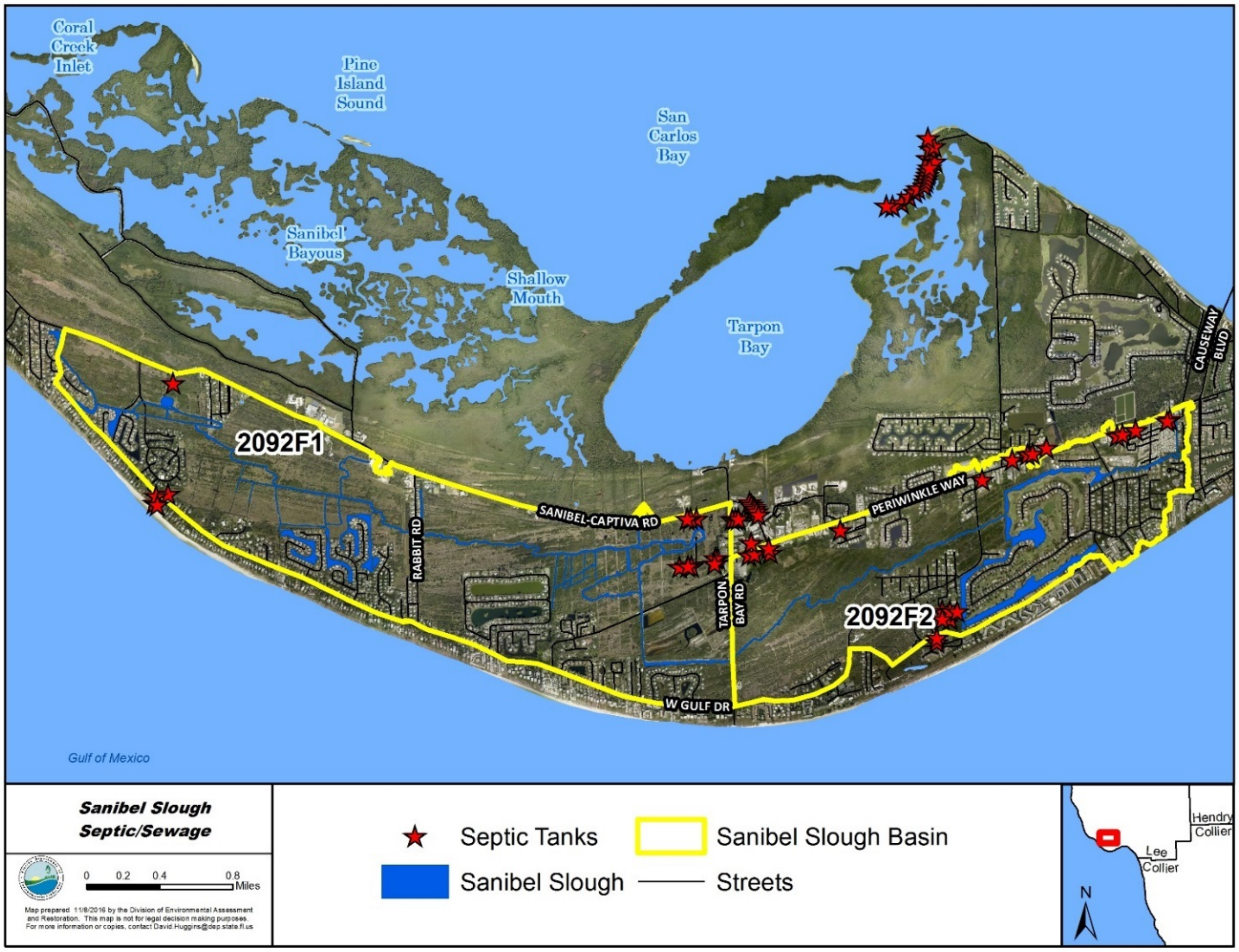

Figure 1.9. Remaining OSTDS (septic tanks) in the Sanibel Slough Watershed

1.4.4 Groundwater

The SCCF Marine Lab conducted an intensive study of potential nutrient loadings from the surficial aquifer to the surface waters of Sanibel Island and determined that the surficial aquifer discharges a significant volume and nutrient load to Sanibel Slough (Thompson and Milbrandt 2016). The study indicated that a steady exchange of groundwater and surface water occurs along Sanibel Slough, and that this groundwater discharge controls the surface water level in the slough. The estimated annual groundwater discharge to the East Basin during the study period was 166,177 cubic meters, and the annual discharge for the West Basin was approximately 74,026 cubic meters. The discharge was proportional to the amount of rainfall during the study period, and this relationship was used to extrapolate the estimated annual groundwater discharge during the model time frame.

Additionally, groundwater nutrient concentrations were measured at several well stations along the slough. The mean groundwater concentration in the West Basin was 3.43 milligrams per liter (mg/L) for TN and 0.10 mg/L for TP, and the mean TN and TP concentrations in the East Basin were 6.69 and 0.75 mg/L, respectively. **Chapter 3** details how the discharge volumes and nutrient concentrations were used in the receiving water model.

The SCCF report indicates that irrigation with reclaimed water, fertilizer leaching through the well-drained sandy soils, and legacy nutrient enrichment from the soils near prior OSTDS or wastewater sites could be sources of higher nutrient concentrations in water infiltrating to the surficial aquifer.

1.4.5 Atmospheric Deposition

Nutrient loadings from the atmosphere are an important component of the nutrient budget in many Florida lakes and marine waters. Nutrient delivery comes through two pathways: wet atmospheric deposition with precipitation and dry particulate-driven deposition. Atmospheric deposition to terrestrial portions of the Sanibel Slough basins are assumed to be accounted for in the Sanibel-specific Event Mean Concentrations (EMCs) used to estimate the watershed loading in **Section 3.1.1**. Loading from atmospheric deposition directly onto the water surface was also considered in the loading estimation. **Chapter 3** details how the atmospheric loads were used in the receiving water model.

Chapter 2: Applicable Water Quality Standards, Pollutants of Concern, and Site-Specific Targets

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the federal Clean Water Act requires states to submit to the EPA lists of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of listed waters on a schedule. DEP has developed such lists, commonly referred to as 303(d) lists, since 1992.

The Florida Watershed Restoration Act (FWRA) (Section 403.067, Florida Statutes [F.S.]) directed DEP to develop, and adopt by rule, a new science-based methodology to identify impaired waters. The Environmental Regulation Commission adopted the new methodology as Chapter 62-303, F.A.C. (Identification of Impaired Surface Waters Rule, or IWR), in April 2001. The rule was amended in 2006, 2007, 2012, 2013 and 2016.

The list of impaired waters in each basin, referred to as the Verified List, is also required by the FWRA (Subsection 403.067[4], F.S.). The state's 303(d) list is amended annually to include basin updates.

2.2 Classification and Numeric Interpretation of the Narrative Nutrient Criterion

Sanibel Slough East (WBID 2092F2) and Sanibel Slough West (WBID 2092F1) are Class III marine waterbodies, with a designated use of fish consumption, recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the verified impairment (nutrients) for this water is the state of Florida's nutrient criterion in Paragraph 62-302.530(48)(b), F.A.C.

Florida incrementally adopted NNC for most estuaries and other marine waters during the period from 2011 to 2014. As part of the analyses conducted to derive nutrient criteria for predominately marine waters, DEP evaluated the available water quality data for individual estuary systems and further subdivided the estuaries into homogeneous segments, or estuary nutrient regions (ENRs). These ENRs represent water segments over which the estuary-specific numeric interpretations of the narrative nutrient criterion (Subsection 62-302.531[1], F.A.C.) apply. NNC do not apply to wetlands, tidal tributaries, or non-ENR estuaries (those not expressly listed by name in Subsection 62-302.532[1], F.A.C., or delineated in the maps of the Florida ENRs incorporated by reference in Subsection 62-302.532[3], F.A.C.), unless a site-specific numeric interpretation of the narrative criterion has been adopted through some other mechanism (e.g., a TMDL, a site-specific alternative criterion [SSAC], a Level II water quality–based effluent limitation [WQBEL], or a Reasonable Assurance Plan [RAP]), as specified in Paragraph 62-302.531(2)(a), F.A.C.

Sanibel Slough East and Sanibel Slough West are classified as non-ENR estuaries and therefore are subject to the narrative nutrient criterion, which states that nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna (Subsection 62-302.531[1], F.A.C.). For non-ENR estuaries, a chlorophyll *a* (Chl*a*) target of 11 µg/L, expressed as an annual geometric mean (AGM) not to be exceeded more than once in any consecutive three-year period, is used to assess nutrient response. The 11 µg/L Chl*a* target represents the level below which a nutrient-related imbalance in flora or fauna is not expected to occur (Subsection 62-303.353[2], F.A.C.). The nutrient TMDLs presented in this report will also serve as the site-specific numeric interpretations of the narrative nutrient criterion, as specified in Paragraph 62-302.531(2)(a), F.A.C.

2.3 Determination of the Pollutant of Concern

2.3.1 Monitoring Results

Data providers for Sanibel Slough include DEP and the City of Sanibel – Natural Resources Department, with the majority of the available data coming from the monitoring conducted by the City of Sanibel. The City of Sanibel sampled quarterly at six stations (21FLSBL…) in Sanibel Slough from 2007 through 2014. DEP sampled quarterly at four stations (21FLFTM…) in Sanibel Slough in 2007. **Figure 2.1** shows the sampling locations.

To ensure that the nutrient TMDL was developed based on current conditions and that recent trends in water quality were adequately captured, monitoring data were compiled for 2007 through 2013, which includes seven complete years of the Cycle 3 verified period (January 1, 2007–June 30, 2014).

The individual water quality measurements used in this analysis are available in the IWR Database (Run 52), and are available on request. Water quality results for the period of record for variables relevant to this TMDL analysis, which were collected by all sampling entities, are available on request.

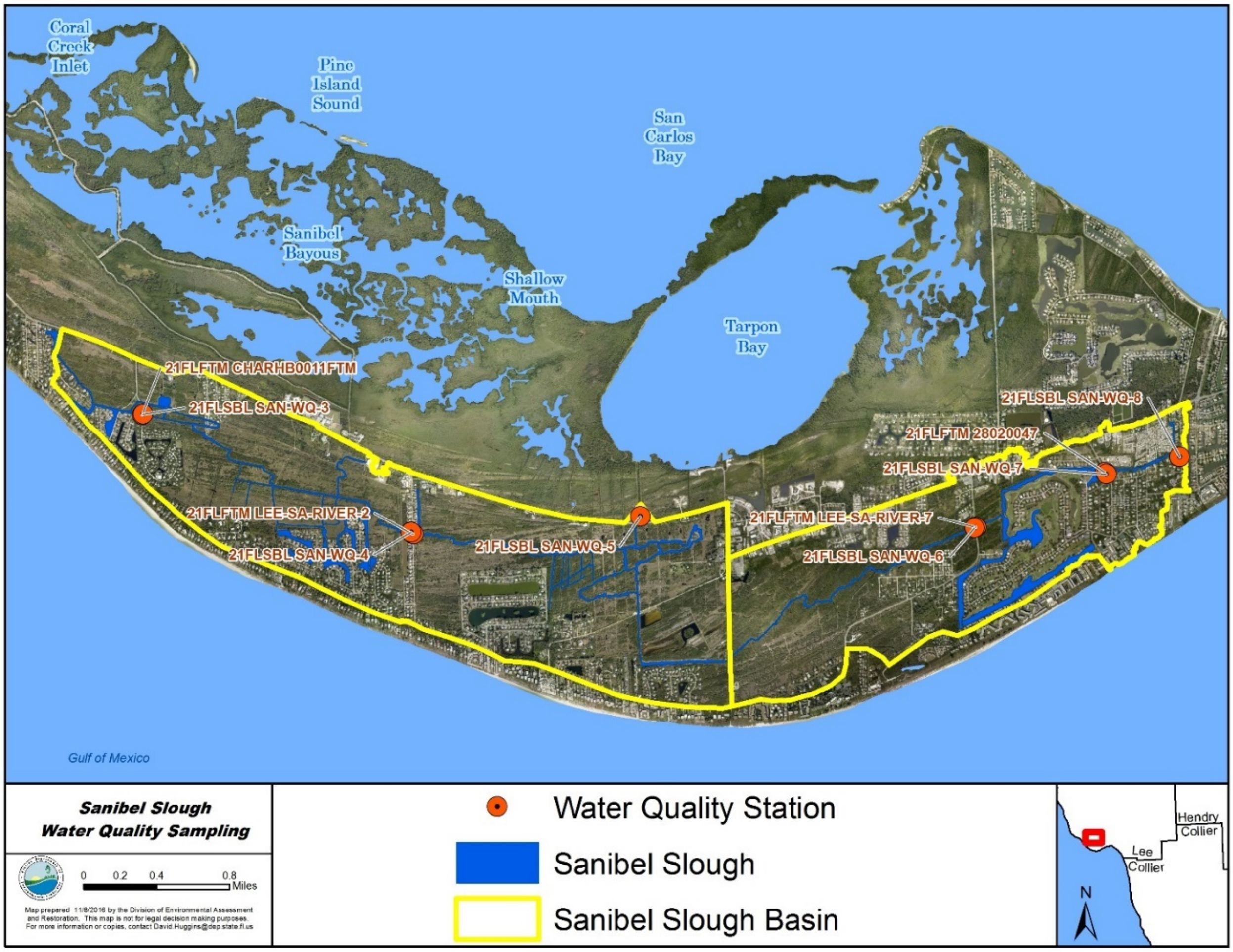

Figure 2.1. Sanibel Slough water quality sampling stations

2.3.2 Information on Verified Impairment

DEP used the IWR database to assess water quality impairments in the original WBID, 2092F, the waterbody was verified as impaired for nutrients based on elevated annual average Trophic State Index (TSI) during the Cycle 1 verified period (the verified period for the Group 2 basins is January 1, 1996–June 30, 2003). At the time the Cycle 1 assessment was performed, WBID 2092F was classified as a high-color lake (color higher than 40 platinum cobalt units [PCU]), and the IWR methodology used the water quality variables TN, TP, and Chl*a* in calculating annual TSI values and in interpreting Florida's narrative nutrient threshold. The TSI threshold (60 for high-color lakes) was exceeded in multiple years during the verified period and was sufficient to identify the waterbody as impaired for nutrients.

