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Mosquito Lagoon
Reasonable Assurance Plan (RAP)

Volusia County and Mosquito Lagoon RAP Stakeholder Group
August 2018

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MOSQUITO LAGOON REASONABLE ASSURANCE PLAN (RAP)

Prepared for

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ACRONYMS AND ABBREVIATIONS

AGM	Annual Geometric Mean
AMO	Atlantic Multidecadal Oscillation
BMAP	Basin Management Action Plan
BOD_5	5-Day Biochemical Oxygen Demand
CI	Confidence Interval
CIP	Capital Improvement Project
CWA	Clean Water Act
DO	Dissolved Oxygen
ENR	Estuary Nutrient Region
EPA	US Environmental Protection Agency
FAC	Florida Administrative Code
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
FWC	Florida Fish and Wildlife Conservation Commission
HUC8	Hydrologic Unit Level 8
IFAS	Institute of Food and Agricultural Sciences
IRL	Indian River Lagoon
lb/yr	Pounds per Year
µg/L	Micrograms per Liter
mg/L	Milligrams per Liter
MTAC	Marine Technical Advisory Committee
NAVD88	North American Vertical Datum of 1988
NNC	Numeric Nutrient Criteria
NPDES	National Pollutant Discharge Elimination System
NOAA	National Oceanic and Atmospheric Administration
OSTD	On-Site Sewage Treatment and Disposal System
SJRWMD	St. Johns River Water Management District
RAP	Reasonable Assurance Plan
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USGS	US Geological Survey
WBID	Waterbody Identification
WWTP	Wastewater Treatment Plant

1 BACKGROUND

Mosquito Lagoon is one of the distinct sections of the larger Indian River Lagoon (IRL) system. The Mosquito Lagoon watershed is approximately 36 miles long and stretches across north Brevard County and south Volusia County. With the exception of a very small piece of the Kennedy Space Center at the south tip of the watershed, nearly all of the urban land uses in the watershed are in Volusia County. The Canaveral National Seashore encompasses nearly all of the watershed in Brevard County and a portion in Volusia County and is encompassed by the larger Merritt Island National Wildlife Refuge Complex. Immediately north of the Canaveral National Seashore is the 4,740-acre Mosquito Lagoon Aquatic Preserve.

The sponsors for this Reasonable Assurance Plan (RAP) are the City of Edgewater, City of New Smyrna Beach, City of Oak Hill, Florida Department of Transportation (FDOT), and Volusia County. Collectively, the sponsors have made significant investments over the past few decades to reduce pollutant loading to Mosquito Lagoon with projects such as converting wastewater treatment surface water discharges to reuse and stormwater retrofit projects. The origin for this RAP began at the June 26, 2014 Water Quality Workshop hosted by the Volusia County Council. By early 2016, the sponsors had developed Joint Project Agreements that covered topics such as authority, governance and management, funding, and responsibilities of parties and Board members for developing the RAP.

In addition to the RAP sponsors, collaborative partners and interested parties have included:

- Applied Technology and Management (representing FDOT).
- Bethune-Cookman University.
- Brevard County.
- Canaveral National Seashore.
- Citizens.
- Florida Department of Environmental Protection (FDEP).
- Daytona News Journal.
- E Sciences (representing FDOT).
- East Central Florida Regional Planning Council.
- ECT Inc.
- Florida Department of Agriculture and Consumer Services (FDACS).
- Florida Department of Health-Volusia County.
- Florida Farm Bureau Association.
- Florida Fish and Wildlife Conservation Commission (FWC).
- Indian River Lagoon Council & National Estuary Program.
- Kennedy Space Center-NASA.
- Marine Discovery Center.
- Merritt Island National Wildlife Refuge.
- Save the Manatee Club.
- St. Johns River Water Management District (SJRWMD).
- Stetson University.
- Wildwood Consulting (as Project Facilitator).

2 DESCRIPTION OF MOSQUITO LAGOON

This Section describes Mosquito Lagoon and its associated watershed, the current water quality conditions, and the sources of pollutants.

2.1 Description of the Water Body and Watershed

Figure 2-1 shows the Mosquito Lagoon watershed, which is 116.5 square miles. Approximately two-thirds of the watershed area is in Volusia County, with the remainder in Brevard County. Three cities have a significant area in the watershed: Edgewater, New Smyrna Beach, and Oak Hill. A small portion of the Town of Ponce Inlet also lies in the north edge of the watershed. The watershed area used in this RAP does not include some closed basin areas that are along the west-central, southwest, and south portions of the watershed border, since these areas do not likely contribute significant load to the watershed. FDEP subdivided Mosquito Lagoon into three Estuary Nutrient Regions (ENRs) for developing numeric nutrient criteria (NNC). Figure 2-1 shows these ENRs.

Slope in the watershed is very flat. The highest elevations, at approximately 30 feet referenced to the North American Vertical Datum of 1988 (NAVD88), are along the west boundary where the watershed extends west of I-95. As Figure 2-1 shows, the size of Mosquito Lagoon and its connected salt marshes is very large compared to the remainder of the watershed. Soils are predominantly well-drained in the north and central portions of the watershed. Soils are predominantly poorly drained in the south portion of the watershed. Table 2-1 summarizes the hydrologic soil groups within the Mosquito Lagoon watershed by ENR beyond the Mosquito Lagoon waterbody and its connected salt marshes by ENR. Additional watershed characteristics are described in the *Watershed Model Development Report* (Jones Edmunds and Janicki Environmental, June 2017).

Table 2-1 Hydrologic Soil Group Percentages

ENR	Hydrologic Soil Group				
	A	B	B/D	C/D	D
North	50%	4%	21%	0%	24%
Central	62%	2%	13%	1%	23%
South	20%	0%	10%	5%	65%

A – Low runoff potential when thoroughly wet.

B – Moderately low runoff potential when thoroughly wet.

C – Moderately high runoff potential when thoroughly wet.

D – High runoff potential when thoroughly wet.

B/D and C/D – Runoff potential is based partly on presence of water table.

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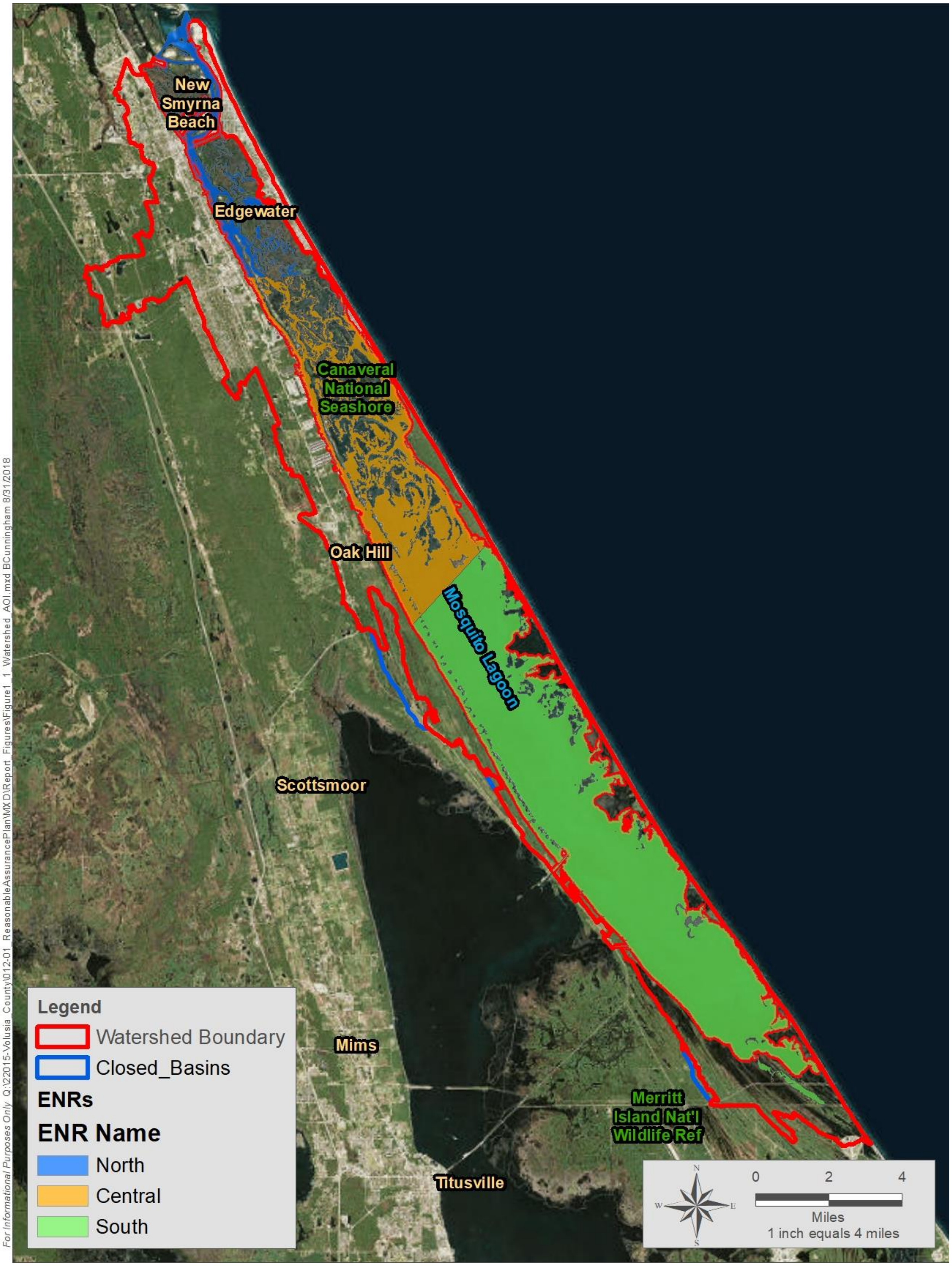
Figure 2-1 Mosquito Lagoon Watershed



2.2 Description of the Impairment

This RAP was under taken by the stakeholder group in anticipation of impairments as a result of the Cycle 3 assessment of the Group 5 Indian River Lagoon Basin. For assessment purposes, FDEP has divided Mosquito Lagoon into three water assessment polygons with unique WaterBody IDentification (WBID) numbers. All three WBIDs are contained within the US Geological Survey (USGS) Hydrologic Unit (HUC8) 03080202. Table 2-2 summarizes the WBIDs (listed from north to south) and the parameters of concern covered by this RAP.

Table 2-2 WBIDs and Parameters Addressed by this RAP

WBID	Waterbody Name	Waterbody Type	Waterbody Class*	Parameter of Concern
2924B2	Mosquito Lagoon	Estuary	3M	Nutrients
2924B1	Mosquito Lagoon (Shellfish Portion)	Estuary	2	Nutrients
2924	Mosquito Lagoon	Estuary	2	Nutrients

Notes: * 2 - Shellfish propagation and/or harvesting.

3M - Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife in marine water.

The three Mosquito Lagoon WBIDs had the following parameters placed on the verified impaired list adopted by Secretarial Order on June 27, 2018:

- WBID 2924B2 – Nutrients (Chlorophyll *a*) and Fecal Coliform (SEAS Classification).
- WBID 2924B1 – Nutrients (Chlorophyll *a*), and Nutrients (Total Nitrogen [TN]).
- WBID 2924 – Nutrients (Chlorophyll *a*), Nutrients (Total Phosphorus [TP]), and Nutrients (TN).

This RAP was prepared to address only the nutrient impairments and not the fecal coliform impairment.

2.3 Description of Loading Sources

The primary pollutants of concern for Mosquito Lagoon are TN and TP. The five primary loading sources of these constituents are direct runoff, base flow, point sources, on-site sewage treatment and disposal systems (OSTDs [i.e., septic systems]), and atmospheric deposition. The relative amount of loading of each constituent varies significantly by ENR and over time. Monthly pollutant loading from 2004 through 2015 was quantified by ENR in the *Watershed Model Report* using measured data and predictive methods. Section 9 presents the results, Output Reporting and Results, of the *Watershed Model Report* by annual totals and percentages over the simulation period and are also provided below.

Figures 2-2 through 2-5, respectively, show the totals for flow volume, the 5-day biochemical oxygen demand (BOD_5), TN, and TP for the three ENRs.

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Figure 2-2 Total Flow Volume by ENR for the Simulation Period

