SOUTH FLORIDA WATER MANAGEMENT DISTRICT

PERFORMANCE MEASURE METHODOLOGIES FOR COLLECTIVE SOURCE CONTROLS IN THE LAKE OKEECHOBEE AND CALOOSAHATCHEE WATERSHEDS

DRAFT – TECHNICAL SUPPORT DOCUMENT: CALOOSAHATCHEE RIVER WATERSHED PERFORMANCE METRIC METHODOLOGIES

The GGI Team **In Association With** **South Florida Water Management District**

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September 30, 2013

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Ms. Ximena Pernett
Everglades Regulation Bureau
Regulation Division
South Florida Water Management District
P.O. Box 24680
West Palm Beach, FL

Subject: **South Florida Water Management District Contract 4600002337 - Performance Measure Methodologies for Collective Source Controls in the Lake Okeechobee and Caloosahatchee River Watersheds**

Dear Ms. Pernett:

I am pleased to submit this Draft report titled "Technical Support Document: Caloosahatchee River Watershed Performance Metric Methodologies". This document constitutes Deliverable 3.15 of the subject contract. This document was prepared in collaboration with the South Florida Water Management District (District) staff and our consulting team, including L. Hornung Consulting, Inc. and Soil & Water Engineering Technology, Inc. Also, Dr. Robert Knight of Wetland Solutions, Inc. provided a survey of available nitrogen data in south Florida that supported the development of the nitrogen performance metrics. In addition, the performance metrics were based in part on historical data analyses conducted by HDR Engineering, Inc. as part of Contract No. ST061298 – WO08 (Data Analysis and Performance Measure Development for the St Lucie and the Caloosahatchee River Source Control Programs) with District.

Sincerely,

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DEFINITIONS

For the purpose of this *Draft Technical Support Document*, the following definitions apply; these definitions may change over the course of the project, and an up-to-date set of definitions will be included in subsequent versions of this *Technical Support Document*.

(1) "Annual Load (or Concentration) Target" means the first component of the two-part performance metric methodology that evaluates whether a basin's runoff nutrient levels are below or above the central measure (e.g., median) of the nutrient level of an appropriate reference period adjusted for source control reductions. The Target may be adjusted for hydrologic variability if a reasonable correlation exists between the nutrient levels and rainfall characteristics of the reference period. Depending on the water quality characteristics of a basin, the Annual Target is expressed either as a load or a concentration. For the Tidal and Coastal Caloosahatchee Sub-watersheds, the Annual Concentration Target is a distribution of monthly concentrations, which can be represented by the median concentration of the distribution.

(2) "Annual Load (or Concentration) Limit" means the second component of the two-part performance metric methodology that evaluates whether a basin's runoff nutrient levels are above the

   a. upper 90 percent confidence limit on the Target for those basins with a predicted Target, or
   b. maximum monthly concentration observed during the reference period, adjusted for source control reductions, for those basins with a Target based on the distribution of monthly concentrations.

   Depending on the water quality characteristics, including availability of data, of a basin, the Annual Limit is expressed either as a load or a concentration.

(3) "Base Period" means the benchmark period of historical observed data on which performance measures are based. Base periods should meet, as much as possible, the

following criteria: having at least eight years of concentration and flow data to adequately represent nutrient levels through a wide range of hydrologic conditions; be representative of current operating conditions affecting nutrient levels (unless these conditions can be corrected through data adjustments); have a reasonable correlation between rainfall and nutrient loads; precede full implementation of collective source control measures; be free of trends in rainfall, flow or loads (unless these trends can be accounted for); and be free of unexplained outliers in the rainfall, flow, or load data.

(4) “Basin” means the contributing surface area for which the District has determined the water quality to be represented by specified monitoring sites.

(5) “Calendar Year” means the twelve months beginning January 1 and extending through December 31.

(6) “Evaluation Period” means the time period for which the observed nutrient levels for a basin will be compared to the Annual Target. This period includes a minimum of three water years, including the most recent complete water year (“Evaluation Year”) but does not include years when the performance determination was suspended because the hydrologic conditions during the Evaluation Period do not reflect the hydrologic conditions that occurred during the benchmark period.

(7) “Evaluation Year” means the Water Year to be evaluated relative to the performance metric methodology.

(8) “Load” is the mass of the nutrient of concern carried past a specific point of discharge during a specific period of time by the movement of water, e.g. metric tons of nutrient per year. Water quality concentration and water quantity (flow) data are required to calculate the nutrients load discharged past the monitoring point, as defined by the following general equation:

nutrient load (mass) = nutrient concentration (mass/volume) x flow (volume)

(9) "Nutrient” means an element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen and phosphorus (USGS 2007).

(10) "Pass-Through Flow" is the portion of inflows to a basin from external sources that is discharged from the basin within a specified time frame (i.e. daily). Basin-level pass-through flows are calculated as the minimum of the basin inflows or outflows.

(11) "Pass-Through Load" is the inflow load resulting from pass-through flow. Basin-level pass-through loads are calculated as the product of the representative inflow concentration and the basin-level pass-through flow.

(12) "Performance Determination" means the process by which nutrient levels for a basin during the evaluation period are compared against an established quantifiable metric.

(13) "Performance Indicator" means a numeric nutrient level or other metric that could be achieved through the implementation of source control programs for a basin, established from available data and best professional judgment; where the criteria for establishing a performance measure are not met, a performance indicator will be recommended and may include a recommendation for additional monitoring adequate to support future performance metric development. A performance indicator reflects the District's commitment to adaptive management and continuous improvement in nutrient reductions.

(14) "Performance Measure" means a numeric nutrient goal that could be achieved through the implementation of source control programs for a basin, established from a representative range of historical flow, nutrient, and rainfall conditions that existed during a specified Base Period. The Performance Measures for source controls are not equivalent to an established Total Maximum Daily Load or water quality-based criteria.

(15) "Performance Metric" is a generic reference to either a performance measure or performance indicator.

(16) "Performance Metric Methodology" means a description of the process for assessing the effectiveness of the collective source control programs within a basin. The methodology could apply to either a performance indicator or performance measure.

(17) "Reference Period" means the benchmark period of historical measured data on which performance indicators are based. Reference Periods shall include, at a minimum, five years of nutrient concentration or load data measured during a representative range of conditions

affecting nutrient concentration or loading from the basin. Exceptions may be considered on a case by case basis.

(18) "Regional Project" means a water quality and/or quantity project, generally funded by public agencies and/or on public land, designed to work in concert with source controls to reduce nutrient levels in basin runoff; these can be regional, sub-regional, and local scale projects, e.g., reservoirs, stormwater treatment areas (STAs), chemical treatment, and local stormwater projects.

(19) "Runoff Concentration" means the annual nutrient concentration measured at the outlets or other representative locations of the basin, adjusted for pass-through loads and regional projects, if applicable.

(20) "Runoff Load" means the annual nutrient load measured at the outlets of the basin minus pass-through loads and adjusted for regional projects, if applicable.

(21) "Scaled Concentrations" means the observed Reference Period concentrations reduced by the anticipated source control reduction.

(22) "Scaled Loads" means the observed Base Period loads reduced by the anticipated source control reduction.

(23) "Water Year" means the period beginning May 1 and continuing until April 30 of the following calendar year. The water year is named for the year in which it ends.

1. EXECUTIVE SUMMARY

1.1 Background and Purpose

This *Draft Technical Support Document* was developed in support of the South Florida Water Management District's Regulatory Source Control Program (Chapter 40E-61, F.A.C, Works of the District) which is being amended to meet mandates of the Northern Everglades and Estuaries Protection Program (NEEPP). In accordance with NEEPP, refinement of existing regulations and development of best management practices (BMPs) complementing existing regulatory programs is a basis for achieving and maintaining compliance with water quality standards including any adopted Total Maximum Daily Loads (TMDLs).

The Regulatory Source Control Program was established in 1989 in the Lake Okeechobee Watershed under the authority of the Surface Water and Improvement Management (SWIM) Act. In 2007, the NEEPP mandated complementary source control programs by the three coordinating agencies (the Florida Department of Environmental Protection (FDEP), the South Florida Water Management District (District) and the Florida Department of Agriculture and Consumer Services (FDACS)), encompassing an expanded Lake Okeechobee Watershed, and the St. Lucie River and the Caloosahatchee River Watersheds. Total phosphorus (TP) is the nutrient of concern for Lake Okeechobee while TP and total nitrogen (TN) have been identified as nutrients of concern[1] for the St. Lucie River and Caloosahatchee River Watersheds. In response to these legislative changes, the District must amend the 1989 Chapter 40E-61, F.A.C., to effectuate the NEEPP requirements.

Fundamental components of the Regulatory Source Control Program are water quality performance metrics coupled with water quality monitoring. The water quality performance metrics currently specified in Chapter 40E-61, F.A.C, are only for a portion of the Lake

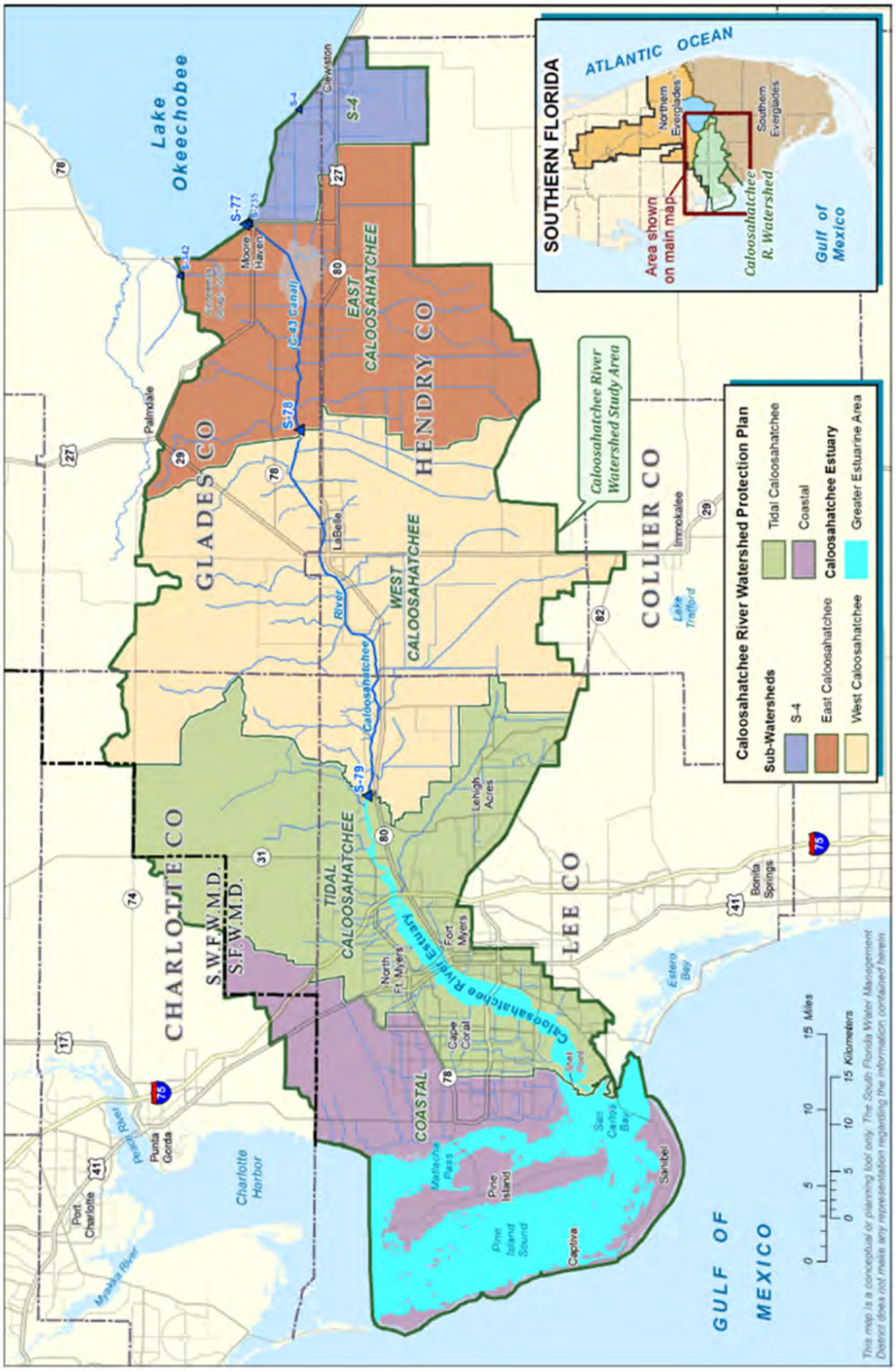
[1] Based on the criteria and assessment methodologies in Chapters 62.302 and 62.303, F.A.C.

Okeechobee Watershed. Although this portion includes the S-4/Industrial Canal and the East Caloosahatchee Sub-watersheds in the Caloosahatchee River Watershed, these metrics are not in alignment with the current water quality goals for the Lake Okeechobee and the Caloosahatchee River Watersheds. The performance metrics of the 1989 Chapter 40E-61, F.A.C., aim at meeting a TP load to Lake Okeechobee of 360 metric tons per year (mt/yr) by implementing concentration-based limits from individual parcels within the watershed. In contrast, the TP TMDL for Lake Okeechobee is set at 140 mt/yr and includes a target load of 0.01 mt for the Western Region (which includes the East Caloosahatchee Sub-watershed) and 9.56 mt for the Southern Region (which includes the S-4/Industrial Canal Sub-watershed, the Everglades Agricultural Area and local Chapter 298 Districts). Additionally, a TN TMDL has been established for the Caloosahatchee Estuary requiring a reduction of 23 percent or approximately 583 mt/yr from the 1996-2005 average discharges from the Caloosahatchee River Watershed (FDEP 2009). Additionally, development of TMDLs for other impaired tributaries of the Caloosahatchee River Watershed is currently underway. The NEEPP mandates that the District or FDEP conduct monitoring at representative sites to verify the effectiveness of agricultural and non-agricultural non-point source best management practices such that water quality problems can be detected and reevaluation of the rules adopting best management practices and appropriate changes can be made, if needed. In addition, the NEEPP states that the District shall, in coordination with other agencies and local governments, establish a monitoring program that is sufficient to carry out, comply with or assess the plans and programs, and other responsibilities created by the statute. It is the intent of the water quality monitoring network and the concepts within this technical support document to serve as the science-based foundation for meeting these directives.

This *Draft Technical Support Document* presents preliminary water quality performance metrics for the Caloosahatchee River Watershed (**Figure 1-1**) recommended for consideration in amendments to Chapter 40E-61, F.A.C. A similar *Draft Technical Support Document* was prepared for the Lake Okeechobee Watershed[2] (Gary Goforth, Inc. 2013). These performance metrics estimate the nutrient reductions in runoff that are reasonably expected from the long term implementation of the source control programs mandated by the NEEPP based on monitoring sites that are representative of runoff. The quantitative methods are referred to as "performance metric methodologies". When the performance metrics are discussed as a whole, the term "basin" will be used to describe the sub-watersheds and tributaries. The resulting metrics are referred to as performance measures or performance indicators depending on the characteristics

[2] Differences between these two technical support documents are identified in a companion memorandum (SFWMD 2013).

Figure 1-1. Map of the Caloosahatchee River Watershed (from SFWMD 2012).



of the data on which they are based. Performance measures are typically nutrient loads incorporating hydrologic variability based on a representative base period dataset. Performance measures are proposed for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds. Performance indicators are recommended when all the criteria for establishing a performance metric are not met. For the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds and their tributaries, performance indicators are proposed. Performance metrics may provide justification for implementation of additional water quality improvement activities, or re-evaluation of the existing activities by the respective agencies. The level of activities that may be triggered in each case will be defined by the coordinating agencies based on jurisdiction. The NEEPP required that a Memorandum of Understanding (MOU) be executed among the agencies to ensure a complementary approach; the MOU was first executed in 2011.

In **Section 1.2** below is a description of how the performance metrics were developed, how performance will be evaluated every year, and a description of the performance metrics for each of the basins. This document contains preliminary recommendations for performance metrics that may be refined during the technical and stakeholder review process prior to adoption.

1.2 Performance Metric Methodologies Development

The S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds utilize a load-based performance metric methodology. The following general activities were conducted to develop the performance metric methodologies for these sub-watersheds.

1. Monthly and annual runoff and TP, TN and total organic nitrogen (TON) loads for each basin were calculated based on available historical data through Water Year 2010 (WY2010) for representative basin structures. When a basin received inflows from

upstream sources (e.g., other basins or Lake Okeechobee) the pass-through load was accounted for using a similar method as was applied to the Everglades Agricultural Area (EAA) under Chapter 40E-63, F.A.C.

2. Representative rainfall monitoring stations were identified, and an equation to estimate basin rainfall using the Thiessen polygon weighting method was developed and applied to create a daily rainfall data set for each basin.

3. A base period was selected for each basin. The base period was the benchmark period of historical observed data on which performance metrics were based. Base periods met, as much as possible, the following criteria: having at least eight years of concentration and flow data to adequately represent nutrient levels through a wide range of hydrologic conditions; being representative of current operating conditions affecting nutrient loading (unless these conditions can be corrected through data adjustments); having a reasonable correlation between rainfall and nutrient loads; preceding full implementation of collective source control measures; being free of trends in rainfall, flow or loads (unless these trends can be accounted for); and being free of unexplained outliers in the rainfall, flow, or load data.

4. Nutrient reduction goals were estimated based on work completed in the development of the watershed protection plans for Lake Okeechobee and Caloosahatchee River (Bottcher 2006 and SWET 2008). These reductions are based on implementation of regulations and BMPs applicable to each land use (e.g., FDACS Notice of Intent owner-implemented BMPs, operational BMPs or activities required by existing permits or regulations). The nutrient reduction goals will be applied to predicted nutrient annual loads each year to identify potential Annual Load Targets and Annual Load Limits. Basin-specific adjustments were made to the estimated nutrient reduction goals. For TN, this

adjustment included derivation of a prediction equation for the estimated background TN load, as estimated by 90 percent of the TON load.

5. Fifty-four prediction equations for annual load were examined for each basin to determine which equation would best estimate the base period annual nutrient load in response to hydrologic variability from year to year. Multiple selection factors were used to select the recommended regression equation including, the strength of the correlation, the statistical significance of the regression coefficients, the standard error of the regression equation, the variance of the residuals, collinearity of predictor variables, the presence of outliers, the presence of temporal trends during the base period, and the absence or presence of overparameterization.

6. A methodology to evaluate the nutrient trends was developed based on the selected base period and preferred prediction equation, and expressed as flow-weighted five-year rolling load reductions.

7. Equations for the Annual Load Targets and Annual Load Limits were derived by applying the nutrient reduction goals to the selected prediction equations.

8. Since the goal of the performance metrics is to evaluate the effectiveness of the source control programs independent from regional water quality treatment projects (e.g., stormwater treatment areas), this *Draft Technical Support Document* provides a methodology that may account for such projects. In such cases, the basin's measured runoff load will be adjusted to account for the load reduction occurring within the regional project. In addition, the basin's calculated Annual Load Target and Limit will be adjusted to account for the land occupied by the regional project. The adjustment is similar to the adjustment used in the EAA under Chapter 40E-63, F.A.C. This methodology may be used once regional projects become operational.

Flow data are generally not available within the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds, and hence concentration-based performance metric methodologies were developed for these areas. The following general activities were conducted to develop the performance metric methodologies for these sub-watersheds.

1. The periods of available water quality data in these sub-watersheds were shorter than for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds, and hence, the periods of record were extended through WY2012. Monthly nutrient concentration data for each basin within the sub-watersheds were compiled through WY2012 for representative water quality monitoring stations. Most downstream stations within each tributary (encompassing the most acreage) were selected because the metrics aim to measure collective performance while optimizing the monitoring costs that would be required to track performance in the long-term.

2. A reference period was selected for each basin. The reference period was the benchmark period of historical observed data on which performance metrics were based. Reference periods include, at a minimum, five years of nutrient concentration data measured during a representative range of conditions affecting nutrient concentration from the basin. Exceptions were considered on a case by case basis, as was done for the Coastal Caloosahatchee Sub-watershed, where only four years of data were available (WY2009-2012). Reference Period monthly median concentrations were calculated for TP, TN and TON. Monthly maximum concentrations were also calculated for TP and TN, and the TON concentration observed at the time of the maximum TN concentration was identified. Composite concentrations were calculated for each sub-watershed using tributary data.

3. Nutrient reduction goals were calculated based on work completed in the development of the watershed protection plans for Lake Okeechobee and Caloosahatchee River (Bottcher 2006 and SWET 2008). These reductions are based on implementation of regulations and BMPs applicable to each land use (e.g., FDACS Notice of Intent owner-implemented BMPs, operational BMPs or activities required by existing permits or regulations). Basin-specific adjustments were made to each calculated nutrient reduction; for TN, this adjustment included a comparison to the background TN concentration, as estimated by 90 percent of the TON concentration.

4. The nutrient reduction goals were applied to the median and maximum TP and TN concentrations to establish Annual Concentration Targets and Annual Concentration Limits, respectively.

1.3 Annual Performance Determination

A load-based performance metric methodology is proposed for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds. For these basins, nutrient loads measured in discharges at each basin's outlet structures, after accounting for pass-through loads and regional projects, will be assessed annually against two performance metrics: an Annual Load Target and an Annual Load Limit (**Figure 1-2**). The Annual Load Targets and the Annual Load Limits for these sub-watersheds are defined in **Sections 3.1, 3.2** and **3.3**.