During the Cycle 2 assessment, WBID 2092F was reclassified as a stream, and the IWR methodology used an annual average corrected Chl*a* threshold of 20 µg/L in interpreting Florida's narrative nutrient threshold. In the Cycle 2 verified period (January 2001–June 2008), annual mean Chl*a* values exceeded the threshold of 20 µg/L in 2007, and the waterbody remained on the Verified List.

The waterbody was again reclassified for the more recent Cycle 3 assessment and was assessed as an estuary. The IWR methodology used an AGM corrected Chl*a* threshold of 11 µg/L to assess the waterbody during the verified period (January 1, 2007–June 30, 2014). The Chl*a* values exceeded the threshold of 11 µg/L during every year of the verified period, and the waterbody remained on the Verified List.

Following the most recent assessment, WBID 2092F was split into WBID 2092F1 (Sanibel Slough West) and 2092F2 (Sanibel Slough East), and the changes will be apparent in IWR Run 53. As explained in **Section 1.3.3**. This division more accurately reflects the condition of the Slough as two separate and distinct systems and will result in more accurate assessments in the future. Data from IWR Run 52 indicate that the two new WBIDs would still be impaired for nutrients based on Chl*a* concentrations that exceed the 11 µg/L threshold for non-ENR estuaries during most years. **Table 2.1** lists the AGM values for Chl*a* during the 2007 to 2014 verified period.

Table 2.1. Sanibel Slough AGM values for the 2007–14 verified period

Note: Values shown in boldface type and shaded are greater than the narrative nutrient threshold for non-ENR estuaries. Rule 62-302.531, F.A.C., states that the threshold for Chl*a* shall not be exceeded more than once in any consecutive three-year period.

Year	Sanibel Slough East (WBID 2092F2) Chl*a* (µg/L)	Sanibel Slough West (WBID 2092F1) Chl*a* (µg/L)
2007	**42**	**15**
2008	**62**	**16**
2009	**50**	**25**
2010	**16**	10
2011	**21**	**12**
2012	**39**	**13**
2013	**26**	**15**
2014	**32**	5

2.4 Site-Specific Target

The nutrient TMDLs presented in this report constitute the site-specific numeric interpretation of the narrative nutrient criterion set forth in Paragraph 62-302.530(47)(b), F.A.C., that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C., for this particular waterbody, pursuant to Paragraph 62-302.531(2)(a), F.A.C. It is important to note that as non-ENR estuaries, Sanibel Slough East and West have no generally applicable NNC criteria for TN and TP. **Appendix B** summarizes the relevant TMDL information, including information that the TMDLs provide for the protection of Sanibel Slough and for the attainment and maintenance of water quality standards in downstream waters (pursuant to Subsection 62-302.531[4], F.A.C.), to support using the TMDL nutrient targets as the site-specific numeric interpretations of the narrative nutrient criterion.

Targets used in TMDL development are designed to restore surface water quality to meet a waterbody's designated use. Similarly, water quality criteria are based on scientific information used to establish specific levels of water quality constituents that protect aquatic life and human health for particular designated use classifications. As a result, TMDL targets and water quality criteria serve the same purpose, as both are designed to protect surface water designated uses.

2.4.1 Target Selection

The development of the NNC is based on the evaluation of a response variable (Chl*a*) and stressor variables (TN and TP) to develop water quality thresholds that are protective of designated uses. For estuarine systems without adopted estuary-specific numeric interpretations of the NNC, such as Sanibel Slough, DEP assesses the waterbody based on a 11 µg/L Chl*a* impairment threshold expressed as an annual geometric mean not to be exceeded more than once in any consecutive three-year period (DEP 2015).

Chl*a* concentration was found to be the most likely basis for explaining the trophic state for estuarine waters in Florida, and a Chl*a* concentration of 11 µg/L was found to represent the breakpoint that separates the high eutrophic condition estuaries from others (Janicki 2000). Based on the best available scientific information, there are no data suggesting that a Chl*a* threshold different from 11 µg/L is necessary to protect the designated uses and maintain a balanced aquatic flora and fauna in Sanibel Slough. The Chl*a* threshold of 11 µg/L will be used as the water quality target to address the nutrient impairment of Sanibel Slough.

2.4.2 Selected Water Quality Indicators and Pollutant Interactions

In attempting to establish a nutrient TMDL for any system, it is important to determine the degree to which stressor and response variables are related in order to appropriately model the impact of nutrients on algal growth and anthropogenic eutrophication, as measured by Chl*a* response. As discussed previously, Sanibel Slough was verified impaired for nutrients in each assessment cycle using different nutrient assessment criteria applied to the slough as a lake, a stream, and an estuary. The current assessment is based on a Chl*a* AGM concentration of 11 µg/L, which is the threshold established for estuarine systems. In Florida waterbodies, nitrogen and phosphorus are most often the limiting nutrients. A limiting nutrient is defined as the nutrient(s) that limits plant growth (both macrophytes and algae) when it is not available in sufficient quantities. In the past, management activities to control eutrophication focused on phosphorus reduction, as phosphorus was generally considered the limiting nutrient in freshwater systems. Recent studies, however, support the reduction of both nitrogen and phosphorus to control algal growth in aquatic systems (Conley 2009, Paerl 2009, Paerl and Otten 2013).

DEP notes that there is a DO impairment for Sanibel Slough East and West and will be working to ascertain whether the current standard is appropriate or whether site-specific criteria will need to be developed. The system was impaired for DO based on the Cycle 3 assessment, and data from IWR Run 52 indicate that WBIDs 2092F1 and 2092F2 would still be impaired for DO based on the DO percent saturation standard of 42 % for predominately marine waters per 62-302.533(2), F.A.C. Analyses showed no significant relationship between nutrients and DO. Due to the nature of the slough system, the existing DO criterion for the system may not be achievable. It is likely that the lower DO in this system is a result of physical alteration and therefore is not directly being addressed in this TMDL. Reducing nutrient loads entering the waterbody will likely have some positive effect on DO levels while not negatively impacting other water quality parameters in the estuary.

Simple linear regression analyses were performed to detect relationships between the nutrient inputs of TN and TP and the response variable of Chl*a*. **Table 2.2** lists the results of these regression analyses, with the relevant r^2 for each parameter pair provided for both the East and West Sloughs. Additionally, simple linear regression analyses were performed to detect relationships between the nutrient inputs and DO (**Table 2.3**). Monthly average concentrations were used in the analyses between nutrients and DO due to the availability of only one year of DO data, in the year 2007. A screening value of r^2 of ≥ 0.5 and p-values of ≤ 0.05 to determine statistically significant relationships between the pairs of parameters of interest. Correlations between TN and Chl*a* were not detected in the East Slough but a significant relationship between these parameters was found in the West Slough with an r^2 of 0.61 at a p-value of 0.02. The only other variables that showed strong significant relationships were TN and TP with the East Slough having an r^2 of 0.72 at a p-value of 0.01. None of the other parameters were found to have statistically significant relationships.

Table 2.2. R^2 and P-values from simple linear regressions of nutrient AGMs

Note: Cells shown shaded have statistically significant p-values at the 95% confidence level, values in boldface type are r^2 values above 0.5.

Basin	TN vs Chl*a*	TP vs Chl*a*	TN vs TP
East	$r^2 = 0.05$, p = 0.59	$r^2 = 0.08$, p = 0.49	**$r^2 = 0.72$**, p = 0.01
West	**$r^2 = 0.61$**, p = 0.02	$r^2 = 0.02$, p = 0.75	$r^2 = 0.25$, p = 0.21

Table 2.3. R^2 and P-values from simple linear regressions of monthly average nutrient and DO pairs

Note: Cells shown shaded have statistically significant p-values at the 95% confidence level.

Basin	DO vs TN	DO vs TP	DO vs Chl*a*
East	$r^2 = 0.01$, p = 0.28	$r^2 = 0.003$, p = 0.48	$r^2 = 0.01$, p = 0.32
West	$r^2 = 0.14$, p = 0.03	$r^2 = 0.07$, p = 0.13	$r^2 = 0.01$, p = 0.56

Two weather stations were used to estimate rainfall in the Sanibel Slough system. One station is located in the J.N. "Ding" Darling National Wildlife Refuge on Sanibel Island, although it lacked data from 2007 and the record from 2008 was incomplete. The second station is in St. James City, a little more than 7 kilometers north of Sanibel Island. This station has a complete data record over the entire model period. Data from the St. James City station were used for the missing period in 2008 in the "Ding" Darling Refuge record.

Sanibel Slough is a highly-managed system with weir structures controlling both the outflow into San Carlos Bay at two points and the flow between the eastern and western portions of the slough. The City of Sanibel owns and operates the three weirs. Discharges are infrequent, less than 45 days of recorded discharges in seven years, and are confined to rare high-rainfall events (**Figure 1.5**). Water levels in both the eastern and western systems generally track precipitation (**Figure 2.2**).

TN and TP concentrations were found to be inversely correlated with rainfall amounts in both segments of Sanibel Slough. In the East Slough the r^2 value for TN was 0.11 with a r^2 for TP of 0.47, and in the West Slough the r^2 values for TN and TP were both 0.31 (**Table 2.4**). The inverse relationships results suggest that factors in addition to external nutrient loadings, such as residence time and internal cycling of nutrients, may have some influence on nutrient levels, since during periods with presumably higher watershed nutrient loadings (i.e., higher precipitation), there is no associated increase in TN and TP results. Regression of Chl*a* on precipitation explained very little of the variation in those parameters, with the West and East both showing an r^2 of less than 0.10.

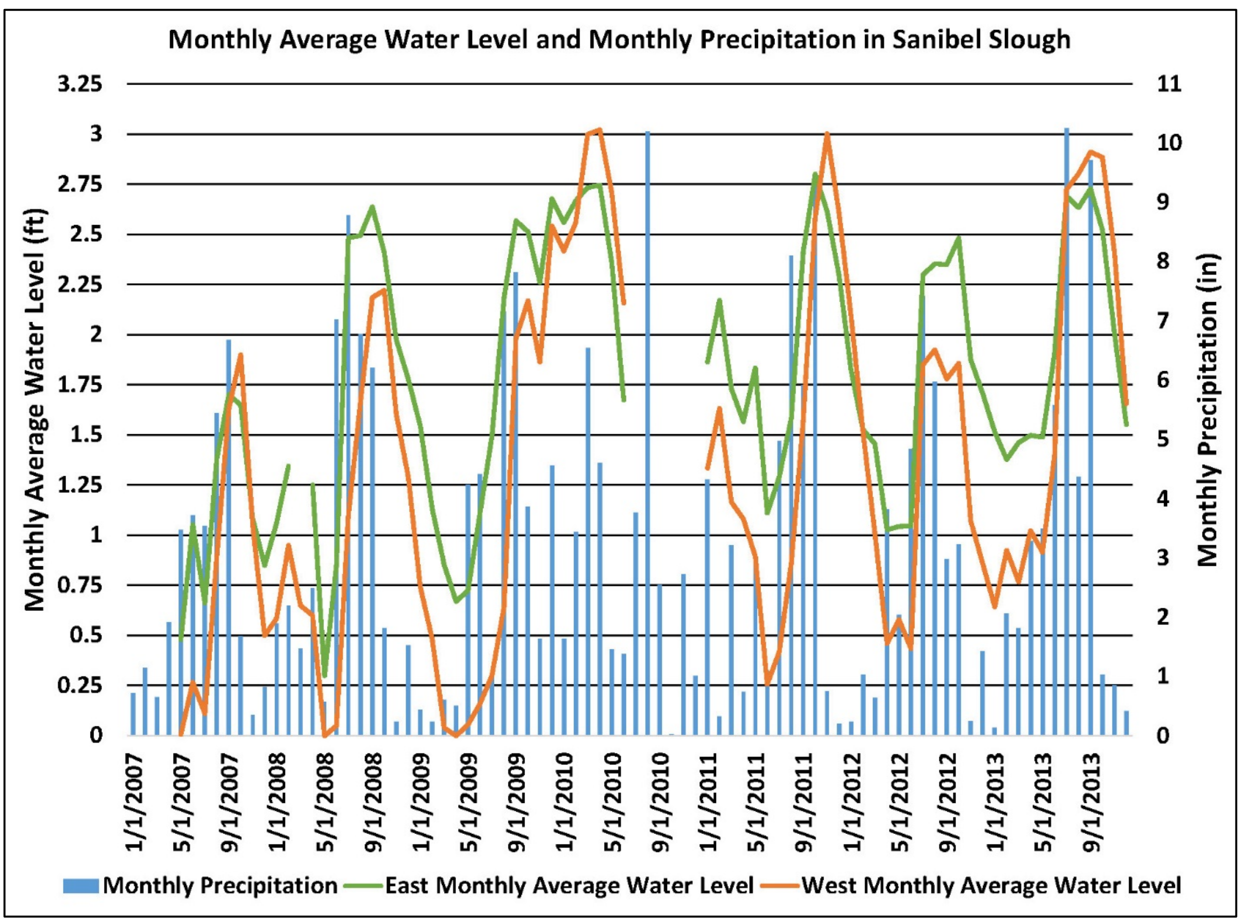

Figure 2.2. Monthly average water level and monthly precipitation in Sanibel Slough

Table 2.4. R^2 and P-values from simple linear regressions of AGM nutrient parameters on precipitation annual sums

Note: Cells shown shaded have statistically significant p-values at the 95% confidence level.