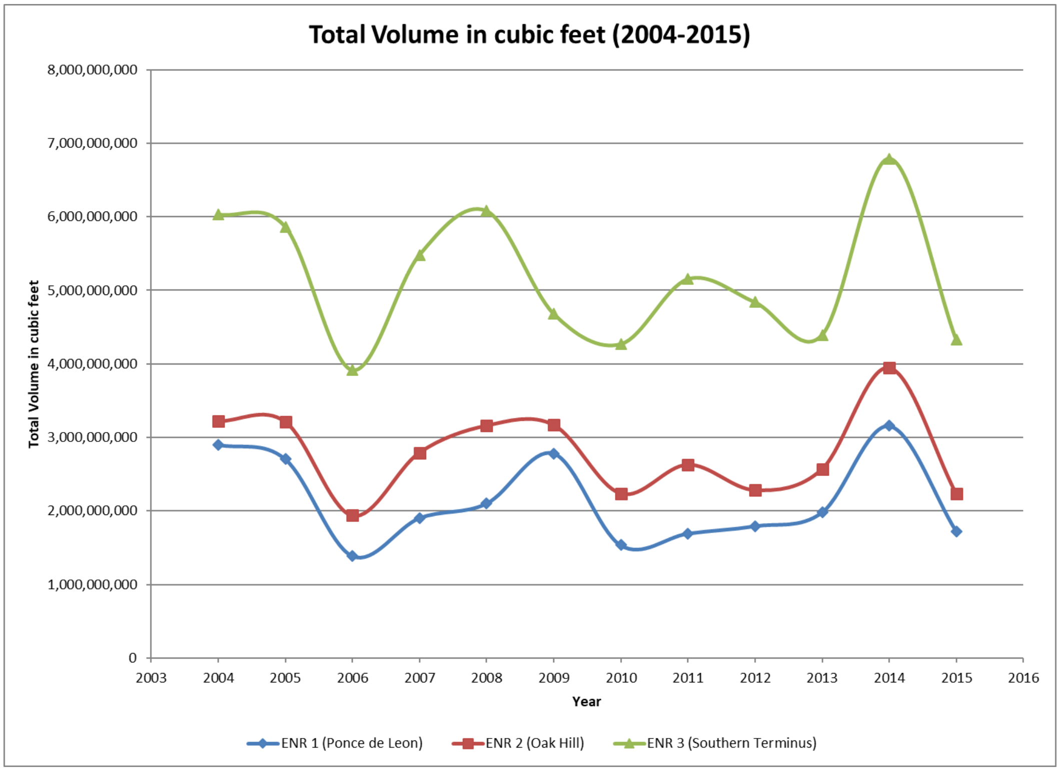

Figure 2-3 BOD Load by ENR for the Simulation Period

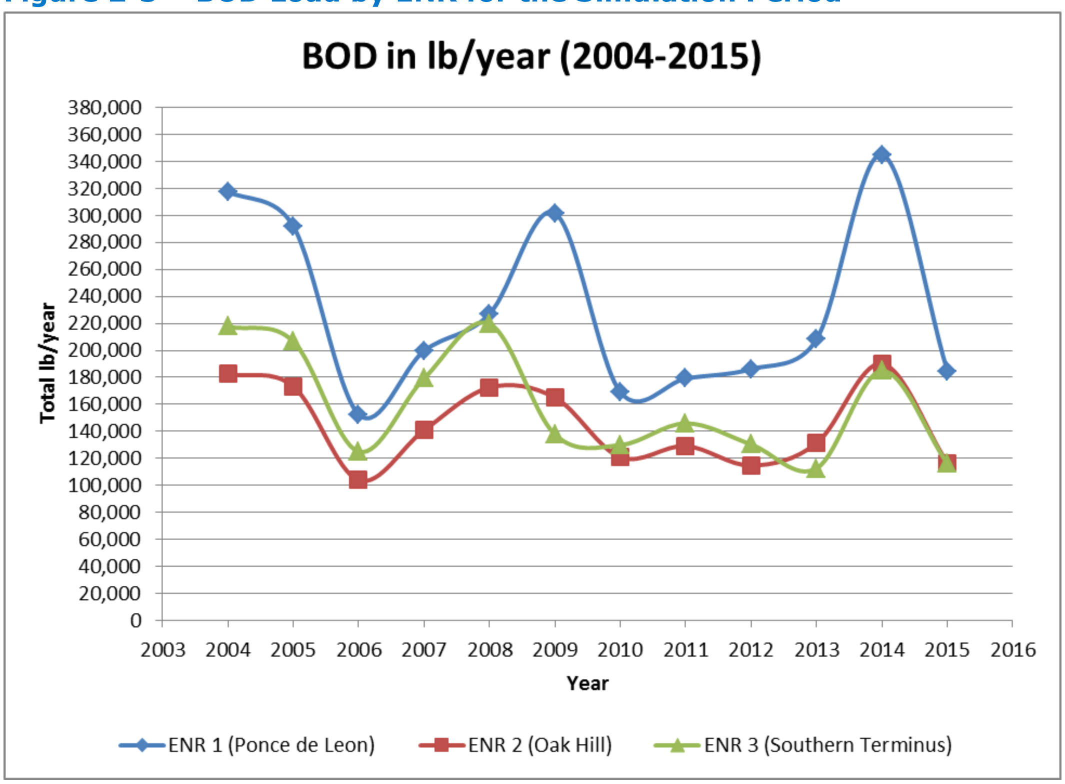

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Figure 2-4 TN Load by ENR for the Simulation Period

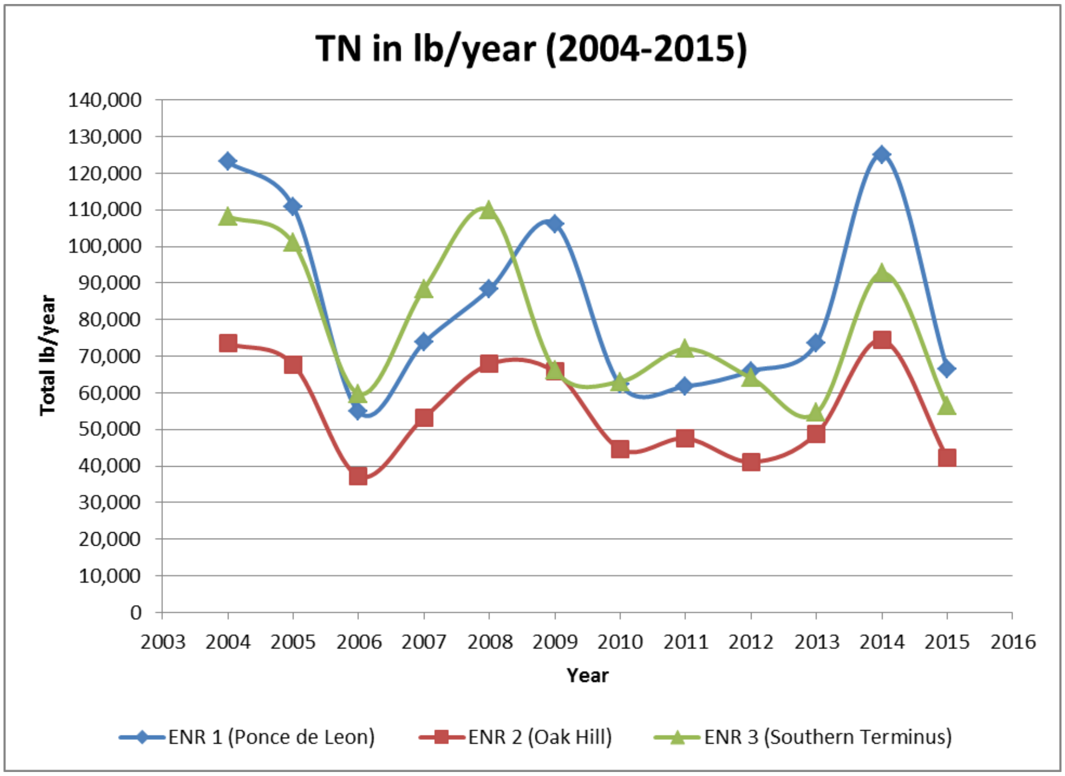
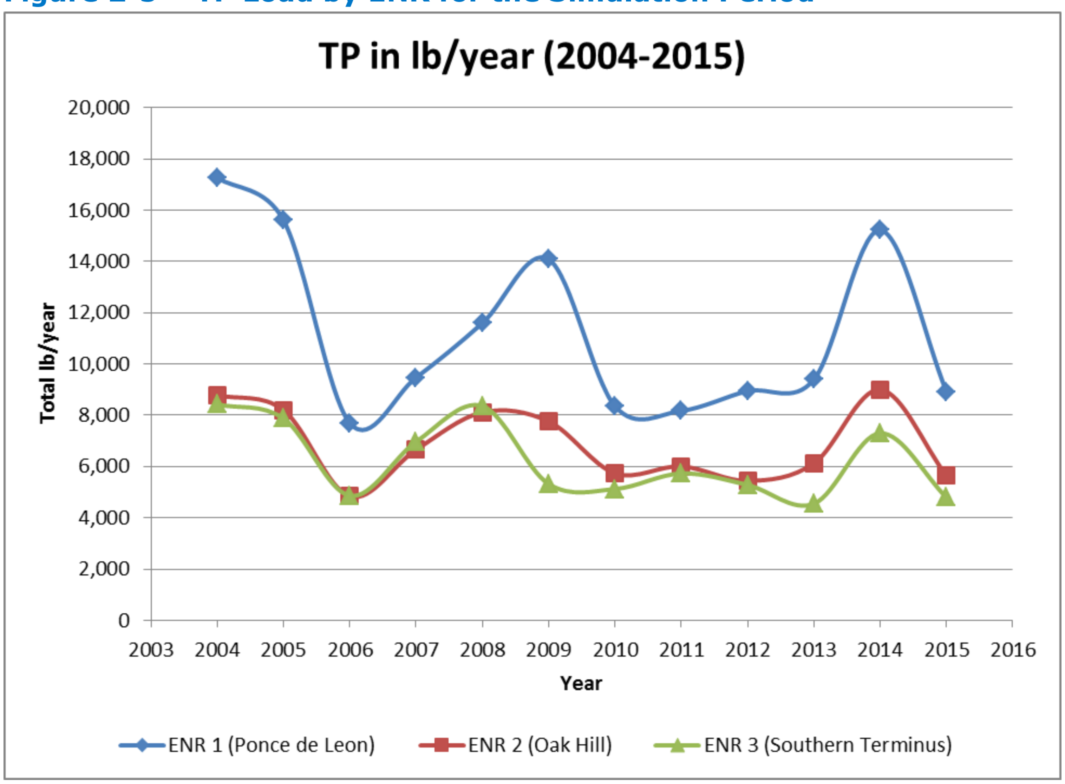


Figure 2-5 TP Load by ENR for the Simulation Period



Figures 2-6 through 2-9 respectively show percentages of the sources of flow volume, BOD_5, TN, and TP for ENR 1 (North ENR).

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Figure 2-6 Percentages of Total Flow Volume for ENR 1 for the Simulation Period

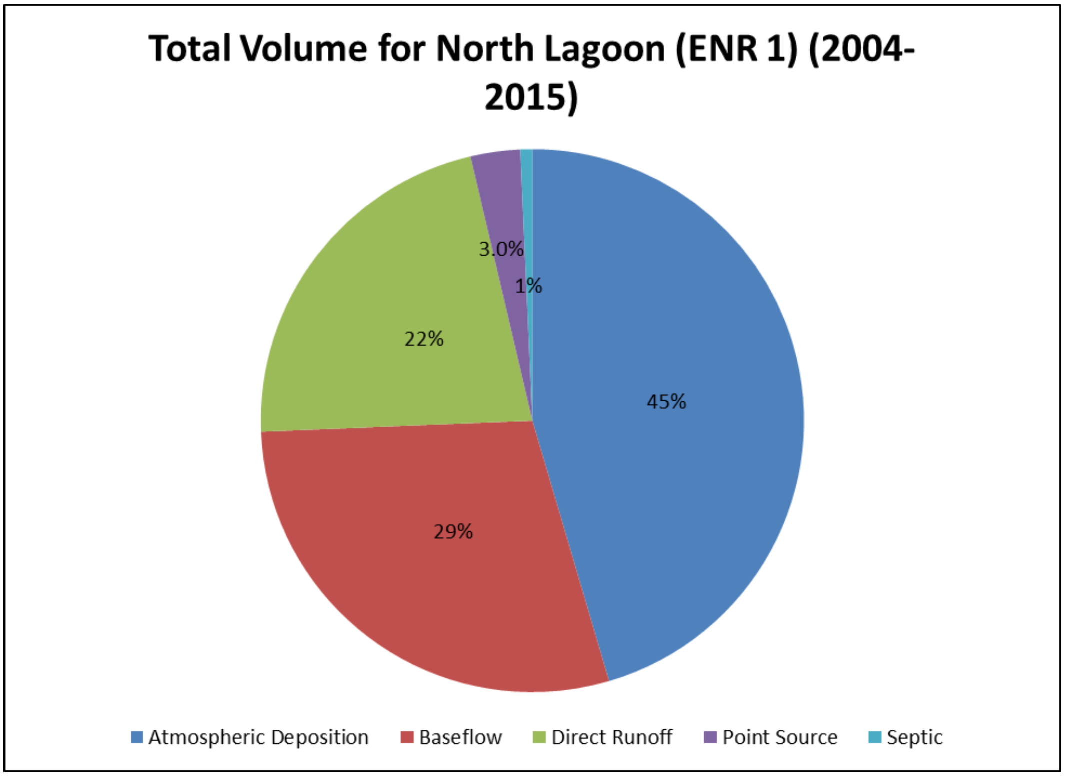

Figure 2-7 Percentages of BOD for ENR 1 for the Simulation Period

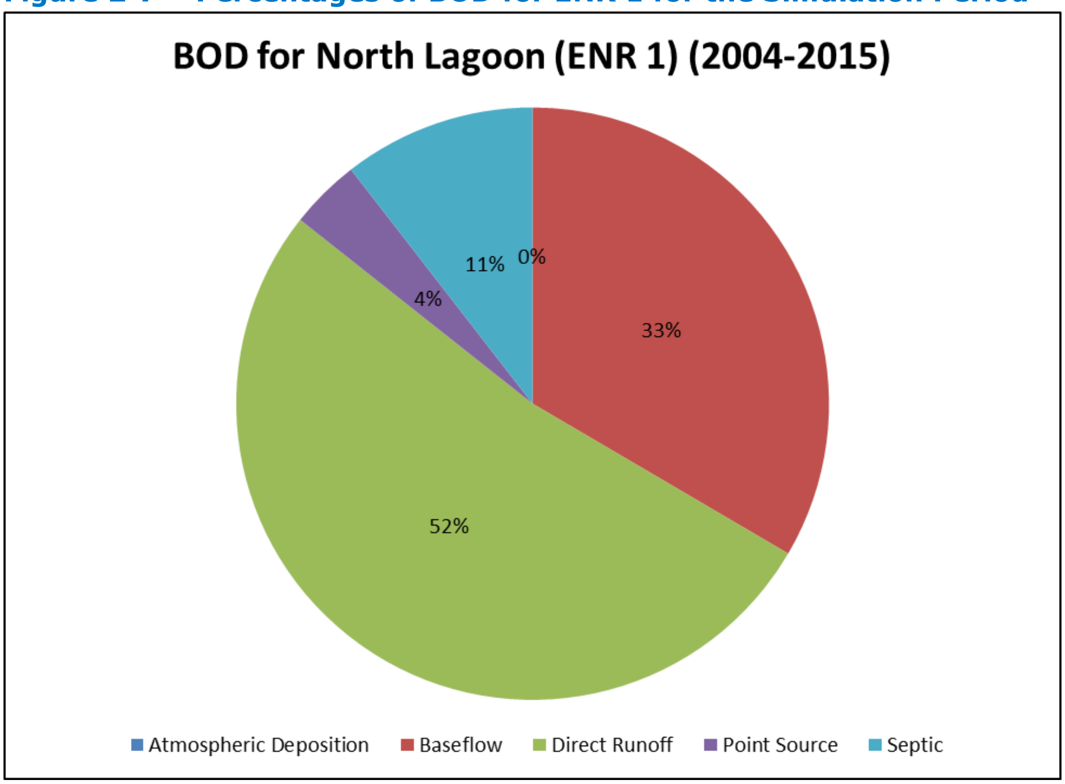

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Figure 2-8 Percentages of TN for ENR 1 for the Simulation Period