A concentration-based performance metric methodology is proposed for the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds. For these basins, monthly nutrient concentrations measured in discharges at representative monitoring locations will be assessed annually against two performance metrics: an Annual Concentration Target and an Annual Concentration Limit (**Figure 1-3**). The Annual Concentration Targets and the Annual

Concentration Limits for these sub-watersheds are defined in **Sections 3.4** and **3.5**. The sub-watershed performance metric indicates how the sub-watershed as a whole is making progress towards the long-term source control reduction goals, assuming monitored areas are representative of those for which monitoring is currently not available (approximately 45 percent and 53 percent of the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds, respectively[3]). Because the monitoring locations and sample frequency do not capture all of the discharge through each tributary, the performance metrics can be considered as relative evaluations.

Tables 1.1 through **1.6** present the performance metrics for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds. The tables include the equations for calculating the annual load targets, limits, and standard errors of the predictions, along with the minimum and maximum rainfall (or adjusted rainfall[4] as applicable) ranges within which the performance metrics can be evaluated. The variables used in the prediction equations are defined below:

X = 12-month total rainfall for the evaluation year (inches), or ln(rainfall), if applicable

X_m = average value of annual rainfall in the base period (inches), or ln(rainfall), if applicable

C = coefficient of variation calculated from 12 monthly rainfall totals, or ln(coefficient of variation), if applicable

C_m = average value of the rainfall coefficient of variation in the base period, or ln(coefficient of variation), if applicable

S = skewness calculated from the 12 monthly rainfall totals

[3] A large portion of the sub-watersheds is open water, and the unmonitored portions excluding open water is 16 percent for Tidal Caloosahatchee and 27 percent for Coastal Caloosahatchee Sub-watersheds.

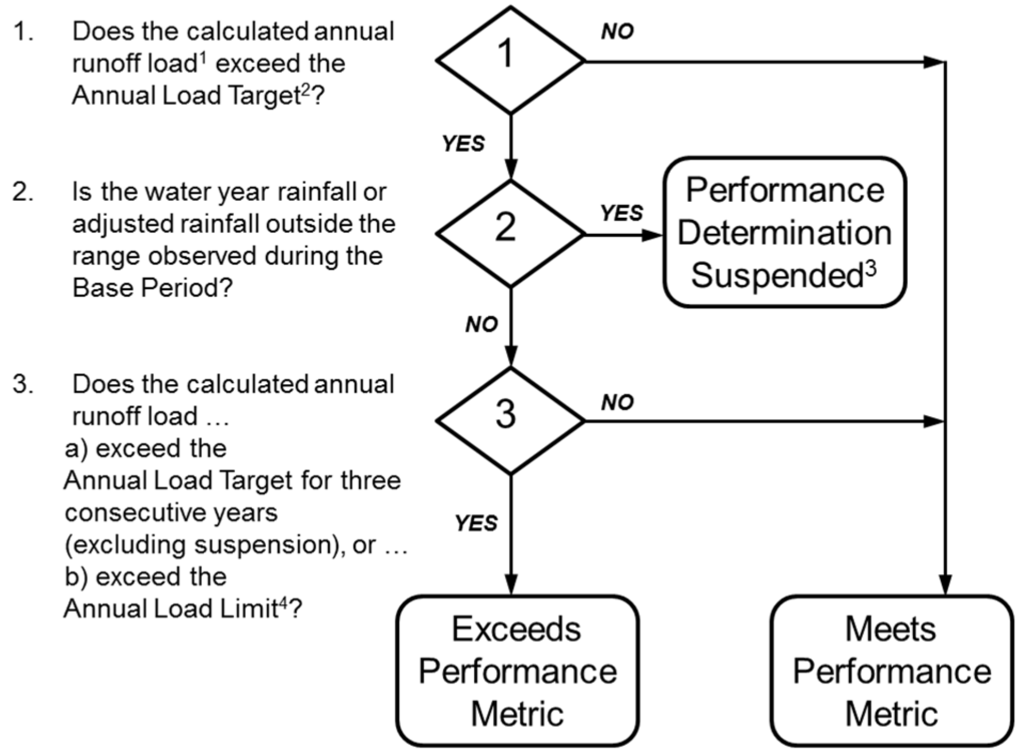
[4] An adjusted rainfall is used when the regression equation for the Annual Load Target includes more than one predictor variable. This adjusted rainfall reflects the cumulative effect of the variables that comprise the load target equation. Section 3.3.2.1.1 describes how the adjusted rainfall term is calculated.

S_m = the average value of the rainfall skewness in the base period

SE = standard error of the prediction (mt, ln(mt) or sqrt(mt) as applicable)

Figures 1-4 through **1-9** present predicted annual nutrient loads derived from the Base Period data using a zero percent load reduction. The solid lines show the five-year trend of load differences (observed vs. predicted), while the diamond (♦) symbols represent the annual difference.

Figure 1-2. Flowchart - annual nutrient performance determination for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds.

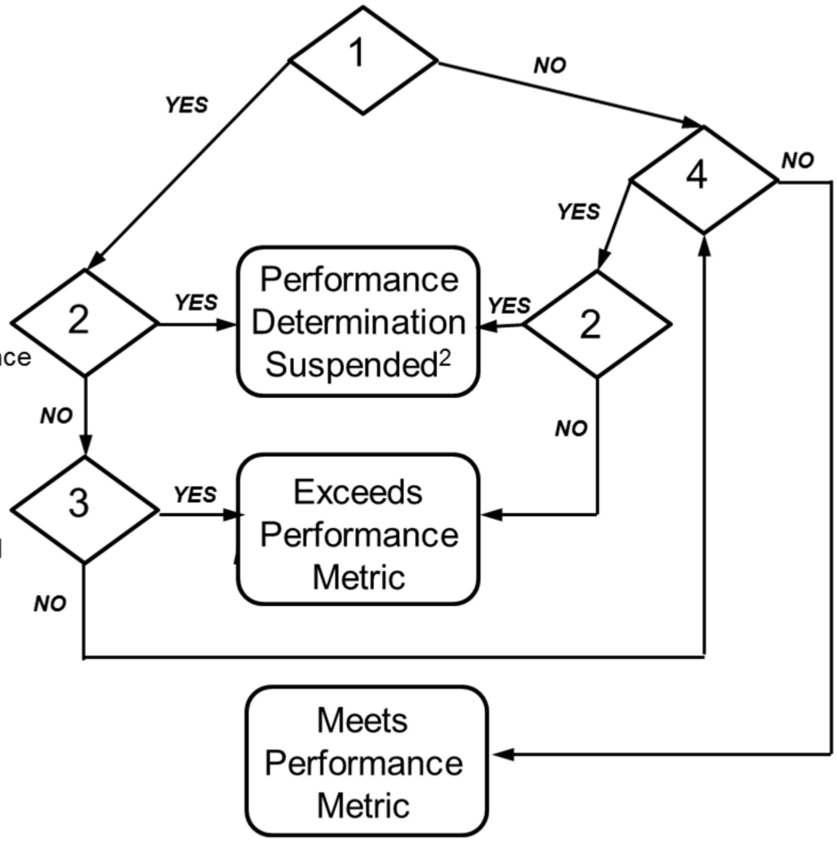


Notes:

1. The calculated annual runoff load is the observed basin load adjusted for pass-through loads and Regional Projects, as applicable. If the calculated load is negative it will be set to zero.
2. For TN, the Annual Load Target is set to the greater of two predicted loads, and the Annual Limit is set as the upper 90th percent confidence limit above the selected prediction. The Annual Load Target is adjusted for Regional Projects, if applicable. If the calculated Target is negative it will be set to zero.
3. If the Annual Load Target is exceeded in a May 1 through April 30 period, and the rainfall or adjusted rainfall for the period is outside the range observed during the Base Period, the performance determination will be suspended and the basin will not be determined to exceed its performance measure for that period only. Any period(s) for which the performance determination is suspended will be excluded from the determination of whether the Annual Load Target has been exceeded in three or more consecutive May 1 through April 30 periods. That is, the basin will exceed its performance measure when the Annual Load Target is exceeded in three or more consecutive May 1 through April 30 periods, even though the three periods may be interrupted by periods of suspension.
4. The Annual Load Limit is adjusted for Regional Projects, if applicable. If the calculated Limit is negative it will be set to zero.

Figure 1-3. Flowchart - annual nutrient performance determination for the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds.

1. Are the observed monthly concentrations significantly larger than the Annual Concentration Target[1]?
2. Is the water year rainfall outside the range observed during the Reference Period?
3. Do the observed monthly concentrations exceed the Annual Concentration Target for three consecutive years (excluding suspensions)?
4. Does one or more observed monthly concentrations exceed the Annual Concentration Limit?



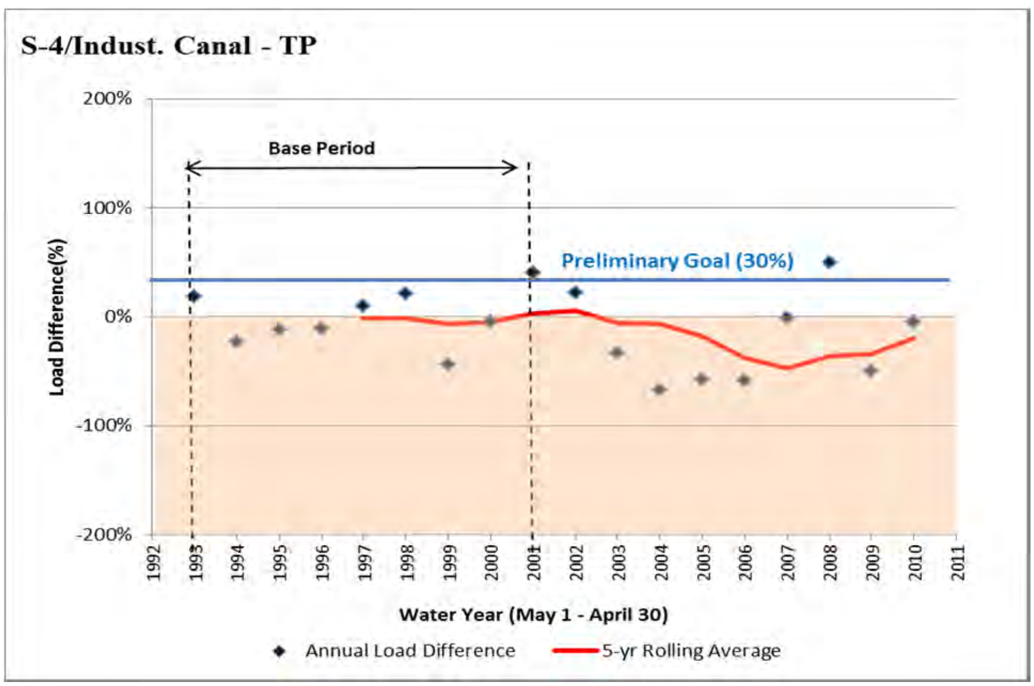
Notes:

1. The Annual Concentration Target is a distribution of monthly concentrations which can be represented by the median concentration of the distribution adjusted by the source reduction goal.
2. If the Annual Concentration Target or Limit is exceeded in a May 1 through April 30 period, and the District determines that the rainfall for the period is outside the range observed during the Reference Period, the performance determination will be suspended and the basin will not be determined to exceed its performance metric for that period only. Any period(s) for which the performance determination is suspended will be excluded from the determination of whether the Annual Concentration Target has been exceeded in three consecutive May 1 through April 30 periods. That is, the basin will exceed its performance metric when the Annual Concentration Target is exceeded in three consecutive May 1 through April 30 periods, even though the three periods may be interrupted by periods of suspension.

Table 1-1. S-4/Industrial Canal Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall[1] Minimum inches	Maximum inches
17.6	76%	26.95	62.81
Target = -14.62787 + 0.41452 X + 8.44621 C			
Limit = Target + 1.43976 SE			
$SE = 3.02608 [1 + 1/9 + 0.00112 (X-X_m)^2 + 2.03794 (C–C_m)^2 + 0.00884 (X-X_m) (C–C_m)]^{0.5}$			
Adjusted Rainfall = X + 20.37588 (C – 0.91367)			

[1] Based on adjusted rainfall values



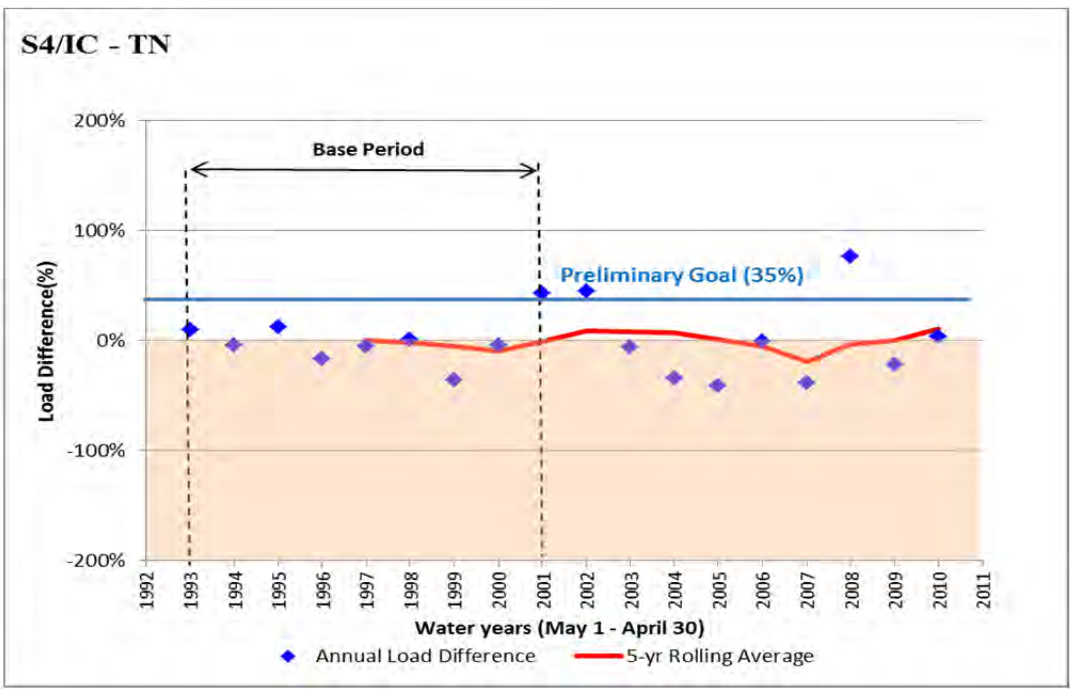
Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-4. S-4/Industrial Canal Sub-watershed TP load trend.

Table 1-2. S-4/Industrial Canal Sub-watershed TN Load Performance Measure.

<table>
<tr><th rowspan="2">Base Period Median Annual Load
mt</th><th rowspan="2">Explained Variance
(R^2)</th><th colspan="2">Base Period Rainfall</th></tr>
<tr><th>Minimum
inches</th><th>Maximum
inches</th></tr>
<tr><td>284.2</td><td>TN-based: 80%
TON-based: 58%</td><td>33.83</td><td>58.34</td></tr>
<tr><td colspan="4">Target = maximum of the following:
TN-based Prediction = -813.31466 + 265.08379 X
TON-based Prediction = -593.98524 + 205.54389 X</td></tr>
<tr><td colspan="4">Limit = Target + 1.41492 SE</td></tr>
<tr><td colspan="4">$SE_{TN} = 34.1305 [1 + 1/9 + (X-X_m)^2 / 0.45062]^{0.5}$
$SE_{TON} = 44.48377 [1 + 1/9 + (X-X_m)^2 / 0.45062]^{0.5}$</td></tr>
</table>

X = ln(Rain) and X_m = the mean of the log transformed annual rain for the base period

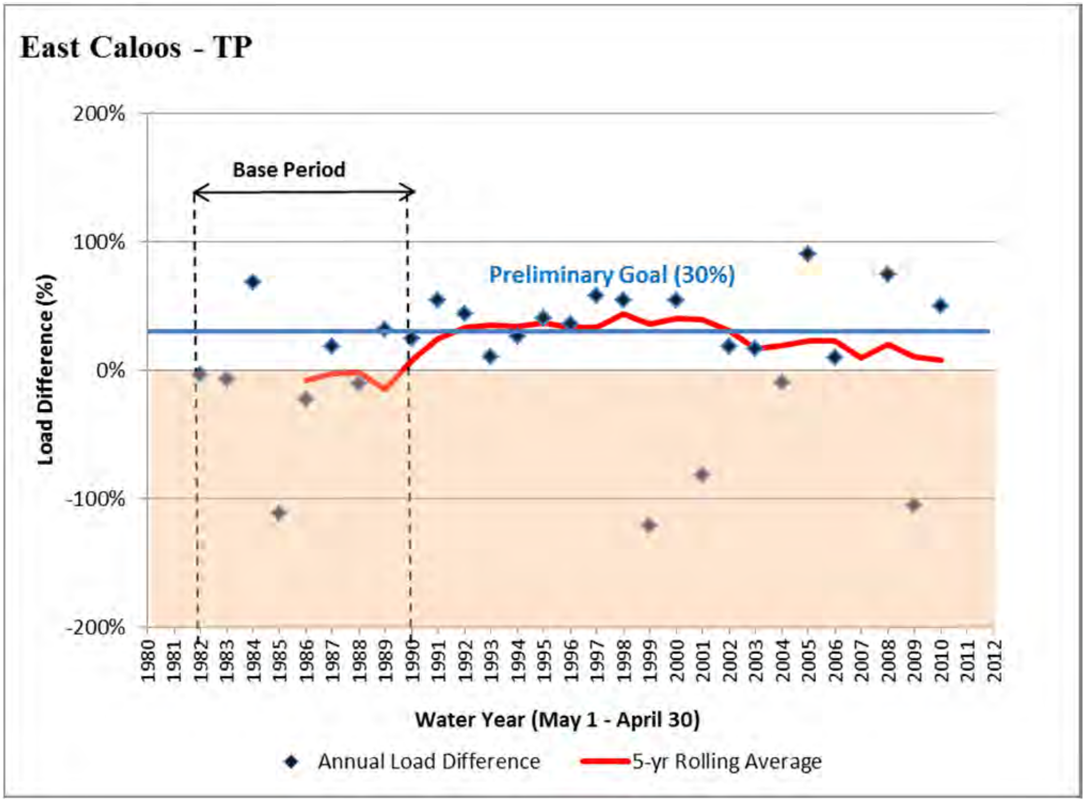


Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-5. S-4/Industrial Canal Sub-watershed TN load trend.

Table 1-3. East Caloosahatchee Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall Minimum inches	Base Period Rainfall Maximum inches
54.9	73%	42.29	72.47
Target = -136.79649 + 3.61048 X			
Limit = Target + 1.41492 SE			
$SE = 21.79661 [1 + 1/9 + (X-X_m)^2 / 675.50602]^{0.5}$			



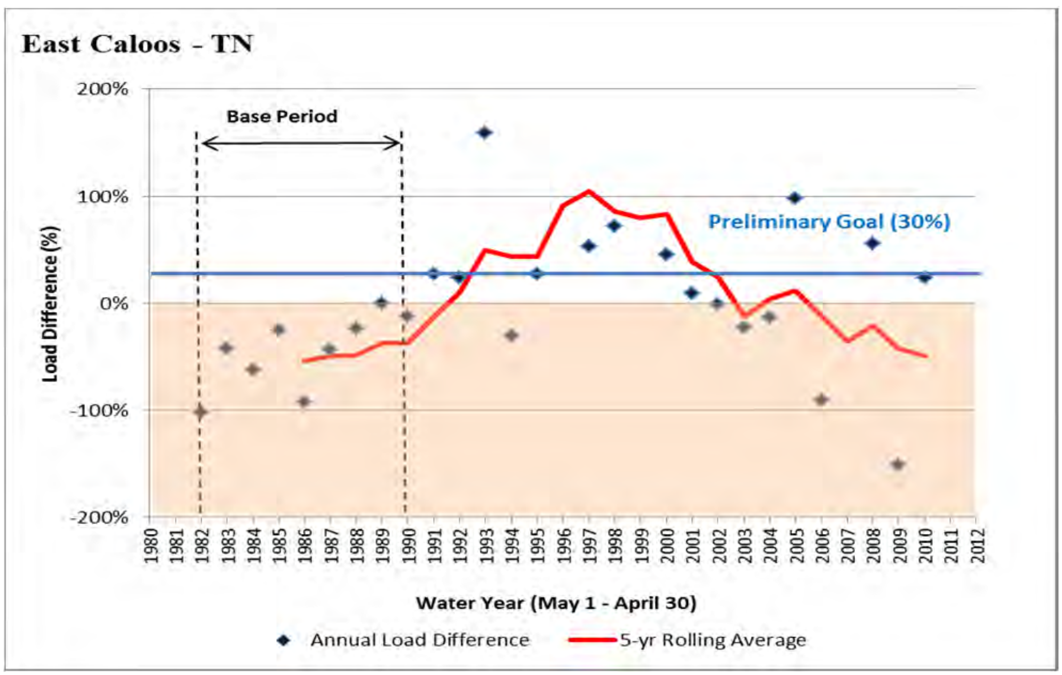
Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-6. East Caloosahatchee Sub-watershed TP load trend.