Basin	TN vs Precip	TP vs Precip	Chl*a* vs Precip
East	$r^2 = 0.11$, $p = 0.01$	$r^2 = 0.47$, $p = 0.01$	$r^2 = 0.09$, $p = 0.49$
West	$r^2 = 0.31$, $p = 0.25$	$r^2 = 0.31$, $p = 0.25$	$r^2 = 0.0002$, $p = 0.98$

2.4.3 Numeric Expression of Target

Due to the distinct nature of the two basins, as discussed in **Section 1.3.3**, individual targets were selected for each basin. The TN and TP targets for the East and West Basins were established using the modeling approach discussed in detail in **Chapter 3** of this TMDL report. This approach links the yearly watershed TN and TP loading simulation to the estuary Chl*a*, TN, and TP concentration simulation for 2007 through 2013.

The relationship between estuary AGM concentrations of Chl*a*, TN, and TP and incoming TN and TP loads was used to derive a distribution of yearly TN and TP loads necessary to meet the Chl*a* target of 11 µg/L. A lagged 3-year rolling average was applied to the distribution of yearly nutrient loads, and the maximum of the resulting 3-year averages was chosen as the target TN and TP loads. The three-year average TN and TP target loads necessary to meet the Chl*a* target of 11 µg/L (TMDL condition) in the West Basin are 966 and 176 kg/yr, respectively (**Table 2.5**). The three-year average TN and TP target loads necessary to meet the Chl*a* target of 11 µg/L (TMDL condition) in the East Basin are 1,644 and 143 kg/yr, respectively (**Table 2.6**).

Table 2.5. Sanibel Slough West TMDL condition nutrient loads

Note: Values shown shaded and in boldface type are the maximum of the three-year rolling averages and the three annual loads corresponding to the maximum three-year rolling average.

Year	TMDL Condition TN Loads (kg/yr)	Lagging 3-Year Rolling Average TN Loads (kg/yr)	TMDL Condition TP Loads (kg/yr)	Lagging 3-Year Rolling Average TP Loads (kg/yr)
2007	632		87	
2008	**891**		138	
2009	**973**	832	**195**	140
2010	**1,033**	**966**	**191**	175
2011	889	965	**142**	**176**
2012	752	891	119	151
2013	976	872	171	144

Table 2.6. Sanibel Slough East TMDL condition nutrient loads

Note: Values shown shaded and in boldface type are the maximum of the three-year rolling averages and the three annual loads corresponding to the maximum three-year rolling average.

Year	TMDL Condition TN Loads (kg/yr)	Lagging 3-Year Rolling Average TN Loads (kg/yr)	TMDL Condition TP Loads (kg/yr)	Lagging 3-Year Rolling Average TP Loads (kg/yr)
2007	1,058		61	
2008	1,519		107	
2009	1,407	1,328	101	90
2010	**1,676**	1,543	**154**	121
2011	**1,630**	1,571	**136**	131
2012	**1,627**	**1,644**	**140**	**143**
2013	1,612	1,623	141	139

Table 2.7 provides the summary of the Chl*a* target concentration as well as the TMDL target loads for TN and TP. The Chl*a* target and the associated TN and TP target loads will serve as the site-specific interpretations of the narrative nutrient criteria pursuant to Paragraph 62-302.530(47)(b), F.A.C. These nutrient loads shall be expressed as a rolling 3-year annual average load not to be exceeded, and the Chl*a* concentration shall be expressed as an AGM concentration not to be exceeded more than once in any consecutive 3-year period.

Table 2.7. Site Specific Interpretations of Narrative Nutrient Criteria

Note: Chlorophyll *a* shall not be exceeded more than once in any consecutive three-year period. TN and TP are not to be exceeded.

WBID	AGM Chlorophyll *a* (µg/L)	Rolling 3-year annual average TN (kg/yr)	Rolling 3-year annual average TP (kg/yr)
2092F1	11	966	176
2092F2	11	1,644	143

The TN and TP reference concentrations represent the simulated estuary TN and TP concentrations corresponding to the estuary Chl*a* concentration of 11 µg/L. A distribution of the yearly simulated nutrient concentrations corresponding to the target Chl*a* condition was derived in the modeling approach, and the 80th percentile of this distribution was selected as the reference TN and TP concentrations. The statistical derivation of the 80th percentile is consistent with a one-in-three-year exceedance rate, as documented in the report, *Overview of Approaches for Numeric Nutrient Criteria Development in Marine Waters* (DEP 2012).

The TN and TP reference concentrations for the West Basin are 1.66 and 0.06 mg/L, respectively, and for the East Basin, 1.60 and 0.05 mg/L, respectively. **Table 2.8** lists the yearly distribution of simulated nutrient concentrations and the resulting 80th percentile reference TN and TP concentrations for the East and West Basins. These reference concentrations are AGMs not to be exceeded more than once in a three-year period. The TMDL loads will be considered as the site-specific interpretation of the narrative criterion. Nutrient concentrations are provided for comparative purposes only.

Table 2.8. Sanibel Slough simulated nutrient AGM concentrations

Year	West Basin AGM TN Concentrations (mg/L)	West Basin AGM TP Concentrations (mg/L)	East Basin AGM TN Concentrations (mg/L)	East Basin AGM TP Concentrations (mg/L)
2007	1.66	0.06	1.60	0.04
2008	1.30	0.06	1.41	0.04
2009	1.65	0.06	1.59	0.04
2010	1.75	0.05	1.72	0.05
2011	1.30	0.05	1.51	0.05
2012	1.44	0.06	1.51	0.05
2013	1.30	0.06	1.41	0.05
80th Percentile	1.66	0.06	1.60	0.05

2.5 Critical Conditions and Seasonal Variation

The estimated assimilative capacity is based on annual conditions, rather than critical/seasonal conditions because (1) the methodology used to determine assimilative capacity does not lend itself very well to short-term assessments, (2) DEP is generally more concerned with the net change in overall primary productivity in the segment, which is better addressed on an annual basis, and (3) the methodology used to determine impairment is based on annual conditions (AGMs or arithmetic means).

2.6 Downstream Protection

As discussed in **Section 1.3.3** and shown in **Figure 1.4**, Sanibel Slough West has a weir control structure at Sanibel-Captiva Road on the northern side of the island that discharges into Tarpon Bay, which eventually flows into San Carlos Bay. Sanibel Slough East has a weir control structure at Beach Road on the eastern side of the island, which drains to a system of canals that eventually mixes with San Carlos Bay.

San Carlos Bay (including Tarpon Bay, WBID 2065H1) is a Class II estuary that has estuary-specific numeric interpretations of the NNC for Chl*a*, TN, and TP. There is no history of nutrients impairments in WBID 2065H1, and based on the most recent assessment, San Carlos Bay is not currently impaired for nutrients. **Table 2.9** lists the applicable NNC values, current assessment data, and assessment status of San Carlos Bay for the most recent assessment period, Cycle 3, which was completed on April 27, 2016, for the Group 2 basins.

Table 2.9. Cycle 3 assessment status for San Carlos Bay

Note: Estuary nutrient criteria for San Carlos Bay (ENRD6) is a long-term average.

Parameters Assessed	NNC expressed as a long-term average	Long-term average of measured data used for Cycle 3 Assessment	Assessment Category	Summary Status
Chl*a*	3.7 µg/L	2.7 µg/L	2	Not Impaired
TN	0.44 mg/L	0.42 mg/L	2	Not Impaired
TP	0.045 mg/L	0.037 mg/L	2	Not Impaired

As evidenced by the healthy existing conditions in San Carlos Bay, the existing loads from Sanibel Slough to San Carlos Bay have not led to an impairment of the downstream water and are not preventing San Carlos Bay from attaining its designated uses. The reductions in nutrient loads prescribed in this TMDL are not expected to cause nutrient impairments downstream but will result in water quality improvements to downstream waters.

Chapter 3: Determination of the TMDL

3.1 Selection of Appropriate Tool

For this TMDL, a calibrated model-based prediction was used to estimate the nutrient loads necessary to achieve an AGM Chl*a* concentration of 11 µg/L. The model period used was 2007 through 2013 in order to encompass the years with complete calendar years' worth of data in the most recent Cycle 3 assessment period (January 1, 2007–June 30, 2014).

3.1.1 Watershed Loading Models

The SCCF Marine Laboratory developed Sanibel Island–specific runoff coefficients using a modified Soil Conservation Service (SCS) curve number (CN) method. The key function of this spreadsheet model is to estimate the annual average runoff coefficient for each land use–soil type combination for each year. The full method and results of the Sanibel CN modeling is available in the report, *Development of Stormwater Runoff Coefficients, Nutrient Concentrations and Loading Estimates for Sanibel Island, Florida* (Thompson and Milbrandt 2014). Once the runoff coefficient is decided, the runoff volume can be calculated as the product of rainfall, runoff coefficient, and acreage of the land use–soil type combination.

The equation used to calculate the land use specific runoff volume is as follows:

$$Q_{W/D} = A \times RC_{W/D} \times P_{W/D}$$

Where:

$Q_{W/D}$ is the wet or dry season runoff volume.

A is the area per land use type.

$RC_{W/D}$ is the land use specific runoff coefficient for the wet or dry season.

$P_{W/D}$ is the annual precipitation for the wet or dry season.

Additionally, Sanibel-specific EMCs were developed to present the most accurate nutrient loading rates from the watershed stormwater runoff. The EMCs used for calculating the stormwater loads are from the report on the development of Sanibel-specific runoff coefficients, EMCs, and loads (Thompson and Milbrandt 2014), except for the runoff coefficient and EMCs for wetlands, which are cited from Dr. Harvey Harper's stormwater review report (2003). **Table 3.1** summarizes the wet and dry season runoff coefficients and nutrient EMCs used in the watershed loading calculations.

Table 3.1. Sanibel-specific runoff coefficients and EMCs by wet and dry seasons

Land Use Type	Dry Season Runoff Coefficient	Wet Season Runoff Coefficient	Dry Season TN (mg/L)	Wet Season TN (mg/L)	Dry Season TP (mg/L)	Wet Season TP (mg/L)
Low-Density Residential	0.33	0.12	1.61	0.71	0.24	0.32
Medium-Density Residential	0.39	0.18	1.22	1.13	0.27	0.36
High-Density Residential	0.45	0.26	1.04	1.33	0.22	0.31
Commercial and Services	0.58	0.43	0.66	0.51	0.15	0.15
Institutional (School)	0.6	0.19	1.18	1.18	0.15	0.15
Recreational (Golf Course)	0.25	0.04	4.32	2.28	1.21	1.69
Recreational (Parks)	0.31	0.21	1.93	1.93	0.40	0.40
Utilities (WWTP)	0.97	0.78	1.82	1.82	0.27	0.27
Shrub and Brushland	0.3	0.14	1.20	1.20	0.07	0.07
Disturbed Land	0.65	0.55	1.50	1.50	0.15	0.15
Upland Hardwood Forests	0.21	0.16	0.20	0.20	0.01	0.01
Wetlands	0.05	0.05	1.01	1.01	0.09	0.09

The Sanibel-specific runoff coefficients and EMCs were used in a modified Pollutant Load Simulation Model (PLSM) spreadsheet to calculate the nutrient loadings for the West and East Basins by wet and dry season. Nutrient loads were calculated for each basin, per season, by multiplying the land use–specific runoff volume and EMCs.

Finally, the wet and dry season loads were summed to provide the annual TN and TP loadings for each basin per year in the modeling period. The resulting annual nutrient runoff loads are summarized in **Table 3.2** and were used as the stormwater inputs for the receiving water model discussed in **Section 3.1.2**.

Table 3.2. Summary of annual watershed loads for Sanibel Slough

Year	West Basin TN Loads (kg/yr)	West Basin TP Loads (kg/yr)	East Basin TN Loads (kg/yr)	East Basin TP Loads (kg/yr)
2007	626	108	754	229
2008	892	157	1,075	322
2009	797	139	903	257
2010	811	157	960	270
2011	893	164	1,066	312
2012	746	128	1,361	437
2013	952	162	1,149	352

3.1.2 Receiving Water Model

The BATHTUB model was chosen for Sanibel Slough because of the reservoir-like nature of the system, caused by the weir controlled water levels (Thompson and Milbrandt 2013). As discussed in **Section 1.3.3**. BATHTUB was set up to simulate estuary TN, TP, and Chl*a* concentrations each year from 2007 to 2013 based on simulated TN and TP loads.

3.1.2.1 BATHTUB Overview

The BATHTUB eutrophication model is a suite of empirically derived steady-state models developed by the U.S. Army Corps of Engineers (ACOE) Waterways Experimental Station. The primary function of these models is to estimate nutrient concentrations and algal biomass resulting from different patterns of nutrient loadings. The procedures for selecting the appropriate model for a particular waterbody are described in the *User's Manual* (Walker 2004). The empirical prediction of eutrophication with this approach is typically a two-stage procedure using the following two categories of models (Walker 1987):

- The **nutrient balance model** relates to the nutrient concentration to external nutrient loadings, morphometrics, and hydraulics of the waterbody.

- The **eutrophication response model** describes the relationships among eutrophication indicators in the waterbody, including nutrient levels, Chl*a*, transparency, and hypolimnetic oxygen depletion.

Figure 3.1 shows the scheme used by BATHTUB to relate the external loading of nutrients to the waterbody nutrient concentrations and the physical, chemical, and biological response of the waterbody to the level of nutrients.

The BATHTUB model includes a suite of phosphorus and nitrogen sedimentation models along with a set of chlorophyll and Secchi depth models. The nutrient balance models assume that the net accumulation of nutrients in a waterbody is the difference between nutrient loadings into the waterbody from various sources and the nutrients carried out through outflow and the losses of nutrients through decay processes inside the waterbody. Different limiting factors such as nitrogen, phosphorus, light, or flushing are considered in the selection of an appropriate Chl*a* model. The variety of models available in BATHTUB allows the user to choose specific models based on a waterbody's particular condition.