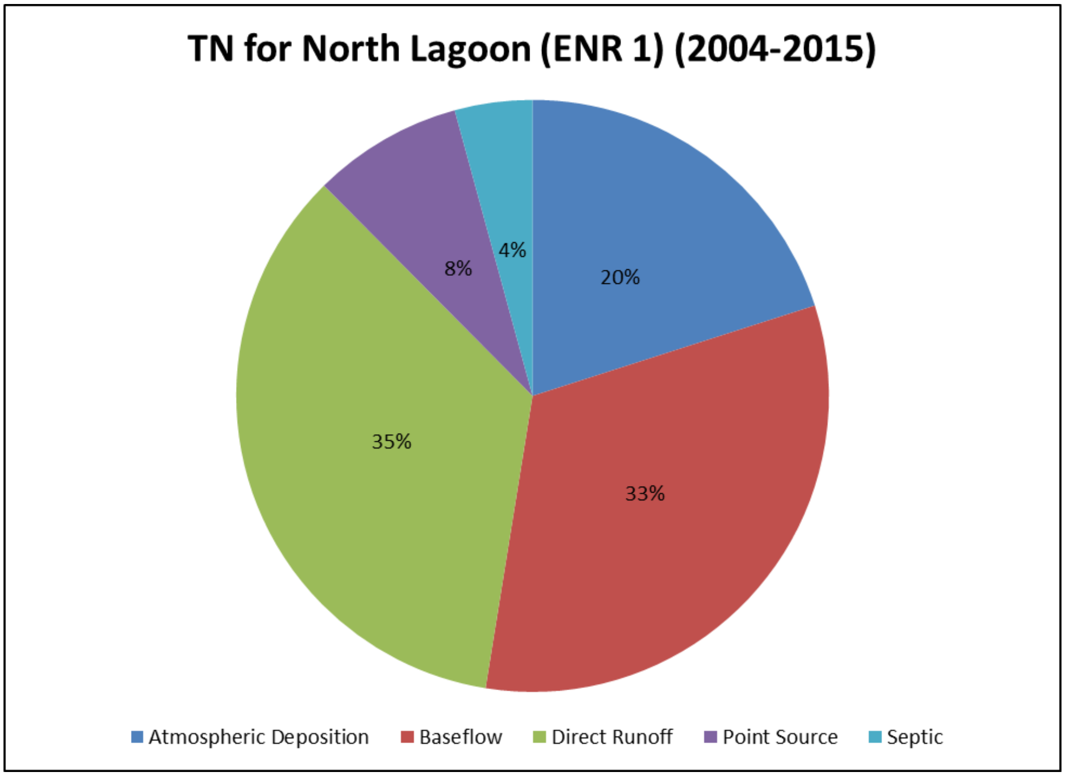
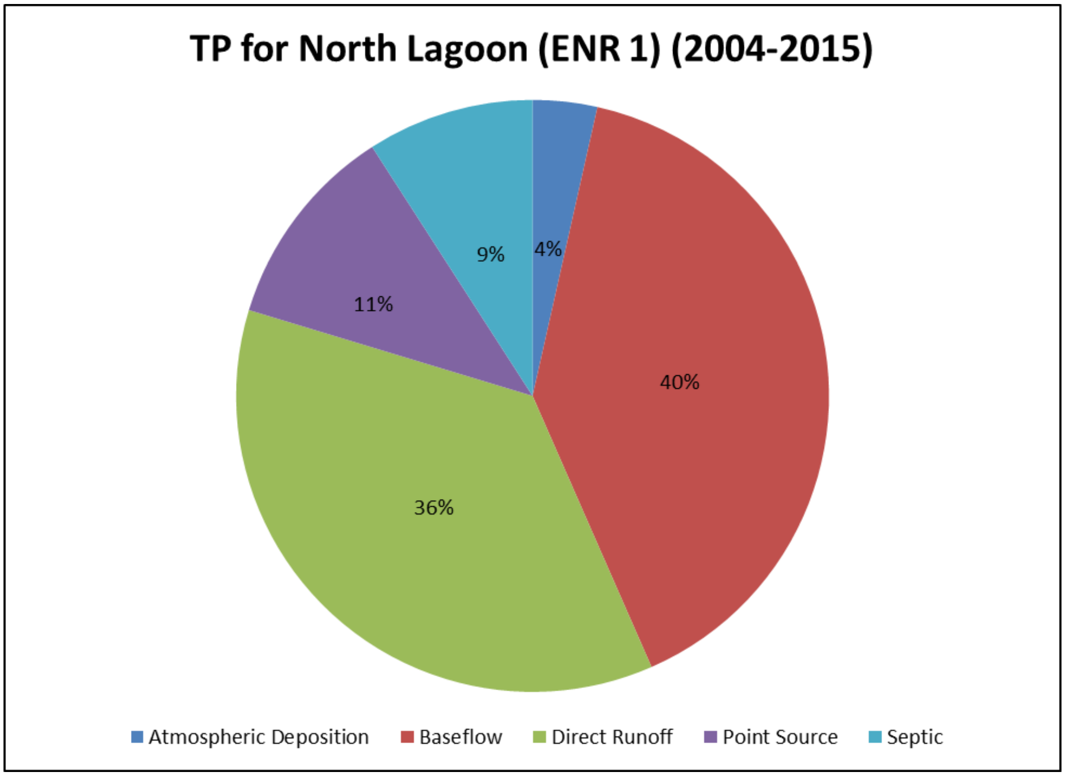


Figure 2-9 Percentages of TP for ENR 1 for the Simulation Period



Figures 2-10 through 2-13 respectively show percentages of the sources of flow volume, BOD_5, TN, and TP for ENR 2 (Central ENR).

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Figure 2-10 Percentages of Total Flow Volume for ENR 2 for the Simulation Period

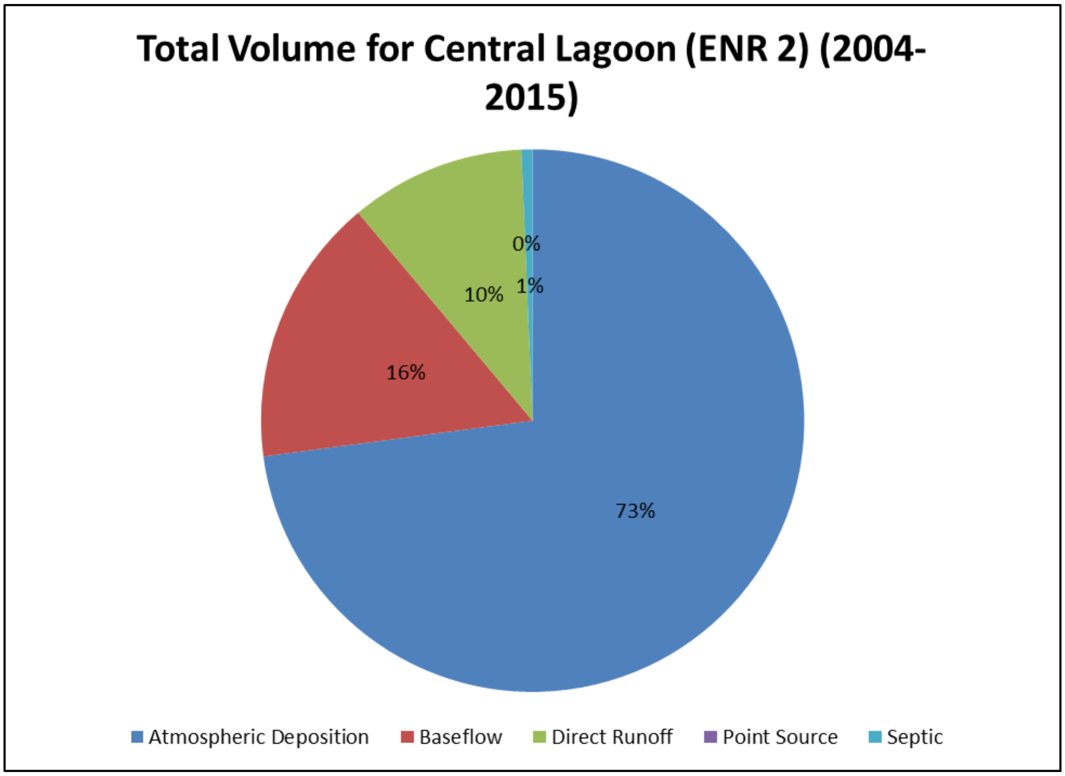


Figure 2-11 Percentages of BOD for ENR 2 for the Simulation Period

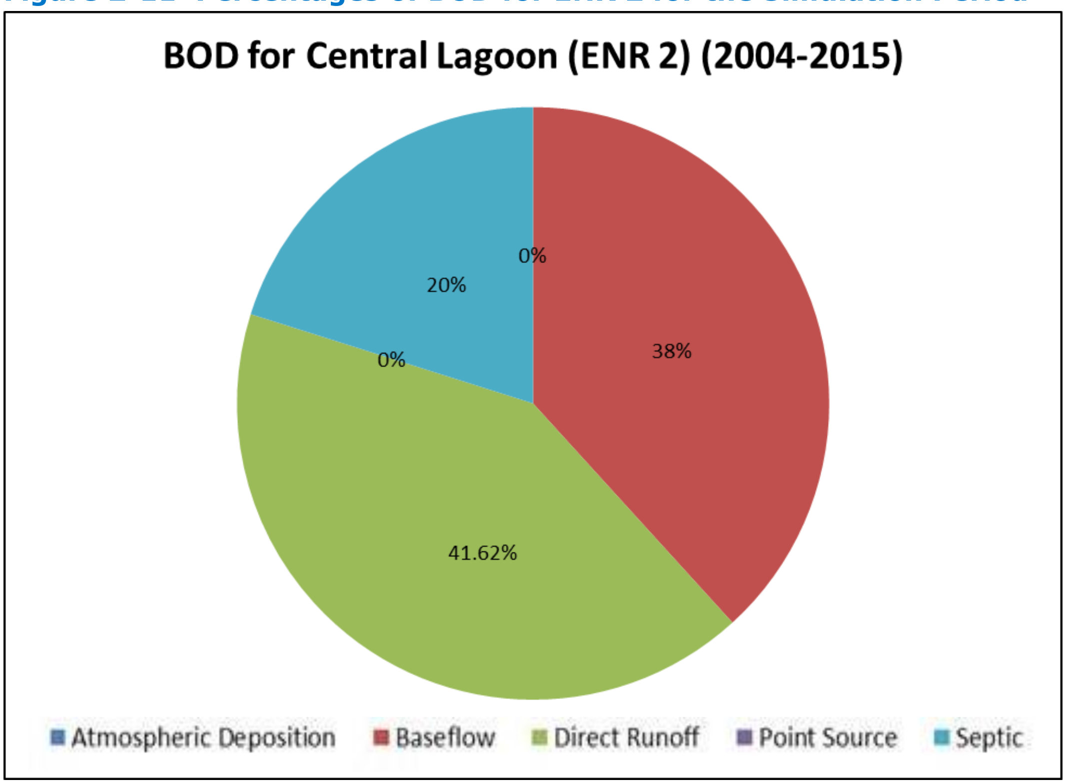


Figure 2-12 Percentages of TN for ENR 2 for the Simulation Period

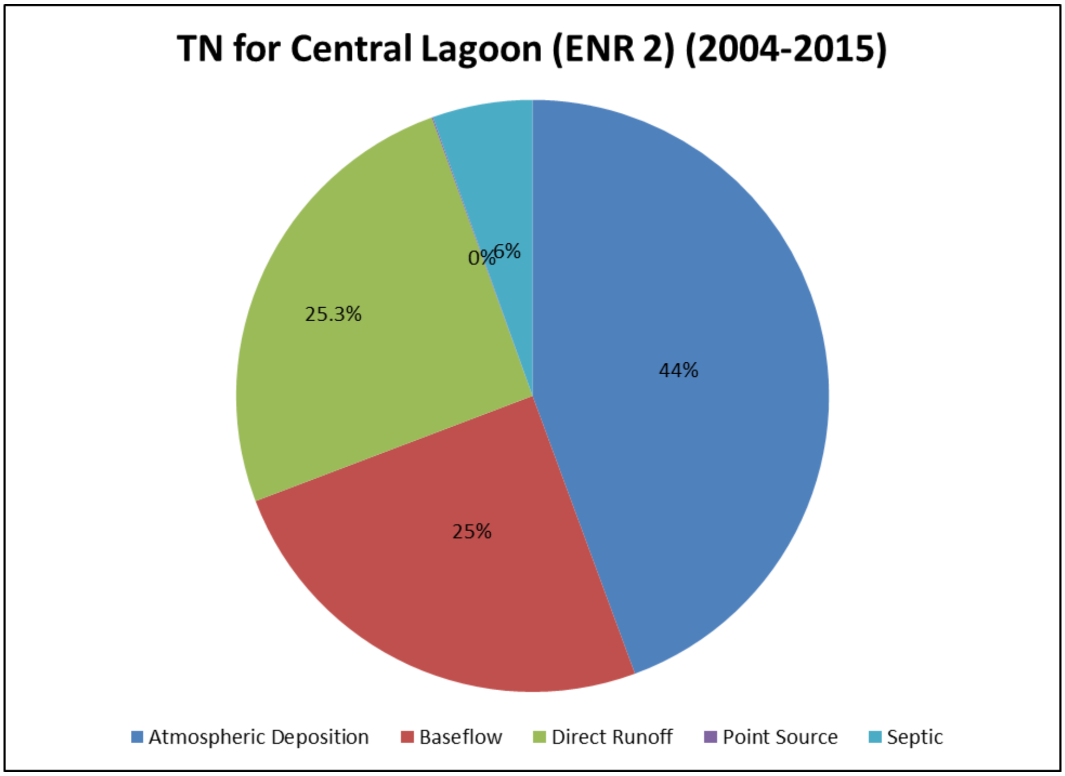
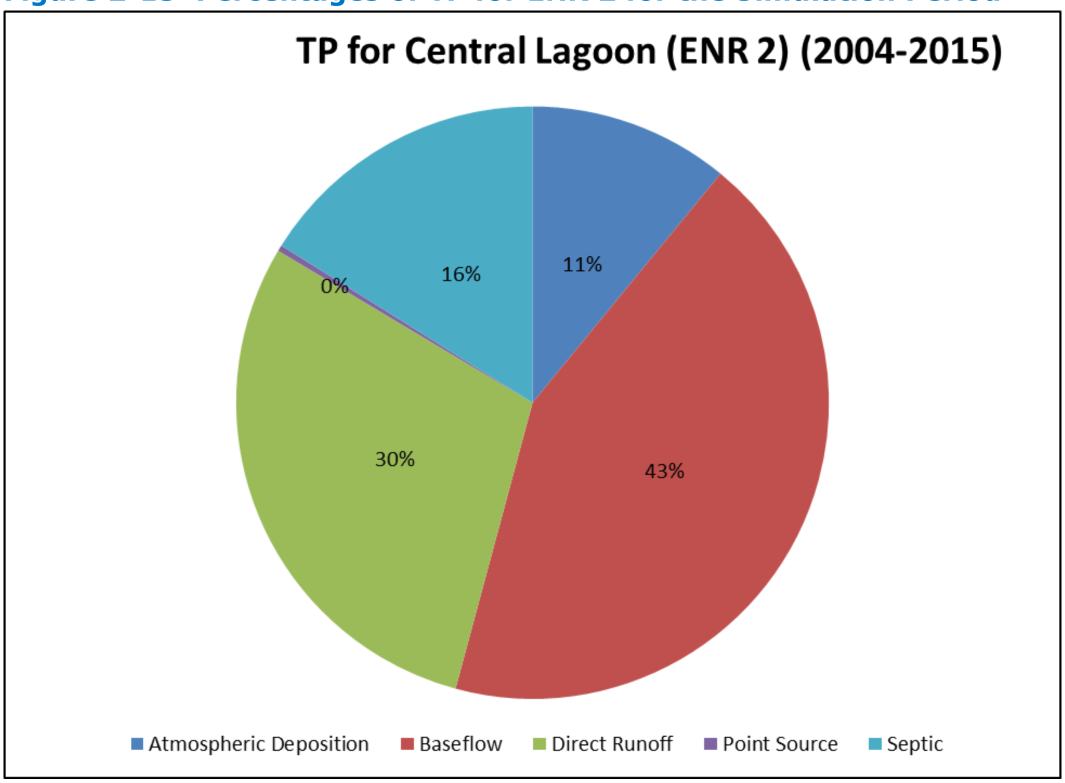


Figure 2-13 Percentages of TP for ENR 2 for the Simulation Period



Figures 2-14 through 2-17 respectively show percentages of the sources of flow volume, BOD_5, TN, and TP for ENR 3 (South ENR) are shown in Figures 2-14 through 2-17, respectively.