Table 1-4. East Caloosahatchee Sub-watershed TN Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall Minimum inches	Base Period Rainfall Maximum inches
430.9	TN-based: 95% TON-based: 85%	42.29	72.47
Target = maximum of the following: TN-based Prediction = -6030.71633 + 1643.10806 X TON-based Prediction = -6890.68249 + 1881.37053 X			
Limit = Target + 1.41492 SE			
$SE_{TN} = 62.43487 [1 + 1/9 + (X-X_m)^2 / 0.21326]^{0.5}$ $SE_{TON} = 137.40342 [1 + 1/9 + (X-X_m)^2 / 0.21326]^{0.5}$			

X = ln(Rain) and X_m = the mean of the log transformed annual rain for the base period



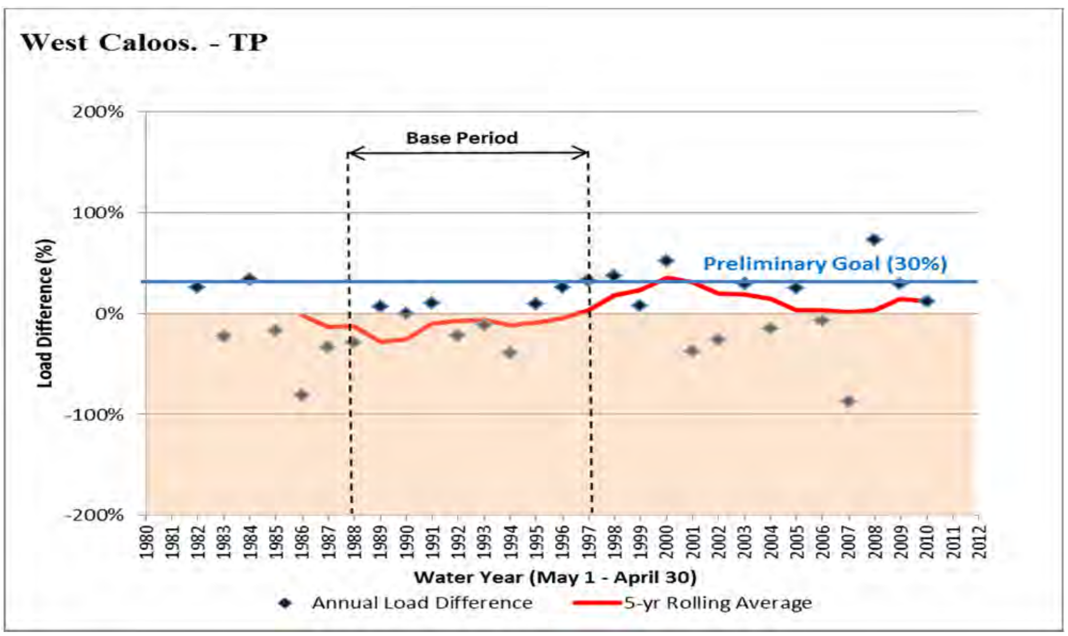
Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-7. East Caloosahatchee Sub-watershed TN load trend.

Table 1-5. West Caloosahatchee Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall[1] Minimum inches	Maximum inches
104.592	82%	43.52	94.54
Target = $[-31.51187 + 9.53218\ X + 3.61761\ S]^2$			
Limit = $[\text{sqrt}(Target) + (1.41492\ SE)]^2$			
SE = $1.13072\ [\ 1 + 1/10 + 8.28187\ (X-X_m)^2 + 0.3467\ (S–S_m)^2\ + 0.83154\ (X-X_m)\ (S–S_m)\ ]^{0.5}$			
Adjusted Rainfall = $\exp\ [X + 0.37952\ (S – 0.70340)]$			

[1] Based on adjusted rainfall values
X = ln(Rain) and X_m = the mean of the log transformed annual rain for the base period



Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

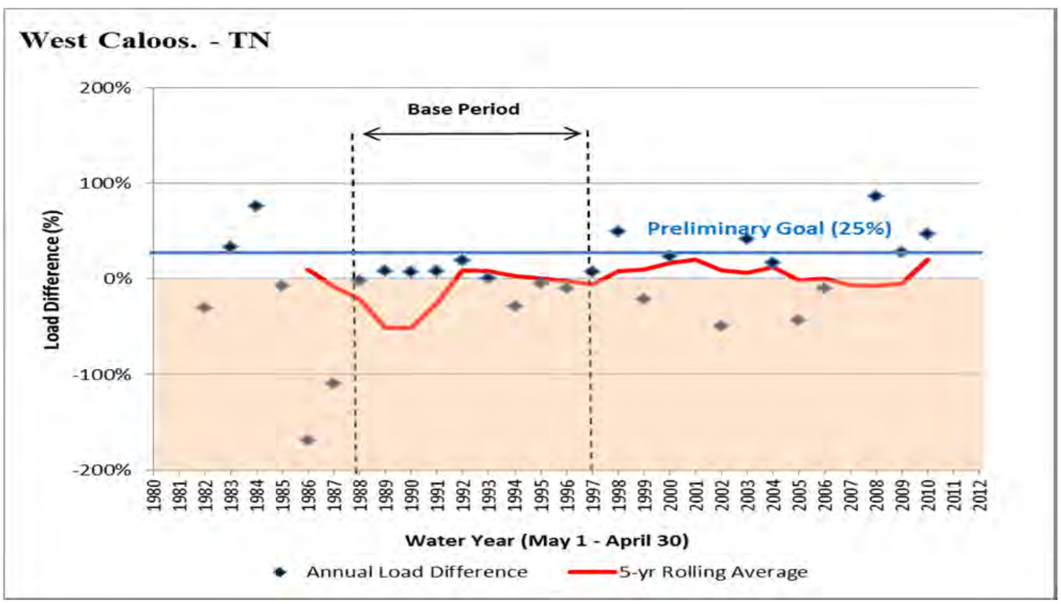
Figure 1-8. West Caloosahatchee Sub-watershed TP load trend.

Table 1-6. West Caloosahatchee Sub-watershed TN Load Performance Measure.

Base Period Median Annual Load	Explained Variance	Base Period Rainfall[1]

mt	(R^2)	Minimum inches	Maximum inches
1,149	TN-based:90% TON-based: 92%	44.60 / 43.36	68.96 / 74.67
Target = maximum of the following: TN-based Prediction = -8377.34747 + 2169.97388 X - 836.56039 C + 543.77106 S TON-based Prediction = -7574.28708 + 1928.62129 X - 950.18979 C + 628.32211 S			
Limit = Target + 1.43976 SE			
$SE_{TN} = 129.12707\ [\ 1 + 1/10 + 8.28199\ (X\text{-}X_m)^2 + 0.58177\ (S–S_m)^2\ + 4.93178\ (C\text{-}C_m)^2$ $+ 0.82314\ (X\text{-}X_m)\ (S–S_m) + 0.03844\ (X\text{-}X_m)\ (C\text{-}C_m) - 2.15336\ (S\text{-}S_m)\ (C\text{-}C_m)\ ]^{0.5}$ $SE_{TON} = 120.8371\ [\ 1 + 1/10 + 8.28199\ (X\text{-}X_m)^2 + 0.58177\ (S–S_m)^2\ + 4.93178\ (C\text{-}C_m)^2$ $+ 0.82314\ (X\text{-}X_m)\ (S–S_m) + 0.03844\ (X\text{-}X_m)\ (C\text{-}C_m) - 2.15336\ (S\text{-}S_m)\ (C\text{-}C_m)\ ]^{0.5}$			
TN-based Adjusted Rainfall = exp [X + 0.25059 (S - 0.7034) - 0.38552 (C + 0.26789)] TON-based Adjusted Rainfall = exp [X + 0.32579 (S- 0.7034) - 0.49268 (C + 0.26789)]			

[1] Based on adjusted rainfall values
X = ln(Rain) and X_m = the mean of the log transformed annual rain for the base period
C = ln(coefficient of variation) and C_m = the mean of the log transformed annual coefficient of variation for the base period



Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-9. West Caloosahatchee Sub-watershed TN load trend.

Table 1-7 summarizes the performance metrics for the sub-watersheds of the Caloosahatchee River Watershed. The metrics for the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds are based on monthly data for TP, TN and TON without an explicit adjustment for hydrologic variability. However, daily rainfall data sets were created for each basin using the Thiessen polygon weighting method to understand the hydrologic conditions that existed during the time of water quality data collection. For the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds, if the sub-watershed performance metrics are not achieved, a performance determination of tributary-specific performance metrics would be warranted, and could assist in prioritizing any necessary follow-up actions. For the Coastal Sub-watershed, although TP is not a limiting nutrient in marine environments, a TP performance metric based on maintaining current levels (i.e., a reduction goal of 0 percent) was developed consistent with the comprehensive planning strategy of the Caloosahatchee River Watershed Protection Plan

Unmonitored areas. Based on the similarity of land uses among the areas that are monitored and the areas that are not monitored, the sub-watershed performance metrics are considered representative of the unmonitored areas.

Table 1-7. Sub-watershed Performance Metrics.

Sub-watershed	Nutrient	Performance Measure (PM) or Performance Indicator (PI)	Base Period	Recommended Source Control Reduction	
S-4 / Industrial Canal	TP	PM	WY1993-2001	30%	
	TN	PM		35%	
East Caloosahatchee	TP	PM	WY1982-1990	30%	
	TN	PM		30%	
West Caloosahatchee	TP	PM	WY1988-1997	30%	
	TN	PM		25%	
			Reference Period	**Target**	**Limit**
Tidal Caloosahatchee	TP	PI	WY2006-2012	10%	15%
	TN	PI		10%	15%
Coastal Caloosahatchee	TP	PI	WY2009-2012	0%	0%
	TN	PI		15%	14%

2. INTRODUCTION AND OBJECTIVES

This *Draft Technical Support Document* was developed in support of the South Florida Water Management District's Regulatory Source Control Program (Chapter 40E-61, F.A.C, Works of the District) which is being amended to meet Northern Everglades and Estuaries Protection Program (NEEPP) mandates. In accordance with NEEPP, refinement of existing regulations and development of best management practices (BMPs) complementing existing regulatory programs is a basis for achieving and maintaining compliance with water quality standards including any adopted Total Maximum Daily Loads (TMDLs).

The Regulatory Source Control Program was established in 1989 in the Lake Okeechobee Watershed under the authority of the Surface Water and Improvement Management (SWIM) Act. In 2007, the NEEPP mandated complementary source control programs by the three coordinating agencies (the Florida Department of Environmental Protection (FDEP), the South Florida Water Management District (District) and the Florida Department of Agriculture and Consumer Services (FDACS)), encompassing an expanded Lake Okeechobee Watershed, and the St. Lucie River and the Caloosahatchee River Watersheds. Total phosphorus (TP) is the nutrient of concern[5] for Lake Okeechobee while TP and total nitrogen (TN) have been identified as nutrients of concern for the St. Lucie River and Caloosahatchee River Watersheds. In response to these legislative changes, the District must amend the 1989 Chapter 40E-61, F.A.C., to effectuate the NEEPP requirements.

Fundamental components of the Regulatory Source Control Program are water quality performance metrics coupled with water quality monitoring. The water quality performance metrics currently specified in Chapter 40E-61, F.A.C, are only for a portion of the Lake Okeechobee Watershed. Although this portion includes the S-4/Industrial Canal and the East Caloosahatchee Sub-watersheds in the Caloosahatchee River Watershed, these metrics are not in

[5] Based on the criteria and assessment methodologies in Chapters 62.302 and 62-303, F.A.C.

alignment with the current water quality goals for the Lake Okeechobee and the Caloosahatchee River Watersheds. The performance metrics of the 1989 Chapter 40E-61, F.A.C., aim at meeting a TP load to Lake Okeechobee of 360 metric tons per year (mt/yr) by implementing concentration-based limits from individual parcels within the watershed. In contrast, the TP TMDL for Lake Okeechobee is set at 140 mt/yr and includes a target load of 0.01 mt for the Western Region (which includes the East Caloosahatchee Sub-watershed) and 9.56 mt for the Southern Region (which includes the S-4/Industrial Canal Sub-watershed, the Everglades Agricultural Area and local Chapter 298 Districts). Additionally, a TN TMDL has been established for the Caloosahatchee Estuary requiring a reduction of 23 percent or approximately 583 mt/yr from the 1996-2005 average discharges from the Caloosahatchee River Watershed (FDEP 2009). Additionally, development of TMDLs for other impaired tributaries of the Caloosahatchee River Watershed is currently underway. The NEEPP mandates that monitoring be conducted at representative sites within the Lake Okeechobee, St Lucie and Caloosahatchee Watersheds which would verify the collective effectiveness of the source control programs.

This *Draft Technical Support Document* presents preliminary water quality performance metrics recommended for consideration in amendments to Chapter 40E-61, F.A.C. These performance metrics intend to estimate the TP and TN reductions in runoff that are reasonably expected from implementation of the source control programs mandated by the NEEPP based on representative runoff monitoring sites. These metrics are referred to as performance measures or performance indicators depending on the characteristics of the data on which they are based. Performance measures are typically nutrient loads incorporating hydrologic variability based on a representative base period dataset and are proposed for the S-4/Industrial, East and West Caloosahatchee Sub-watersheds. Performance indicators are generally concentration-based and may be based on the central tendency of a multi-year dataset. For the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds and tributaries, performance indicators are proposed. Performance metrics may provide justification for implementation of additional water quality improvement activities or re-evaluation of the existing activities by the respective agencies. The level of activities that may be triggered in each case will be defined by the coordinating agencies based on jurisdiction. The NEEPP established that a Memorandum of Understanding (MOU) be executed among the agencies to ensure a complementary approach; the MOU was first executed on April 14, 2011.

These performance metric methodologies can be revised as a result of the public consultation process. For the purpose of a regulatory program, performance metric methodologies are not final until adopted by rule.

2.1 Organization of the Draft Technical Support Document

Section 1 of this *Draft Technical Support Document* provides general background information for the Project. **Section 2** contains a brief history of source controls in the Caloosahatchee River Watershed, a discussion of the regulatory framework for this *Technical Support Document*, a comparison between the performance metrics proposed herein and the reduction goals of the TN Total Maximum Daily Load (TMDL) for the Caloosahatchee Estuary, a comparison between the performance metrics proposed herein and the reduction goals of the Caloosahatchee River and Lake Okeechobee Watershed Protection Plans, and a description of the common elements of the performance metric methodologies. **Section 3** presents the development of TP and TN performance metric methodologies for basins within the Caloosahatchee River Watershed. **Section 3.1** presents the TP and TN performance metrics for the S-4/Industrial Canal Sub-watershed. **Section 3.2** presents the TP and TN performance metrics for the East Caloosahatchee Sub-watershed. **Section 3.3** presents the TP and TN performance metrics for the West Caloosahatchee Sub-watershed. **Section 3.4** presents the TP and TN performance metrics for the Tidal Caloosahatchee Sub-watershed. **Section 3.5** presents the TP and TN performance metrics for the Coastal Caloosahatchee Sub-watershed. **Appendix A** presents supplemental technical details of the derivation of the Caloosahatchee River Watershed performance metrics. **Appendix B** presents a summary of the data sources used in the performance metric methodologies. **Appendix C** describes the methods used to establish the recommended nutrient reductions that could be reasonably expected to result from implementation of collective source control programs. **Appendix D** presents one method that the performance metric methodologies may account for regional projects. The Excel spreadsheets containing the specific analyses used in the derivation of the performance metrics are included as **Attachment 1** to this *Draft Technical Support Document*.

Where possible, consistency was maintained with previously documented naming and delineations of various hydrologic basins. However, this was not always possible as this expansive area has been referenced in a variety of prior documents using different terms. For purposes of this document, the terms "sub-watershed" and "tributary" are used when making specific references, while the term "basin" is used when making generic references.

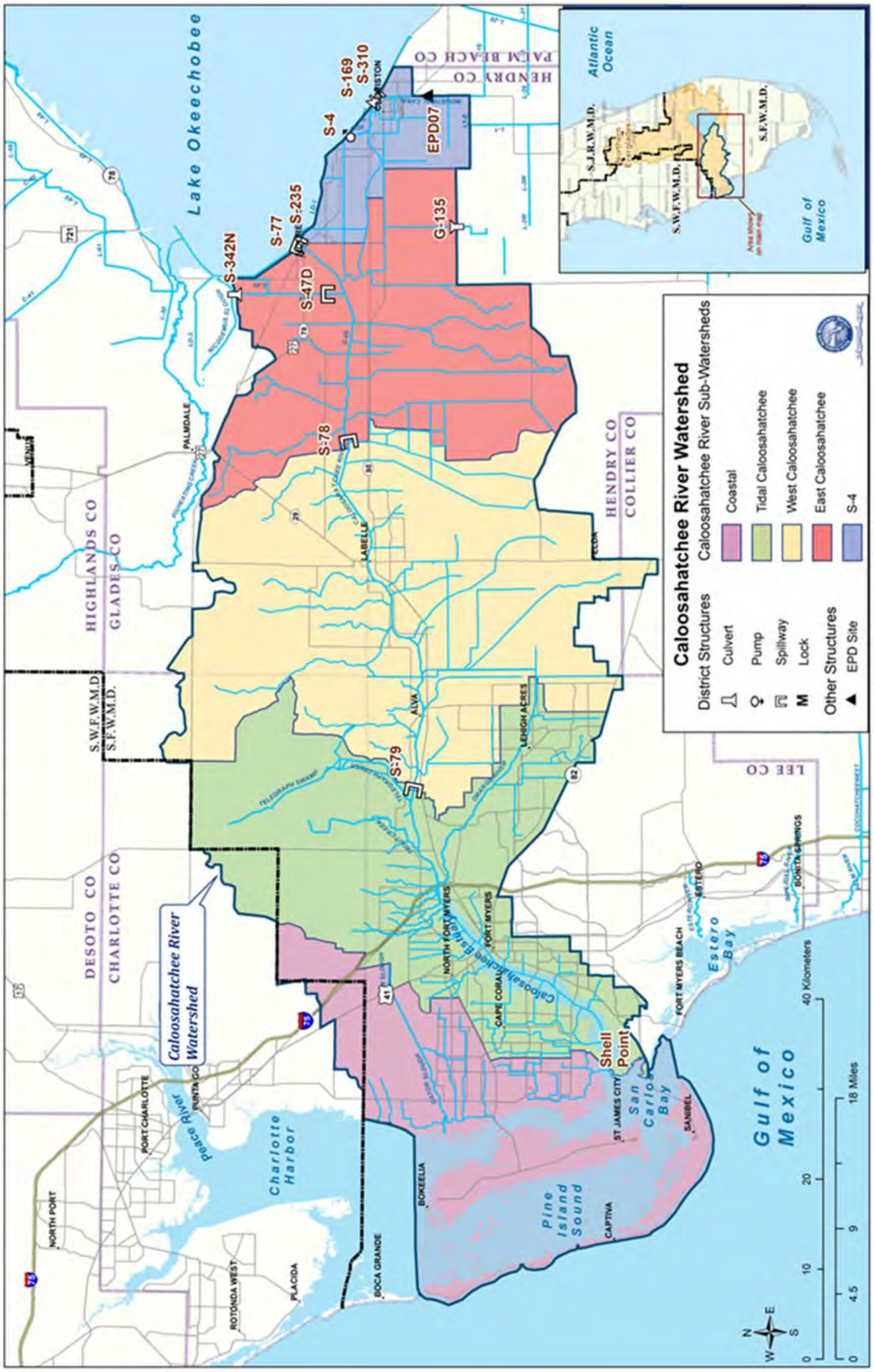
2.2 Authorization and Scope

This *Draft Technical Support Document* constitutes Deliverable 3.13 of Contract 4600002337 - Performance Measure Methodologies for Collective Source Controls in the Lake Okeechobee and Caloosahatchee River Watersheds - between the District and Gary Goforth, Inc. (GGI) dated January 31, 2011, and amended in January 2012, June 2012 and November 2012. This document was prepared through collaboration between staff of the South Florida Water Management District (SFWMD or District), GGI, L. Hornung Consulting, Inc., and Soil and Water Engineering Technology, Inc. (SWET).

2.3 Background

The Caloosahatchee River and Estuary (CRE) is located on the lower west coast of Florida. The river, also known as the C-43 canal, runs 70 kilometers (km) [43 miles (mi)] from Lake Okeechobee at Moore Haven (S-77) to the Franklin Lock and Dam (S-79) at Olga (**Figure 2-1**). The Franklin Lock demarcates the head of the Caloosahatchee Estuary. The estuary extends about 42 km (26 mi) downstream to Shell Point, where it empties into San Carlos Bay in the southern portion of the greater Charlotte Harbor system. The CRE provides tremendous opportunities for population and economic growth, luring both year-round and seasonal residents

Figure 2-1. Map of Caloosahatchee River Watershed (SFWMD 2012)



along with agricultural, recreational, and business interests. It serves as a nursery ground for many commercial and recreational fish species and is also home (seasonally or annually) to several threatened and endangered aquatic and avian species. For these reasons, it is essential to maintain the health of the estuary for both the local economy and the environment. Like most populated areas in the state, natural habitats, drainage patterns, and land uses within the Caloosahatchee River Watershed have been significantly altered over time. Loss of natural habitat from riverfront and coastal development, increased urban development and stormwater runoff, construction of drainage canals, and agricultural activities have affected the quality, quantity, timing, and distribution of flows to the estuary. Land clearing and impervious areas have increased both the volume and timing of wet season flows from the watershed, while dry season flows have decreased due to the lack of natural storage and increased water supply demand for agricultural and urban development. Storage within the watershed has decreased from the drainage of land to accommodate grazing, citrus farms, and other agricultural and urban development.

The Caloosahatchee River Watershed contains 1,090,376 acres within five sub-watersheds:

1. S-4/Industrial Canal Sub-watershed, containing 42,145 acres,
2. East Caloosahatchee Sub-watershed, containing 204,094 acres,
3. West Caloosahatchee Sub-watershed, containing 350,114 acres,
4. Tidal Caloosahatchee Sub-watershed, containing 264,705 acres, and
5. Coastal Caloosahatchee Sub-watershed, containing 229,317 acres.