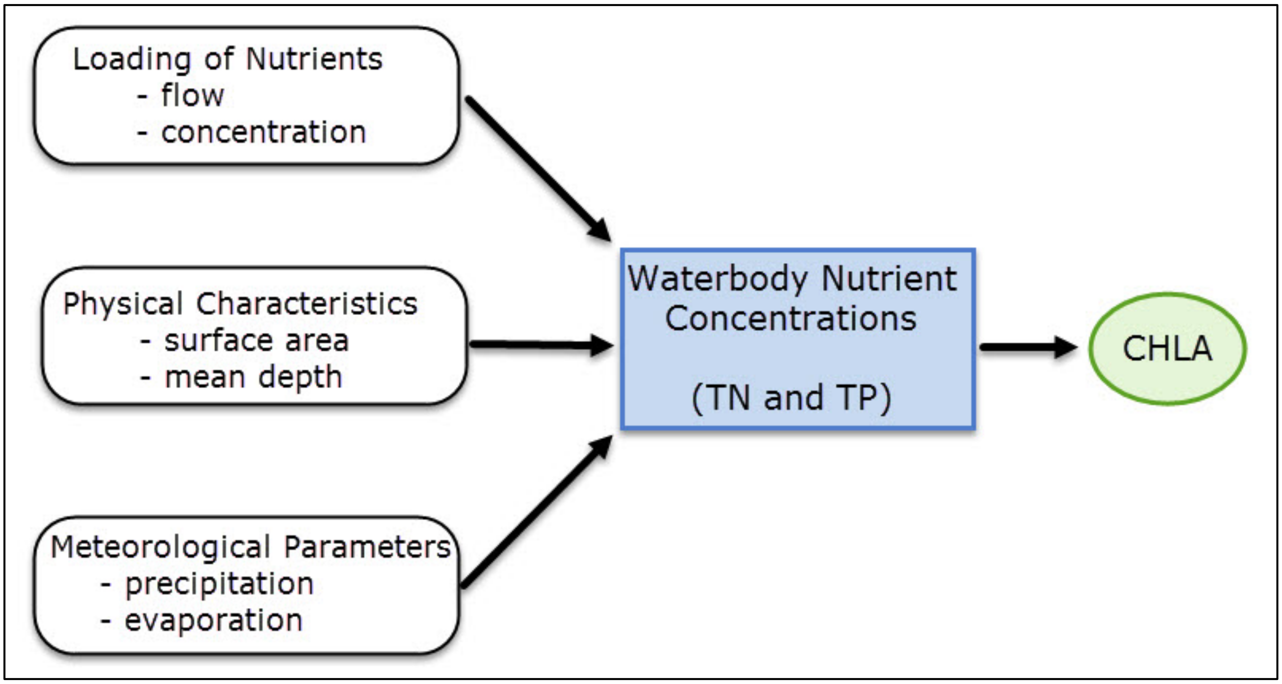

Figure 3.1. BATHTUB concept scheme

3.1.2.2 BATHTUB Inputs

MORPHOLOGICAL

The morphological measurements of Sanibel Slough were estimated based on the GIS coverage of the slough waterbody and measured water level recordings taken by the City of Sanibel. The geometric area of the GIS layer was used as the estimated surface area of the waterbody. The surface area for Sanibel Slough West was 0.29 square kilometers (km^2), and the surface area for Sanibel Slough East was 0.22 km^2. The length of the West and East Slough were measured in ArcGIS with the Measure tool. The lengths of Sanibel Slough West and Sanibel Slough East were 18.1 and 6.6 km, respectively. Records of the water levels taken by City of Sanibel employees at several staff gauges along the slough in each basin were used to estimate the annual mean depth. The water level readings from the gauges were used as the slough depth, and the readings were averaged for each year from 2007 to 2013. **Table 3.3** summarizes the annual average water depths.

Table 3.3. Mean depths for Sanibel Slough

Year	Sanibel Slough West Mean Depth (meters)	Sanibel Slough East Mean Depth (meters)
2007	0.28	0.35
2008	0.39	0.52
2009	0.39	0.50
2010	0.85	0.75
2011	0.43	0.59
2012	0.39	0.53
2013	0.56	0.59

METEOROLOGICAL

Daily rainfall data collected at MesoWest Station TS755 (University of Utah), located at the J.N. "Ding" Darling National Wildlife Refuge, was used to calculate the seasonal precipitation measurements per year for May 2008 through December 2013. Data for 2007 and the first four months of 2008 were missing in the MesoWest rainfall dataset. To complete the dataset, the rainfall data from the closest station, located at Ruby Ave. and Henley Canal in St. James, Florida, were used to fill the gaps. The wet season on Sanibel Island is July 1 through October 15, with the remainder of the year being described as the dry season (Thompson and Milbrandt 2014). **Table 3.4** summarizes wet and dry season precipitation per year.

Table 3.4. Annual rainfall in the Sanibel Slough Watershed, 2007–13

Year	Dry Season (meters)	Wet Season (meters)	Yearly Total (meters)
2007	0.31	0.41	0.72
2008	0.48	0.57	1.05
2009	0.52	0.41	0.93
2010	0.58	0.42	1.00
2011	0.54	0.52	1.07
2012	0.36	0.50	0.86
2013	0.45	0.64	1.09

Evaporation from the surface of Sanibel Slough was predicted using measurements of water surface evaporation, which were based on cumulative literature and lysimeter studies and evaporation and evapotranspiration measurements and estimations. Estimations from the SFWMD suggest an open water evaporation rate of 1.35 m/yr (53 in/yr) for the southern portion of Florida (Abtew et al. 2003). This evaporation rate was used as an input to the BATHTUB receiving waterbody model.

Nutrient Loads

Nutrient loading inputs into the BATHTUB model were added through three pathways: atmospheric deposition loads, groundwater loads, and stormwater runoff loads from the watershed model discussed in **Section 3.1.1**.

The estimated total atmospheric nutrient loading directly to the slough in the West Basin is 63 kg/yr for TN and 1 kg/yr for TP, and for the East Basin it is 50 kg/yr and 1 kg/yr for TN and TP, respectively (Thompson and Milbrandt 2013). The atmospheric deposition loads of TN and TP were entered as global variables in the BATHTUB model inputs, expressed as a per area loading rate on an annual scale, as listed in **Table 3.5**.

Table 3.5. Sanibel Slough atmospheric deposition loads

Basin	TN (mg/m2/yr)	TP (mg/m2/yr)
West	217	3
East	228	4

The extrapolated annual discharge and the mean nutrient concentrations, discussed in **Section 1.4.4**, were used to determine the annual groundwater nutrient loads in the East and West Basins (**Table 3.6**) for each year of the modeling period.

Table 3.6. Sanibel Slough groundwater nutrient loads

Year	West Basin TN Loads (kg/yr)	West Basin TP Loads (kg/yr)	East Basin TN Loads (kg/yr)	East Basin TP Loads (kg/yr)
2007	108	3	754	81
2008	157	4	1,119	121
2009	139	4	1,170	127
2010	157	4	1,305	141
2011	164	5	1,249	135
2012	128	4	940	103
2013	162	5	1,075	117

Groundwater loads and stormwater loads were added as individual tributaries to the receiving water segments in the BATHTUB model inputs. **Table 3.7** summarizes simulated total nutrient loadings from all sources for the West and East Basins and highlights the values that represent the maximum loads for the model period for each basin. **Figures 3.2** and **3.3** illustrate the average percent contribution of all sources for the West and East Basins, respectively.

Table 3.7. Sanibel Slough simulated existing condition nutrient loads

Note: Values shown shaded and in boldface type are maximum loads for the model period.

Year	West Basin Existing Condition TN Loads (kg/yr)	West Basin Existing Condition TP Loads (kg/yr)	East Basin Existing Condition TN Loads (kg/yr)	East Basin Existing Condition TP Loads (kg/yr)
2007	785	158	1,570	313
2008	1.109	222	2,271	447
2009	983	199	2,121	384
2010	1,033	191	2,336	413
2011	**1,112**	217	2,351	445
2012	938	190	**2,371**	**544**
2013	**1,172**	**242**	2,258	467

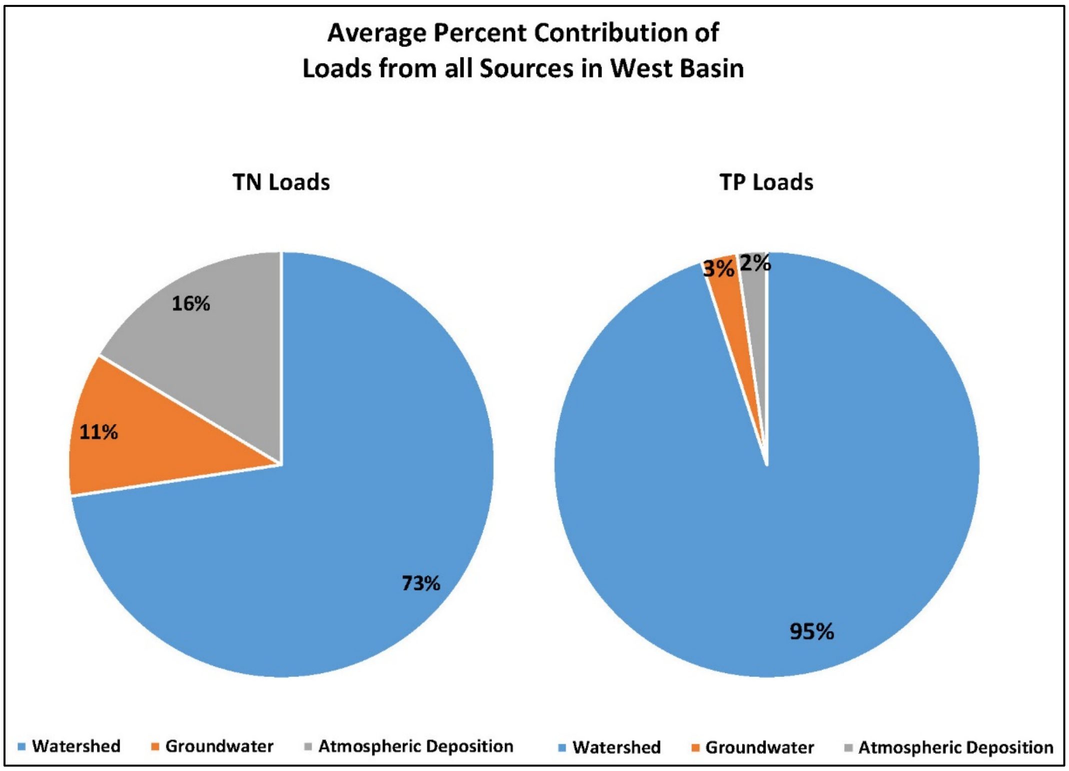

Figure 3.2. Average Percent Contribution of Loads from all Sources in West Basin

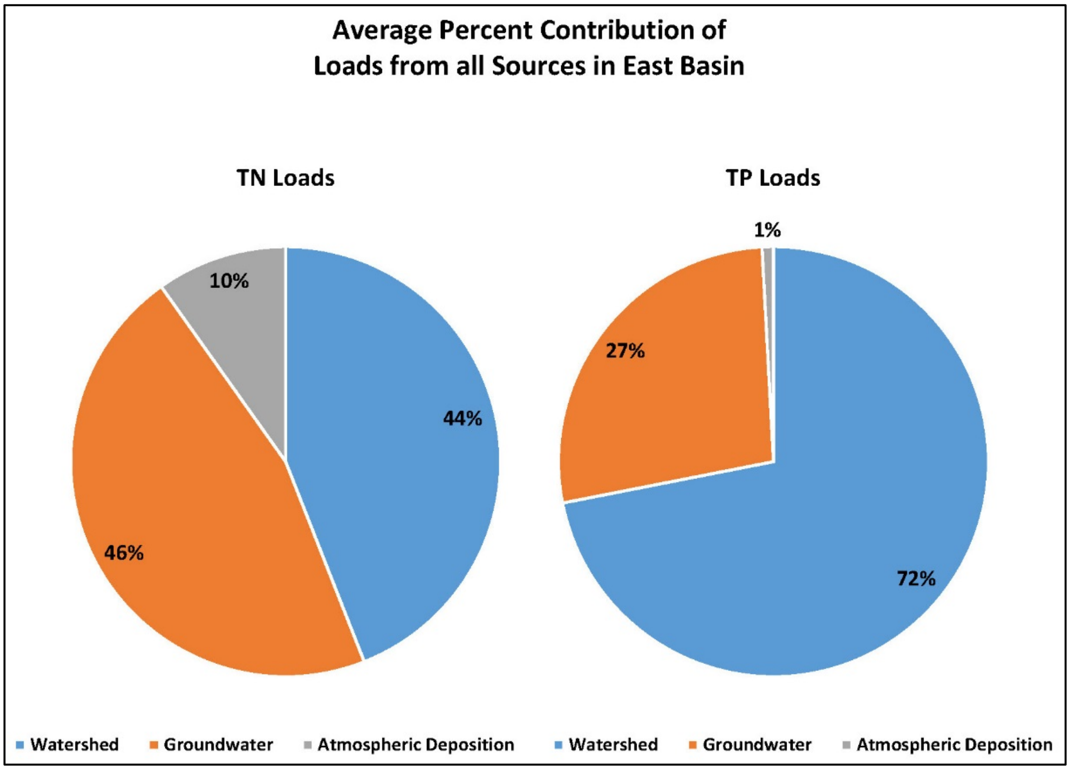

Figure 3.3. Average Percent Contribution of Loads from all Sources in East Basin

NUTRIENT BALANCE MODEL SELECTION

The BATHTUB model package can use a range of model equations to predict a waterbody's responses to long-term physical and chemical factors. The model equations are chosen based on the model's ability to predict the measured nutrient concentrations. For the West Slough, the phosphorus Model Option 4, based on the mass balance phosphorus loading model developed by Canfield & Bachmann's for reservoirs (1981), and nitrogen Model Option 6, based on a simple first-order decay rate, were chosen to represent the nutrient dynamics of the waterbody. For the Chl*a* simulation, chlorophyll *a* Model Option 4 was chosen based on the linear relationship between Chl*a* and TP.