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Figure 2-14 Percentages of Total Flow Volume for ENR 3 for the Simulation Period

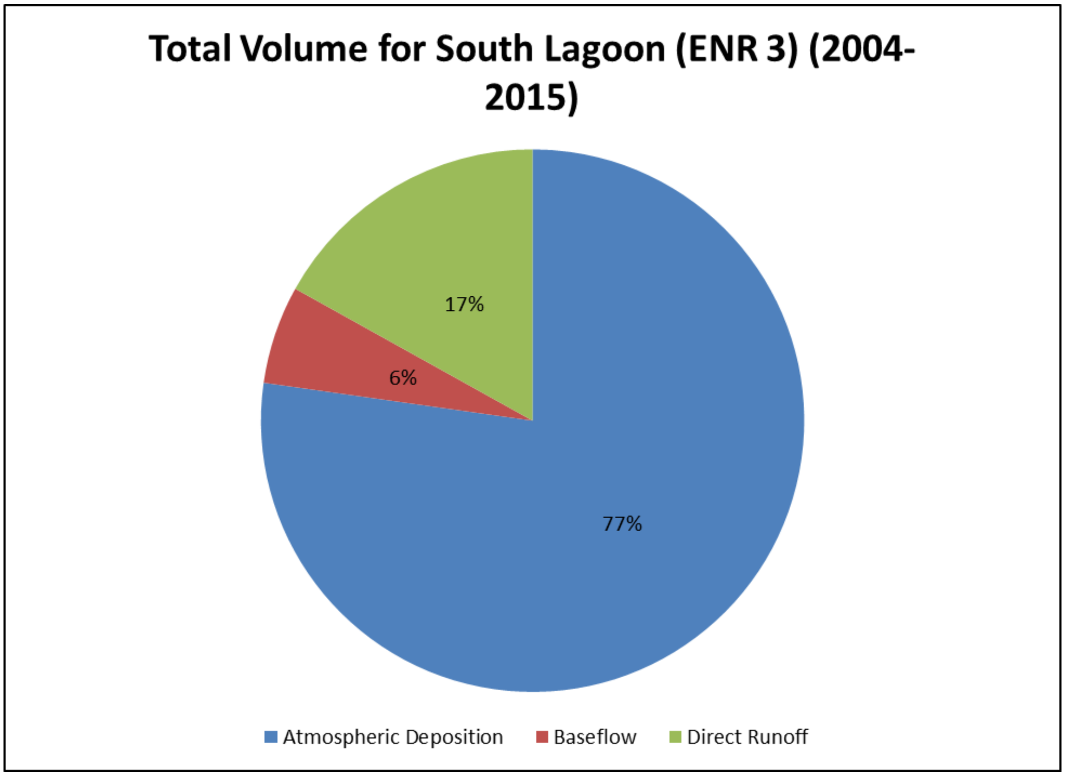


Figure 2-15 Percentages of BOD for ENR 3 for the Simulation Period

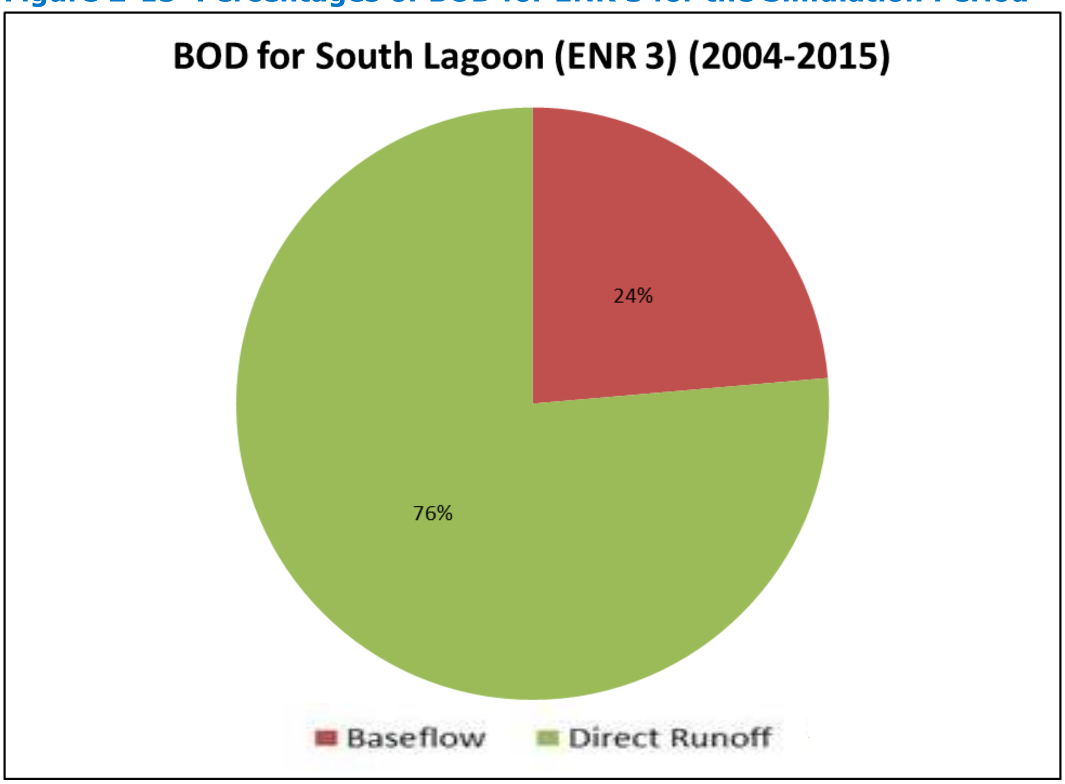


Figure 2-16 Percentages of TN for ENR 3 for the Simulation Period

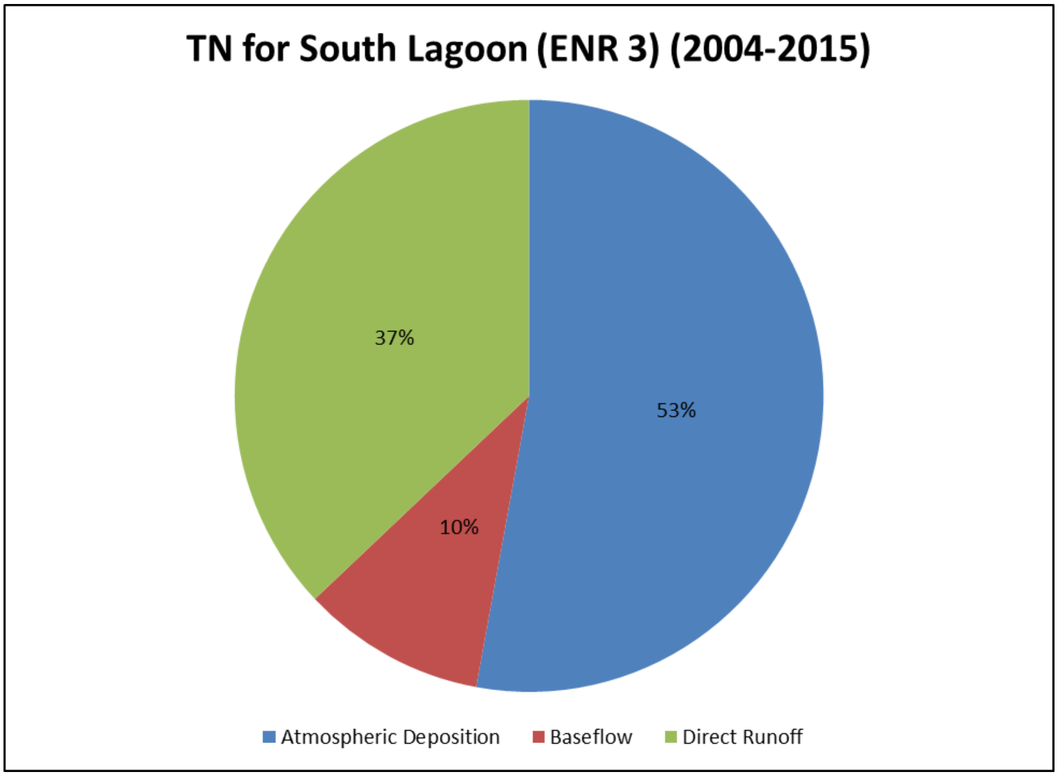
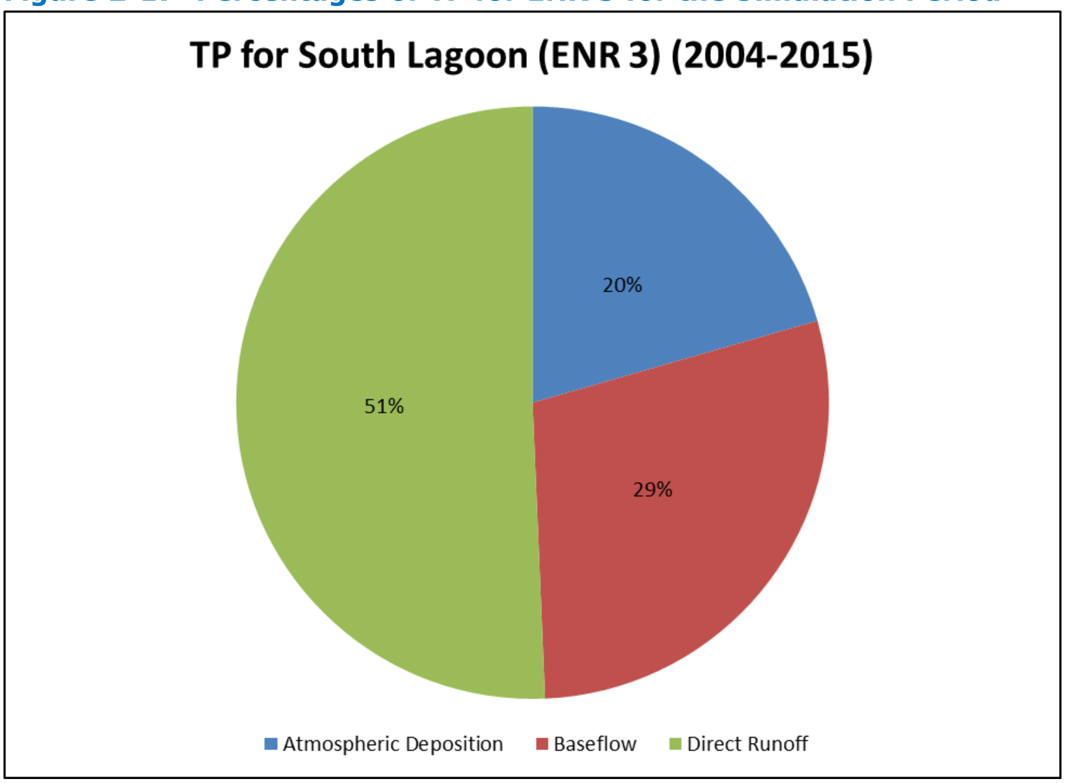


Figure 2-17 Percentages of TP for ENR 3 for the Simulation Period



3 DESCRIPTION OF WATER QUALITY GOALS

When developing a RAP, the first step is to determine the appropriate water quality targets for the parameters and waterbodies of concern. Establishing water quality targets for an estuary is typically achieved by following five steps:

1. Identify resource of concern.
2. Identify appropriate, measurable metrics.
3. Identify the appropriate data sources.
4. Define a reference period.
5. Determine water quality targets.

In this case, the starting point is the NNC for TN, TP, and chlorophyll *a*. The method for determining the current criteria is detailed in the *Report on Numeric Nutrient Criteria for Estuaries* (FDEP, 2014).

Our review of the FDEP approach, as described in *Determination of the Mosquito Lagoon Nutrient Loading Targets* (Janicki Environmental, 2017), concluded that:

- Seagrasses are the appropriate resource of concern.
- TN, TP, and chlorophyll *a* are the appropriate, measurable metrics to be used.
- The primary data source is the FDEP impaired waters database updated for this process to include data collected through 2015.
- Using the annual geometric means (AGMs) as a metric accounts for extreme values within any given year.
- The FDEP approach to calculating the NNC was appropriate and statistically sound. In particular, using the 80-percent-prediction interval is defensible.
- Lastly, the definition of the reference period becomes paramount. Several points of concern regarding the 2004–2008 reference period were previously identified:
    - The 2004–2008 reference period was the 5-year period that had the lowest concentrations observed during the 1989–2008 period for which data were available. This is overly conservative based on seagrass coverage for multiple periods. Duarte et al. (2009) made that significant point when they concluded, *Understanding ecosystem response to multiple shifting baselines is essential to set reliable targets for restoration efforts*.
    - Significantly more data are available that can be used effectively in defining the reference period, including seagrass and water quality data. Figure 3-1 presents seagrass coverage and median depth of the deep edges of the seagrasses in each ENR. Clearly, the seagrass area and deep edges have remained relatively consistent through the period displayed. Therefore, one can reasonably conclude that the water quality conditions, particularly light attenuation, during that period supported the observed seagrass conditions.