The S-4/Industrial Canal Sub-watershed and East Caloosahatchee Sub-watershed are also contained in the Lake Okeechobee Watershed since part of the runoff from these basins is directed to the lake during certain storm events.

2.3.1 History of Source Controls in the Caloosahatchee River Watershed

The following section describes over thirty years of federal, state and regional efforts leading up to the current source control programs in the Caloosahatchee River Watershed (CRW). A summary of the source control implementation time frame for the CRW is presented in **Table 2-1**.

PROGRAMS THAT BEGAN IN THE 1970s

Federal Clean Water Act

The Federal Clean Water Act was enacted in 1972 and included the National Pollution Discharge Elimination System (NPDES) and Total Maximum Daily Load (TMDL) Programs. The U.S. Environmental Protection Agency (USEPA) delegated responsibility for administration of these programs to the FDEP which until the mid-1990s was known as the Florida Department of Environmental Regulation (FDER). In October 2000, the USEPA authorized the FDEP to implement the NPDES stormwater permitting program in the State of Florida (in all areas except Indian Country lands). The NPDES stormwater program regulates point source discharges of stormwater into surface waters of the State of Florida from certain municipal, industrial and construction activities.

Florida Dairy Programs and Feed Operations

In the Lake Okeechobee Watershed, the dairy lagoon regulatory program was implemented by the Federal Soil and Water Conservation Service (which is now the Natural Resource Conservation Service) in the 1970s and required wastewater retention onsite.

Table 2-1. Summary of the source control implementation time frame for the CRW.

Time Frame	Event
1972	Clean Water Act (CWA)and Florida Water Resources Act
	South Florida Water Management District Stormwater Permitting Begins
1978	Florida Established Non-Point Source Management Programs based on CWA Section 208
1984	Florida Department of Environmental Protection (FDEP) adopted biosolids regulations under solid waste regulations
1985	Florida State stormwater rule adopted, retention ponds became required for new development
1986	Florida passed the Feedlot and Dairy Wastewater Treatment and Management Requirements.
	New citrus groves were required to include onsite reservoirs for stormwater runoff
1987	CWA Section 319 Amendment – Nonpoint Source Management Programs – Nationwide requirements to develop NPS Management Plans. EPA provides grants to assist states with implementation
1987	Surface Water Improvement and Management Act for Lake Okeechobee enacted
1989	Chapter 40E-61, F.A.C., the Lake Okeechobee Works of the District Rule adopted by SFWMD
1989	Florida fully implements revised NPS program after US EPA approval
1990	National Pollutant Discharge Elimination System Programs
1995	SFWMD Environmental Resource Permitting Regulatory Program adopted
1999	Florida Watershed Restoration Act (FWRA)
2000	The Lake Okeechobee SWIM Act is revised to become the Lake Okeechobee Protection Act (LOPA)
2003	FDOH septage application requires Agricultural Use Plan
2003	Passage of the Federal Concentrated Animal Feeding Operations (CAFO) Rule
2004	FDOH Wastewater Master Plans
2005	FDACS expands BMP Rule 5M-3 to the entire Lake Okeechobee Watershed
2007	The LOPA is revised to become the Northern Everglades and Estuaries Protection Plan (NEEPP)
2007	FDACS Urban Turf Fertilization Rule (Rule 5E-1.003)
2009	Total Nitrogen (TN) TMDL for the Caloosahatchee Estuary is adopted
2011	FDACS amends BMP Rule 5M-3 to the entire Northern Everglades
2012	Tidal Caloosahatchee Sub-watershed Basin Management Action Plan (BMAP) for implementation of the Caloosahatchee Estuary TN TMDL is developed
2012	FDEP Numeric Nutrient Criteria approved by US EPA
2012	Elimination of land application of biosolids, unless a nutrient management plan is developed

In 1996, Rule 62-670, the Feedlot and Dairy Wastewater Treatment and Management program was adopted, which required dairies with over 700 cows to apply for an Industrial Waste permit and a concentrated animal feeding operation (CAFO) permit by 1989 for discharge of pollutants. In 2003, EPA finalized the CAFOs Rule under the CWA which required all large operations to obtain permits. In Florida, FDEP administers the permitting program. Large CAFOs (dairies with more than 700 cows) are required to develop and implement nutrient management plans that ensure manure is properly managed in ways that assure utilization by crops and reduce pollution. Dairies were required to convert from their prior IW permits to NPDES permits.

PROGRAMS THAT BEGAN IN THE 1980s

Florida Biosolids/Domestic Wastewater Residuals Regulations

The regulation of domestic wastewater residuals (now referred to as biosolids) began in 1984 and was originally adopted under solid waste regulations (Chapter 17-7). Regulations were adopted under Chapter 62-640, F.A.C. (water regulations) in 1991 and revised in 1998. The latest rule revision, adopted on August 28, 2010, intends to: improve land application site management and accountability, address critical nutrient issues in Florida, address continuing and heightened public concerns and county interest, and support public confidence in the beneficial use of biosolids.

The revised rule prohibits the application of Class B biosolids in the Northern Everglades, including the Caloosahatchee River Watershed after December 31, 2012, unless the applicant completes a nutrient balance demonstration which is FDEP approved. This prohibition does not apply to Class AA biosolids that are marketed and distributed as fertilizer products in accordance with Rule 62-640.850, F.A.C. This could impact the extent of land application of residuals in the watershed and associated nutrient loading. Biosolids provide a low cost agricultural fertilizer. If land application is prohibited, fertilization may be reduced due to the additional regulatory burden of applying Class AA or B biosolids.

Florida Stormwater Rule

In 1981, the statewide Florida stormwater rule was adopted by the Environmental Regulation Commission with an effective date of February 1982. This rule required a permit for new stormwater discharges for the purpose of protecting the designated use of the receiving water. Any new stormwater management system that discharged to waters of the state was required to obtain a permit under this rule. FDEP immediately delegated the authority for administering this rule to the water management districts (except the Northwest Florida Water Management District). Permits required that post development flow rates, flow volumes, and nutrient loads be equal to, or less than pre-development levels. In the mid-1990s, the Environmental Reorganization Act provided the water management districts independent authority under Chapter 373, F.S., to regulate stormwater quality under the Environmental Resource Permit program.

SFWMD Management and Storage of Surface Waters Program

In 1986, SFWMD amended Rule 40E-4 requiring new applicants to meet specific detention and retention criteria. As a result, new citrus groves included detention reservoirs in their surface water management plans.

In 1995, the management and storage of surface waters permitting program merged with the wetland resource permitting program from Chapter 403, F.S. to form the Environmental Resource Permit Program. The ERP program requires that new activities or modification of existing activities provide reasonable assurances that they will not cause adverse water quality such that state water quality standards will not be violated, cause adverse flooding or water quantity impacts, or harm wetland of other surface water systems.

Florida Surface Water Improvement and Management Program (Section 373.451, F.S.)

In 1987, the State of Florida enacted the Surface Water Improvement and Management (SWIM) Act. This Act required the water management districts to develop and implement plans for restoring and protecting degraded water bodies in the state. The Lake Okeechobee SWIM Plan was prepared by the SFWMD in 1989 and the TP load target for Lake Okeechobee at that time was 360 metric tons. The SWIM Plan was subsequently updated in 1993, 1997, and 2002. The SWIM Plan has led to implementation of many initiatives that have been directed at improving the quality of water discharged to Lake Okeechobee. Information about projects initiated as a part of the SWIM program can be found in the 1989, 1993, 1997 and 2002 SWIM Plan Reports (SFWMD 1989, SFWMD 1993, SFWMD 1997, SFWMD 2002).

SFWMD Works of the District Rule 40E-61, F.A.C.

In 1989, the District adopted Rule 40E-61 regulating surface water discharges of phosphorus from certain land uses in the Lake Okeechobee Watershed. At that time, the program included the S4/Industrial Canal and East Caloosahatchee Sub-watersheds, as well as the Lower Kissimmee, Indian Prairie, Fisheating Creek-Nicodemus Slough, South Lake Okeechobee, East Lake Okeechobee, and Taylor Creek/Nubbin Slough Sub-watersheds. Approximately 800 permits were issued on parcels of land five (5) acres and greater for the following land uses: improved pasture, heifer farms, vegetable farms, hog farms, poultry farms, goat farms, urban stormwater, golf courses, sugar cane, horse farms, nurseries, land spreading of sludge (biosolids), and sod farms. At the time the rule became effective, the assumption was that landowners were in compliance until their monitoring data indicated otherwise. The permits set a concentration based discharge limit based on the load reductions set forth under the SWIM plan. The current rule requires permittees to submit a statement from permit holders on how they planned to control phosphorus. Farm-level grab sample monitoring was required and was funded by the SFWMD. Monitoring funds were limited thus the number of landowners required to implement additional BMPs for not meeting the TP concentration limit was relatively few. Also, since performance was measured at the parcel level and it has been difficult to determine the overall program performance in reducing phosphorus loading.

PROGRAMS THAT BEGAN IN THE 1990s

Federal National Pollutant Discharge Elimination System Programs

The USEPA developed the NPDES stormwater permitting program in two phases. Phase I, promulgated in 1990, addresses “large" and "medium" municipal separate storm sewer systems (MS4s) located in incorporated places and counties with populations of 100,000 or more, and eleven categories of industrial activity, one of which is large construction activity that disturbs five or more acres of land. Phase II, promulgated in 1999, addresses additional sources, including MS4s not regulated under Phase I, and small construction activity disturbing between one and five acres. FDEP's authority to administer the NPDES program is set forth in Section 403.0885, Florida Statutes (F.S.). As the NPDES stormwater permitting authority, FDEP is responsible for promulgating rules and issuing permits, managing and reviewing permit applications, and performing compliance and enforcement activities.

SFWMD Everglades Works of the District Rule 40E-63, F.A.C.

The 1994 Everglades Forever Act defined that Stormwater Treatment Areas and BMP implementation for the Everglades Construction Project basins are the best available technology for achieving interim phosphorus water quality goals for the Everglades Protection Area. In order to carry out these activities, the Everglades Forever Act mandated the creation of an Everglades

Program, including a regulatory component to oversee implementation of BMPs. The District promulgated Chapter 40E-63, F.A.C., which details the scope of the Everglades Regulatory Program for the Everglades Agricultural Area (a portion of which is located in the South Lake Okeechobee Sub-watershed) and the C-139 basins. In this rule, the District describes the implementation procedures and compliance measures for the BMP program mandated in the Everglades Forever Act including (1) enforcing implementation of BMPs, (2) conducting a water quality monitoring program to evaluate the effectiveness of BMPs, (3) tracking area-wide phosphorus loads, and (4) developing a mandatory BMP research program for phosphorus and other water quality parameters of concern.

SFWMD Environmental Resource Permit program

In the mid-1990s, the State of Florida's Environmental Reorganization Act provided the water management districts independent authority under Chapter 373, F.S., to regulate stormwater quality under the Environmental Resource Permit program.

Florida Watershed Restoration Act

The Florida Watershed Restoration Act of 1999 established definitions, schedules, and procedures for the FDEP's implementation of the state's total maximum daily load (TMDL) program. The basic steps of the TMDL program are as follows:

1. Assess whether water bodies are meeting their water quality standards,
2. Determine which waters are impaired (i.e., are not meeting water quality standards for a particular pollutant),
3. Establish and adopt, by rule, a TMDL for each impaired water for the pollutants of concern,
4. May develop, with extensive stakeholder input, a Basin Management Action Plan (BMAP).

5. Implement the strategies and actions in the BMAP,
6. Measure the effectiveness of the BMAP, and
7. Reassess the quality of surface waters continuously.

In December 2009, FDEP adopted the Caloosahatchee Estuary TMDL for total nitrogen (TN). The TMDL accounts for the total load at the estuary, inclusive of loads from the upstream freshwater portions of the Caloosahatchee River as well as Lake Okeechobee, and requires a 23 percent reduction in this total TN load (FDEP, 2009). In November 2012, the Basin Management Action Plan (BMAP) to address TN load reductions in the portion of the watershed that drains to the Caloosahatchee Estuary below S-79 was adopted. Currently, FDEP is revising the model that was used to develop the Caloosahatchee Estuary TMDL and is also developing TMDLs in the tributaries and freshwater segments. In addition, **Table 2-2** describes water bodies that have been identified as impaired by FDEP and will require development of TMDLs.

PROGRAMS THAT BEGAN IN THE 2000s

Florida Lake Okeechobee Protection Act/Northern Everglades and Estuaries Protection Program

In 2000, the Florida legislature revised the Lake Okeechobee SWIM statute and it became the Lake Okeechobee Protection Act (LOPA) (Section 373.4595, F.S.) The LOPA required the Coordinating Agencies (SFWMD, FDEP, and FDACS) to collaborate in the preparation and implementation of a Lake Okeechobee Protection Plan (LOPP). The LOPP provided a road-map for a comprehensive program that was directed at meeting the Lake Okeechobee TP TMDL. The TMDL was under development at the time the Act was passed, but was finalized in 2000 prior to completion of the LOPP which was developed in 2004 and updated in 2007 and 2011. The LOPP required implementation of a two-phase Lake Okeechobee Construction Project, implementation of urban and agricultural source control measures, and a research and monitoring program.

Table 2-2. Impaired water bodies listed by FDEP under Section 303(d), Clean Water Act.

Planning Unit	Water Segment Name	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Current Assessment Status	Priority for TMDL Development
Caloosahatchee Estuary	Hancock Creek	Mercury (in fish tissue)	Impaired	High
Caloosahatchee Estuary	Caloosahatchee Estuary (Tidal Segment1)	Mercury (in fish tissue)	Impaired	High
Caloosahatchee Estuary	Cape Coral (Tidal Segment)	Mercury (in fish tissue)	Impaired	High
Caloosahatchee Estuary	Cape Coral	Nutrients (Historic Chlorophyll)	Impaired	Medium
Caloosahatchee Estuary	Deep Lagoon Canal	Dissolved Oxygen (Nutrients)	Impaired	Medium
Caloosahatchee Estuary	Deep Lagoon Canal	Mercury (in fish tissue)	Impaired	High
Caloosahatchee Estuary	Deep Lagoon Canal	Nutrients (Chlorophyll a)	Impaired	Medium
Caloosahatchee Estuary	Caloosahatchee Estuary (Tidal Segment2)	Mercury (in fish tissue)	Impaired	High
Caloosahatchee Estuary	Chapel Creek / Bayshore Creek	Fecal Coliform	Impaired	Low
Caloosahatchee Estuary	Chapel Creek / Bayshore Creek	Mercury (in fish tissue)	Impaired	High
Caloosahatchee Estuary	Palm Creek	Fecal Coliform	Impaired	Low
Caloosahatchee Estuary	Yellow Fever Creek	Mercury (in fish tissue)	Impaired	High
Caloosahatchee Estuary	Manuel Branch	Mercury (in fish tissue)	Impaired	High
East Caloosahatchee	S-4 Basin	Nutrients (Chlorophyll a)	Impaired	2011
East Caloosahatchee	Lake Hicpochee	Dissolved Oxygen (Nutrients)	Impaired	Medium
East Caloosahatchee	Lake Hicpochee	Dissolved Oxygen (Nutrients)	Impaired	Medium
East Caloosahatchee	Ninemile Canal	Dissolved Oxygen (Nutrients)	Impaired	High
East Caloosahatchee	Ninemile Canal	Dissolved Oxygen (Nutrients)	Impaired	High
Orange River	Billy Creek	Dissolved Oxygen (Nutrients)	Impaired	High
Orange River	Billy Creek	Mercury (in fish tissue)	Impaired	High
Telegraph Swamp	Telegraph Creek	Fecal Coliform	Impaired	Low
West Caloosahatchee	Caloosahatchee River Between S-79 And S-78	Nutrients (Chlorophyll a)	Impaired	Medium
West Caloosahatchee	Cypress Creek	Fecal Coliform	Impaired	Low
West Caloosahatchee	Jacks Branch	Fecal Coliform	Impaired	Low
West Caloosahatchee	Bee Branch	Fecal Coliform	Impaired	Low
West Caloosahatchee	Pollywog Creek	Fecal Coliform	Impaired	Low
West Caloosahatchee	Cypress Branch	Dissolved Oxygen (Nutrients)	Impaired	Medium
West Caloosahatchee	Cypress Branch	Lead	Impaired	Medium
West Caloosahatchee	Townsend Canal	Dissolved Oxygen (Nutrients)	Impaired	Medium
West Caloosahatchee	Townsend Canal	Nutrients (Chlorophyll a)	Impaired	Medium

Subsequent renewals of the Lake Okeechobee Operating Permit incorporated specific conditions to assess the achievement with the lake TMDL.

In 2005, LOPA was revised further and the Upper Kissimmee and Lake Istokpoga Sub-watersheds were included in the Lake Okeechobee Watershed boundary. The 2005 revisions to LOPA directed that phosphorus load reductions be achieved through a phased program of implementing long-term solutions based on the Lake Okeechobee TMDL of 140 metric tons for TP (105 metric tons from contributing sub-watersheds and 35 from atmospheric deposition). In 2007, LOPA was subsumed by Northern Everglades and Estuaries Protection Program (NEEPP), which further refined the responsibilities of the coordinating agencies to achieve TP reduction objectives faster for the Lake Okeechobee, and also mandated the development of protection programs to reduce pollutant loading, restoration of the natural hydrology, and compliance with applicable water quality standards (TMDL) for the St. Lucie and the Caloosahatchee watersheds. One of the programs being a Pollutant Control Program included (1) continued implementation of existing regulations and incentive-based BMPs, (2) development and implementation of improved BMPs, (3) improvement and restoration of hydrologic function of natural and managed systems, and (4) use of alternative technologies for nutrient reduction Accordingly, changes were identified for Chapter 40E-61, F.A.C. to incorporate NEEPP mandates that modify the boundary of the program through the inclusion of the Upper Kissimmee Sub-watershed, Lake Istokpoga Sub-watershed, Caloosahatchee River Watershed, and St. Lucie River Watershed; (see **Figure 2-2** for proposed revisions to the boundary of Chapter 40E-61, F.A.C).

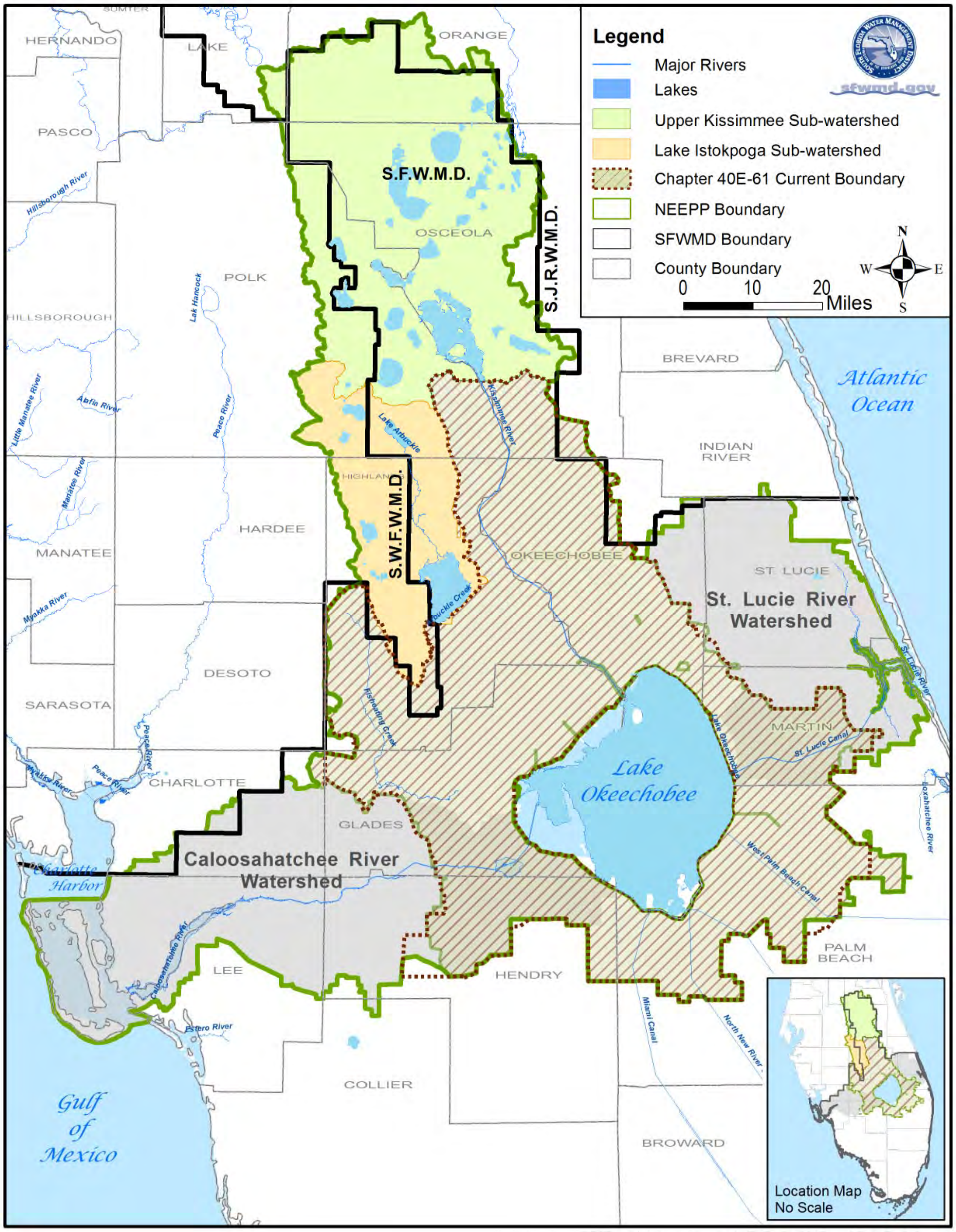
The 2012 Caloosahatchee River Watershed Protection Plan update provided detailed information on near term and long term activities. These activities include such items as continued implementation of BMP programs, and regional, sub-regional, and local scale water quality and quantity projects (e.g., reservoirs, stormwater treatment areas (STAs), chemical treatment, and local stormwater projects).