The phosphorus Model Option 4, based on the Canfield and Bachmann (1981) equation for phosphorus sedimentation rates in reservoirs, and nitrogen Model Option 6, based on a simple first-order decay rate, were used to simulate both nitrogen and phosphorus sedimentation in Sanibel Slough East. Model Option 2, which includes phosphorus, light/transparency, and flushing as potential limiting factors to algal production, was selected for the simulation of Chl*a* in the East Slough.

3.1.2.3 BATHTUB Calibration

The BATHTUB model includes calibration factors as a mean for adjusting model predictions to account for site-specific conditions. Calibration variables include TP, TN, and Chl*a*, and calibration factors apply to sedimentation rates (default) or predicted concentrations. The measured AGM concentrations for TN, TP, and Chl*a* were calculated from available water quality data and used to calibrate the BATHTUB model by adjusting the simulated concentrations until they were within an acceptable range of the measured values. In order to calibrate the West Basin, a calibration factor of 1.2 was applied to

TN, a calibration factor of 2 was applied to TP and a calibration factor of 0.75 was used for Chl*a*. No calibration factor was applied to the TN sedimentation rates in the East Basin, but a factor of 2 was used for TP and a calibration factor of 0.5 was used for Chl*a*.

Tables 3.8 through **3.10** present the results of the model calibration using the percent difference between the measured and simulated values as the measure of model performance. Overall, the percent differences were generally within a range that is described as "good" to "very good" according to generally accepted model calibration tolerances (Donigian 2000). The Chl*a* concentrations were poorly predicted in the BATHTUB model for the East Basin in the years 2008 and 2009, however the remaining years were closely predicted. **Figures 3.4** through **3.9** present the visual interpretation of the calibration results with error bars representing +/- 35 % difference in the simulated values. Once the BATHTUB models are calibrated, they can be used to evaluate different scenarios by changing the incoming nutrient loads.

Table 3.8. BATHTUB calibration for TN, average AGM 2007–13

ppb = Parts per billion

Year	West Basin Simulated TN (ppb)	West Basin Measured TN (ppb)	West Basin TN % Difference	East Basin Simulated TN (ppb)	East Basin Measured TN (ppb)	East Basin TN % Difference
2007	2,059	1,870	9	2,367	2,168	8
2008	1,623	1,476	9	2,115	1,835	13
2009	1,665	1,982	19	2,389	2,223	7
2010	1,750	2,108	20	2,400	1,743	27
2011	1,629	1,945	19	2,180	1,882	14
2012	1,793	1,974	10	1,834	1,911	4
2013	1,554	1,736	12	1,973	2,163	10
Average			**14**			**12**

Table 3.9. BATHTUB calibration for TP, average AGM 2007–13

Year	West Basin Simulated TP (ppb)	West Basin Measured TP (ppb)	West Basin TP % Difference	East Basin Simulated TP (ppb)	East Basin Measured TP (ppb)	East Basin TP % Difference
2007	77	73	5	104	128	23
2008	73	42	43	100	84	16
2009	55	94	72	97	128	32
2010	54	58	8	87	76	12
2011	69	54	22	96	85	12
2012	71	64	10	106	97	8
2013	66	59	11	97	97	0
Average			**24**			**15**

Table 3.10. BATHTUB calibration for Chl*a*, average AGM 2007–13

Year	West Basin Simulated Chl*a* (ppb)	West Basin Measured Chl*a* (ppb)	West Basin Chl*a* % Difference	East Basin Simulated Chl*a* (ppb)	East Basin Measured Chl*a* (ppb)	East Basin Chl*a* % Difference
2007	16	15	6	36	42	18
2008	15	16	9	30	62	105
2009	12	25	106	27	50	85
2010	11	10	7	20	16	18
2011	15	12	21	23	21	10
2012	15	13	12	30	39	29
2013	14	15	4	23	26	12
Average			**23**			**39**

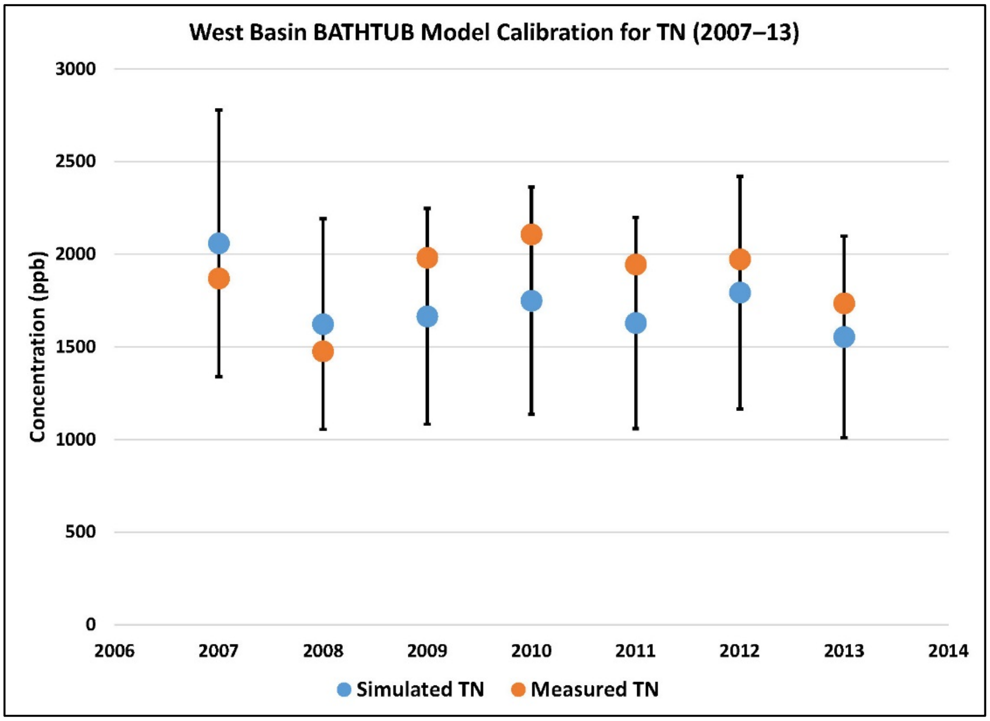

Figure 3.4. West Basin BATHTUB Model Calibration for TN (2007–13)

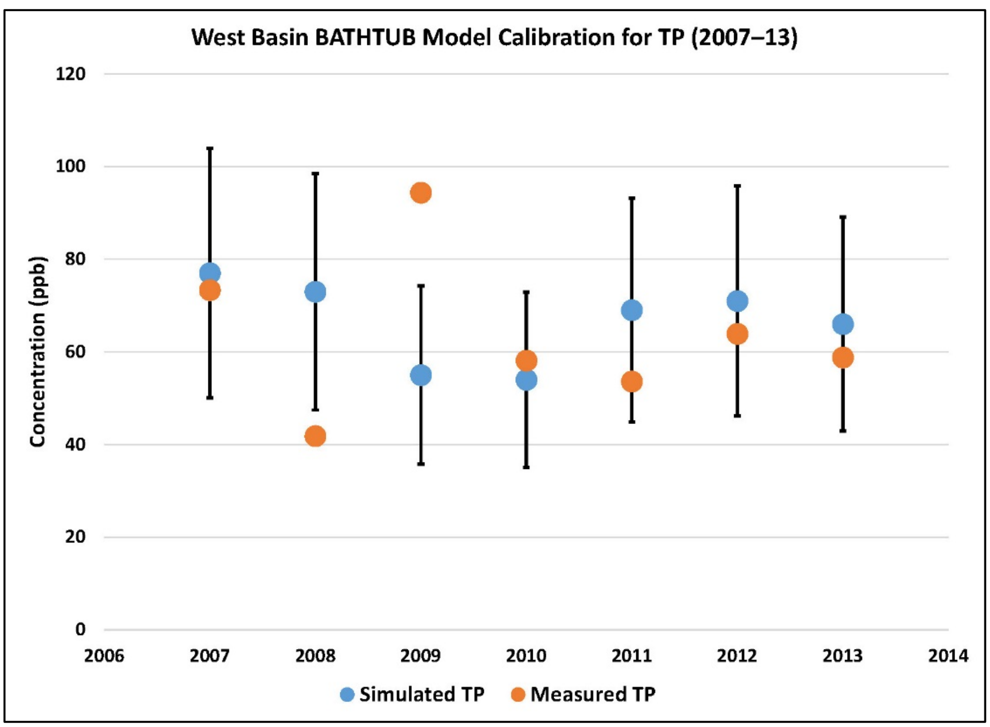

Figure 3.5. West Basin BATHTUB Model Calibration for TP (2007–13)

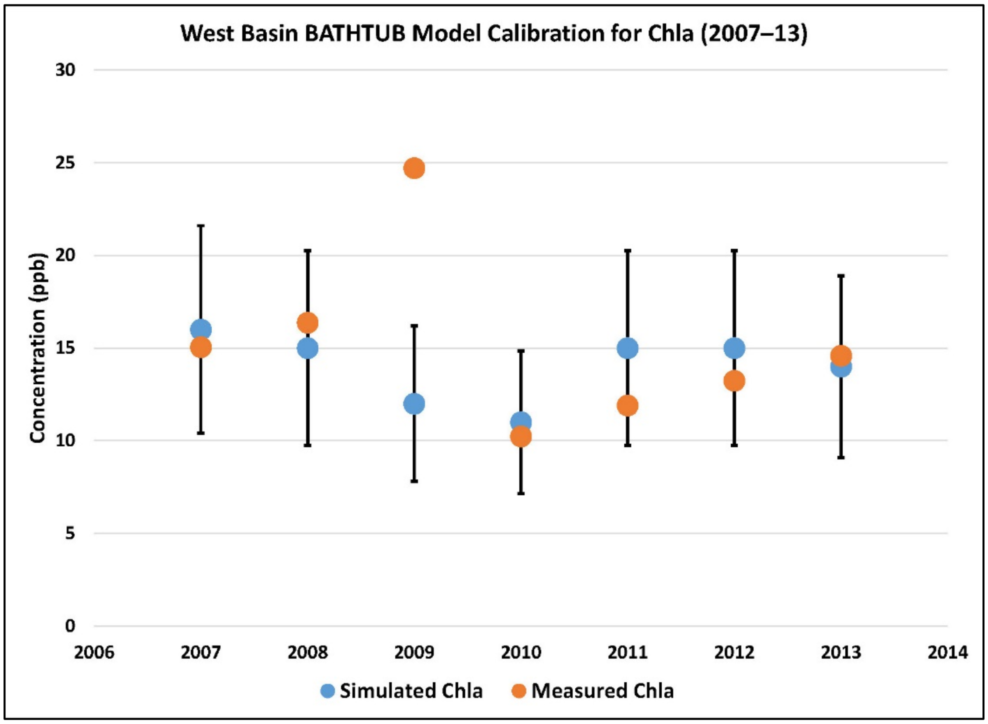

Figure 3.6. West Basin BATHTUB Model Calibration for Chl*a* (2007–13)

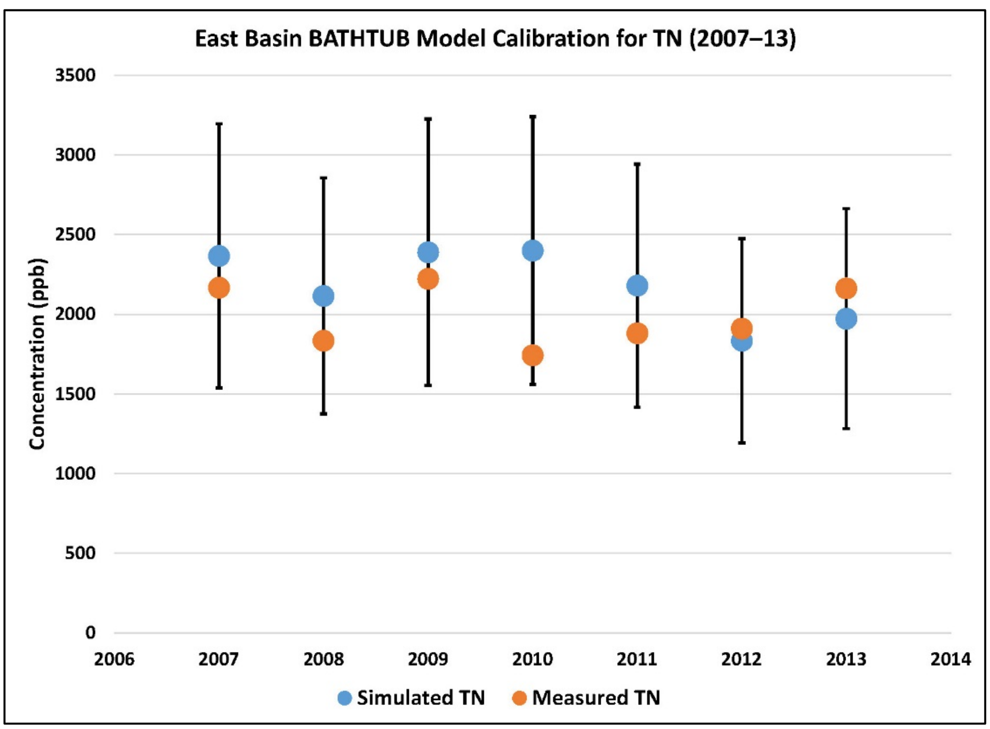

Figure 3.7. East Basin BATHTUB Model Calibration for TN (2007–13)