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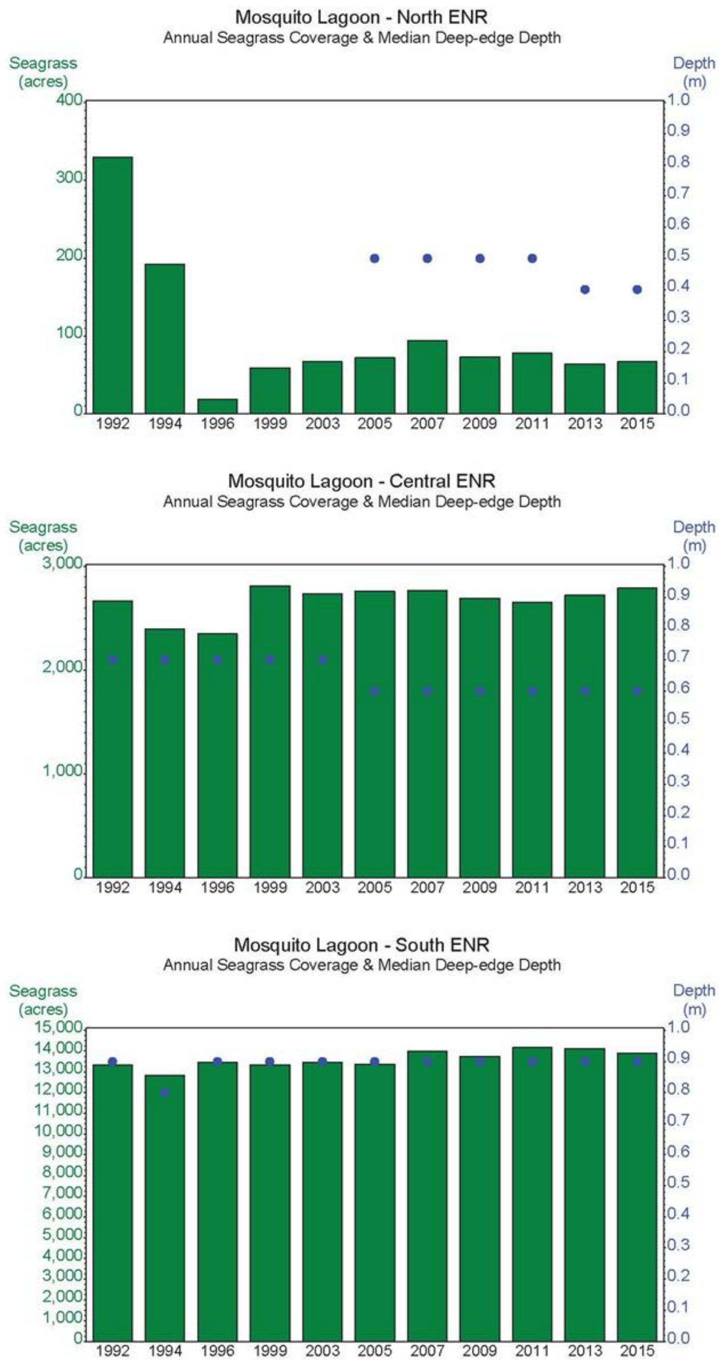
Figure 3-1 Seagrass Coverage (Green Bars) in the North (Top), Central (Middle) and South (Bottom) ENRs of Mosquito Lagoon
Median deep-edge depths are represented by blue dots.



- The increase in available data also provides a more representative long-term set of meteorological conditions.
- As FDEP (2012) summarized, *Criteria established to maintain an existing condition must account for the full range of variance so that realistic expectations of future conditions may be established. Estimates of variance that do not include both spatial and temporal components fail to fully account for the range of natural variability within a system, and thus, criteria derived from such estimates are prone to more statistical error, particularly Type I, than intended.*

Given the availability of additional data over a wider variety of environmental conditions, we propose an alternative reference period described below.

3.1 Proposed Reference Period

A defensible reference period should represent a period during which support for a waterbody's designated use is demonstrated; i.e., relatively healthy condition. The metrics of interest should be quantitatively represented. The reference period should also represent long-term variability in the resource of concern and the chosen metrics by which the water quality targets are defined.

3.2 Seagrass Reference Period

Seagrasses have been used as the biological indicator in estuaries throughout Florida, including the adjacent IRL. Figure 3-1 shows plots of seagrass acreages and median deep-edge depths for each Mosquito Lagoon ENR. Mosquito Lagoon has been identified as the northernmost extent of seagrasses on Florida's East Coast (US Environmental Protection Agency [EPA], 2012). Mosquito Lagoon is also generally held as the location where oysters become the dominant subaquatic habitat, particularly in the North ENR. Losses shown in the North ENR (Lori Morris, personal communication), but since seagrasses are not the dominant habitat perhaps the earlier photographs were interpreting oysters as seagrasses. In the Central and South ENRs, the seagrass area and deep edges have remained stable over a long period and demonstrate that the waters in that period must have been of sufficient quality to maintain seagrasses during the 1992–2015 period. However, there are significant concerns regarding a series of algal blooms that have been observed since 2011 in Mosquito Lagoon. A report by a consortium of experts concluded that attempts to explain the initiation and persistence of the 2011 superbloom using available data highlighted some key gaps in understanding (IRL 2011 Consortium, 2015). Questions remain about the nature and causes of blooms in the IRL. However, the report concluded that variations in external loading could not explain the superbloom occurrence. Given these uncertainties in the causes of the algal blooms that have occurred during 2011–2016, a seagrass reference period between 1992–2010 is proposed for the Mosquito Lagoon RAP.

3.3 Justification of the Proposed Reference Period

In the 2014 FDEP report, *Report on Numeric Nutrient Criteria for Estuaries*, FDEP outlined a method for evaluating the proposed reference period that follows guidance provided by EPA. Often referred to as the *Three-Legged Stool*, this method includes evaluating three parameters:

- Water clarity.

- Dissolved oxygen (DO).
- Chlorophyll *a*.

Justification of the proposed reference period is achieved by demonstrating the compliance of the water quality conditions within that period with thresholds for each of these parameters. Compliance for the clarity leg of the stool is met if the 90-percent confidence interval (CI) of the mean annual Secchi depth for a given year and ENR is greater than the SD_{target} of 0.5 meter, 0.5 meter, and 0.8 meter for the North, Central, and South ENRs, respectively. To evaluate compliance with the DO leg, the daily mean percent DO saturation was calculated for each station. These values are then compared to the 42-percent saturation water quality criterion for marine waters. Compliance is achieved if fewer than 10 percent of the daily mean values in a given year fall below 42-percent DO saturation. For the third leg, chlorophyll *a* data were assessed by determining the percentage of samples within a given ENR and year with more than 20 micrograms per liter (µg/L) chlorophyll *a*. If the result was less than 10 percent, the designated use was deemed as met.

Evaluating the compliance of the proposed reference period included analyzing all three legs. We evaluated each of these parameters for each year in the proposed reference period of 1992–2015. Table 3-1 shows our tabulated results. By ENR, all years that complied with the three legs are shown in regular font. In contrast, those that did not comply are shown in **bold font**. If a leg was found to be in non-compliance in any year, that year was removed from consideration as part of the reference period. Thus, 2011–2015 were removed as part of the reference period. Therefore, the proposed reference period to use in developing the water quality targets for each of the Mosquito Lagoon ENRs includes 1992–2010, a period when seagrasses were stable and when water quality met the Three-Legged Stool test.

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Table 3-1 Evaluation of Water Quality Data by ENR Regarding the EPA Three-Legged Stool

Year	90 Percent CI Mean Annual Secchi Depth (meters)			Percent of Mean Daily Values with DO Saturation < 42 Percent			Percent of Samples with Chlorophyll *a* > 20 µg/L		
	North	Central	South	North	Central	South	North	Central	South
1992	1.4	1.1	1.3	0	0.5	3.1	2.1	2.7	5.9
1993	1.5	1.2	1.7	0	0	0	0.0	1.5	0.0
1994	1.3	1.1	1.2	0	0	0	0.0	0.6	0.0
1995	1.4	1.2	1.6	0	0	0	0.0	1.2	0.0
1996	1.4	1.3	1.3	0	0	0	1.4	3.0	0.0
1997	1.5	1.2	1.2	0	0	0	0.0	0.0	0.0
1998	1.4	1.1	1.0	0	0	0	0.0	2.6	1.7
1999	1.4	1.1	0.8	0	0	0	0.0	1.5	0.0
2000	1.2	1.1	1.5	0	0	0	0.0	0.0	0.0
2001	1.5	1.0	1.5	0	0	0	0.0	0.9	0.0
2002	1.2	1.1	1.3	0	0	0	0.0	0.6	0.0
2003	1.5	1.1	1.4	0	0	0	0.0	0.0	0.0
2004	1.3	1.0	1.1	0	0	0	0.0	0.0	0.0
2005	1.4	1.0	1.3	0	0	0	8.3	0.0	0.0
2006	1.2	1.0	1.2	0	0	0	0.0	0.0	0.0
2007	1.2	1.0	1.5	0	0	0	0.0	0.0	0.0
2008	1.3	1.0	1.8	0	0	0	0.0	0.0	0.0
2009	1.4	1.0	1.6	0	0	0	0.0	8.3	0.0
2010	1.5	1.0	1.6	0	0	0	0.0	5.4	0.0
2011	1.4	0.9	1.1	0	0	0	3.0	8.7	**33.3**
2012	1.4	0.8	1.0	0	**10.8**	0	9.5	**23.1**	**33.3**
2013	1.6	1.0	1.4	0	0	0	**34.2**	**31.6**	**31.3**
2014	1.3	1.0	1.8	0	**21.4**	0	0.0	3.0	0.0
2015	1.2	0.8	0.9	0	0	5	0.0	**16.1**	**50.0**

Note: **Bolded** numbers reflect sample results not in compliance with the three legs method.

3.4 Summary of Water Quality Targets

To develop the water quality targets to be achieved, we followed the approach used by FDEP in the 2014 report on NNCs. The primary objective of the reference period (healthy existing conditions) approach is to establish magnitude and frequency limit(s), which if exceeded in the future would allow one to conclude with sufficient statistical certainty that the new distribution is not consistent with the reference period condition. As FDEP (2012) concluded, it is prudent that a future AGM is consistent with the reference period distribution. Thus, the use of a prediction interval is the *most appropriate statistical tool*. Appendix A presents the algorithm used to determine the 80-percent upper prediction limit and the AGMs used.

Table 3-2 shows the resulting water quality targets using this method. Compliance would be achieved if these targets are not exceeded more than once in any 3-year period. These values will replace the current criteria as determined in FDEP, 2014.

Table 3-2 Water Quality Targets Based on the Upper 80-Percent Prediction Interval

ENR	TN (mg/L)	TP (mg/L)	Chlorophyll *a* (µg/L)
North Mosquito Lagoon	0.65	0.06	4.9
Central Mosquito Lagoon	0.85	0.06	5.0
South Mosquito Lagoon	1.31	0.05	5.2

Note: mg/L = milligrams per liter.

3.5 Summary of Nutrient Loading Targets

3.5.1 Loading Targets

Loading targets provide the basis for identifying projects that are needed to provide the reasonable assurance that the proposed management actions can achieve the designated uses of the waterbody.

EPA and others have identified three analytical approaches for developing nutrient targets:

- Stressor-response analysis.
- Mechanistic modeling.
- Reference condition approach.

All three approaches were attempted and the analyses are described in *Determination of the Mosquito Lagoon Nutrient Loading Targets* (Janicki Environmental, 2017). Since the empirical stressor-response model approach was lacking and did not provide statistical relationships between parameters and a mechanistic model that is useful for this purpose is still under development, the application of a Reference Period approach was investigated and chosen as the most defensible means to determine the loading targets. The period of 2006–2010 was selected as the reference period as it represented the most conservative 5-year period in terms of loadings for TN and TP (Figure 3-2 and Figure 3-3, respectively), was without blooms, was not biased regarding rainfall, and was the most reflective of management actions that have already occurred.