Florida Agricultural BMP Program

In response to the LOPA's requirements, the FDACS, in collaboration with the USDA's National Resource Conservation Service and the University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS), initiated an agricultural BMP program throughout the state including the Lake Okeechobee Watershed. The program provides technical assistance for the development of appropriate management plans and financial assistance for implementation. According to the NEEPP, agricultural land owners that do not implement BMPs are required to implement a monitoring program to demonstrate that the water quality objectives of the

District's Lake Okeechobee Works of the District program (Chapter 40E-61, F.A.C) are met. In 2003, FDACS adopted the Rule 5M-3 requiring BMPs for the Lake Okeechobee priority basins S-191, S-154, S-65 D and E. In 2006, this rule was expanded to the entire Lake Okeechobee

Figure 2-2. Chapter 40E-61, F.A.C. proposed boundary changes.


Legend
Major Rivers
Lakes
Upper Kissimmee Sub-watershed
Lake Istokpoga Sub-watershed
Chapter 40E-61 Current Boundary
NEEPP Boundary
SFWMD Boundary
County Boundary
0 10 20 Miles
sfwmd.gov
S.F.W.M.D.
S.J.R.W.M.D.
S.W.F.W.M.D.
St. Lucie River Watershed
Caloosahatchee River Watershed
Lake Okeechobee
Atlantic Ocean
Gulf of Mexico
Charlotte Harbor
HERNANDO
LAKE
ORANGE
PASCO
OSCEOLA
POLK
HILLSBOROUGH
BREVARD
INDIAN RIVER
HARDEE
MANATEE
OKEECHOBEE
ST. LUCIE
DESOTO
SARASOTA
MARTIN
CHARLOTTE
GLADES
PALM BEACH
LEE
HENDRY
COLLIER
BROWARD
Location Map
No Scale

Watershed. In 2011, FDACS amended the BMP Rule 5M-3 to include the entire Northern Everglades (including the St. Lucie and Caloosahatchee Watersheds). The FDACS develops and adopts BMPs by rule for different types of agricultural operations. Most of the BMPs are outlined in commodity-specific manuals, which can be found at http://www.floridaagwaterpolicy.com/.

FDACS Rules

In 2003, FDACS adopted the Land Application of Animal Wastes Rule which was included as part of Rule 5M-3. It specified areas (i.e. wetlands and water setbacks) in which animal manure cannot be applied and required soil and/or plant tissue tests to determine a phosphorus-based application rate. For applications in excess of one ton per year, a nutrient management plan is required.

In 2007, the FDACS adopted the Urban Turf Fertilization Rule (Rule 5E-1.003) requiring specific labeling on commercial fertilizers. Products labeled for use on sports turf, urban turf or lawns shall contain no phosphate or low phosphate, and if they are low in phosphate must include specific application directions. Products labeled for sports turf at golf courses, parks and athletic fields shall include directions to follow the procedures described in "BMPs for the Enhancement of Environmental Quality on Florida Golf Courses," published by the FDEP in January 2007.

Florida Department of Health Septage Application

In 2003, the Florida Department of Health initiated a requirement that septage applied in the Northern Everglades watersheds include an agricultural use plan to limit application based on phosphorus. Based on soil testing and the UF/IFAS Standardized Fertilization Recommendations for Agronomic Crops phosphorus demand, the appropriate application rate is determined. By 2005, the phosphorus concentrations originating from these sites were required by the NEEPP to be below the limits established in the SFWMD's Works of the District program under Chapter 40E-61, F.A.C.

To date, the collective source control programs in place or being developed are presented in **Table 2-3**.

2.4 Regulatory Framework

Chapter 40E-61, F.A.C., is a long-standing regulation that establishes criteria to ensure that discharges from nonpoint sources meet legislative objectives for water quality protection. The District will coordinate with the state Office of Fiscal Accountability and Regulatory Reform prior to initiating rule development to amend Chapter 40E-61, F.A.C., to expand the regulatory source control program to encompass phosphorus and nitrogen reductions in the Caloosahatchee River Watershed. The program will be complementary to the local and state-wide source control programs.

2.4.1 Total Maximum Daily Loads

A total maximum daily load (TMDL) represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for water segments that are verified as not meeting their water quality standards (FDEP, 2009). Florida's 303(d) list identifies impaired water segments and the basis for impairment.

Table 2-3. Nutrient control programs within the Northern Everglades.

Lead Agency	Program[1]	Non-Point Source	Point Source
South Florida Water Management District (SFWMD)	Works of the District BMP Program[2] - Chapter 40E-61,F.A.C.	√	
	Environmental Resource Permitting Program - Chapter 373, F.S. Part IV	√	
	Dairy remediation projects[3,5]		√
	Dairy Best Available Technologies Project[3,5]		√
Florida Department of Agriculture and Consumer Services (FDACS)	Agricultural BMP Program - Chapter 5M-3, F.A.C.	√	
	Animal Manure Application - Chapter 5M-3, F.A.C.	√	
	Urban Turf Fertilizer Rule - Chapter 5E-1, F.A.C.	√	
Florida Department of Environmental Protection (FDEP)	Dairy Rule/Confined Animal Feeding Operation (CAFO) - Chapter 62-670, F.A.C.		√
	Environmental Resource Permitting Program - Chapter 373, F.S. Part IV[5]	√	
	Stormwater Infrastructure Updates and Master Planning - Chapter 187, F.S. [5]	√	
	Municipal Separate Storm Sewer System Permit Program - Chapter 62-624, F.A.C.		√
	Comprehensive Planning – Land Development Regulations - Chapter 163, F.S. Part II[5]	√	
	Biosolids Rule - Chapter 62-640, F.A.C.	√	
Florida Department of Health (FDOH)	Application of Septage - Section 373.4595, F.S.	√	
University of Florida Institute of Food and Agricultural Sciences[4] (UF/IFAS)	Florida-Friendly Landscaping Program - Section 373.185, F.S.	√	

[1]Applicable to all three Northern Everglades watersheds except where noted in the other footnotes below.

[2]The rule currently applies to the Lake Okeechobee Watershed. However, as directed by the NEEPP, the rule will be amended to include the adjacent Caloosahatchee River and St. Lucie River watersheds.

[3]Applicable to only the Lake Okeechobee Watershed.

[4]Partially funded by FDEP.

[5]No reductions considered.

In 2009, FDEP adopted a nutrient TMDL for the Caloosahatchee Estuary that includes the impaired main stem of the tidal portion. The final TMDL for the Caloosahatchee Estuary is 4,121 mt/yr of TN, which represents a load reduction of approximately 23 percent (Rule 62-302, Florida Administrative Code (FAC); FDEP 2009).[6] The Caloosahatchee Estuary extends westward from the S-79 structure to the entrance to San Carlos Bay. Stormwater runoff, Lake Okeechobee deliveries and a limited number of point sources from four of the five basins within the Caloosahatchee River Watershed contribute nutrient loads to the Caloosahatchee Estuary:

1. S-4/Industrial Canal Sub-watershed,
2. East Caloosahatchee Sub-watershed,
3. West Caloosahatchee Sub-watershed, and
4. Tidal Caloosahatchee Sub-watershed

The Coastal Caloosahatchee Sub-watershed does not contribute nutrient loads to the Caloosahatchee Estuary or the Caloosahatchee River.

In implementing a TMDL, a basin management action plan (BMAP) that addresses some or all of the tributary basins can be developed. A BMAP includes management strategies to achieve the TMDL and equitably allocates pollutant reductions, as deemed appropriate. In November 2012, FDEP completed a BMAP to address the first phase of TN reductions required from the Tidal Caloosahatchee Sub-watershed towards achieving the Caloosahatchee Estuary TMDL. TN loads for the Tidal Caloosahatchee Sub-watershed were estimated to be approximately 15 percent of the total TN loads to the estuary, while contributions from the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds were estimated to be approximately 25 percent, with the balance resulting from Lake Okeechobee pass-through loads (60 percent) (FDEP 2012). A BMAP has not been developed yet for the S-4/Industrial Canal,

[6] For the purposes of this document only the adopted state TMDL for the Caloosahatchee Estuary was considered.

East Caloosahatchee, or West Caloosahatchee Sub-watersheds. TMDLs have not been developed for other impaired segments of the Caloosahatchee River Watershed.

Currently, the District is working with local and state agencies to design and implement initiatives to reduce nutrient loads as necessary to achieve and maintain water quality criteria in the watershed as a whole, including the estuary TMDL (SFWMD 2012, FDEP 2013). The 2013 Caloosahatchee Estuary BMAP (FDEP 2013) and the 2012 update to the Caloosahatchee River Watershed Protection Plan (CRWPP) detail applicable management measures (SFWMD 2012). The relationship between the TMDL regulatory framework and the performance metric methodologies contained in this document can be described by identifying the similarities and dissimilarities. While some of the similarities and contrasts vary among the sub-watersheds, a general description is provided below. Basin-specific contrasts are clarified in the subsequent section. Since the Coastal Caloosahatchee Sub-watershed does not contribute runoff loads to the Caloosahatchee Estuary, the following comparison does not pertain to that sub-watershed.

Similarities. A common feature between the approaches described herein and the FDEP TMDL regulatory framework is the requirement for an annual performance determination of TN levels. In addition, part of the monitoring network, as defined in the BMAP, is used also for the performance metrics.

General Contrasts. General differences between the FDEP TMDL regulatory framework and the proposed Caloosahatchee River Watershed (CRW) performance metric methodologies are described below.

1. **Geographic Scope.**

FDEP TMDL. The Caloosahatchee Estuary TMDL applies to loads entering the estuary from S-79 and the Tidal Caloosahatchee Sub-watershed. The current BMAP only addresses TN load reductions in the Tidal Caloosahatchee Sub-watershed.

CRW Performance Metric Methodology. Performance metric methodologies are presented herein for the S-4/Industrial Canal, East Caloosahatchee, West Caloosahatchee and Tidal Caloosahatchee Sub-watersheds that discharge to the Caloosahatchee Estuary. In addition, a performance metric methodology is presented for the Coastal Caloosahatchee Sub-watershed, which is outside the scope of the FDEP estuary TMDL.

2. **Annual Targets and Limits for TP.**

FDEP TMDL. Although the watershed is identified as impaired for nutrients, TMDLs have not yet been developed for TP.

CRW Performance Metric Methodology. The performance metric methodologies described herein include annual targets and limits for TP since the watershed is identified as impaired for nutrients.

3. **Annual Targets and Limits for TN.**

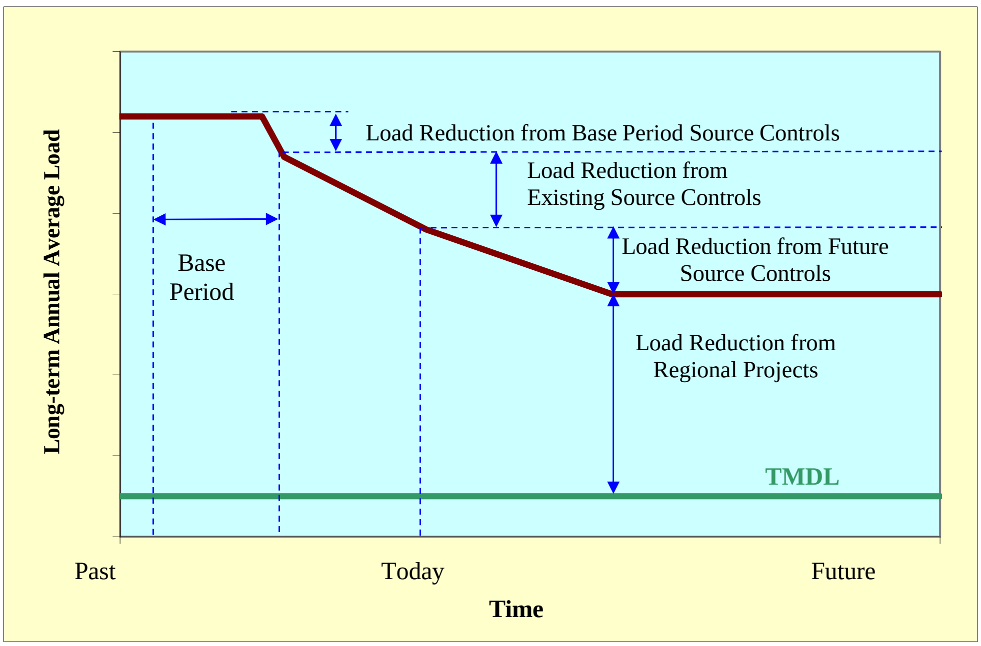
FDEP TMDL. The TMDL for the Caloosahatchee Estuary is 4,121 metric tons (mt) per year of TN, which represents a load reduction of 23 percent (FDEP, 2009).

CRW Performance Metric Methodology. The performance metric methodologies described herein include annual Targets and Limits (load or concentration) for TN.

4. Achievement of the Caloosahatchee Estuary TMDL.

FDEP TMDL. The load targets in the TMDL are intended to result in the estuary meeting water quality standards for TN. Collectively, source control measures and regional projects described in the CRWPP and in the Caloosahatchee Estuary BMAP are intended to work in concert to meet the applicable TMDL and other water quality objectives (see **Figure 2-3**).

Figure 2-3. Conceptual diagram of collective source control and regional projects' nutrient load reductions to achieve water quality objectives.



CRW Performance Metric Methodology. The performance metric methodologies described herein are technology-based water quality goals associated with the implementation of the collective source controls mandated by the NEEPP. Thus, reductions from the source control programs may not be sufficient to achieve the Caloosahatchee Estuary TMDL. Although an apples-to-apples comparison of the

Caloosahatchee Estuary TMDL and the performance metrics is not feasible given the difference in methodologies, the relationship between the goals may be exemplified as follows:

- The TMDL TN load to the estuary from the S-4/Industrial Canal, East Caloosahatchee, and West Caloosahatchee Sub-watersheds combined is approximately 954 mt/year (assuming a 23 percent reduction), while the sum of the TN performance metrics for these basins based on the Base Period median loads and reductions, as presented in **Table 2-4**, is approximately 1,350 mt/year.

Table 2-4. Comparison of TN loads for basins upstream of S-79.

TMDL		This Technical Support Document	
Baseline TN Load mt/yr	TN TMDL TN Load mt/yr	Base Period TN Load mt/yr	After Source Controls TN Load mt/yr
1,239	954	1864.1	1348.3

- For the Tidal Sub-watershed, the first phase of the Caloosahatchee Estuary BMAP requires a TN load of 590 mt equivalent to a TN concentration of 750 ppb while the TN performance metric proposed for this sub-watershed requires a TN concentration of 816 ppb based on the reference period monthly median concentration and reduction.

5. The receiving water body, or bodies.

FDEP TMDL. The TMDL was developed only for TN loads to the Caloosahatchee Estuary.

CRW Performance metric Methodology. The performance metrics described herein establish annual nutrient targets and limits for the basins regardless of receiving body, e.g., to the estuary, to coastal waters or to Lake Okeechobee. In other words, the performance metrics evaluate the collective source control program regardless of receiving body.

6. **Potentially different evaluation periods.**

FDEP TMDL. For the Tidal Caloosahatchee TN BMAP, FDEP will organize the monitoring data, track project implementation, and present this information in an annual report. The methodology for assessing progress towards attainment of the TMDL for the remaining basins has not yet been defined.

CRW Performance metric Methodology. The proposed performance metrics presented herein are based on annual nutrient levels and a two-part (Target/Limit) methodology. One part of the methodology, the Target, evaluates whether the basin's runoff levels are below or above the long-term goal.

7. **Different Base Periods for derivation of targets.**

FDEP TMDL. For the Caloosahatchee Estuary TMDL, the target loads were estimated from models using flows and nutrient concentrations for the three-year period from January 2003 through December 2005. Flow data covering the period 1995 – 2005 were used in calibrating and verifying the models; nutrient data for the period 2002 – 2005 were used in calibrating and verifying the models.

CRW Performance Metric Methodology. The performance metric methodologies described in this document used measured water quality data for basin-specific periods that were selected based on criteria described in Section 2.5, ranging in duration from four years for the Coastal Caloosahatchee Sub-watershed and its tributaries (WY2009-2012) to ten years for the West Caloosahatchee Sub-watershed (WY1988-1997).

2.4.2 Caloosahatchee River Watershed Protection Plan

The 2012 update to the *Caloosahatchee River Watershed Protection Plan* (CRWPP) contains planning-level estimates of the nutrient load reductions that may be achievable through source controls and dispersed, local, and regional projects within each sub-watershed, and these are summarized in **Table 2-5** through **Table 2-7**. The objectives of the projects and programs within the CRWPP are to reduce loads to the estuary sufficient to achieve any adopted TMDLs, to restore the natural hydrology of the watershed, and maintain compliance with applicable water quality standards. In the CRWPP, two general types of source controls are identified and simulated using spreadsheet tools for each of the sub-watersheds.

1. Projected reductions resulting from BMPs, and
2. Projected reductions resulting from ongoing watershed nutrient source control projects.

Table 2-5. Summary of estimated TN load reductions described in the CRWPP.

Sub-watershed	Baseline TN Load (mt/yr)	TN Load Reductions (mt/yr)						TN Loads after Reductions
		Source Controls			*Dispersed/ Local/Regional Projects*			
		Current	Near-Term	Long-Term	Current	Near-Term	Long-Term	
Coastal Caloosahatchee	282.4	2.6	8.1	21.0	0.0	0.0	27.9	222.9
Tidal Caloosahatchee	629.5	4.8	22.9	52.6	11.3	2.0	37.9	498.1
West Caloosahatchee	957.9	120.1	38.4	28.4	1.2	4.1	185.6	580.1
East Caloosahatchee	508.7	72.6	22.9	12.7	7.2	41.5	59.2	292.7
S4/Industrial Canal	157.6	33.7	5.5	4.5	0.0	2.0	11.9	100.1
Total	**2536.1**	**233.8**	**97.7**	**119.1**	**19.7**	**49.5**	**322.5**	**1693.9**

Table 2-6. Summary of estimated TP load reductions described in the CRWPP.

Sub-watershed	Baseline TP Load (mt/yr)	TP Load Reductions (mt/yr)						TP Loads after Reductions
		Source Controls			*Dispersed/ Local/Regional Projects*			
		Current	Near-Term	Long-Term	Current	Near-Term	Long-Term	
Coastal Caloosahatchee	29.7	0.1	1.2	3.0	0.0	0.0	3.9	21.4
Tidal Caloosahatchee	93.7	0.2	4.2	9.6	2.6	0.5	7.3	69.3
West Caloosahatchee	108.1	17.0	5.2	3.9	0.1	1.0	22.8	58.0
East Caloosahatchee	49.6	7.7	2.2	0.0	1.1	9.1	0.2	29.3
S4/Industrial Canal	9.8	1.6	0.3	0.4	0.0	0.2	1.1	6.1
Total	**290.7**	**26.6**	**13.1**	**17.0**	**3.7**	**10.9**	**35.4**	**184.0**

Table 2-7. Comparison of nutrient load reductions described in the CRWPP with those in this document.

	CRWPP		Technical Support Document	
Sub-watershed	**TP Reductions**	**TN Reductions**	**TP Target Reductions**	**TN Target Reductions**
Coastal Caloosahatchee	15%	11%	0%	15%
Tidal Caloosahatchee	15%	13%	10%	10%
West Caloosahatchee	24%	20%	30%	25%
East Caloosahatchee	20%	21%	30%	30%
S4/Industrial Canal	20%	28%	30%	35%

The TMDL for the Caloosahatchee Estuary was adopted in 2009 and incorporated as the water quality goal of the CRWPP. The Estuary TMDL is currently being revisited concurrent with the development of the Caloosahatchee fresh water/tributary TMDL and if revised, the CRWPP will be updated accordingly and coordinated with the BMAP process.

It should be noted that the objective of the source control programs considered for this project is to reduce nutrients in runoff by implementing onsite BMPs. The relationship between the 2012

CRWPP planning level estimates and the performance metric methodologies proposed in this document can be described by identifying the similarities and dissimilarities. While the contrasts vary among the sub-watersheds, a general description is provided below.

Similarities. A common feature between the approach described herein and the CRWPP is that the nutrient reduction estimates were based on specific land use estimates of reasonable source controls.

Dissimilarities. Differences between the 2012 CRWPP planning level estimates and the proposed performance metric methodologies are described below.

1. **Nutrient Reduction Estimates.**

   CRWPP. The 2012 CRWPP presents planning-level nutrient load reduction estimates for all sub-watersheds within the Caloosahatchee River Watershed (**Tables 2-5** through **2-6** above). The load reduction estimates in the 2012 CRWPP reflect nutrient reductions resulting from all initiatives described in the CRWPP, including both source control and regional projects (SFWMD 2012). Ideally, source control measures and regional projects described in the CRWPP will combine to meet the applicable TMDL and other water quality objectives.