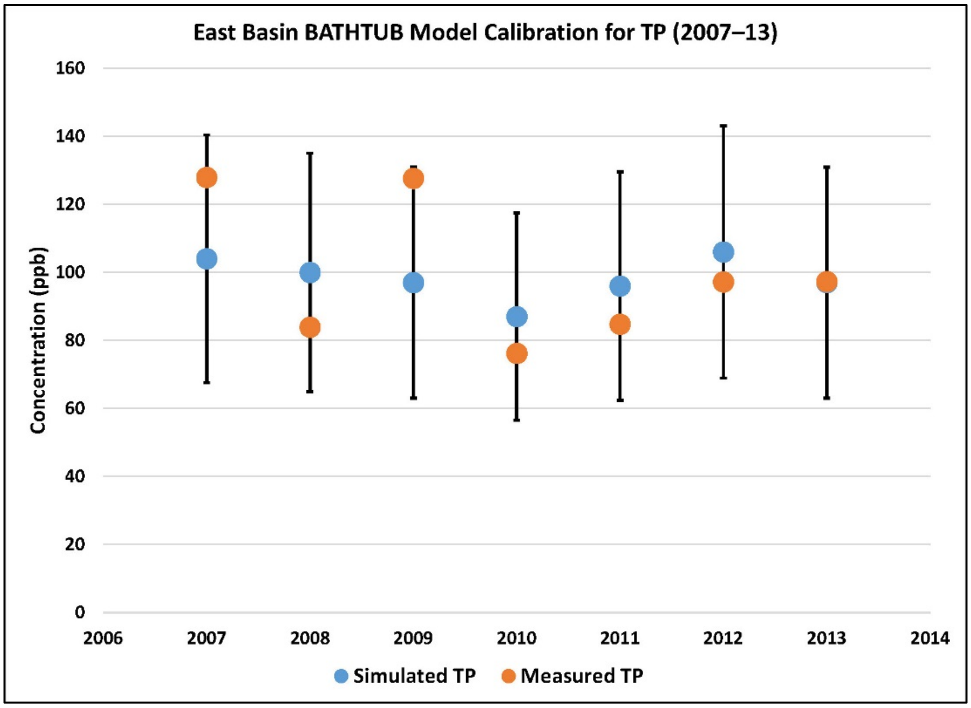

Figure 3.8.   East Basin BATHTUB Model Calibration for TP (2007–13)

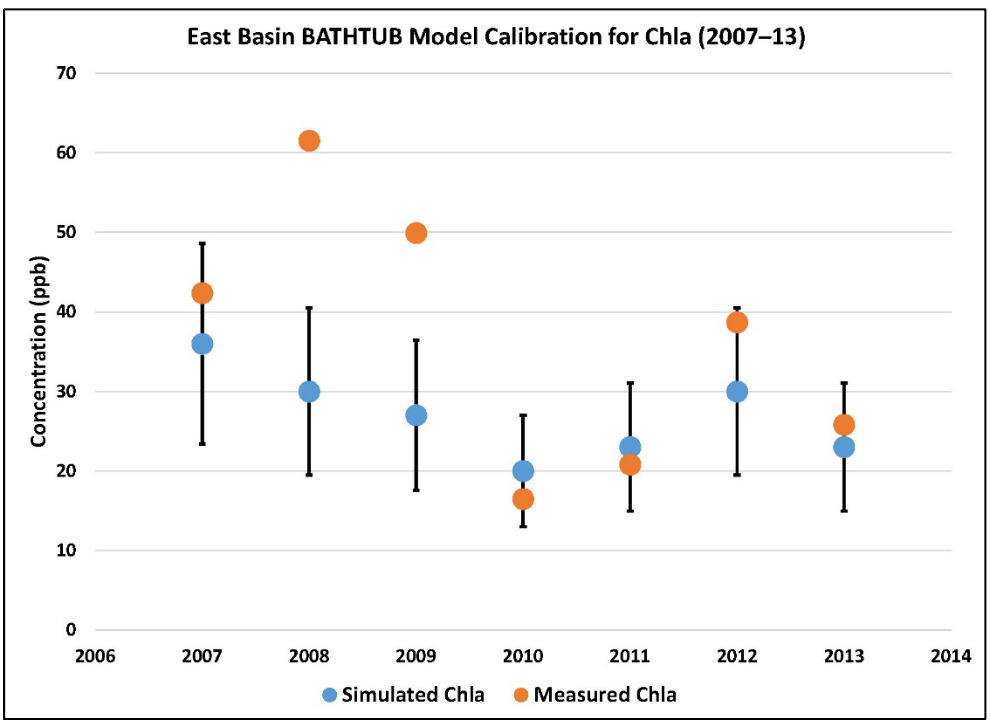

Figure 3.9.   East Basin BATHTUB Model Calibration for Chl*a* (2007–13)

3.4 Scenarios to Achieve the Target Condition

To achieve the 11 µg/L Chl*a* target every year, the TN and TP loads that achieve the Chl*a* target were simulated using the BATHTUB model. A background condition scenario was run to ensure that the TMDL condition would not abate the natural conditions. The background condition model runs were created by converting all anthropogenic land use types to natural land uses, dividing evenly between forested land and wetlands. A background groundwater loading rate was simulated by selecting the lowest mean groundwater TN and TP concentrations measured along the slough during the 2015-2016 groundwater study conducted by the SCCF Marine Lab (Thompson and Milbrandt 2016), and multiplying the concentrations by the groundwater discharge volume that was calculated for the years 2007 through 2013. The loads from the natural background condition were subtracted from the loads from the existing condition, and the remaining load was considered to be the anthropogenic load. The anthropogenic loads were incrementally decreased until the estuary Chl*a* geometric mean concentration of 11 µg/L was achieved every year (TMDL condition).

Figures 3.10 through **3.12** show the annual TN and TP loads and Chl*a* concentrations under the existing and TMDL conditions for the West Basin, and **Figures 3.13** through **3.15** show the scenarios for the East Basin.

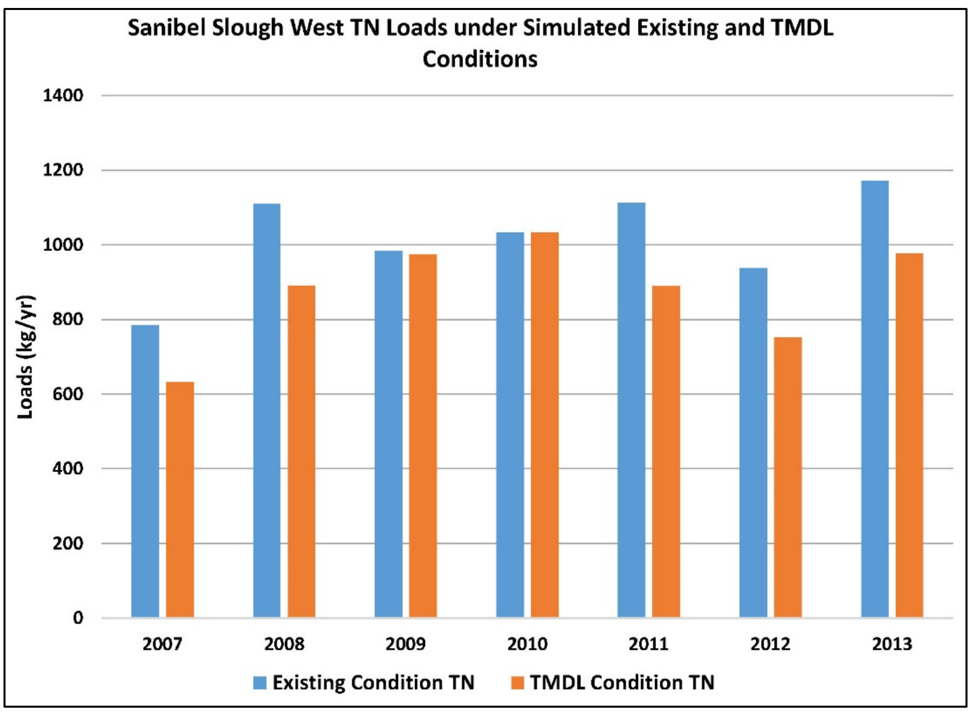

Figure 3.10. Sanibel Slough West simulated TN loads under existing and TMDL conditions

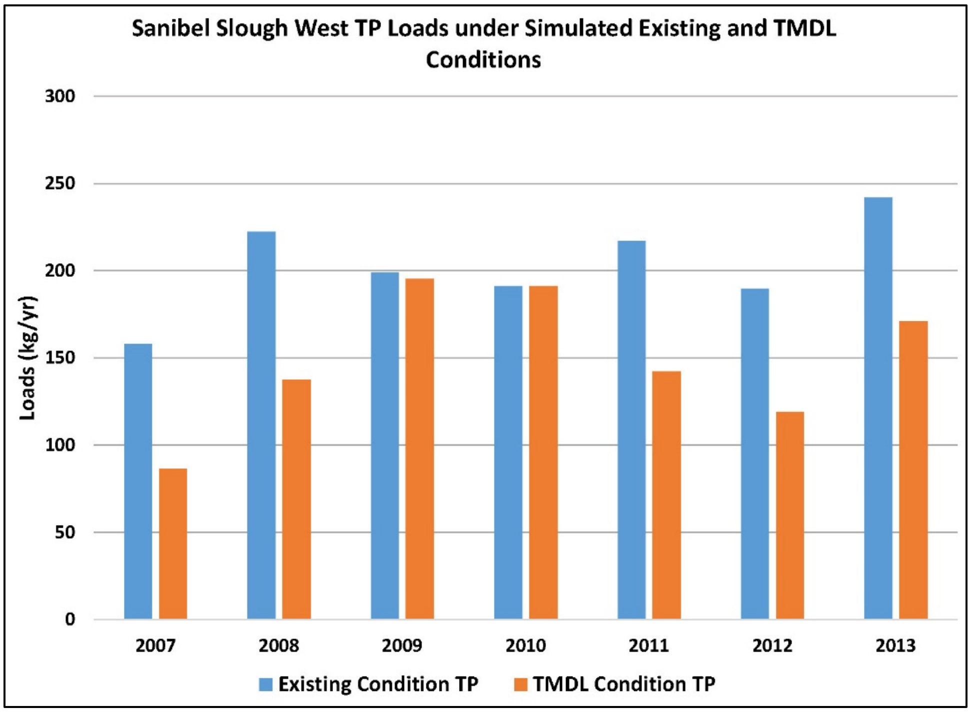

Figure 3.11. Sanibel Slough West simulated TP loads under existing and TMDL conditions

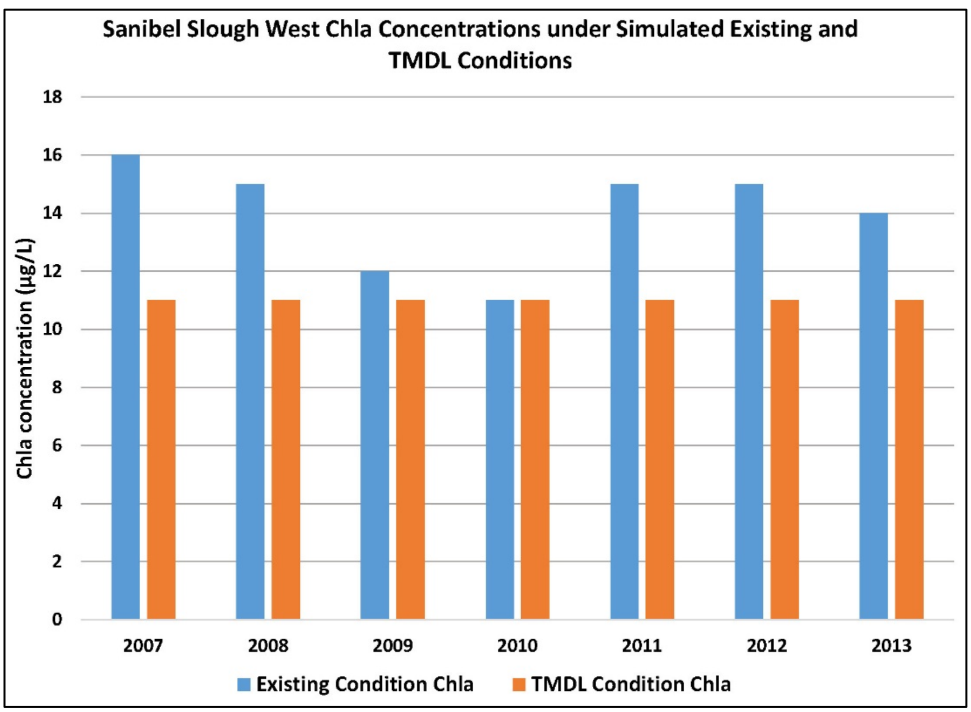

Figure 3.12. Sanibel Slough West simulated Chl*a* concentrations under existing and TMDL conditions