Figure 3-2 Mean Annual TN loads for a Series of 5-Year Increments for Each ENR

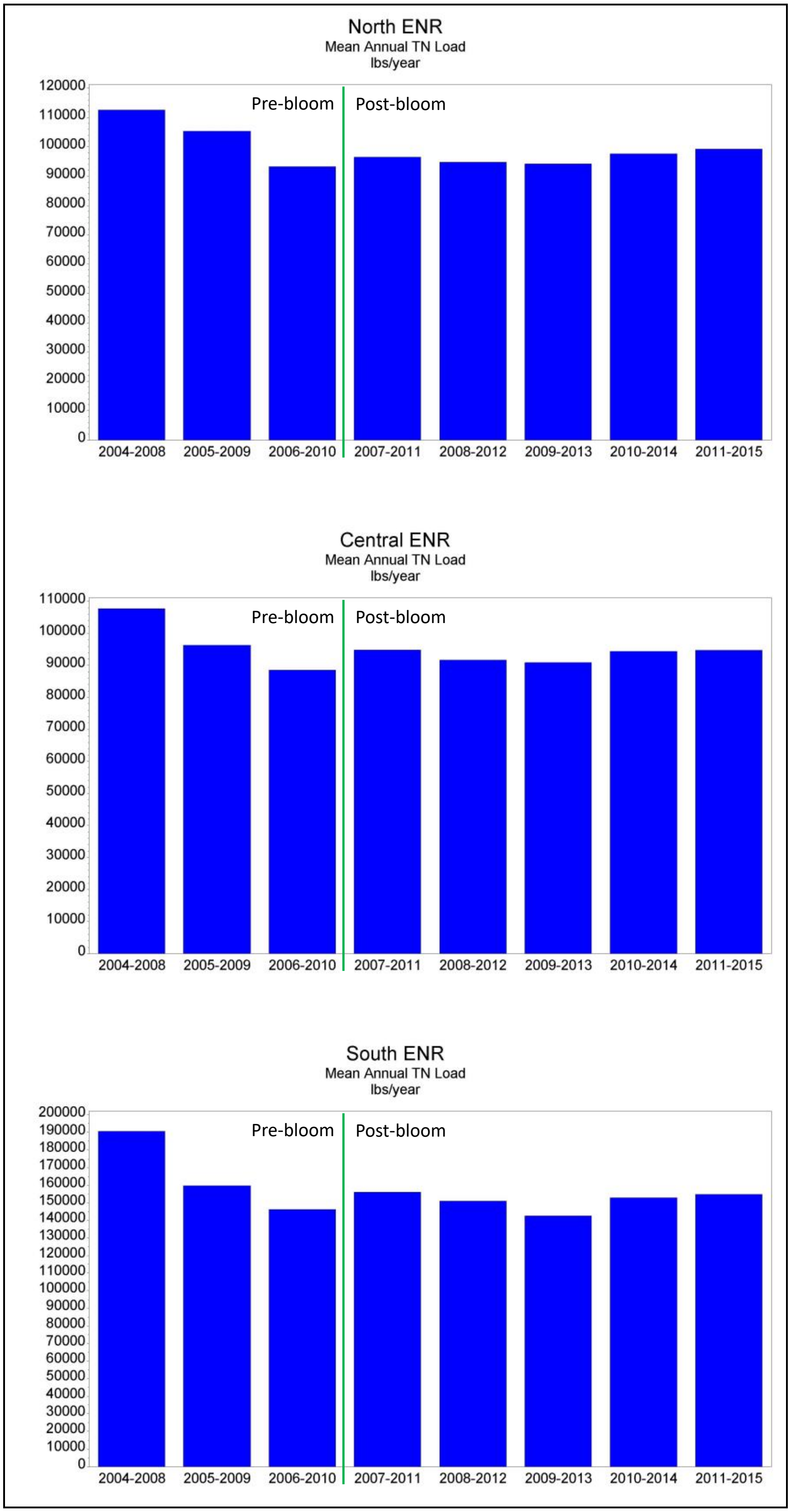
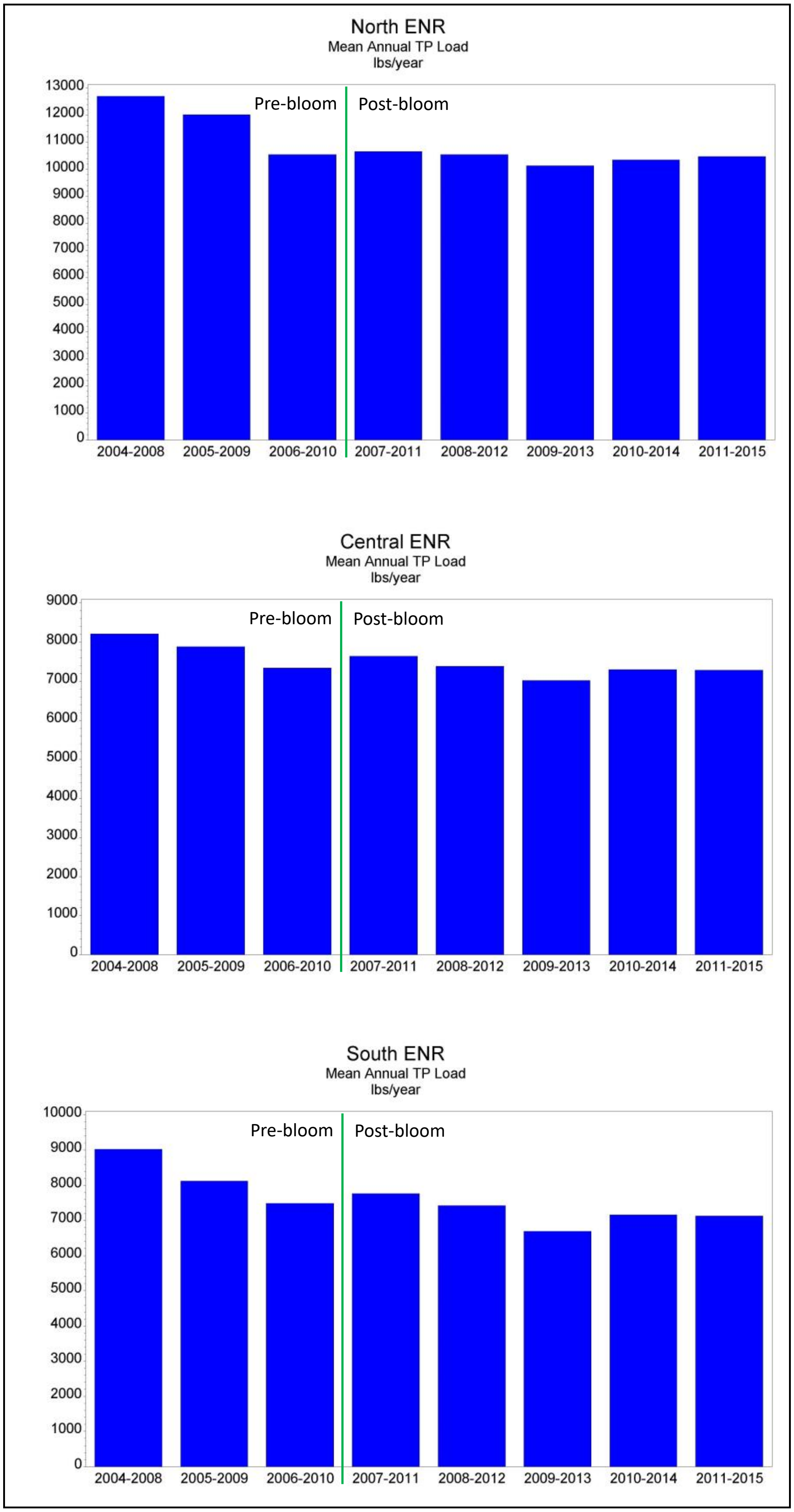


Figure 3-3 Mean Annual TN Loads for a Series of 5-Year Increments for Each ENR



The selection of this reference period was validated by comparing ambient water quality and seagrass data from the three periods available before the bloom period. These estuarine characteristics, including DO, are typically used to assess estuarine health (National Oceanic and Atmospheric Administration [NOAA], 1996; FDEP, 2014; EPA, 2009). Table 3-3 compares the AGM TN, TP, and chlorophyll *a* concentrations and the seagrass coverage.

Table 3-3 Comparison of the AGM Concentrations of TN, TP, and Chlorophyll *a* and Seagrass Cover from Three Potential Reference Periods

Reference Period	TN (mg/L)	TP (mg/L)	Chlorophyll *a* (µg/L)	Seagrass Cover (acres)
North ENR				
2004–2008	0.39	0.04	3.3	83
2005–2009	0.39	0.04	4.0	
2006–2010	0.40	0.04	3.7	84
Central ENR				
2004–2008	0.54	0.04	2.5	2,764
2005–2009	0.51	0.04	3.1	
2006–2010	0.51	0.03	3.5	2,729
South ENR				
2004–2008	0.88	0.02	1.7	13,669
2005–2009	0.84	0.02	1.9	
2006–2010	0.82	0.03	2.4	13,859

Regarding the nutrient (i.e., TN and TP) concentrations, the differences between the 2006–2010 period and the other two periods are very small in all three ENRs. The chlorophyll *a* concentrations from the 2006–2010 period are all well within 1 µg/L of those from the other two periods in all three ENRs. The differences in seagrass cover between the 2004–2008 and 2006–2010 periods are also very small in all three ENRs, which is not surprising given the very stable seagrass coverage that had been seen before the bloom period. Therefore, it can be concluded that the loadings from the 2006–2010 period can be expected to protect estuarine health as measured by the nutrient and chlorophyll *a* concentrations and seagrass cover.

The DO standard for marine waters in Florida is currently expressed as percent saturation and has been defined as 42 percent. None of the samples collected in the three ENRs during 2004–2010 exceeded the 42-percent standard. Therefore, since one of the important estuarine effects to nutrient loading are changes in ambient DO concentrations, it further can be concluded that the 2006–2010 loadings can be expected to protect estuarine health as measured by DO.

3.5.2 Recommendations of Nutrient Loading Targets

Based on the results previously presented, we identified the following loading targets:

- TN Loading (pounds per year [lb/yr])
  - North ENR – 93,328
  - Central ENR – 88,557
  - South ENR – 146,245
- TP Loading (lb/yr)
  - North ENR – 10,538
  - Central ENR – 7,343
  - South ENR – 7,492

3.6 Percent-Load Reductions

Developing percent-loading reductions is an essential element in the Mosquito Lagoon RAP. Given the recommended nutrient loading targets, the next step is to identify a defensible baseline period to provide the basis for the calculation of percent-load reductions.

The period of record for which nutrient loadings have been estimated is 2004–2015 (Jones Edmunds, 2017). This period includes years during which bloom conditions occurred in the IRL. Therefore, using the entire period of record to define the baseline from which load reductions would be calculated is not appropriate. As a result, the recommended baseline loading period is 2004–2010, i.e., the pre-bloom period of record from which loading estimates are available. Extending the baseline to include the entire pre-bloom period reduces the effect of the abnormally high loadings experienced in 2004 resulting from three hurricanes (Charley, Frances, and Jeanne) affecting this portion of Florida.

Table 3-4 compares the nutrient loading targets to the baseline loadings and the estimated percent reduction from the baseline to achieve the loading targets. These loadings represent the total loadings delivered to the IRL including direct runoff, baseflow, OSDS, point sources, and atmospheric deposition.

Table 3-4 Total Baseline and Target Nutrient Loadings and Percent Load Reduction for Each ENR

ENR	Baseline Loading (lb/yr)	Target Loading (lb/yr)	Percent Load Reduction (%)
TN Loading			
North	110,059	93,328	15
Central	102,905	88,557	14
South	173,125	146,245	16
TP Loading			
North	12,370	10,538	15
Central	8,000	7,343	8
South	8,414	7,492	10

The recommendation of a percent-load-reduction target to assess the expected load reductions that will comprise the Plan is based on the recognition that the nutrient loading that the stakeholders can address does not include atmospheric deposition. Thus, the recommended percent-load-reductions will be applied to the treatable loadings, i.e., the total loadings less atmospheric deposition. Table 3-5 presents the recommended load reductions from the treatable loadings.

Table 3-5 Recommended Load Reductions from the Treatable Loadings for Each ENR

ENR	Baseline Loading (lb/yr)	Percent Load Reduction (%)	Load Reductions (lb/yr)
TN Loading			
North	77,096	15	11,564
Central	53,716	14	7,520
South	77,441	16	12,391
TP Loading			
North	10,195	15	1,529
Central	6,620	8	530
South	6,125	10	613

4 DESCRIPTION OF PROPOSED MANAGEMENT ACTIONS

The proposed management actions for Mosquito Lagoon are a combination of capital improvement projects (CIPs), maintenance of stormwater management systems, and programmatic elements.

4.1 Summary of Pollutant Load Reductions Projects Report

As part of the *Pollutant Load-Reduction Projects Report* (Jones Edmunds and Janicki Environmental, February 2018), we evaluated 13 project options. Nine of the 13 projects are stormwater/base flow retrofit projects. The other four projects are a quantification of the load reductions from the septic-to-sewer projects in the *2015 Volusia County Water Quality Plan*, a quantification of load reductions from public education and outreach, an evaluation of potential load reductions from dragline ditch restoration, and a quantification of the load reduction expected from the North IRL meeting its Total Maximum Daily Load (TMDL). Four of the nine stormwater/base flow retrofit projects are intended as back-up projects in case issues arise with some of the other larger implementations (i.e., they treat some of the same areas as larger downstream projects).

4.2 Planned Management Activities

Table 4-1 summarizes the stormwater/base flow retrofit projects that the sponsors plan to implement from the *Pollutant Load-Reduction Projects Report*. Detailed cost estimates for the projects were provided in Section 2 of the *Pollutant Load-Reduction Projects Report*.

Smaller-scale stormwater retrofit projects, such as some of those identified in the City of Edgewater *Stormwater Master Plan CIP Update* (Quentin L. Hampton Associates, 2013) are also planned for implementation. These projects generally treat less than 20 acres and remove less than 100 lb/yr TN and less than 10 lb/yr TP. As discussed further in Section 5, these projects and their associated load reductions will be tracked and will provide additional reductions beyond the large-scale planned projects.

Relatively recent public education and outreach would qualify three cities (Edgewater, New Smyrna Beach, and Oak Hill) and Volusia County for a 3-percent load reduction and FDOT for a 1-percent reduction by following the approach currently used in Basin Management Action Plans (BMAPs). The three cities and Volusia County are committed to identifying homeowner groups for the University of Florida's Institute of Food and Agricultural Sciences (IFAS) to contact and set up education efforts with them. This additional effort will allow them to be eligible for the additional 3-percent credit available through the Florida Yards and Neighborhoods Program. Table 4-2 shows the total load reduction from these credits applicable to the North and Central ENRs.

As discussed in Section 2.13 of the *Pollutant Load-Reduction Projects Report*, the estimated load reduction in the South ENR from the North IRL meeting its TMDL is approximately an order of magnitude greater than the South ENR reduction goals of 12,400 lb/yr TN and 613 lb/yr TP. The ongoing dragline ditch restoration in Mosquito Lagoon is likely also providing pollutant-load reductions. However, site-specific research will need to be done before FDEP can allow load-reduction credits to be taken for that activity.

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Table 4-1 Large-Scale Stormwater/Base Flow Retrofit Projects

Project Number and Name	ENR	TN Reduction (lb/yr)	TP Reduction (lb/yr)	Schedule (Years After Plan Adoption)
Project 1: Diversion to Borrow Pit South of New Smyrna Beach Airport	North	1,300	320	5–10
Project 2: 10th Street Treatment Facility	North	5,600	1,400	1–5
Project 4: East Indian River Boulevard Bioreactor	North[1]	3,900	730	5–10
Project 8: Septic to Sewer[2]	North and Central	>2,200	>100	5–10
Project 9: Ariel Canal Water Quality Improvement Enhancement (aka River Breeze Stormwater Park)	Central	1,300	210	1–5
Project 10: Lighthouse Cove Treatment Facility	Central	760	180	5–10
Project 12: Public Education and Outreach	North and Central	4,100	570	1–5

Notes: 1 – Discharge is at the north/central ENR border.
2 – Specific septic-to-sewer projects are not identified as a part of the RAP. Instead, the sponsors have specified that they will implement septic-to-sewer projects to achieve the remainder of the pollutant load-reduction requirements.

Table 4-2 Public Education and Outreach Pollutant Load Reductions

Stakeholder	Percent Reduction	Annual Load Reduction (lb/yr)	
		TP	TN
City of Edgewater	6	180	1,300
City of New Smyrna Beach	6	210	1,500
City of Oak Hill	6	43	310
FDOT	1	9	70
Volusia County	6	130	920

The large-scale stormwater projects shown in Table 4-1 and public education and outreach reductions shown in Table 4-2 provide 17,000 lb/yr TN reduction of the 19,100 lb/yr needed for the North and Central ENRs combined and 3,400 lb/yr TP reduction of the 2,100 lb/yr needed. Implementation of enough small stormwater retrofit projects is unlikely to meet the remaining TN load-reduction goal. Therefore, the remaining TN reduction will come from septic-to-sewer projects. The highest priority septic-to-sewer project identified in the *2015 Volusia County Water Quality Plan* (Indian Harbor Estates) is estimated to remove between 3,600 to 6,000 lb/yr TN, which is more than the balance of TN reduction needed. This project is conservatively scheduled for implementation between 5–10 years after adoption of this RAP. With adequate funding, the Indian Harbor Estates project, and possibly other septic-to-sewer projects, may be implemented sooner.

4.3 Responsible Participating Entities

The following are the responsible participating entities in this RAP:

- City of Edgewater.
- City of New Smyrna Beach.
- City of Oak Hill.
- FDOT.
- Volusia County.

4.4 Point Sources with National Pollutant Discharge Elimination System (NPDES) Permits

Two significant wastewater treatment plants (WWTPs) are permitted to discharge treated effluent into the Mosquito Lagoon watershed:

- Edgewater (NPDES Permit No. FL0021431).
- New Smyrna Beach (NPDES Permit No. FL0172090).