   CRW Performance Metric Methodology. A comparison of the load reduction targets between the CRWPP and this Technical Support Document was summarized in **Table 2-7** above. Load-based performance metrics were developed for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds and account for hydrologic variability. In addition, concentration-based performance metrics were developed for the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds and their twenty-two tributaries, whereas the CRWPP provided nutrient reduction estimates for just the two sub-watersheds. The goal for the collective nutrient source control programs in the Caloosahatchee River Watershed is based on nutrient reductions that can reasonably be expected to be achieved through full implementation of BMPs. The performance metric methodologies described herein can be used to make annual performance determinations to establish if the BMPs implemented within individual basins are achieving reasonable progress towards achieving the nutrient reductions that are expected. Therefore, other initiatives such as regional projects will result in larger nutrient reductions than those established in the metrics.

2. **Different Base Periods for Derivation of Targets and Limits.**

CRWPP. For the 2012 CRWPP, the baseline nutrient loads were established for the 10-year base period of January 1, 1996 through December 1, 2005, and include simulated flow and water quality data.

CRW Performance Metric Methodology. The performance metric methodologies described in this document use observed water quality data for basin-specific benchmark periods, ranging from four to ten years.

3. **Additional threshold for TN reduction estimates.**

CRWPP. The TN load reduction estimates presented in the 2012 CRWPP do not include an additional threshold to account for natural background nitrogen levels.

CRW Performance Metric Methodology. Since a large portion of nitrogen in the environment is from natural sources and a majority of it is likely to be present as total organic nitrogen (TON), the performance metric methodologies incorporate an additional threshold to ensure that TN reduction goals do not go beyond what could be reasonably expected from source controls on anthropogenic activities. Based on review of literature and nitrogen levels at nine sites in south Florida, a preliminary threshold of 90 percent of the TON level is proposed (Bedregal 2012, Knight 2013). This approach assumes that a TN level equal to 90 percent of the reference period TON is a reasonable approximation of the natural background TN, and that the remaining ten percent is attributable to anthropogenic activities (e.g., use of organic fertilizers and cycling of inorganic nitrogen into TON) which could potentially be reduced through source controls.

4. **Calendar Year vs. Water Year.**

   CRWPP. In the 2012 CRWPP, the long-term average annual load reduction is based on a calendar year averaging interval (January 1- December 31).

   CRW Performance Metric Methodology. The approaches described herein are based on the District's May 1 – April 30 Water Year.

Summary of comparison with CRWPP.

The comparison below presents a general idea of how the CRWPP estimates and the performance metrics compare using the medians of the base period as reference (see **Table 2-8**). Please note, however, that the performance metrics are not single constant numbers, but rather that there is a series of steps for performance determination to account for hydrologic variability and statistical uncertainty. For example, the performance metrics for the S-4/Industrial, West Caloosahatchee and East Caloosahatchee Sub-watersheds will vary based on hydrologic conditions (i.e., the target and limits will be higher in years of high rainfall than in lower rainfall years), and for the Tidal and Coastal Sub-watersheds, the performance determination is based on the overall distribution of the water quality data being significantly different from the distribution during the reference period and not merely the median concentrations. Nevertheless, for these sub-watersheds the medians are in relatively close proximity (assumed as 20 percent) or differences are explained. It shall also be noted that planning estimates are adjusted in each protection plan update. The comparisons provided next are in relation to the most recent protection plan update (2012).

Table 2-8. Comparison of nutrient levels between the CRWPP and the performance metrics within this Technical Support Document

	CRWPP				Technical Support Document			
Sub-watershed	Baseline TN Load (mt/yr)	Baseline TN Concentration (ppb)	TN Load after Source Controls (mt/yr)	TN Concentration after Source Controls (ppb)	TN Base Period Median Load (mt/yr)	TN Base Period Median Concentration (ppb)	TN Median Load after Source Controls (mt/yr)	TN Target Concentration (ppb)
Coastal Caloosahatchee	282.4	1030	250.8	912	-	991	-	842
Tidal Caloosahatchee	629.5	1168	549.3	997	-	907	-	816
West Caloosahatchee	957.9	1310	771.0	-	1149.0	1689	862.0	-
East Caloosahatchee	508.7	1356	400.6	-	430.9	1970	301.6	-
S4/Industrial Canal	157.6	2027	113.9	-	284.2	2627	184.7	-
Total TN Load	**2536.1**		**2085.5**		**1864.1**		**1348.3**	

	CRWPP				Technical Support Document			
Sub-watershed	Baseline TP Load (mt/yr)	Baseline TP Concentration (ppb)	TP Load after Source Controls (mt/yr)	TP Concentration after Source Controls (ppb)	TP Base Period Median Load (mt/yr)	TP Base Period Median Concentration (ppb)	TP Median Load after Source Controls (mt/yr)	TP Target Concentration (ppb)
Coastal Caloosahatchee	29.7	108	25.3	92	-	47	-	47
Tidal Caloosahatchee	93.7	174	79.7	142	-	83	-	75
West Caloosahatchee	108.1	148	81.9	-	104.6	158	73.2	-
East Caloosahatchee	49.6	132	39.7	-	54.9	195	38.4	-
S4/Industrial Canal	9.8	126	7.4	-	17.6	147	12.3	-
Total TP Load	**290.7**		**234.0**		**177.1**		**124.0**	

TP reduction estimates:

- For the S4/Industrial Canal Sub-watershed and the East Caloosahatchee Sub-watershed the comparison between the TP performance metrics and the planning estimates must consider both the discharges to the Caloosahatchee River Watershed and to Lake Okeechobee. Therefore, please refer to Section 2.4.3 which consolidates the comparison including the LOPP and the CRWPP.

- For the West Caloosahatchee Sub-watershed, the long-term planning load estimates because of source controls and the median of the performance metric are within 11 percent. The median of the performance metric is lower because of a lower baseline and because it assumes full implementation of agricultural BMPs in the long-term (100 percent of the agricultural acreage) in contrast with 65 percent, as indicated in the CRWPP.
- For the Tidal Caloosahatchee Sub-watershed, the planning concentration estimates are twice the median performance metric. This is because the planning baseline, which is based on modeled data, also is twice the estimate of available measured data. However, the percent reductions applied for source controls are similar: the performance metric estimate a 10 percent reduction while the CRWPP estimates a reduction of 15 percent.
- For the Coastal Caloosahatchee Sub-watershed, the performance metrics propose maintaining current concentrations, while the CRWPP estimates a reduction of 15 percent for source controls. Same as with the Tidal Caloosahatchee, the modeled planning baseline is based on models and is twice the performance metric median baseline.

TN reduction estimates:

- For the S-4/Industrial Canal Sub-watershed, it is difficult to make a comparison between the CRWPP and the performance metrics because the planning estimates are only based on discharges to the Caloosahatchee River Watershed while the metrics are based on total discharges which include those to the Caloosahatchee River Watershed and to Lake Okeechobee. However, based on the assumption that TN discharges to Lake Okeechobee and the Caloosahatchee River watersheds are in the same proportion as the TP discharges, the planning estimate and the median of the performance metric are within 20 percent.

- For the East Caloosahatchee Sub-watershed, the planning load estimates and the median of the performance metric are within 25 percent. The TN performance metric at the median condition suggests a higher reduction than the protection plan estimate because of the combined effect of a lower Base Period nutrient load (431 mt/yr vs. 509 mt/yr) and slightly higher BMP reduction percentages than the CRWPP. Another contributing factor to this difference is the use of a 0.8 adjustment factor used in the CRWPP to account for Lake Okeechobee inputs, while pass-through loads are directly calculated for the performance metrics.
- For the West Caloosahatchee Sub-watershed, the planning load estimates and the median of the performance metric are within 11 percent. This difference is due in part to the fact that the median load of the performance metric Base Period (1149 mt/yr) is higher than the baseline of the CRWPP (958 mt/yr).
- For the Tidal Caloosahatchee Sub-watershed, the planning concentration estimates are based on modeled data and are higher than the median of the performance metric, which is based on observed data. However, the percent reductions applied for source controls are very similar: the performance metrics propose a 10 percent reduction in concentration for source controls, while the CRWPP estimates a long-term reduction of 13 percent.
- For the Coastal Caloosahatchee Sub-watershed, the planning concentration estimates are based on modeled data and are higher than the median of the performance metric, which is based on observed data. However, the percent reductions applied for source controls are very similar: the performance metrics propose a 15 percent reduction in concentration for source controls, while the CRWPP estimates a long-term reduction of 11 percent for source controls.

2.4.3 Lake Okeechobee Protection Plan

Two sub-watersheds are also part of the Lake Okeechobee Watershed since a portion of their basin loads discharge to the lake: the S-4/Industrial Canal Sub-watershed and the East Caloosahatchee Sub-watershed. The TP performance metric methodologies proposed herein for these two sub-watersheds are compared to the *Lake Okeechobee Protection Plan*[7]. The 2011 update to the *Lake Okeechobee Protection Plan* contains planning-level estimates of the TP load reductions that may be achievable through source controls and regional projects within each sub-watershed, and these are summarized in **Table 2-9**, reprinted from the *Lake Okeechobee Protection Plan 2011 Update* (SFWMD et al. 2011a). The objective of the LOPP is to reduce loads to the lake sufficient to achieve the TMDL. In the LOPP, two general types of source controls are identified for each of the sub-watersheds:

1. Reductions resulting from BMPs simulated by the Watershed Assessment Model (applied to all basins except EAA basins), and
2. Reductions resulting from ongoing watershed TP source control projects.

It should be noted that the objective of the regulatory source control program considered for this project is to reduce loads in runoff by implementing onsite BMPs. The relationship between the 2011 LOPP planning level estimates and the performance metric methodologies proposed in this document can be described by identifying the similarities and dissimilarities. While the contrasts vary among the sub-watersheds, a general description is provided below.

Similarities. A common feature between the approach described herein and the LOPP is that the estimated load reductions attributable to source controls were developed by Soil and Water Engineering Technology, Inc. (Bottcher 2006, SWET 2008). In the LOPP, these estimates are used for planning purposes and to calculate the load reductions expected from implementation of agricultural and non-agricultural BMPs.

[7] The *Lake Okeechobee Protection Plan* does not contain TN targets or limits and so no comparisons are made for that nutrient.

Table 2-9. Estimates of TP Load reductions in the Lake Okeechobee Watershed (from SFWMD et al. 2011).

Table C-1: Summary of Estimated P Load Reductions to Lake Okeechobee under the Lake Okeechobee Protection Plan

Sub-watershed	Watershed Baseline Data				Current Activities								Near-Term P Reduction Activities (2011 to 2013) (5)		P Reduction Strategies (6)			
					Owner and Cost share Implemented BMPs (1)		Watershed P Control Projects (2)		Regional Public Works Projects (3)		Other Regional and Sub-Regional Projects (4)							
	Area (acres)	Average Annual Discharge (Measured) (2001-2009) (Acre-ft)	Average Annual P Load (Measured)(2001-2009) (Mtons)	Average Annual P Conc. (Calculated) (2001-2009) (ppb)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain Load (Mtons)	Load Red. (Mtons)	Remain Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain Load (Mtons)	Load Red. (Mtons)	Remain Load (Mtons)	Remain. Conc. (ppb)	Adjusted Remain. Load* (Mtons)
Upper Kissimmee (S-65)	1,021,674	853,368	97	92	0	97	0	97	13	84	0	84	0	83	30	53	50	53
Lower Kissimmee (S-65A,B,C,D,E)	429,283	359,254	57	129	18	39	7	33	8	25	0	25	6	19	6	13	30	13
Taylor Creek/Nubbin Slough (S-191,154,133,135)	198,299	146,900	105	578	18	87	19	68	5	63	2	60	20	40	35	5	30	5
Lake Istokpoga (S-68)	392,147	290,826	40	110	0	39	0	39	0	39	2	38	0	37	27	11	30	11
Indian Prairie Basins (12 basins)	294,147	219,581	101	373	10	91	0	91	0	91	8	82	9	74	66	8	30	8
Fisheating Creek & Nicodemus Slough	315,007	295,324	86	238	6	80	0	80	0	80	0	80	15	65	18	47	128	47
West Lake Okeechobee Basin (S-77)	200,993	29,270	5	139	0	5	0	5	0	5	1	4	0	4	2	2	53	2
EAA Basins	361,707	107,419	20	152	0	20	0	20	9	11	0	11	0	10	3	8	60	8
East Lake Okeechobee Basins (C-44, L-8)	237,831	131,522	29	180	0	29	0	29	0	29	1	28	7	22	2	19	120	19
Total Reductions to the Lake	3,451,087	2,433,464	539	180	52	487	26	461	35	426	15	411	57	355	188	167	56	167
TMDL (not including 35 t of atmospheric deposition)																		105
Remaining Load																		62

(1) Reduction resulting from owner implemented and cost-share BMPs simulated by Watershed Assessment Model (applied to all basins except EAA basins).

(2) Reduction due to ongoing watershed P source control projects.

(3) Reduction resulting from implementation of LO Critical Projects (5.0 t), Kissimmee River Restoration (KRR) (20.6 t), and the ECP/Diversions (9.4 t).

(4) Reduction resulting from other regional and sub-regional projects: FRESP (5.9 t), HWTT (1.1 t), and Dispersed Water Management Projects (7.6 t).

(5) Reduction resulting from the planned regional and sub-regional projects: Dispersed Water Management Projects (16.5 t), FDACS owner-implemented and cost-share BMPs (16.8 t), HWTT at Grassy site (2.9 t), Lakeside Ranch STA Phase I (9 t), Aquifer Storage Recovery (Kissimmee Pilot ASR and Taylor Creek ASR Reactivation) (1.3 t), Fisheating Creek Wetland Reserve Special Project (3.5 t), and C-44 project (6.7 t).

(6) Reduction resulting from owner-implemented and cost-share BMPs (18.0 t), the Dispersed WMP - potential sites (6.1 t), Brady Ranch (2 t), Aquifer Storage and Recovery (11.2 t), Chemical treatment to LOWP reservoirs (14.3 t), S-68 STA (8 t), Istokpoga/Kissimmee RASTA (8.9 t), Kissimmee reservoir east (6.5 t), additional P reductions resulting from chemical treatment at the parcel level (46.4 t), Lakeside Ranch STA Phase II (10.0 t), Clewiston STA (2.5 t), and CERP LOWP (54 t).

* To be conservative, where reductions were projected to result in concentrations less than 30 ppb, the remaining load was estimated by multiplying the basin flow by 30 ppb instead of a lower projected concentration.

Dissimilarities. Differences between the 2011 LOPP planning level estimates and the proposed performance metric methodologies for the S-4/Industrial Canal and East Caloosahatchee Sub-watersheds are described below.

1. **The direction of discharge and location of the monitoring stations used for the annual performance determination.**

   LOPP. In the 2011 LOPP, the baseline TP load and load reductions are associated with only the structures that discharge into Lake Okeechobee, e.g. S-77 for the East Caloosahatchee Sub-watershed.

   CRW Performance Metric Methodology. The performance metrics and performance indicators described herein establish annual TP targets for the basins, and include TP loads from all structures through which the basin can discharge. For example, the methodology for the East Caloosahatchee Sub-watershed includes TP loads at S-77 (which discharges into Lake Okeechobee) combined with TP loads at S-78 (which discharges into the Caloosahatchee River) and with TP loads at S-235 (which discharges to and from the S-4/Industrial Canal Sub-watershed).

2. **Calculation of pass-through loads.**

   LOPP. While both the 2011 LOPP and the proposed approach differentiate between basin runoff loads and those loads that pass through the basin from upstream sources, different algorithms are used to calculate pass-through loads. Please refer to the 2011 LOPP for a description of the algorithm used to calculate pass-through loads.

   CRW Performance Metric Methodology. The algorithms used to calculate pass-through loads for the proposed approach are described in Section 2.5.1. When a downstream basin receives pass-through loads from an upstream basin these loads are outside the control of the collective source control programs within the basin. Therefore, the incoming loads from the upstream basin will be accounted for in the annual performance determination process.

3. **Load Reduction Estimates.**

LOPP. The planning-level load reduction estimates in the 2011 LOPP reflect load reductions resulting from all initiatives described in the *Lake Okeechobee Protection Plan*, including both source control and regional projects (SFWMD et al 2011a). Collectively, source control measures and regional projects described in the *Lake Okeechobee Protection Plan* will combine to meet the applicable TMDL and other water quality objectives.

CRW Performance Metric Methodology. The goal for the collective TP source control programs in the Lake Okeechobee Watershed (and Caloosahatchee River Watershed) will be based on TP load reductions that can reasonably be expected to be achieved through full implementation of BMPs. The performance metric methodologies described herein are used to make annual performance determinations to establish the progress of the BMPs implemented within individual basins. Unlike the planning-level estimates in the 2011 LOPP, the performance metric methodologies only consider BMPs and do not consider the effectiveness of other initiatives like regional projects.

4. **Different evaluation periods.**

LOPP. In the 2011 LOPP, the planning-level load reduction estimates reflect a long-term average annual load reduction.

CRW Performance Metric Methodology. In contrast, the proposed performance metrics presented herein are based on annual TP loads, with hydrologic variability explicitly addressed through the use of a regression equation that incorporates rainfall characteristics, and with a two-part (Target/Limit) methodology which evaluates loads over a three year period.

5. **Consideration of hydrologic variability.**

   LOPP. The load reduction estimates presented in the 2011 LOPP do not include adjustments for future hydrologic variability.

   CRW Performance Metric Methodology. The recommended performance metric methodologies explicitly account for hydrologic variability through prediction equations that use one or more annual rainfall characteristics for the S4/Industrial Canal and East Caloosahatchee sub-watersheds.

6. **Calendar Year vs. Water Year.**

   LOPP. In the 2011 LOPP, the long-term average annual load reduction is based on a calendar year averaging interval (January 1- December 31) in order to be consistent with the TMDL target which is a 5-year moving average based on calendar year averaging intervals (January 1 – December 31).

   CRW Performance Metric Methodology. The approaches described herein are based on the District's May 1 – April 30 Water Year.

Summary of comparison TP reduction estimates with LOPP.

- For the S4/Industrial Canal Sub-watershed, the LOPP and CRWPP combined propose a reduction of approximately 26 percent from a baseline of 20 metric tons of TP discharged to both the Caloosahatchee River Watershed and to Lake Okeechobee. The planning load estimates and the median of the performance metric are within 20 percent. The protection plans estimate a TP load after source controls of approximately 14 metric tons in comparison to 12 metric tons for the median of the performance metric. The difference is because, although the expected reductions under the plans and the metrics are relatively close, the baseline for the combined plans (18 metric tons) is higher than the baseline for the performance metric (21 metric tons).

- For the East Caloosahatchee Sub-watershed, the combined plans propose a reduction of approximately 20 percent from a baseline of 55 metric tons discharged to both the Caloosahatchee Watershed and Lake Okeechobee. The planning load estimates and the median of the performance metric are within 15 percent. The protection plans estimate a TP load of 44 metric tons under the combined plans versus 38 metric tons for the median of the performance metric. The difference is because the performance metric is based on long-term implementation of BMPs in 100 percent of the agricultural acreage in contrast with 65 percent for the CRWPP estimates and no reductions due to BMPs for the LOPP estimates.

2.5 Common Elements of the Performance Metric Methodologies

This section presents common elements of the proposed performance metric methodologies for the basins within the Caloosahatchee River Watershed.

2.5.1 Consideration of Pass-through Flows and Loads

The performance metric methodologies for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds account for pass-through flows and nutrient loads. If a basin receives flow and nutrient load from an upstream basin or water body, the performance metric methodology adjusts the overall observed flow and loads to account for the component passing through, yielding only flow and loads from basin runoff for the performance determination (described in Section 2.6.8). The pass through calculation follows a similar protocol as was used in Chapter 40E-63, F.A.C. Pass-through loads are estimated by comparing the total basin inflows to the total basin outflows on a daily basis, as generally described below.

$Inflow_{Basin}$ = cumulative inflow at basin boundary structures

$Outflow_{Basin}$ = cumulative outflow at basin boundary structures

$PassThroughFlow_{Basin} = minimum\ (Inflow_{Basin}\ ,\ Outflow_{Basin})$

Basin runoff is then calculated as the difference between the total outflow and the pass-through flow:

$Runoff_{Basin} = Outflow_{Basin} - PassThroughFlow_{Basin}$

Pass through nutrient loads are calculated as the product of the pass-through flow and the flow weighted mean inflow concentration measured at all of the basin's boundary structures:

$InflowLoad_{Basin}$ = cumulative inflow load at all basin boundary structures

$InflowConcentration_{Basin} = InflowLoad_{Basin}\ /\ Inflow_{Basin}$

$PassThroughLoad_{Basin} = PassThroughFlow_{Basin} * InflowConcentration_{Basin}$

The basin runoff nutrient load is the difference between the total outflow load and the pass-through load:

$OutflowLoad_{Basin}$ = cumulative outflow load at all basin boundary structures

$RunoffLoad_{Basin} = OutflowLoad_{Basin} - PassThroughLoad_{Basin}$

Basin-specific details of the pass through calculations are provided in **Section 3** and in **Appendix A**.

2.5.2 Data Precision and Significant Digits

The development of the performance metric methodologies used the following protocol for rounding off data values during calculations:

- Daily rainfall station source data were available at the nearest 0.01 inch. Average daily rainfall values were calculated by the District from the individual station source data using Thiessen weights, and rounded to the nearest 0.001 inch.
- Monthly rainfall values were calculated by the District as the sum of the daily values and rounded to the nearest 0.01 inch.
- Annual rainfall values were calculated by the District as the sum of the monthly values and rounded to the nearest 0.01 inch.
- Monthly runoff volumes were rounded to the nearest 0.1 acre foot (AF).
- Nutrient concentration source data were measured from samples collected at representative structures/sites, and were reported at the nearest part per billion (ppb or µg/L).
- In order to preserve the above precision,
    - calculations involving log and square root transformations were carried out to the fifth decimal place, and
    - most intermediate calculations were carried out to two more decimal places and then rounded to achieve the above significant digits.
- For final calculations of Targets and Limits, nutrient levels were rounded to three significant digits.