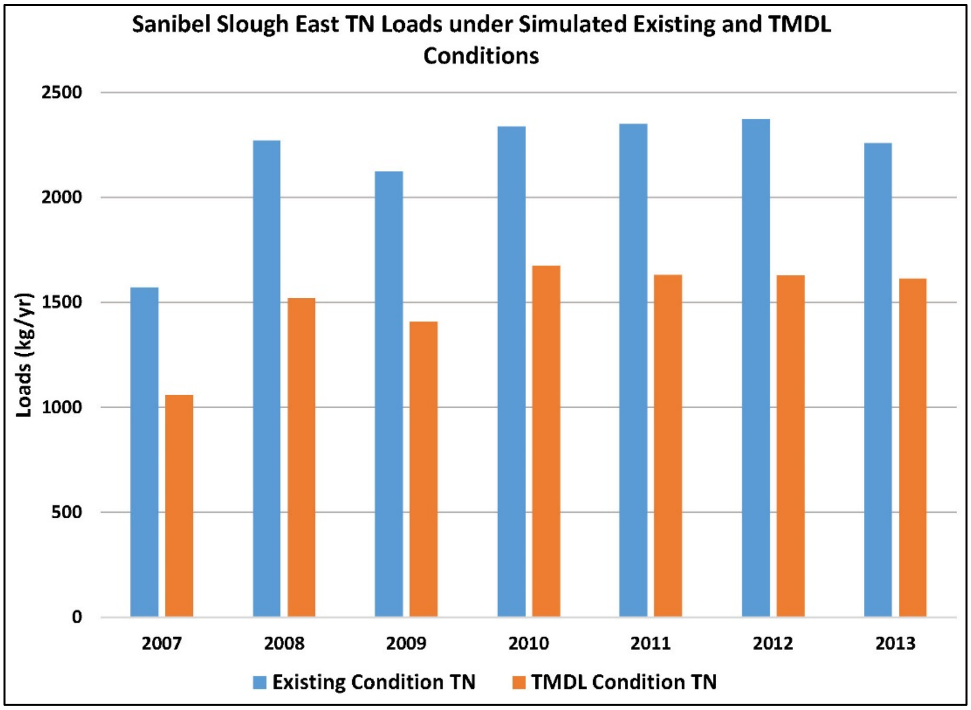

Figure 3.13. Sanibel Slough East simulated TN loads under existing and TMDL conditions

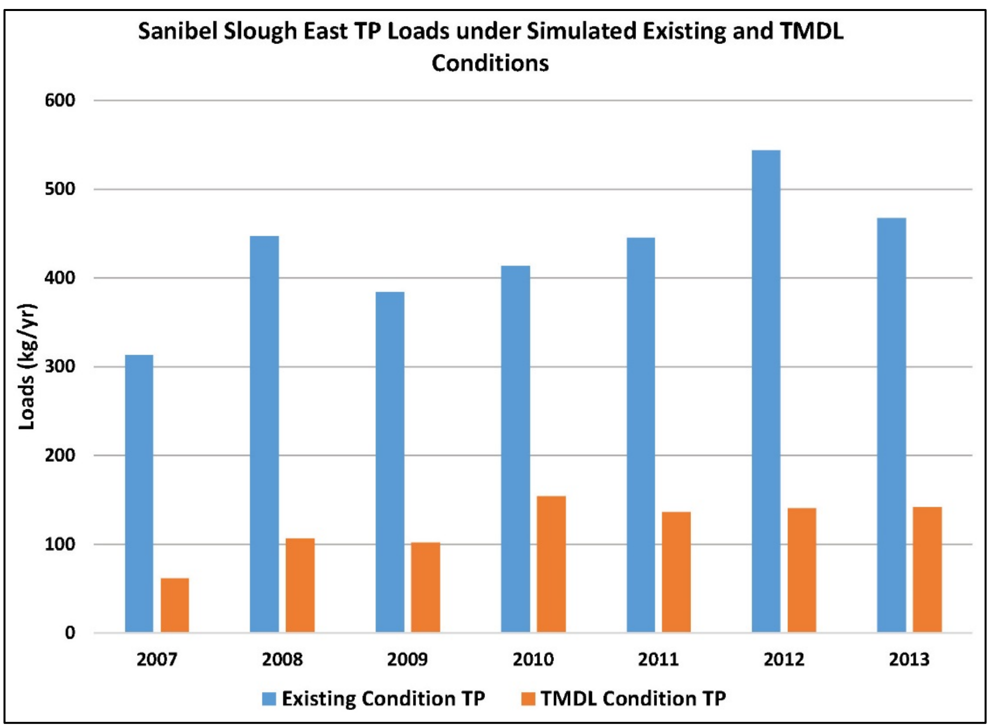

Figure 3.14. Sanibel Slough East simulated TP loads under existing and TMDL conditions

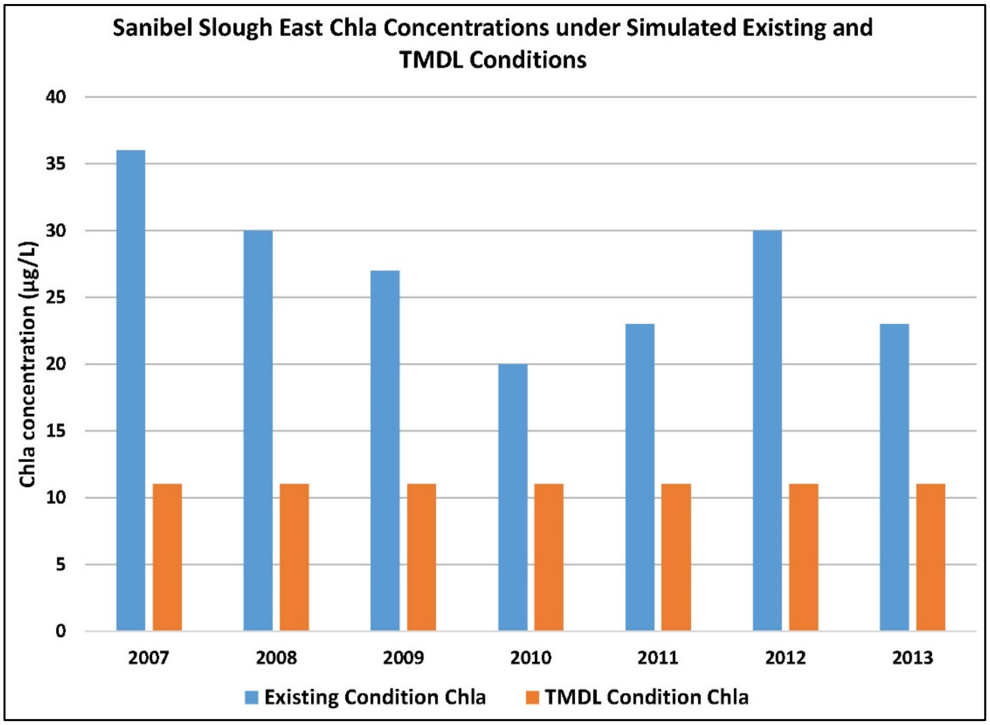

Figure 3.15. Sanibel Slough East simulated Chl*a* concentrations under existing and TMDL conditions

3.5 Calculation of TMDL

The existing conditions evaluated for establishing the TMDL were the TN and TP loads as simulated for the 2007–13 period, as described in **Section 3.1.2** and summarized in **Table 3.7**. For the purpose of establishing the TMDLs, the existing condition nutrient loads used in the percent reduction calculation are the maximum simulated annual TN and TP loads in the model period. The maximum simulated existing condition nutrient loads for TN are 1,172 kg/yr in the West Basin and 2,371 kg/yr in the East Basin, and the maximum TP loads in the West and East Basins are 242 and 544 kg/yr, respectively. The use of the maximum value in setting the TMDL is considered a conservative assumption for establishing reductions, as this will ensure that all exceedances of the nutrient targets are addressed. For the purpose of the percent reduction calculation in the following equation, the "target loads" are the three-year rolling averages of the annual loads necessary to meet the Chl*a* target of 11 µg/L every year, as described in **Section 2.4.3** and summarized in **Tables 2.5 and 2.6**. The target loads for TN are 966 kg/yr in the West Basin and 1,644 kg/yr in the East Basin, and the target TP loads in the West and East Basins are 176 and 143 kg/yr, respectively. **Table 3.11** summarizes the variables and the percent reduction.

The equation used to calculate the percent reduction is as follows:

$$\frac{[\text{maximum existing load} - \text{target load}]}{\text{maximum existing load}} \times 100$$

Table 3.11. Summary of variables for the percent reduction calculations

Condition	West Basin TN Loads (kg/yr)	West Basin TP Loads (kg/yr)	East Basin TN Loads (kg/yr)	East Basin TP Loads (kg/yr)
Maximum Existing Load	1,172	242	2,371	544
Target Load	966	176	1,644	143
% Reduction	18%	27 %	31 %	74 %

For Sanibel West Slough, an 18 % reduction in the existing TN loads and a 27 % reduction in the existing TP loads are necessary to meet the target conditions. The Sanibel East Slough TMDLs represent a 31 % reduction for TN and a 74 % reduction in TP to achieve the target conditions. The nutrient TMDL values, which are expressed as a rolling 3-year average load not to be exceeded, address the anthropogenic nutrient inputs that contribute to the exceedances of the Chl*a* restoration target.

Chapter 4: Determination of Loading Allocations

4.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\textbf{TMDL} = \sum \textbf{WLAs} + \sum \textbf{LAs} + \textbf{MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\textbf{TMDL} \cong \sum \textbf{WLAs}_{\textbf{wastewater}} + \sum \textbf{WLAs}_{\textbf{NPDES Stormwater}} + \sum \textbf{LAs} + \textbf{MOS}$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because (1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as "percent reduction" because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of best management practices (BMPs).

This approach is consistent with federal regulations (40 Code of Federal Regulations § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure. The TMDLs for the Sanibel Slough Basins are expressed in terms of kg/yr and percent reduction of TN and TP, and represent the annual load of TN and TP that the waterbody can assimilate while maintaining a balanced aquatic flora and fauna (see **Table 4.1**). These TMDLs were based on 3-year rolling averages of simulated data from 2007 to 2013. The restoration goal is to achieve the generally applicable Chl*a* criterion of 11 µg/L, as an AGM not to be exceeded more than once in any consecutive three-year period.

Table 4.1. TMDL components for nutrients in Sanibel Slough West (WBID 2092F1) and Sanibel Slough East (WBID 2092F2)

Note: The required percent reductions listed in this table represent the reduction from all sources.

Waterbody (WBID)	Parameter	TMDL (kg/yr)	WLA Wastewater (% reduction)	WLA NPDES Stormwater (% reduction)	LA (% reduction)	MOS
2092F1	TN	966	N/A	18 %	18 %	Implicit
2092F1	TP	176	N/A	27 %	27 %	Implicit
2092F2	TN	1,644	N/A	31 %	31%	Implicit
2092F2	TP	143	N/A	74 %	74 %	Implicit

4.2 Load Allocation

To achieve the load allocation (LA), current TN and TP loads require a 18 % and 27 % reduction in the Sanibel Slough West Basin and a 31 % and 74 % reduction in the Sanibel Slough East Basin, respectively.

As the TMDLs are based on the percent reduction in total watershed loading and any natural land uses are held harmless, the percent reductions for anthropogenic sources may be greater. It should be noted that the LA includes loading from stormwater discharges regulated by DEP and the water management districts that are not part of the NPDES stormwater program (see **Appendix A**).

4.3 Wasteload Allocation

4.3.1 NPDES Wastewater Discharges

There are two NPDES wastewater facilities in the Sanibel Slough basins: IWA (NPDES FL0025593) and Donax WRF (FLA014430). However, there are no direct discharges to surface waters of Sanibel Slough. As such, a WLA for wastewater discharges is not applicable.

4.3.2 NPDES Stormwater Discharges

Lee County and Co-Permittees (FDOT District 1 and the City of Sanibel) are covered by a Phase I NPDES MS4 permit (FLS000035), and areas within their jurisdiction in the Sanibel Slough Watershed are responsible for an 18 % reduction in TN and a 27 % reduction in TP from the current anthropogenic loading in the West Basin. Likewise, a 31 % reduction in TN and a 74 % reduction in TP will be necessary in the East Basin.

4.4 Margin of Safety (MOS)

The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings. Consistent with the recommendations of the Allocation Technical Advisory Committee (DEP 2001), an implicit MOS was used in the development of these TMDLs. The MOS is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving waterbody (Clean Water Act, Section 303[d][1][c]). Considerable uncertainty is usually inherent in estimating nutrient loading from nonpoint sources, as well as predicting water quality response. The effectiveness of management activities (e.g., stormwater management plans) in reducing loading is also subject to uncertainty.

An implicit MOS was used because the TMDLs were based on the conservative decisions associated with a number of the modeling assumptions in determining assimilative capacity (i.e., loading and water quality response for Sanibel Slough). The TMDLs were developed using water quality results from both high- and low-rainfall years, and the attenuation of nutrients in transport from nonpoint source areas to Sanibel Slough was not considered. Therefore, the required load reductions may lead to lower-than-anticipated nutrient concentrations by the time the loads reach the waterbody.

Additionally, the TMDL nutrient load targets are established as annual limits not to be exceeded based on the development of site-specific alternative water quality targets, and reductions are based on maximum existing conditions to ensure that all exceedances of the nutrient targets are addressed. Furthermore, the TMDL nutrient load targets were derived based on the target Chl*a* concentration of 11 µg/L being met in every year of the model simulation, providing a margin of safety for achieving the restoration goal of a Chl*a* concentration of 11 µg/L, expressed as an AGM, not to be exceeded more than once in any consecutive three-year period.

Chapter 5: Implementation Plan Development and Beyond

5.1 Implementation Mechanisms

Following the adoption of a TMDL, implementation takes place through various measures. The implementation of TMDLs may occur through specific requirements in NPDES wastewater and MS4 permits, and, as appropriate, through local or regional water quality initiatives or basin management action plans (BMAPs).

Facilities with NPDES permits that discharge to the TMDL waterbody must respond to the permit conditions that reflect target concentrations, reductions, or wasteload allocations identified in the TMDL. NPDES permits are required for Phase I and Phase II MS4s as well as domestic and industrial wastewater facilities. MS4 Phase I permits require a permit holder to prioritize and take action to address a TMDL unless management actions are already defined in a BMAP for that particular TMDL. MS4 Phase II permit holders must also implement responsibilities defined in a BMAP.