Four NPDES concrete batch plants also exist within the Mosquito Lagoon watershed:

- Florida Rock-Edgewater (NPDES Permit No. FLG110765).
- Balduf Concrete (NPDES Permit No. FLG110798).
- Titan Florida Edgewater RMP (NPDES Permit No. FLG 110583).
- CEMEX Construction Materials Florida, LLC – New Smyrna Beach Ready Mix Plant (NPDES Permit No. FLG110670).

Volusia County Utilities also has a WWTP (NPDES Permit No. FLA017413) that applies a portion of its reuse within the Mosquito Lagoon watershed. Section 6 of the *Watershed Model Report* provides additional details on point sources.

The WWTPs have invested extensively in reuse and processes to reduce their nutrient concentrations. For example, the New Smyrna Beach WWTP has not had a surface discharge since 2009. Because of the past investments made in the WWTPs and their relatively small contributions to nutrient loading (see Figures 2-6 through 2-17), further reductions of these sources are not being considered as a part of this RAP.

4.5 List of Non-Point Source Categories

Mosquito Lagoon receives non-point-source pollutant loading from the following categories:

- Direct runoff.
- Base flow.
- OSTDS (also known as septic systems).
- Atmospheric deposition directly on the Mosquito Lagoon.

Sections 4 through 9 of the *Watershed Model Report* provide quantification of the pollutant loads from these sources.

4.6 Confirmed Sources of Funding and Identification of Deficiencies

Funding sources include general funds and stormwater utility funds from the sponsors. The sponsors will also seek grant funding where possible. No deficiencies are currently identified for a 15-year implementation. The stakeholders have approved the projects in their jurisdiction.

5 DESCRIPTION OF PROCEDURES FOR MONITORING, COMPLIANCE ASSESSMENT, AND REPORTING

5.1 Reporting

An annual report will be prepared each year that will outline the progress of the RAP. The annual report will include:

- Results of the water quality and seagrass assessments.
- Explanation of deficiencies in achieving targets.
- Status of the monitoring plan.
- Updates on the status of project implementation.
- Estimates of the load reductions made to date.

Every 5 years an update to the RAP will be completed. Items to be included are:

- Results of the water quality and seagrass assessments.
- An update of the annual pollutant loads.
- Explanation of deficiencies in achieving targets.
- Status of the monitoring plan.
- Updates on the status of project implementation.
- Estimates of the load reductions made to date.
- Any additional projects needed to meet the load-reduction requirements.

5.2 Water Quality Monitoring

Volusia County and SJRWMD have a partnership that collects water quality samples in the Volusia County portion of Mosquito Lagoon. The County collects the samples, and SJRWMD analyzes and uploads the data to FDEP's data repository for analysis and as part of the water quality assessment cycle. We recommend that the stakeholders maintain this level of spatial resolution in the North and Central ENRs. The spatial distribution in the South ENR will be expanded to include two additional sites not under the direct influence of the Haulover Canal.

Regarding the temporal scale, while quarterly monitoring is deemed acceptable in terms of meeting the data sufficiency of the Impaired Waters Rule, it limits the understanding of the intra-annual variability. To address the intra-annual variability, the sampling frequency will revert to monthly as had been achieved before 2010. Since the proposed water quality targets were based on a monthly sampling frequency, the assessment of compliance with those targets is more defensible if also based on a monthly sampling frequency.

5.3 Seagrass Monitoring

The stakeholders will continue to support the seagrass monitoring efforts conducted by SJRWMD and their partners. Of particular importance is the aerial mapping effort. This product provided the basis for formulating the water quality targets. The Central and South ENRs have seagrass acreage and depth colonization targets that would be useful to assess when new data become available.

5.4 Pollutant-Loading Assessment

As part of the 5-year RAP update (see Section 5.1), pollutant loadings will be estimated following the methods defined in Jones Edmunds *Watershed Model Report* (2017). The updates will account for changes in land use, implementation of stormwater best management practices, and other additional management actions put in place during that period. These estimates will be used to assess compliance with the proposed loading targets.

5.5 Verification of Compliance

Compliance with the RAP will be based on evaluating the ambient water quality, seagrass extent, and pollutant-loading targets.

On an annual basis, ENR-specific AGMs will be estimated following the methods required by the Impaired Waters Rule or Chapter 62-303 of the Florida Administrative Code (FAC). These values will be compared to the water quality targets that will be adopted as NNC as part of this RAP. Following the methods used by FDEP, compliance will be achieved if the water quality targets are met at least twice in every 3-year period. This will maintain consistency with past and future FDEP assessments.

Given the importance of seagrasses to the Mosquito Lagoon and to the development of the water quality targets, a seagrass assessment will be conducted as additional data become available. Comparisons of seagrass coverage (area) and mean deep-edge depth to established seagrass targets will be conducted in each of the three ENRs.

Every 5 years, the pollutant-loading estimates will be compared to the proposed targets.

5.6 Summary of Compliance

As described, at various points in the 5-year RAP cycle key indicators are being assessed to provide assurance that the stakeholders are moving in the right direction to meet the water quality criteria. These include seagrasses as the primary biological end point, water quality as the key stressor, and pollutant loading as the main driver. A system will be in place (see Section 6.1) that will allow stakeholders an opportunity to assess any failures and adjust the plan accordingly in case the failures are not caused simply by changes in rainfall patterns. The outcomes of these assessments will be included in the annual report (water quality/ seagrass) and as part of the 5-year update (water quality/seagrass/loadings).

6 COMMITMENT TO CORRECTIVE ACTIONS

6.1 Description of Potential Corrective Actions

The annual report will include an assessment of the ambient water quality data where the AGMs will be estimated and compared to the NNC. Also, as part of the 5-year compliance report, an assessment of the updated watershed loads and seagrass coverage will take place.

Table 6-1 shows the decision framework which the annual report and the 5-year compliance report will follow to guide the actions of the stakeholders if any of the criteria are not met. This framework follows similar steps used by the Tampa Bay Nitrogen Management Consortium for implementing the Tampa Bay RAP. The framework recommends a series of actions to follow if a criterion is not met. This will include a comparison of any updated aerial mapped seagrass coverages, if available, to assess seagrass target attainment.

Table 6-1 Assessment Steps for the Mosquito Lagoon RAP

Assessment Step	Result	Action
I. Determine the ENR specific AGM TN, TP, and Chlorophyll *a* concentrations for assessing water quality target attainment.	Yes	Stakeholder Action 1
	No	Go to II.
II. Review data and determine if an anomalous event(s) influenced non-attainment of the ENR specific criteria.	Yes	Stakeholder Action 2
	No	Go to III.
III. Determine if the ENR specific criteria have been exceeded more than once in a 3-year period.	Yes	Go to IV.
	No	Stakeholder Action 1.
IV. Determine if the ENR specific loading criteria have been achieved.	Yes	Stakeholder Action 3
	No	Go to V.
V. For a given year or for multiple years, compile and report source loads compared to the reasonable assurance target load.	Compile and Report	Stakeholder Action 4

Stakeholder actions outlined in Table 6-1 performed during RAP implementation is as follows:

Stakeholder Action 1. A report assessing attainment of ENR specific AGM TN, TP, and Chlorophyll *a* concentrations is delivered to FDEP.

Stakeholder Action 2. A report of the anomalous event(s) or data that influenced the ENR specific exceedance(s) is delivered to FDEP upon review of the stakeholders.

Stakeholder Action 3. Consider re-evaluation of the ENR specific assimilative capacity based on non-attainment of region-specific criteria while meeting the annual loading targets.

Stakeholder Action 4. If loading targets are not achieved, compile the results including a hydrologic evaluation for FDEP's review, and identify potential further actions needed to achieve reasonable assurance for ENR loading targets.

7 REFERENCES

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Appendix A

Algorithm and Annual Geometric Means

ANNUAL GEOMETRIC MEANS

Table A-1 contains the ENR specific annual geometric means (AGMs) used to determine the 80-percent upper prediction interval.

Table A-1 AGMs for Each Segment of Mosquito Lagoon

Segment	North			Central			South		
Year	TN (mg/L)	TP (mg/L)	Chlorophyll *a* (μg/L)	TN (mg/L)	TP (mg/L)	Chlorophyll *a* (μg/L)	TN (mg/L)	TP (mg/L)	Chlorophyll *a* (μg/L)
1992	1.12	0.07	5.2	1.05	0.07	5.8	1.08	0.05	4
1993	0.73	0.04	5.8	0.54	0.04	5.4	0.45	0.04	4.5
1994	0.75	0.06	4.8	0.82	0.07	4.9	0.97	0.06	5.9
1995	0.6	0.06	4.1	0.84	0.06	4	0.94	0.04	5.2
1996	0.58	0.06	4	0.7	0.05	3.5	0.89	0.02	4.3
1997	0.54	0.05	3.5	0.78	0.06	3.6	1.41	0.04	3.5
1998	0.48	0.05	4	0.78	0.06	5	1.77	0.04	4.4
1999	0.5	0.05	4.7	0.7	0.05	5	1.51	0.05	7.8
2000	0.45	0.05	2.7	0.62	0.05	3.4	1	0.02	3.9
2001	0.5	0.04	3.2	0.77	0.04	3.2	0.91	0.02	4.3
2002	0.46	0.04	3.1	1.24	0.04	2.7	1.47	0.02	3.2
2003	0.46	0.06	2.6	0.74	0.05	1.5	1.13	0.02	0.8
2004	0.43	0.05	1.9	0.61	0.05	1.5	1.01	0.02	1.7
2005	0.38	0.05	4.9	0.58	0.05	3.3	1.08	0.02	1.9
2006	0.34	0.03	2	0.48	0.03	2	0.9	0.03	1.7
2007	0.38	0.04	2.9	0.51	0.04	2.1	0.73	0.02	1.1
2008	0.44	0.04	4.8	0.5	0.03	3.6	0.69	0.02	2.1
2009	0.42	0.04	5.3	0.49	0.03	4.5	0.79	0.02	2.5
2010	0.4	0.03	3.3	0.57	0.04	5.2	0.99	0.04	4.8

DETERMINING THE UPPER 80 PERCENT PREDICTION INTERVAL

Taken from *Overview of Approaches for Numeric Nutrient Criteria Development in Marine Waters*, FDEP 2012.

FREQUENCY AND DURATION

To be protective, the duration of the criteria (e.g., AGM, long-term mean) must be linked to the response timeframe of the sensitive endpoint. For example, when criteria are derived based on 96-hour acute toxicity testing, a 1- to 24-hour averaging period would be fully appropriate. Likewise, a 4-day averaging period is protective when criteria are based on chronic toxicity testing. If a sufficiently robust cause-effect relationship demonstrates that an adverse response occurs over a short timeframe, then short-term averaging periods (e.g., 1 to 30 days) would be appropriate for nutrient criteria, provided the response can be linked to nonattainment of the designated use. If, however, such a short-term response cannot be demonstrated or there is no indication of designated use impairment, longer averaging periods are scientifically defensible.

For example, nutrient averaging periods over a year were used by FDEP and EPA to assess the chlorophyll *a* response to nutrient enrichment in Florida lakes. Regression analyses using daily sample data were extremely weak. When data were evaluated based on annual average natural log-transformed data, sufficiently robust relationships were found. EPA used these relationships to propose nutrient criteria for Florida lakes expressed as AGMs. Coincidentally, the use of an AGM was consistent with the derivation of the magnitude and observed response timeframe.

Because criteria derived using the *healthy existing conditions* approach are not linked to any particular response timeframe, this approach does not suggest any inherently protective duration. However, an analysis of the relationships between chlorophyll *a* and phosphorus and nitrogen concentration in Florida's healthy estuaries demonstrates the linkage between long-term nutrient levels and response. FDEP has preliminary evidence suggesting that a long-term duration is in fact appropriate for the purposes of establishing NNC (Figure A-1). Also, decisions regarding the duration of the averaging period should involve practical considerations, such as establishing an effective strategy for describing the baseline distribution and the development of a reasonable assessment test for determining whether future monitoring data are consistent with the baseline.

As previously stated, there is an established precedent for using AGMs for this type of application. Since the goal of a reference-based approach is to maintain the long-term average condition (trophic status), describing and assessing the variability around the AGM are especially suitable for this purpose. Durations over shorter periods would be associated with much greater variability around the central tendency and would not be any more effective at detecting deviations from the baseline distribution. Therefore, FDEP is proposing that the duration be expressed over a period of 1 to 5 years.

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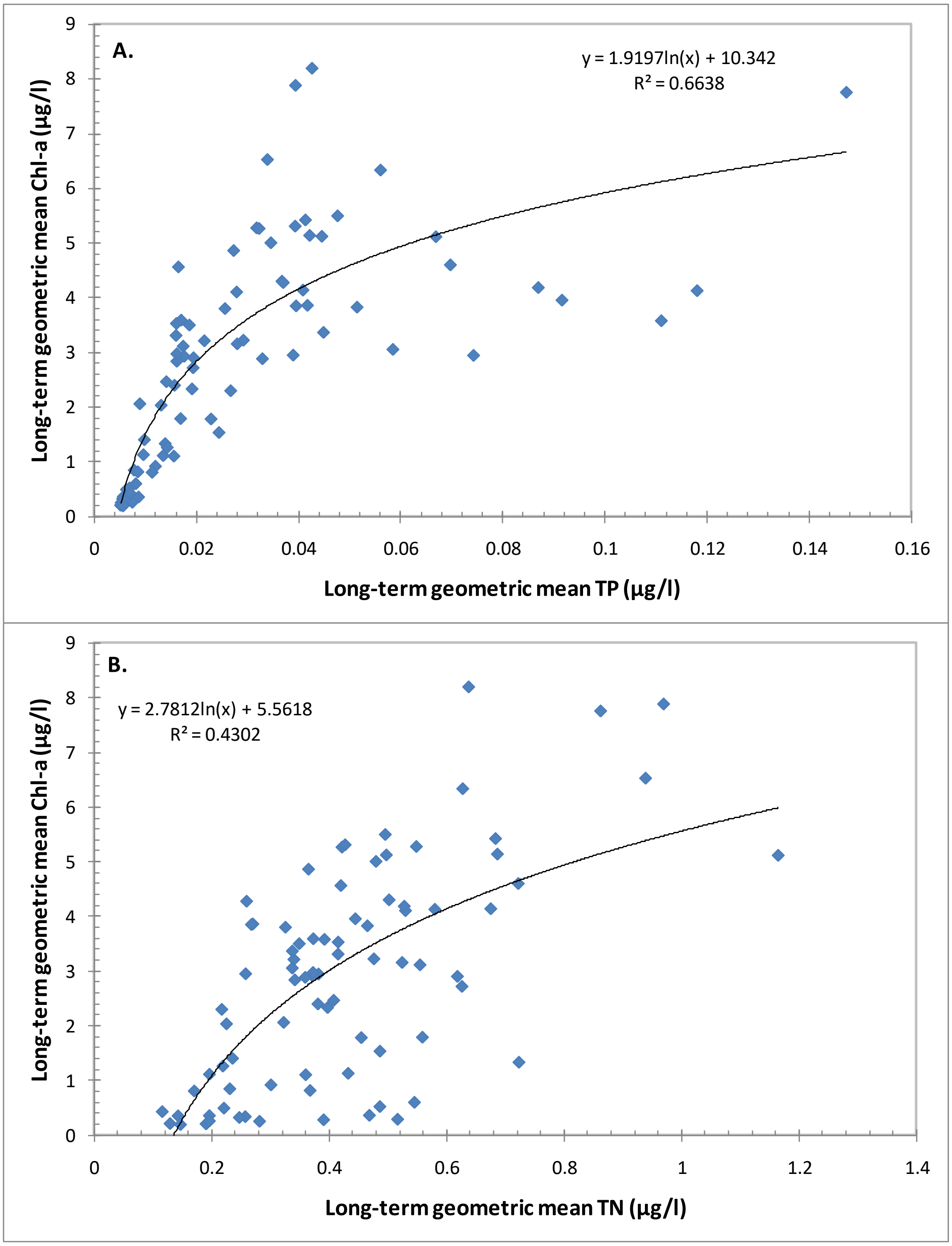
Figure A-1 Relationship between Long-Term Geometric Mean Chlorophyll *a* and TP (Upper Panel) and TN (Lower Panel) from 75 Healthy Florida Estuary Segments



Annual Limit

Given the goal of maintaining an existing frequency distribution, a scientifically defensible approach would be to use the frequency and duration components, in conjunction with magnitude, to assess whether the distribution has shifted upward (or potentially downward in estuaries such as Apalachicola Bay). Such an assessment methodology may be derived statistically when given the stated management goal of no more than a 10 percent Type I error rate. This assessment of the Type I error rate is related only to addressing the null hypothesis that future monitoring data are equivalent to the baseline distribution. This Type I error does not take into account the possibility that a higher nutrient threshold would be fully protective of the use. The Type I error rate for the current application may be defined as the rate of incorrectly identifying waters as nutrient impaired based simply on an exceedance of the statistically derived threshold, when in fact the system is biologically healthy.