2.5.3 Identification of Potential Outliers

Flow and nutrient concentration data were screened for outliers, using the Maximum Normed Residuals technique (Snedecor and Cochran 1989). Potential outliers were identified, and

District staff and the consultant team reviewed the comments and other information associated with the data in order to assess whether the value should be retained in future analyses. In addition to statistical outliers, agency staff screened the data to exclude samples collected during periods of atypical basin runoff conditions, e.g., construction, incoming tides and large amounts of floating aquatic vegetation.

2.5.4 Selection of the Base Period and Load Prediction Equations

The Base Period is the benchmark period of historical observed data on which performance measures are based. Base periods should meet, as much as possible, the following criteria: having at least eight years of concentration and flow data to adequately represent nutrient levels through a wide range of hydrologic conditions; be representative of current operating conditions affecting nutrient loading (unless these conditions can be corrected through data adjustments); have a reasonable correlation between rainfall and nutrient loads; precede full implementation of collective source control measures; be free of trends in rainfall, flow or loads (unless these trends can be accounted for); and be free of unexplained outliers in the rainfall, flow, or load data.

For the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds, the Base Periods selected met, as much as possible, the above criteria:

- S-4/Industrial Canal Sub-watershed: Base Period of WY1993-2001 (May 1992 – April 2001)
- East Caloosahatchee Sub-watershed: Base Period of WY1983-1990 (May 1982 – April 1990)
- West Caloosahatchee Sub-watershed: Base Period of WY1988-1997 (May 1987 – April 1997)

Prediction equations for annual nutrient load, expressed as a function of the annual rainfall, were examined to account for hydrologic variability. Fifty-four regression equations correlating annual load with annual rainfall and monthly rainfall characteristics (coefficient of variation, skewness and kurtosis) were evaluated (see **Table 2-10**).

Table 2-10. Regression equations evaluated to express annual nutrient load as a function of hydrologic variability.

Regr. No.	Response Variable	Predictor Variables	Regression Equation
1	Load	Rain	Annual Load Target = a + b Rain
2	ln(Load)	ln(Rain)	Annual Load Target = exp (a + b ln(Rain))
3	ln(Load)	ln(Rain), S	Annual Load Target = exp (a + b1 ln(Rain) + b2 S)
4	ln(Load)	Ln(Rain), CV, S	Annual Load Target = exp (a + b1 ln(Rain) + b2 CV + b3 S)
5	ln(Load)	ln(Rain), CV, S, K	Annual Load Target = exp (a + b1 ln(Rain) + b2 CV + b3 S + b3 K)
6	ln(Load)	ln(Rain), CV	Annual Load Target = exp (a + b1 ln(Rain) + b2 CV)
7	ln(Load)	ln(Rain), ln(last year's Rain)	Annual Load Target = exp (a + b1 ln(Rain) + b2 ln(last year's Rain))
8	Load	S, CV, Rain	Annual Load Target = a + b1 S + b2 CV + b3 Rain
9	Load	CV, S, K, Rain	Annual Load Target = a + b1 CV + b2 S + b3 K + b4 Rain
10	ln(Load)	ln(Rain), ln(last year's Rain), CV, S, K	Annual Load Target = exp (a + b1 ln(Rain) + b2 ln(last year's Rain) +b3 CV + b4 S + b5 K)
11	ln(Load)	ln(Rain), ln(last year's Rain), CV	Annual Load Target = exp (a + b1 ln(Rain) + b2 ln(last year's Rain) +b3 CV)
12	Load	Rain, last year's Rain	Annual Load Target = a + b1 Rain + b2 (last yr's Rain)
13	Load	S, CV, Rain, last year's Rain	Annual Load Target = a + b1 S + b2 CV + b3 Rain + b4 (last yr's Rain)
14	Load	CV, Rain	Annual Load Target = a + b1 CV + b2 Rain
15	Load	Rain, S	Annual Load Target = a + b1 Rain b2 S
16	Load	ln(Rain)	Annual Load Target = a + b ln(Rain)
17	ln(Load)	Rain	Annual Load Target = exp (a + b Rain)
18	Load	ln(Rain), ln(last year's Rain)	Annual Load Target = a + b1 ln(Rain) + b2 ln(last year's Rain)
19	Load	ln(Rain), S	Annual Load Target = a + b1 ln(Rain) + b2 S
20	Load	Ln(Rain), CV, S	Annual Load Target = a + b1 ln(Rain) + b2 CV + b3 S
21	Load	ln(Rain), CV, S, K	Annual Load Target = a + b1 ln(Rain) + b2 CV + b3 S + b4 K
22	Load	ln(Rain), CV	Annual Load Target = a + b1 ln(Rain) + b2 CV
23	ln(Load)	S, CV, Rain	Annual Load Target = exp (a + b1 S + b2 CV + b3 Rain)
24	ln(Load)	CV, S, K, Rain	Annual Load Target = exp (a + b1 CV + b2 S + b3 K + b4 Rain)
25	Load	ln(Rain), ln(last year's Rain), CV, S, K	Annual Load Target = a + b1 ln(Rain) + b2 ln(last year's Rain) +b3 CV + b4 S + b5 K
26	Load	ln(Rain), ln(last year's Rain), CV	Annual Load Target = a + b1 ln(Rain) + b2 ln(last year's Rain) +b3 CV
27	ln(Load)	Rain, last year's Rain	Annual Load Target = exp (a + b1 Rain + b2 (last yr's Rain))
28	ln(Load)	S, CV, Rain, last year's Rain	Annual Load Target = exp (a + b1 S + b2 CV + b3 Rain + b4 (last yr's Rain))
29	ln(Load)	CV, Rain	Annual Load Target = exp (a + b1 CV + b2 Rain)
30	ln(Load)	Rain, S	Annual Load Target = exp (a + b1 Rain + b2 S)
31	Load	ln(Rain), S, CV*S	Annual Load Target = a + b1 ln(Rain) + b2 S + b3 CV*S
32	ln(Load)	ln(Rain), S, CV*S	Annual Load Target = exp (a + b1 ln(Rain) + b2 S + b3 CV*S)
33	Load	ln(CV), ln(Rain)	Annual Load Target = a + b1 ln(CV) + b2 ln(Rain)
34	ln(Load)	ln(CV), ln(Rain)	Annual Load Target = exp (a + b1 ln(CV) + b2 ln(Rain))
35	Load	ln(CV), ln(Rain), S	Annual Load Target = a + b1 ln(CV) + b2 ln(Rain) + b3 S
36	ln(Load)	ln(CV), ln(Rain), S	Annual Load Target = exp (a + b1 ln(CV) + b2 ln(Rain) + b3 S)
37	sqrt(Load)	Rain	Annual Load Target = $(a + b \text{ Rain})^2$
38	sqrt(Load)	S, CV, Rain	Annual Load Target = $(a + b1 \text{ S} + b2 \text{ CV} + b3 \text{ Rain})^2$
39	sqrt(Load)	CV, S, K, Rain	Annual Load Target = $(a + b1 \text{ CV} + b2 \text{ S} + b3 \text{ K} + b4 \text{ Rain})^2$
40	sqrt(Load)	Rain, last year's Rain	Annual Load Target = $(a + b1 \text{ Rain} + b2 \text{ (last yr's Rain)})^2$
41	sqrt(Load)	S, CV, Rain, last year's Rain	Annual Load Target = $(a + b1 \text{ S} + b2 \text{ CV} + b3 \text{ Rain} + b4 \text{ (last yr's Rain)})^2$
42	sqrt(Load)	CV, Rain	Annual Load Target = $(a + b1 \text{ CV} + b2 \text{ Rain})^2$
43	sqrt(Load)	Rain, S	Annual Load Target = $(a + b1 \text{ Rain } b2 \text{ S})^2$
44	sqrt(Load)	ln(Rain)	Annual Load Target = $(a + b \ln(\text{Rain}))^2$
45	sqrt(Load)	ln(Rain), ln(last year's Rain)	Annual Load Target = $(a + b1 \ln(\text{Rain}) + b2 \ln(\text{last year's Rain}))^2$
46	sqrt(Load)	ln(Rain), S	Annual Load Target = $(a + b1 \ln(\text{Rain}) + b2 \text{ S})^2$
47	sqrt(Load)	Ln(Rain), CV, S	Annual Load Target = $(a + b1 \ln(\text{Rain}) + b2 \text{ CV} + b3 \text{ S})^2$
48	sqrt(Load)	ln(Rain), CV, S, K	Annual Load Target = $(a + b1 \ln(\text{Rain}) + b2 \text{ CV} + b3 \text{ S} + b4 \text{ K})^2$
49	sqrt(Load)	ln(Rain), CV	Annual Load Target = $(a + b1 \ln(\text{Rain}) + b2 \text{ CV})^2$
50	sqrt(Load)	ln(Rain), ln(last year's Rain), CV, S, K	Annual Load Target = $(a + b1 \ln(\text{Rain}) + b2 \ln(\text{last year's Rain}) + b3 \text{ CV} + b4 \text{ S} + b5 \text{ K})^2$
51	sqrt(Load)	ln(Rain), ln(last year's Rain), CV	Annual Load Target = $(a + b1 \ln(\text{Rain}) + b2 \ln(\text{last year's Rain}) + b3 \text{ CV})^2$
52	sqrt(Load)	ln(Rain), S, CV*S	Annual Load Target = $(a + b1 \ln(\text{Rain}) + b2 \text{ S} + b3 \text{ CV*S})^2$
53	sqrt(Load)	ln(CV), ln(Rain)	Annual Load Target = $(a + b1 \ln(\text{CV}) + b2 \ln(\text{Rain}))^2$
54	sqrt(Load)	ln(CV), ln(Rain), S	Annual Load Target = $(a + b1 \ln(\text{CV}) + b2 \ln(\text{Rain}) + b3 \text{ S})^2$

The multiple selection factors used to identify the recommended regression equation are described below.

1. **Testing the assumption of normality.** Many statistical tests, including linear regression, assume that the data values or their residuals in the case of regression equations, are drawn from a normal distribution. Tests for normality were conducted for the annual values (loads, concentrations, unit area loads and rainfall) and for the residuals resulting from the regression equations, where

   residual = observed value minus the predicted value

   To assess the validity of this assumption, the method of Chambers *et al.* (1983) was used. This is an approximate method using graphical procedures. The data are plotted against a theoretical normal distribution so that the points should form an approximately straight line. Departures from a straight line suggest a non-normal distribution. The plot is formed by placing ordered response values on the Y-axis and normal order statistic medians on the X-axis.

   The test for approximate significance is then based on the probability associated with the Pearson's Correlation Coefficient between the two sets of statistics. A test for the lognormal distribution was achieved by converting the observed data values to the logarithm of the value then re-applying the Chambers *et al*. method (1983).

2. **Standard error of the regression equation** (also known as the standard error of the estimate and the standard error of the prediction residuals). The smaller the standard error of the regression equation, the better the equation "fits" the observed data. To compare the standard error of the regression equation that is based on log-transformed variables, a back-transformed standard error was calculated, estimated by transforming the predicted and original values back to original units of the dependent variable.

3. **Strength of the correlation.** A measure of the strength of the regression relationship is the Coefficient of Determination, commonly expressed as R^2, which represents the proportion of the variance in the dependent variable that can be explained by the linear relationship with the predictor variable(s). In general, the higher the value of R^2, the stronger the correlation between the dependent variable and the predictor variable(s). By itself, R^2 is not sufficient to demonstrate the strength of the correlation, and so other tests are performed (see below). The adjusted R^2, which accounts for multiple predictor variables, was also used to help determine the best regression equation.

4. **Statistical significance of the regression coefficients.** In a simple linear regression equation, where there is one predictor variable (say, annual rainfall) and one dependent variable (say, annual load), a Student's t-test is performed to determine whether the regression coefficient (the slope of the line in this simple case) is significantly different from 0. When the regression equation has multiple independent variables, a Student's t-test is performed to determine if all the regression coefficients are significantly different from 0. Regression equations in which one or more of the predictor variable coefficients were not significantly different from 0 were not used.

5. **Uniform variance of the residuals (homoscedasticity).** Typically, standard tests are performed to determine whether there is heteroscedasticity in the residuals of the regression equation, e.g., White's test or the Bruesch-Pagan test. However, the sample sizes for those tests need to be larger than 30, considerably larger than the sample sizes available in the Base Periods used for developing the performance metric methodologies (9 years for the S-4/Industrial Canal and East Caloosahatchee Sub-watersheds and 10 years for the West Caloosahatchee Sub-watershed). As an alternative, scatterplots of standardized residuals were prepared for each independent variable to visually inspect for non-uniform variance, such as increasing or decreasing variance. In addition, the presence of a trend in the square of the residuals was also tested for the response variable

by performing a Student's t-test on the regression coefficients: if the coefficients were not statistically different from 0, then it was determined that a trend in the variance was not present, i.e., homoscedasticity as opposed to heteroscedasticity.

6. **Collinearity.** For multiple linear regression equations, i.e., those with more than one predictor variable, the correlation between the predictor variables was calculated using the Pearson's Correlation Coefficient. A value less than 50 percent was deemed to be free of collinearity. A value greater than 90 percent triggered a positive hit on collinearity, and the regression equation was considered unacceptable. Values between 50 percent and 90 percent triggered an additional check, and the relative standard error of the regression coefficients (standard error for the coefficient divided by the coefficient) was evaluated. A value above 200 percent in conjunction with a correlation of greater than 50 percent triggered a positive hit on collinearity, and the regression equation was considered unacceptable. In general, the use of the previous year's rainfall as a predictor variable was avoided due to concerns of collinearity between rainfall and the previous year's rainfall.

7. **Absence of a temporal trend during the Base Period.** Seasonal Kendall Tau (SKT) trend analyses using monthly data were performed to determine the presence of a temporal trend in the data. The presence of a trend in monthly loads or concentrations during the Base Period that is not related to variations in annual rainfall may indicate the presence of one or more factors that are contributing to variations in nutrient levels. For example, phased implementation of source controls in the watershed could result in a trend in the monthly nutrient levels. If a trend is detected that is not related to variation in rainfall, de-trending the data may be necessary. One common approach would be to perform an SKT trend analysis using the monthly load or concentration data, and then subtracting the "trend," defined as the slope of the SKT trend line times the elapsed time since the beginning of the data record.

8. **Avoid overparameterization.** Overparameterization occurs when the number of predictor variables approaches the sample size, artificially inflating the value of R^2. All other factors being equal, a regression equation with only one predictor variable would be given precedence over a regression equation with two or more independent variables. A ratio was used help quantify the degree of parameterization:

   Ratio = years in the Base Period / number of predictor variables

   Haan (1977) suggests a rule of thumb that the ratio should be above 2.86. As a reference, the regression equation used for the EAA Basin in Chapter 40E-63, F.A.C. had a ratio of 9 / 3 = 3.0.

2.5.5 Selection of Reference Period and Concentration Distributions

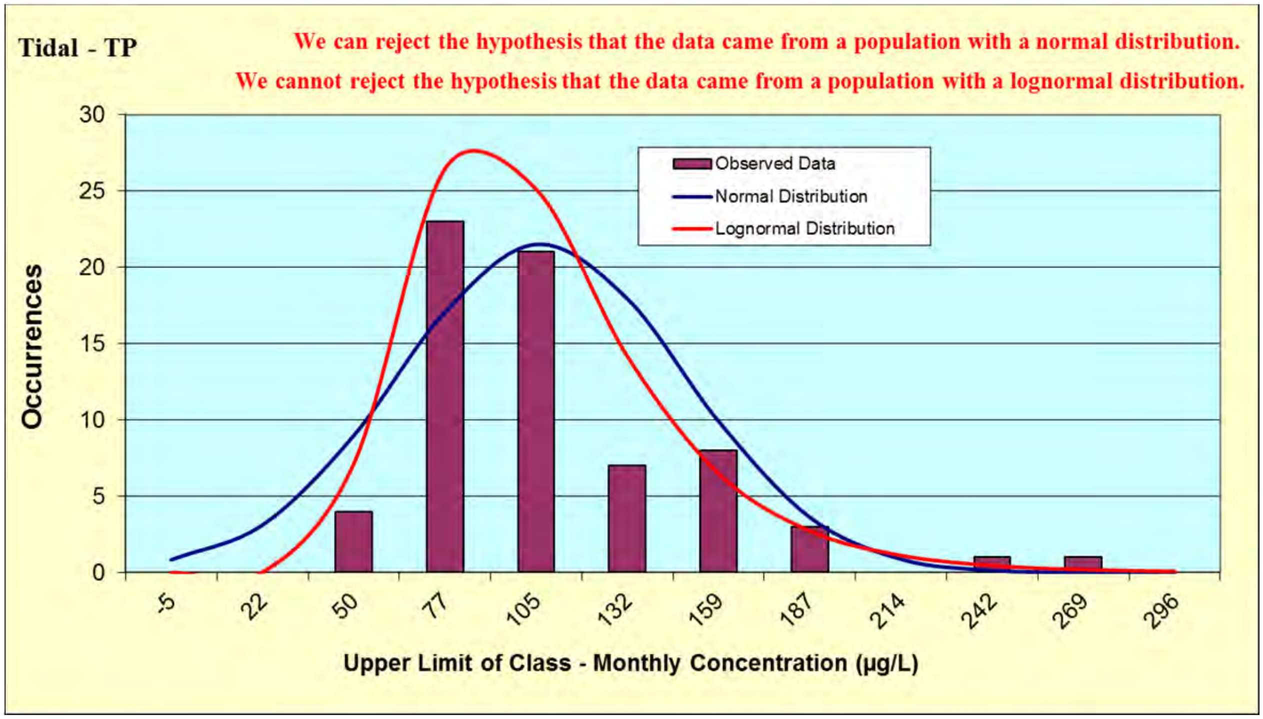
The Reference Period is the benchmark period of historical measured data on which performance indicators are based. Reference Periods shall include, at a minimum, five years of nutrient concentration or load data measured during a representative range of conditions affecting nutrient concentration or loading from the basin.

For the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds, the Reference Periods selected met, as much as possible, the above criteria:

- Tidal Caloosahatchee Sub-watershed: Reference Period of WY2006-2012 (May 2005 – April 2012)
- Coastal Caloosahatchee Sub-watershed: Water quality data covering five water years were not available, so a four-year Reference Period was selected: WY2009-2012 (May 2008 – April 2012).

The performance indicators for these sub-watersheds are based on the distribution of monthly nutrient concentrations observed during the Reference Period (see for example **Figure 2-4**). The Annual Concentration Target is a distribution of monthly concentrations, represented by the median concentration of the distribution, and equal to the Reference Period monthly concentrations multiplied by the respective nutrient reduction goal for the basin.

Figure 2-4. Distribution of monthly TP concentration data for the Tidal Caloosahatchee Sub-watershed for the Reference Period WY2006-2012.



2.5.6 Consideration of Nitrogen Background Levels

Since a large portion of nitrogen in the environment is from natural sources and a majority of it is likely to be present as total organic nitrogen (TON), the performance metric methodologies incorporate an additional threshold to ensure that estimates of TN reductions do not go beyond what could be reasonably expected from source controls on anthropogenic activities. Based on review of literature and nitrogen levels at nine sites in south Florida, a preliminary threshold of 90 percent of the TON level is proposed (Bedregal 2012, Knight 2013). This approach assumes that a TN level equal to 90 percent of the reference period TON level is a reasonable approximation of the natural background TN, and that the remaining ten percent would be attributable to anthropogenic activities (e.g., use of organic fertilizers and cycling of inorganic nitrogen into TON) which could potentially be reduced through source controls.

2.5.7 Strength and Defensibility

For each basin an evaluation of the strength and defensibility of the performance metric was conducted by reviewing the data (uncertainty in the data set, duration of Base or Reference Period, ability to account for hydrologic variability, etc.), and the assumptions made in the development of the performance metric. All of the basins that had load-based performance measures (S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds) were ranked high or moderate for their overall technical strength and defensibility. All of the basins with concentration-based performance indicators (Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds) were ranked low for their overall technical strength and defensibility due to the uncertainty in the data sets, limited duration of Reference Period, lack of flow data, and inability to account for hydrologic variability.

2.5.8 Regional Projects

A description of existing and proposed regional projects can be found in the 2012 Caloosahatchee River Watershed Protection Plan Update (SFWMD 2012). Performance metric methodologies may be able to account for regional projects in a similar manner as in Chapter 40E-63, F.A.C., based on the nature of those projects (**Appendix D**).

2.5.9 Source Control Effectiveness

The effectiveness of source controls is ultimately measured by the reduction of nutrients in runoff. Source control programs are classified as non-point or point sources. Conservative reduction estimates from the implementation of collective source control programs in comparison to a period were developed as a preliminary benchmark to establish progress. As discussed earlier in this document, these estimates are within reasonable ranges to existing or parallel planning and regulatory efforts, such as the protection plans and BMAPs. Reductions were not considered for programs whose nutrient reductions are uncertain in the long term or for projects primarily intended to maintain current nutrient levels.