5.2 BMAPs

BMAPs are discretionary and are not initiated for all TMDLs. A BMAP is a TMDL implementation tool that integrates the appropriate management strategies applicable through existing water quality protection programs. DEP or a local entity may develop a BMAP that addresses some or all of the contributing areas to the TMDL waterbody.

Section 403.067, F.S. (the Florida Watershed Restoration Act), provides for the development and implementation of BMAPs. BMAPs are adopted by the DEP Secretary and are legally enforceable.

BMAPs describe the management strategies that will be implemented as well as funding strategies, project tracking mechanisms, water quality monitoring, and the fair and equitable allocations of pollution reduction responsibilities to the sources in the watershed. BMAPs can also identify mechanisms to address potential pollutant loading from future growth and development.

The most important component of a BMAP is the list of management strategies to reduce pollution sources, as these are the activities needed to implement the TMDLs. The local entities that will conduct these management strategies are identified and their responsibilities are enforceable. Management strategies may include wastewater treatment upgrades, stormwater improvements, and agricultural BMPs.

Additional information about BMAPs is available online.

5.3 Implementation Considerations for the Waterbody

In addition to addressing reductions in watershed pollutant contributions to impaired waters during the implementation phase, it may also be necessary to consider the impacts of internal sources (e.g., sediment nutrient fluxes or the presence of nitrogen-fixing cyanobacteria) and the results of any associated remediation projects on surface water quality. Approaches for addressing these other factors should be included in a comprehensive management plan for the waterbody. Additionally, the current water quality and water level monitoring of Sanibel Slough should continue and be expanded, as necessary, during the implementation phase to ensure that adequate information is available for tracking restoration progress.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Rule 62-40, F.A.C. In 1994, DEP stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations, as authorized under Part IV of Chapter 373, F.S.

Rule 62-40 also requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES stormwater program in 1990 to address stormwater discharges associated with industrial activity, which includes 11 categories of industrial activity, construction activities disturbing 5 or more acres of land, and large and medium MS4s located in incorporated places and counties with populations of 100,000 or more. However, because the master drainage systems of most local governments in Florida are physically interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 special districts; community development districts, water control districts, and FDOT throughout the 15 counties meeting the population criteria. DEP received authorization to implement the NPDES stormwater program in October 2000. DEP authority to administer the program is set forth in Section 403.0885 F.S.

Phase II NPDES stormwater program, promulgated in 1999, addresses additional sources, including small MS4s and small construction activities disturbing between 1 and 5 acres, and urbanized areas serving a minimum resident population of at least 1,000 individuals. While these urban stormwater discharges are technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that Phase I MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: Information in Support of Site-Specific Interpretations of the Narrative Nutrient Criterion

Table B-1. Spatial extent of the numeric interpretation of the narrative nutrient criterion

Location	Description
Waterbody name	Sanibel Slough West; Sanibel Slough East
Waterbody type(s)	Estuary
Waterbody ID (WBID)	WBID 2092F1 and 2092F2 (see **Figure 1.1** of the TMDL report)
Description	Sanibel Slough is located on Sanibel Island in Lee County, Florida. Sanibel Slough is divided into East and West Basins by a control weir located at Tarpon Bay Road. Sanibel Slough West has an estimated surface area of 0.29 km^2 and an average depth of 0.47 meters, and it has rare discharges to Tarpon Bay at a control weir at Sanibel-Captiva Road. The Sanibel Slough West Watershed covers 1,978 acres, of which wetlands is the largest land use type (55 %), followed by low-and medium-density residential, which make up 18 % and 11 % of the watershed, respectively. Sanibel Slough East has an estimated surface area of 0.22 km^2 and average depth of 0.55 m, and it discharges to San Carlos Bay at a control weir at Beach Road. The Sanibel Slough East Watershed covers 1,255 acres, of which wetlands is the largest land use type (40 %), followed by medium- and low-density residential, which make up 19 % and 9 % of the watershed, respectively. A more detailed description of the Sanibel Slough system is provided in **Chapter 1** of the TMDL Report.
Specific location (latitude/ longitude or river miles)	The center of Sanibel Slough West is located at N: 26°26'17.8"/ W: 82°6'26.3". The site-specific criteria apply as a spatial average for the estuary, as defined by WBID 2092F1. The center of Sanibel Slough East is located at N: 26°26'6.7"/ W: 82°3'18.6". The site-specific criteria apply as a spatial average for the estuary, as defined by WBID 2092F2.
Map	**Figure 1.1** shows the general location of Sanibel Slough and its watershed, and **Figure 1.7** shows the land uses in the watershed.
Classification(s)	Class III Marine
Basin name (HUC 8)	Charlotte Harbor Basin (03100103)

Table B-2. Description of the numeric interpretation of the narrative nutrient criterion

Numeric Interpretation of Narrative Nutrient Criterion	Parameter Information Related to Numeric Interpretation of the Narrative Nutrient Criterion
NNC summary: Default estuary classification (if applicable) and corresponding NNC	Sanibel Slough East and Sanibel Slough West are classified as Class III non-ENR estuaries, meaning that the they are not expressly provided by name in Subsection 62-302.532(1), F.A.C., or delineated in the maps of the Florida ENRs incorporated by reference in Subsection 62-302.532(3), F.A.C., and therefore the narrative nutrient criterion applies. The interpretation of the narrative nutrient criterion for non-ENR estuaries is a Chl*a* target of 11 µg/L, expressed as an AGM not to be exceeded more than once in any consecutive three-year period.
Proposed TN, TP, Chl*a*, and/or nitrate + nitrite concentrations (magnitude, duration, and frequency)	Numeric interpretations of the narrative nutrient criterion: This TMDL is adding TN and TP criteria for Sanibel Slough East and West, as there are no generally applicable TN and TP NNC for non-ENR estuaries. The TMDL is not changing the default NNC for Chl*a* because DEP has no evidence that the default criteria are not protective of the designated uses of the estuaries. The TN and TP NNC are expressed as three-year average loads not to be exceeded. The Sanibel Slough West TN and TP loads are 966 and 176 kg/yr, respectively. The Sanibel Slough East TN and TP loads are 1,644 and 143 kg/yr, respectively. The Chl*a* criterion is the default 11 µg/L as an AGM not to be exceeded more than once in any consecutive three-year period for both Sanibel Slough West and Sanibel Slough East.
Period of record used to develop numeric interpretations of the narrative nutrient criteria for TN and TP	The criteria were developed based on the application of a modified Soil Conservation Service (SCS) curve number (CN) and Pollutant Load Simulation Model (PLSM) watershed model and the receiving water BATHTUB model that simulated hydrology and water quality conditions over the 2007–13 period. The primary datasets for this period include the water quality data from the IWR Database (Run 52). Rainfall data were obtained from two weather stations, the MesoWest station in the J.N. "Ding" Darling National Wildlife Refuge and the St. James station on Pine Island, Florida. Evapotranspiration data were based on data from the SFWMD, and stage data for 2007–13 were obtained from the City of Sanibel. Land use data used to establish watershed nutrient loads for the 2007–13 simulation period were obtained from the SFWMD 2008–09 land use layer. A complete description of the data used in the derivation of the proposed site-specific criteria is provided in **Sections 2.3** and **3.1** of the TMDL Report.
How the criteria developed are spatially and temporally representative of the waterbody or critical condition.	The model calibration for Sanibel Slough used all available data for the estuary from 2007 to 2013. The annual average rainfall for 2007–13 ranged from 28.5 to 43.0 in/yr, and the median was 37.8 in/yr. The years 2007, 2009, and 2012 were dry, and 2008, 2011, and 2013 were wet. This time span captures the hydrologic variability of the Sanibel Slough system. In addition, model calibration for the Sanibel Slough West and Sanibel Slough East TMDLs was based on water quality data collected across the individual basins. **Figure 2.1** shows the locations of the sampling stations in Sanibel Slough. Monitoring stations were found across the spatial extent, with three sites sampled in each basin, and represent the spatial distribution of nutrient dynamics in the estuary systems. Data were collected from the City of Sanibel (21FLSBL…) and the DEP (21FLFTM…). Water quality data for variables relevant to TMDL development are available on request.

Table B-3. Summary of how designated use(s) are demonstrated to be protected by the criterion

Designated Use Requirements	Information Related to Designated Use Requirements
History of assessment of designated use support	DEP used the IWR database to assess water quality impairments in the Sanibel River (WBID 2092F). The waterbody was verified as impaired for nutrients based on an elevated annual average TSI during the Cycle 1 verified period (the verified period for the Group 2 basins is January 1, 1996–June 30, 2003). At the time the Cycle 1 assessment was performed, WBID 2092F was classified as a high-color lake (color higher than 40 PCU), and the IWR methodology used the water quality variables TN, TP, and Chl*a* in calculating annual TSI values and in interpreting Florida's narrative nutrient threshold. The TSI threshold (60 for high-color lakes) was exceeded in multiple years during the verified period and was sufficient to identify the waterbody as impaired for nutrients. During the Cycle 2 assessment, WBID 2092F was reclassified as a stream, and the IWR methodology used an annual average Chl*a* threshold of 20 µg/L in interpreting Florida's narrative nutrient threshold. In the Cycle 2 verified period (January 2001–June 2008), annual mean Chl*a* values exceeded the threshold of 20 µg/L in 2007, and the waterbody remained on the Verified List. The waterbody was again reclassified for the more recent Cycle 3 assessment and was assessed as an estuary. The IWR methodology used an AGM Chl*a* threshold of 11 µg/L to assess the waterbody during the verified period (January 1, 2007–June 30, 2014). Chl*a* values exceeded the threshold of 11 µg/L during every year of the verified period, and the waterbody remained on the Verified List. See **Section 2.3** of the TMDL Report for a detailed discussion.
Basis for use support	The site-specific TN and TP targets for this TMDL were established to achieve the generally applicable Chl*a* criterion (11 µg/L) for estuaries without site-specific numeric interpretations of the NNC. At the time this TMDL was developed, there was no site-specific information indicating that 11 µg/L is not protective of the designated use for this waterbody.
Approach used to develop criteria and how it protects uses	For the Sanibel Slough nutrient TMDLs, DEP created loading-based criteria using a watershed loading model to simulate loading from the Sanibel Slough watershed, and this information was fed into individual receiving water models (BATHTUB) for Sanibel Slough West and Sanibel Slough East. The maximum of the three-year rolling averages of TN and TP loadings to achieve the 11 µg/L Chl*a* target was determined by incrementally decreasing the TN and TP loads from anthropogenic sources into the slough until the Chl*a* target was achieved. A more detailed description of the derivation of the TMDL and criteria are provided in **Section 2.4** of the TMDL Report.
How the TMDL analysis will ensure that nutrient-related parameters are attained to demonstrate that the TMDLs will not negatively impact other water quality criteria.	DEP notes that there is a DO impairment for Sanibel Slough East and West and will be working to ascertain whether the current standard is appropriate or whether site-specific criteria will need to be developed. The system is impaired for DO based on current assessments applying the DO percent saturation standard of 42 %, and analyses showed no significant relationship between nutrients and DO. Due to the nature of the slough system, the existing DO criterion for the system may not be achievable. It is likely that the lower DO in this system is a result of physical alteration and therefore not directly being addressed in this TMDL. Reducing nutrient loads entering the waterbody will likely have some positive effect on DO levels while not negatively impacting other water quality parameters in for the estuary.

Table B-4. Documentation of the means to attain and maintain water quality standards for downstream waters

Downstream Waters Protection and Monitoring Requirements	Information Related to Downstream Waters Protection and Monitoring Requirements
Identification of downstream waters: List receiving waters and identify technical justification for concluding downstream waters are protected.	Sanibel Slough West has a weir control structure at Sanibel-Captiva Road on the northern side of the island that discharges into Tarpon Bay, which eventually flows into San Carlos Bay. Sanibel Slough East has a weir control structure at Beach Road on the eastern side of the island, which drains to a system of canals that eventually flows into San Carlos Bay. San Carlos Bay (including Tarpon Bay, WBID 2065H1) is a Class II estuary which has estuary-specific numeric interpretations of the NNC for Chl*a*, TN, and TP. Based on the most recent assessment, completed on April 27, 2016 for Group 2 Basins, San Carlos Bay is not impaired for nutrients. As evidenced by the healthy existing condition in San Carlos Bay, the existing loads from Sanibel Slough to San Carlos Bay have not led to an impairment of the downstream water. Therefore, the reductions in nutrient loads prescribed in the TMDL are not expected to cause nutrient impairments downstream. See **Section 2.6** of the TMDL Report.
Summary of existing monitoring and assessment related to the implementation of Subsection 62-302.531(4), F.A.C., and trends tests in Chapter 62-303, F.A.C.	The City of Sanibel and DEP conduct routine monitoring of Sanibel Slough. The data collected through these monitoring activities will be used to evaluate the effect of BMPs implemented in the watershed on estuary TN and TP loads in subsequent water quality assessment cycles.

Table B-5. Documentation to demonstrate administrative requirements are met

Administrative Requirements	Information for Administrative Requirements
Notice and comment notifications	DEP published a Notice of Development of Rulemaking on January 17, 2017 to initiate TMDL development for impaired waters in the Charlotte Harbor Basin. A rule development public workshop for the TMDLs was held on February 17, 2017. Public comments were received for the TMDLs after that. DEP has prepared a responsiveness summary for these comments.
Hearing requirements and adoption format used; responsiveness summary	Following the publication of the Notice of Proposed Rule, DEP will provide a 21-day challenge period and a Public hearing that will be noticed no less than 45 days prior.
Official submittal to EPA for review and General Counsel certification	If DEP does not receive a rule challenge, the certification package for the rule will be prepared by the DEP program attorney. DEP will prepare the TMDLs and submittal package for the TMDLs to be considered a site-specific interpretation of the narrative nutrient criterion, and submit these documents to the EPA.