The target error rate may be achieved by establishing an NNC that acknowledges inherent natural and analytical variability of the dataset that represents the current condition. This involves targeting maintenance of the current condition on average by using representations of confidence limits around the mean of the dataset, with a specified frequency and duration. Setting a cap using this upper confidence level (assessment limit) represents an upper end of the frequency distribution around the long-term average target. If conditions remain below that limit, then confidence is provided that long-term concentrations have not increased. Previous proposals by EPA have used 3-year assessment periods to express the magnitude and duration nutrient criteria components. Although constructing a test that achieves the 10-percent Type I error rate target over a 3-year period is possible, a slightly longer period (5 years) will provide better long-term control Type I errors where there is significant autocorrelation between years and Type II error rates and will more fully capture climatic cycles (e.g., El Niño, La Niña, and the Atlantic Multidecadal Oscillation [AMO]).

An acceptable excursion frequency can be set using a 3-year period as the basis of assessment. The excursion frequency should account for inter-annual nutrient patterns and be established at a frequency that allows for effective and timely nutrient control; that is, accounting for and allowing natural inter-annual variability associated with climatic cycles and recognizing that multiple high nutrient years can occur in succession. A consideration of this inter-annual correlation would suggest that the excursion frequency should allow for multiple excursions in a 3-year period, such as 2 out of 5 or 3 out of 5 years. However, regulatory agencies often target a more rapid assessment period to allow for the implementation of corrective action in a timely manner, making less frequent excursions more desirable for expressing the criteria (e.g., only once in a 3-year period).

Once an acceptable excursion frequency has been selected, a nutrient target can be set at a level that is expected to result in no more than a 10-percent Type I error rate, given the observed variability in the baseline dataset. The target is set at a percentile or upper prediction interval that corresponds with a 3-year cumulative exceedance probability of no more than 0.8, calculated using the binomial probability function. For example, an exceedance frequency of no more than once in a 3-year period can be set at the long-term 80^{th} percentile (Table A-2). The appropriate exceedance probability was selected by using the Excel goal seek function to find a percentile (i.e., the probability of an AGM greater than the given percentile) that would achieve a cumulative 1- out of 3-year probability of an exceedance rate of no more than 0.9.[1]

In this example, an exceedance of the 1-in-3-year test accurately predicts that the long-term average concentration has increased. Likewise, the target of a 10-percent Type I error can also be achieved by setting the allowable excursion frequency to 0 or 2 years out of 3 years by setting the annual criterion magnitude to approximately the long-term 97th or 54th percentiles, respectively. From a management perspective, allowing less frequent excursions (e.g., once in a 3-year period) would provide a more effective nutrient control strategy than waiting for a full 3 years to take corrective actions. Furthermore, not allowing for any exceedances (i.e., 0 in 3 years) is not realistic, since this would not allow for the full range of natural variability and would result in an excessive number of false positive exceedances. Therefore, FDEP is proposing to derive protective nutrient thresholds based on a no more than 1-in-3 year excursion frequency.

Table A-2 Probability and Cumulative Probability of Observing X and ≤ X Exceedances, Respectively, in a 3-Year Period, Given an Annual Exceedance Probability of 0.20

(Probabilities were calculated based on the binomial probability function.)

X (# exceedances)	P(X) (probability of X exceedances in 3 trials)	Cumulative P (probability of ≤X exceedances)
0	0.512	0.512
1	0.384	0.896
2	0.096	0.992
3	0.008	1.000

Because nutrient data very typically follow or approximate a log-normal distribution, FDEP has historically used a geometric mean and log-normal statistics to describe nutrient distributions and calculate upper percentiles (Section 62-302.530, FAC; Payne *et al.* 1999, 2000, 2003). The approximation of a percentile using this method requires knowing or estimating the long-term mean (X) and standard deviation (σ^2). For the determination of applicable NNC, the mean is set to the long-term network geometric mean (e.g., 13.1 µg/L for the example of St. Joseph Bay), and the standard deviation is based on the variability observed within the baseline dataset.

The parameters X and σ^2 are estimated from available data that were collected over a given period. Because the goal of the criterion is to maintain a long-term average concentration, estimating the full range of variability within a waterbody is imperative, given all sources of variance. Furthermore, Section 62-302.530, FAC, states that *in applying the water quality standards, the Department shall take into account the variability occurring in nature and shall recognize the statistical variability inherent in sampling and testing procedures*. The

[1] The 10-percent Type I error rate may be confirmed by using the binomial probability function and summing the probabilities of observing 0 and 1 exceedances, given that *p* equals 0.20.

full range of variability or true inter-annual variance is composed of annual, spatial, and within-year (sampling) effects, such that the annual average concentration on the log scale is given as:

Ln (AGM concentration) = mean + year effect + site effect + within year effect + error.

The variances associated with site and year effects are based on TP concentrations that have been averaged over spatial or temporal scales and are less influenced by short-term events. The site effect provides an estimate of the spatial variability within the waterbody, while the year effect represents inter-annual variability, which is largely driven by climatic and hydrologic cycles. However, realizing that long-term variability is still influenced to some degree by shorter-term phenomena is also important. The overall influence of these phenomena will diminish with longer averaging periods. For example, a single storm event can result in TP concentrations that are elevated well above the long-term average concentrations for a short period (due to factors such as sediment resuspension). If a sample were collected during this period, then the influence of the storm would clearly affect the results for the given sample date and the within-year variance, and the event would also result in a higher overall annual average for the year. Furthermore, the influence of this single short-term event would affect longer-term averages of the annual averages (e.g., 3, 4, and 5 years). However, the overall influence of a single event, no matter how unusually high, will diminish as more data over longer periods are averaged.

In ecosystems minimally affected by human disturbance, the observed or sampled average condition within a waterbody (and resulting data distribution) is the result of the sum of a number of random processes operating on different temporal and spatial scales. Criteria established to maintain an existing condition must account for the full range of variance so that realistic expectations of future conditions may be established. Estimates of variance that do not include both spatial and temporal components fail to fully account for the range of natural variability within a system, and criteria derived from such estimates are prone to more statistical error, particularly Type I, than intended.

Methods of sampling to measure compliance with established nutrient criteria should be compatible with the procedures to establish the criteria (Davis *et al.* 2001). The compatibility of sampling methods for distributional derived criteria would require that future sampling be conducted across the same number of stations within a specified geographic area (or even the same set of stations) and with a consistent sampling methodology, including number of annual samples. For additional discussion on this topic, see Section 6. However, while regulatory agencies are required to assess criteria compliance at all times and in all places, funding to conduct fixed long-term monitoring is limited. To meet the requirements of the Clean Water Act (CWA) within budgetary constraints, regulatory agencies are typically forced to use *found data*—i.e., agencies are not typically making ambient compliance determinations based on fixed monitoring stations or consistent monitoring designs. The *found data* are collected for a variety of purposes over varying spatial and temporal scales, with a range of sampling frequencies. Therefore, future compliance data are highly unlikely to be wholly consistent with the baseline dataset used to derive NNC. The location of stations will change over time, as will the number of samples used to assess waters, and the true long-term variance in the system will be greater than would be calculated based on a straight calculation of inter-annual variance. In other words, spatial and within-year variance cannot be assumed to be fixed.

One solution to this problem is to account for the influence of spatial and sample (within-year) variance. This approach attempts to account for the added variability expected from a non-fixed monitoring design. The true inter-annual standard deviation for a network of stations is calculated as:

$$\sigma_{tyr} = \sqrt{\sigma_{yr}^2 + \frac{\sigma_s^2}{n} + \frac{\sigma_{sd}^2}{n \cdot k}} \quad (1)$$

where,

σ_{tyr} = true interannual standard deviation
σ^2_{yr} = the year-to-year variance (year effect)
σ^2_s = variance among stations (site effect)
σ^2_{sd} = within year variance for a station (date effect)
n = average number of stations within the network
k = average number of annual samples collected at a station

The within-year variance is calculated as the pooled within-year variance across stations and years. Equation 1 applies if criteria are intended to be applied as a spatial average across a waterbody and was developed based on the variance analysis describe by Walker (1981) and Knowlton *et al.* (1984). The use of this approach assumes that the baseline dataset was drawn from a reasonably homogeneous waterbody and that there are not significant temporal trends in the dataset. If the waterbody is not homogeneous, then it should be further segmented before criteria derivation. The values of *n* and *k* are not fixed and could be assumed to be random variables, although the values will fall within a limited range. The average number of stations and annual number of samples per station were used as the best estimates of expected *n* and *k*, respectively.

Alternatively, the set values of *n* or *k* could be used to investigate the influence of more or less intensive future monitoring designs. Equation 1 can be used to calculate the true (expected) long-term inter-annual variability around the network long-term average network concentration. An example of a calculation for the Central Florida Bay segment of Florida Bay is presented to illustrate the approach. Only site-years with at least four samples were included in the calculations. Table A-3 summarizes the spatial and temporal variance components and potential criterion components.

Table A-3 Summary of TP, TN, and Chlorophyll *a* Variance Components, Long-Term Average Concentrations, and Upper Prediction Limits for the Central Florida Bay Segment of Florida Bay

Component	TP (mg/L)	TN (mg/L)	Chlorophyll *a* (µg/L)
Spatial variance (σ^2_s)	0.2767	0.0636	0.3208
Inter-annual variance(σ^2_{yr})	0.2992	0.3446	0.4621
Within-year standard variance (σ^2_{sd})	0.5039	0.3780	0.9820
Average number of stations within the network (n)	4	4	4
Average number of annual samples collected at a station (k)	11.7	11.7	11.6
Average network Ln	-4.274	-0.324	0.315
Spatially averaged geometric mean (µg/L)	0.0139	0.723	1.371
True inter-annual standard deviation (σ_{tyr})	0.3384	0.3504	0.5098
N (Number of Years	14	14	14
One-sided *t* value	0.870	0.870	0.870
Upper 80% prediction limit (1:3 years)	0.0189	0.992	2.17

The variance components and average network concentrations are on the natural log scale. Calculations were based on sites with at least four samples per year. Limits are presented for illustration purposes and do not represent final criteria recommendations or proposal. The segmentation of Florida Bay is explained in the Florida Bay technical support document.

The primary objective of the healthy existing conditions approach is to establish magnitude and frequency limit(s), which if exceeded in the future, would allow one to conclude with sufficient statistical certainty that the new distribution is not consistent with the baseline distribution. In other words, FDEP wants to be confident that a future AGM is consistent with the baseline dataset distribution, rather than from some different data distribution. Given this goal, the use of a *prediction interval* is the most appropriate statistical tool. Prediction intervals are used to estimate the range of future data, such that 100(1-α) % of the future data will fall within the prediction interval and 100(α) % will fall outside the interval (Helsel and Hirsch, 2002). Helsel and Hirsch (2002) provide an equation to calculate an asymmetric (log-normal) prediction interval. An upper prediction limit can be calculated as:

$$P.I. = e^{\left(\bar{y}+t_{(\alpha,n-1)}*\sqrt{\sigma^2_{\bar{y}}+\sigma^2_{\bar{y}}/n}\right)} \qquad (2)$$

where,

$\bar{y}$ = the mean of the log-transformed data
σ^2_y = the variance of the log-transformed data
n=sample size (number of years)

Equation 1 and the estimate of the true long-term standard deviation (σ_{tyr}) from Equation 1 were used to calculate the upper 80 percent[2] prediction limits on AGM nutrient concentrations for Florida's estuaries. The upper limit is used because the resulting value represents a level that should not be routinely exceeded, resulting in maintenance of current conditions or lower. In other words, if the cap is not exceeded, we have confidence that nutrient concentration conditions have not increased. These limits correspond to AGM concentrations that are expected to be higher in only 10 percent of future years, given the range of spatial and temporal variability measured during the baseline periods for these waters. Therefore, a level is also represented that would be expected to result in a no more than 10 percent Type I error if applied as an AGM, not to be exceeded more than once in a 5-year period. Table A-3 presents an example of the upper 80 percent prediction limits for Central Florida Bay.

Prediction limits are generally greater than the corresponding percentile value and may be thought of as the percentile plus a CI. While FDEP concluded that this is appropriate given the uncertainty associated with future monitoring data, Marine Technical Advisory Committee (MTAC) members requested an example the magnitude of difference between an upper prediction interval and the corresponding percentile. For the Central Florida Bay segment, the 80-percent prediction limit (not to be exceeded more than once in a 3-year period), is 0.0189 mg/L for TP, 0.992 mg/L for TN, and 2.17 µg/L for chlorophyll *a*. For the same dataset, the 80th percentile of the data distribution is 0.0185 mg/L for TP, 0.971 mg/L for TN, and 2.10 µg/L for chlorophyll *a*.

[2] An upper (one-sided) 80 percent prediction limit is equivalent to a (two-sided) 60 percent prediction interval.