Source control programs include BMPs and regulations with requirements for BMP implementation. These programs are complementary to each other to address various sources based on statutory mandates and agency jurisdiction. The BMPs upon which the nutrient reductions are based represent what would be expected to result from reasonably funded cost share programs or a modest regulatory approach (Bottcher 2006 and SWET 2008). The programs and BMPs applicable to the primary land uses in the Caloosahatchee River Watershed are presented in **Table 2-11**; reductions used for the full set of land uses are presented in **Appendix C**. Spreadsheets were developed for each basin, and conservative modifications were made based on best professional judgment, as discussed in **Appendix C**, to arrive at the reductions presented in **Table 2-12**. Note that reductions for tributaries to the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds were estimated to assist in prioritizing any necessary follow-up actions in case the sub-watershed performance metrics are not met. These source control reduction levels, relative to the respective reference periods, provide a preliminary recommendation for development of performance metrics. As additional information is obtained during the stakeholder technical review process, the nutrient reduction percentages presented in **Table 2-12** will be refined. Please refer to **Appendix C** for additional clarification on the source control effectiveness methodologies.

Table 2-11. BMPs assumed to be implemented for estimates of nutrient load reductions.

Land Use	Citrus	Improved Pastures	Residential and Urban	Dairies	Other agriculture
Watershed Acreage Percentage	9 %	11 %	14 %	0.01 %	23 %
Nutrient Management	*Typical:* • P: Soil testing • N: Use of standard recommendations, e.g., use slow release forms of N. • Split application, e.g., fertigation. • Controlled application (timing & placement, fertigation) • Spill prevention • Includes implementation of domestic wastewater residuals rule	*Typical:* • P: Soil testing • N: Use of standard recommendations, e.g., use slow release forms of N. • Split application, e.g., fertigation. • Spill prevention • Includes implementation of domestic wastewater residuals rule, the animal manure implementation rule, and the septage application rule • Grass management[1] and rotational grazing • Reduced cattle density • Alternate water sources, shade, restricted placement of feeders, supplements, and water, fencing	*Typical:* • Reduced fertilization in accordance with the Urban Turf Fertilizer Rule • Use slow release forms of N. • Split application, e.g., fertigation. • Controlled application (timing & placement) • Spill prevention	*Typical:* • P: Soil testing • Includes implementation of the CAFO rule, • Feed management • Grass management[1] and rotational grazing • Improved forage/sprayfield management - P balanced with high P uptake crop rotations	*Typical:* • P: Soil testing • N: Use of standard recommendations, e.g., use slow release forms of N. • Split application, e.g., fertigation. • Controlled application (timing & placement, fertigation) • Spill prevention • Includes implementation of domestic wastewater residuals rule
Water Management	*Typical:* • Improved Irrigation and Drainage Management • Storm water detention/ retention and water reuse for irrigation • ERP permitted systems	*Typical:* • Operation of existing control structures resulting in moderate wetland restoration • Retention of runoff from working pens by directing away from waterways	*Typical:* • Dry detention swales (0.25 inch) and wet detention (0.25 inch) • Rain gardens	*Typical:* • Improved Irrigation and Drainage Management • Wetland restoration	*Typical:* • Improved Irrigation and Drainage Management • Storm water detention/ retention and water reuse for irrigation • ERP permitted systems
Particulate Matter and Sediment Controls	*Typical:* • Grass management between trees • Sediment traps	Note: Grass management will also apply to particulate matter and sediment controls	*Typical:* • Street sweeping • Sediment traps / baffle boxes	*Typical:* • Buffer strips Note: Grass management and improved forage/sprayfield management will also apply to particulate matter and sediment controls	*Typical:* • Cover crops • Sediment traps

[1] Includes selecting the appropriate grass variety and mowing to ensure healthy and uniform grass coverage.

Table 2-12. Proposed source control nutrient reductions for the sub-watersheds, and their tributaries, of the Caloosahatchee River Watershed.

Basin	Nutrient	Performance Measure (PM) or Performance Indicator (PI)	Base Period	Recommended Source Control Reduction	
S-4 / Industrial Canal	TP	PM	WY1993-2001	30%	
	TN	PM		35%	
East Caloosahatchee	TP	PM	WY1982-1990	30%	
	TN	PM		30%	
West Caloosahatchee	TP	PM	WY1988-1997	30%	
	TN	PM		25%	
			Reference Period	**Target**	**Limit**
Tidal Caloosahatchee	TP	PI	WY2006-2012	10%	15%
	TN	PI		10%	15%
Bayshore Creek	TP	PI	WY2006-2012	24%	24%
	TN	PI		16%	19%
Billy Creek	TP	PI	WY2006-2011	7%	10%
	TN	PI		25%	11%
Chapel Branch	TP	PI	WY2006-2012	11%	13%
	TN	PI		18%	15%
Daughtrey Creek	TP	PI	WY2006-2012	11%	13%
	TN	PI		5%	12%
Deep Lagoon	TP	PI	WY2006-2012	5%	9%
	TN	PI		16%	11%
Hancock Creek	TP	PI	WY2006-2012	6%	9%
	TN	PI		10%	19%
Lower Orange River	TP	PI	WY2006-2012	0%	13%
	TN	PI		11%	14%
Marsh Point	TP	PI	WY2006-2012	6%	9%
	TN	PI		21%	14%
Otter Creek	TP	PI	WY2006-2012	20%	21%
	TN	PI		9%	12%
Owl Creek	TP	PI	WY2006-2012	23%	23%
	TN	PI		9%	22%
Palm Creek	TP	PI	WY2006-2012	20%	20%
	TN	PI		17%	14%
Popash Creek	TP	PI	WY2006-2012	12%	14%
	TN	PI		5%	11%
Powell Creek	TP	PI	WY2006-2012	9%	11%
	TN	PI		16%	18%
SE Cape Coral	TP	PI	WY2006-2012	0%	9%
	TN	PI		3%	24%
Stroud Creek	TP	PI	WY2006-2012	18%	20%
	TN	PI		16%	12%
Telegraph Creek	TP	PI	WY2006-2012	19%	20%
	TN	PI		8%	14%
Trout Creek	TP	PI	WY2006-2012	0%	25%
	TN	PI		17%	13%
Whiskey Creek	TP	PI	WY2006-2012	0%	12%
	TN	PI		0%	33%
Coastal Caloosahatchee	TP	PI	WY2009-2012	0%	0%
	TN	PI		15%	14%
Durden Creek	TP	PI	WY2009-2012	0%	0%
	TN	PI		6%	12%
NW Cape Coral	TP	PI	WY2009-2012	0%	0%
	TN	PI		17%	14%
Sanibel Island	TP	PI	WY2009-2011	0%	0%
	TN	PI		11%	14%
SW Cape Coral	TP	PI	WY2009-2012	0%	0%
	TN	PI		17%	14%

2.5.10 Minimum Sample Size

There is no minimum number of samples for the annual performance determination for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds as water quality for these basins is based on continued collection of data using auto samplers. For the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds, the Wilcoxon Rank Sum approach is used, and a minimum of at least one monthly sample each quarter per tributary, for at least 75 percent of the tributaries, during the Evaluation Year is recommended to properly account for observed seasonal variability.

2.5.11 Exceedance Frequency Analysis

For the sub-watersheds with a load-based performance measure, the last step in the development of the performance measure was to review the results to determine if they were reasonable and defensible compared to theoretical statistical analysis. The performance determination for annual nutrient load is composed of two parts:

1. an Annual Load Target, and
2. an Annual Load Limit.

The cumulative exceedance frequency for the 2-part method is greater than the exceedance frequencies of either of the individual components. An approximation of the cumulative exceedance frequency for the performance determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual nutrient loads of the Base Period. The general approach used is described below.

1. A 10,000-year set of annual rainfall data was created that corresponded to the normal distribution described by the mean and standard deviation of the rainfall (or log-

transformed rainfall if that transformation was used in the regression equation) observed during the Base Period.[8]

2. If the regression equation for the Annual Load Target included the rainfall coefficient of variation, skewness or kurtosis, similar 10,000-year sets of annual values were also created that corresponded to the normal distributions described by the respective mean and standard deviation of those parameters for the Base Period.
3. If the performance determination method includes adjusted rainfall, a 10,000-year set of adjusted rainfall values was then generated.
4. A 10,000-year set of annual residuals was then created that corresponded to the normal distribution of the residuals during the base period. That is, the normal distribution was defined by the mean and standard deviation of the residuals of the loads predicted using the regression equation and the actual loads during the Base Period.
5. 10,000-year sets of Annual Load Targets and Annual Load Limits were then generated using the appropriate equations.
6. A 10,000-year set of annual nutrient loads was generated by adding the calculated annual residual to the calculated Annual Load Target.
7. The 10,000-year set of annual nutrient loads was then compared to the Annual Load Target and the Annual Load Limit, and the cumulative exceedance frequency was calculated.

2.5.12 Annual Performance Determination

The following sections describe the annual performance determination for the basins within the Caloosahatchee River Watershed.

[8] The Excel random number generator was used to populate the 10,000-year synthetic record of annual rainfall values, with the mean and standard deviation matching the Base Period values to within 0.01 inches.

2.5.12.1 Load-Based Performance Determinations

The following section describes the annual performance determination for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds.

Hydrology, specifically discharge and rainfall, is a dominant factor when computing nutrient loads. Because rainfall and discharge are subject to large temporal and spatial variation in south Florida, the performance metric methodology adjusts the nutrient load for hydrologic variability. The adjustment for hydrologic variability includes two components.

1. **A model to estimate future nutrient loads.** The model estimates a future nutrient load from the Base Period rainfall characteristics by substituting future hydrologic conditions, i.e., during the Evaluation Year, for the conditions that occurred during the Base Period. This predicted future nutrient load is based on the regression equation described above, and is referred to as the Annual Load Target.

2. **Accommodation for statistical error in the model.** Statistical error in the model was accounted for by specifying a required level of statistical confidence in the prediction of the long-term average nutrient load. The upper 90 percent confidence limit was selected as reasonable, and is consistent with Chapter 40E-63, F.A.C. This upper confidence limit is referred to as the Annual Load Limit.

Basin runoff nutrient loads discharged at each basin's outlet structures, after accounting for pass-through loads and regional projects, will be assessed annually against the Annual Load Target and the Annual Load Limit, as described below:

- **Annual Load Target: One in three year test.** If a basin's performance is matching expectations, the probability of the observed annual load being above the Annual Load

Target is 50 percent for any given year. Given this assumption, the probability that the load is above the Target for three consecutive years is 12.5 percent (= 0.50 x 0.50 x 0.50). In other words, at an 87.5 percent confidence level, we can infer that the basin achieves its long-term load reduction goal if the observed annual load does not exceed the Annual Load Target for three consecutive years. The use of a three-year cycle for the Annual Load Target is consistent with the District's Chapter 40E-63, F.A.C., and has a theoretical Type I error (i.e., false positive) rate of 12.5 percent[9].

- **Annual Load Limit.** Consistent with the District's Chapter 40E-63, F.A.C., the Annual Load Limit was derived as the upper 90 percent confidence limit above the prediction equation for the Annual Load Target, with an associated theoretical Type I error rate of 10 percent. In deriving the upper 90 percent confidence limit on the Annual Load Target, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the Annual Load Target.

Separate performance determinations will be conducted for TP and TN, although the sequence of steps is similar for both nutrients. Because the performance determinations for the nutrients are carried out independently, the possibility exists that the basin could be determined to achieve the performance metric for one nutrient and not the other. The annual performance determination will be conducted using data collected by Water Year (May 1 through April 30) in accordance with the following steps.

1. The Annual Load Target and Annual Load Limit will be calculated according to the basin-specific equations described in Sections 3.1, 3.2 and 3.3. For TN, the Annual Load Target is set to the greater of two predicted loads, one based on TN and one based on

[9] The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the nutrient load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.

TON, and the Annual Load Limit is set as the upper 90th percent confidence limit above the selected prediction. If the calculated Annual Load Target or Annual Load Limit is negative, a value of 0 will be assigned for the purpose of the performance determination.

2. The Annual Load Target and Annual Load Limit may include an area adjustment factor to account for regional projects. Each basin's Runoff Load is determined as the annual observed discharge load less calculated pass-through load plus load reductions attributable to the regional project. If the calculated Runoff Load is negative, a value of 0 will be assigned for the purpose of the performance determination. Additional details regarding the calculations to account for regional projects are contained in Appendix D. System changes affecting the number or location of inflows and outflows, including regional projects, shall be reflected in updated Annual Load Target, Annual Load Limit, and Runoff Load calculations.

3. If the Runoff Load in the Evaluation Year is less than or equal to the Annual Load Target, then the basin will be determined to have met its performance metric, that is, it will have not exceeded the collective median annual loading that would have occurred during the Base Period, adjusted for hydrologic variability and adjusted for the source control load reduction goal.

4. Extreme rainfall conditions will be assessed by comparing the Evaluation Year's rainfall amount to the range of rainfall observed during the Base Period. In those basins where the regression equation for the Annual Load Target includes more than one predictor variable, an adjusted rainfall amount will be calculated which reflects the cumulative effect of the variables that comprise the load target equation. The annual performance determination will be suspended if the rainfall (or adjusted rainfall) for the Evaluation Year is outside the range observed during the Base Period and the Runoff Load exceeds the Annual Load Target calculated above. There exists the possibility that the

performance determination for one nutrient could be suspended due to extreme rainfall, while the performance determination for the other nutrient is not suspended if the 2^{nd} nutrient's Runoff Load is at or below the respective Annual Load Target. Since the performance determinations for the nutrients are carried out independently, the possibility of conflicting suspension decisions does not adversely affect the overall basin performance determination.

5. If the Runoff Load exceeds the Annual Load Target in three or more consecutive Evaluation Years, and if the annual performance determination is not suspended due to extreme rainfall for the Evaluation Year, the basin will be determined to have not met its performance metric, that is, it will have exceeded the annual nutrient loading that would be expected to occur during the Base Period, adjusted for hydrologic variability and adjusted for the source control load reduction goal. Any Evaluation Year for which the performance determination is suspended will be excluded from the determination of whether the Annual Load Target has been exceeded in three or more consecutive Evaluation Years, and will be replaced by the subsequent year. That is, the basin will exceed its performance metric when the Annual Load Target is exceeded in three consecutive May 1 through April 30 periods, even though the three periods may be interrupted by periods of suspension.

6. If the Runoff Load exceeds the Annual Load Limit in any Evaluation Year, and if the annual performance determination is not suspended due to extreme rainfall for the Evaluation Year, the basin will be determined to have not met its performance metric, that is, it will have exceeded the annual loading that would be expected to occur during the Base Period, adjusted for hydrologic variability and adjusted for the source control load reduction goal.

These steps are depicted in **Figure 1-2.**

2.5.12.2 Concentration-Based Performance Determinations

The performance metric methodologies for the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds include two components.

1. **Comparison to long-term target concentrations.** Implementation of collective source controls within the basins should result in the achievement of desired long-term concentration levels. This desired distribution of nutrient concentrations is referred to as the Annual Concentration Target, and consists of the respective Reference Period's monthly concentrations reduced by an appropriate nutrient reduction goal. Each year, the observed distribution of monthly concentrations within the basins will be compared to the desired distribution of nutrient concentrations (i.e., the Annual Concentration Target), and a determination will be made as to whether the observed values are statistically similar to, or larger than, the desired distribution of nutrient concentrations. Natural variability is inherent in monthly concentrations observed over the twelve months of a water year, and the comparison not only evaluates the relative magnitude of the concentrations, but also the distribution of concentrations over the course of the year. Statistical error in the comparison was accounted for by specifying a required level of statistical confidence. A 95 percent confidence level was selected as reasonable, and is consistent with the 5 percent exceedance frequency associated with the Annual Load Limit of Chapter 40E-63, F.A.C.
2. **Evaluation of extreme conditions.** While monthly variations in nutrient concentrations are normal, it is important to distinguish natural variability from the occurrence of extreme conditions which may indicate a departure from the desired distribution of nutrient concentrations. Each year, the observed monthly concentrations will be compared to the maximum monthly concentration observed during the basin's Reference Period, reduced by an appropriate nutrient reduction goal. This concentration threshold is referred to as the Annual Concentration Limit. Statistical error and other uncertainties in

the comparison were accounted for by selecting both the maximum monthly concentration as the basis for the Annual Concentration Limit and an appropriate source control reduction goal.

For these two sub-watersheds, a monthly composite concentration will be calculated for the entire sub-watershed using individual tributary data measured near each tributary's outlet. TP and TN concentrations will be assessed annually against the Annual Concentration Target and the Annual Concentration Limit, as described below.

- **Annual Concentration Target: One in three year test.** If a basin's performance is matching expectations, the probability of the observed distribution of monthly concentrations being equal to or less than the Annual Concentration Target is 50 percent for any given year. Given this assumption, the probability that the observed concentration distribution is achieving the Target distribution for three consecutive years is 12.5 percent (= 0.50 x 0.50 x 0.50). In other words, at an 87.5 percent confidence level, we can infer that the basin achieves its long-term concentration reduction goal, subject to the Annual Limit test (described below), if the observed annual concentrations are not greater than the Target distribution for three consecutive years. The use of a three-year cycle for the Annual Concentration Target is consistent with the District's Chapter 40E-63, F.A.C., and has a theoretical Type I error (i.e., false positive) rate of 12.5 percent[10].

- **Annual Concentration Limit.** The Annual Concentration Limit was derived as the maximum monthly concentration observed during the Reference Period, reduced by an appropriate nutrient reduction goal. If the basin's monthly concentrations during the

[10] The Type I error rate is the probability that the performance metric methodology will reject the null hypothesis (i.e., a determination that the nutrient concentrations do not meet the performance metric) when in reality the null hypothesis is true – the annual concentrations meets the performance metric, and is therefore also known as the false positive rate.

Evaluation Year do not exceed the Annual Concentration Limit, and if the basin achieves the one-in-three year Target, we can infer that the basin achieves its long-term concentration reduction goal.

Separate performance determinations will be conducted for TP and TN, although the sequence of steps is identical for both nutrients. Because the performance determinations for the nutrients are carried out independently, the possibility exists that the basin could be determined to achieve the performance metric for one nutrient and not the other. The annual nutrient performance determination will be conducted using data collected by water year (May 1 through April 30) in accordance with the following steps:

1. Monthly nutrient concentrations will be monitored at the stations described in Sections 3.4 and 3.5.

2. The basin's Annual Concentration Target and Annual Concentration Limit may include an adjustment to account for regional projects on a case-by-case basis, if applicable. System changes affecting the number or location of inflows and outflows, including regional projects, may be reflected in updated Annual Concentration Target and Annual Concentration Limit calculations.

3. If the distribution of monthly nutrient concentrations in the Evaluation Year is not significantly greater than the Annual Concentration Target, then the basin will be determined to have met the Target component of its performance metric, subject to meeting the Limit test below.

4. Extreme rainfall conditions will be assessed by comparing the Evaluation Year's rainfall amount to the range of rainfall observed during the Reference Period. The annual performance determination will be suspended if the rainfall for the Evaluation Year is outside the range observed during the Reference Period and

   a. the distribution of monthly nutrient concentrations is significantly greater than the Annual Concentration Target, or
   b. the maximum monthly concentration is above the Annual Concentration Limit.

5. If the distribution of monthly nutrient concentrations is significantly greater than the Annual Concentration Target in three or more consecutive Evaluation Years, and if the annual performance determination is not suspended due to extreme rainfall for the Evaluation Year, the basin will be determined to have not met its performance metric. Any Evaluation Year for which the performance determination is suspended will be excluded from the determination of whether the Annual Concentration Target has been exceeded in three or more consecutive Evaluation Years, and will be replaced by the subsequent year. That is, the basin will exceed its performance metric when the Annual Concentration Target is exceeded in three consecutive May 1 through April 30 periods, even though the three periods may be interrupted by periods of suspension.

6. If one monthly concentration exceeds the Annual Concentration Limit in any Evaluation Year, and if the annual performance determination is not suspended due to extreme rainfall for the Evaluation Year, the basin will be determined to have not met its performance metric.

These steps are depicted in **Figure 1-3**. If the sub-watershed performance metrics are not achieved, a performance determination of the tributary-specific performance metrics in **Table 2-12** above would be warranted, and could assist in prioritizing any necessary follow-up actions.

Unmonitored areas. Based on the similarity of land uses, the sub-watershed performance metrics are considered representative of the areas that are not monitored. If the sub-watershed performance metrics are not met, it is anticipated that the rule will indicate trigger actions for unmonitored areas (e.g., synoptic monitoring). The data collected will be used to determine tributary-specific performance metrics, if needed.

3. PERFORMANCE METRIC METHODOLOGIES FOR BASINS OF THE CALOOSAHATCHEE RIVER WATERSHED

The following sections describe the historical water quality data analyses, nutrient reduction goals for the collective source control programs, and development of performance metrics for the sub-watersheds within the Caloosahatchee River Watershed.

3.1 S-4/Industrial Canal Sub-watershed

The following sections present a description of the S-4/Industrial Canal Sub-watershed, a summary of historical flow and nutrient levels, nutrient reduction goals for the collective source control programs, and development of performance metrics.

3.1.1 Background

The S-4/Industrial Canal Sub-watershed consists of 42,145 acres located along the southwest shore of Lake Okeechobee between the East Caloosahatchee Sub-watershed and the Everglades Agricultural Area (**Figure 3-1**). The S-4/Industrial Canal Sub-watershed contains two interconnected sub-basins: S-4 and Industrial Canal. S-169 is a culvert structure that discharges in both directions between the Industrial Canal Sub-basin and the S-4 Sub-basin (**Figure 3-2**). The S-4/Industrial Canal Sub-watershed has four primary structures on its borders:

- S-235 is a culvert that discharges in both directions between S-4/Industrial Canal and the East Caloosahatchee Sub-watersheds;

- S-4 is a pump station that discharges from the S-4/Industrial Canal Sub-watershed to Lake Okeechobee;

Figure 3-1. S-4/Industrial Canal Sub-watershed schematic (from SFWMD).

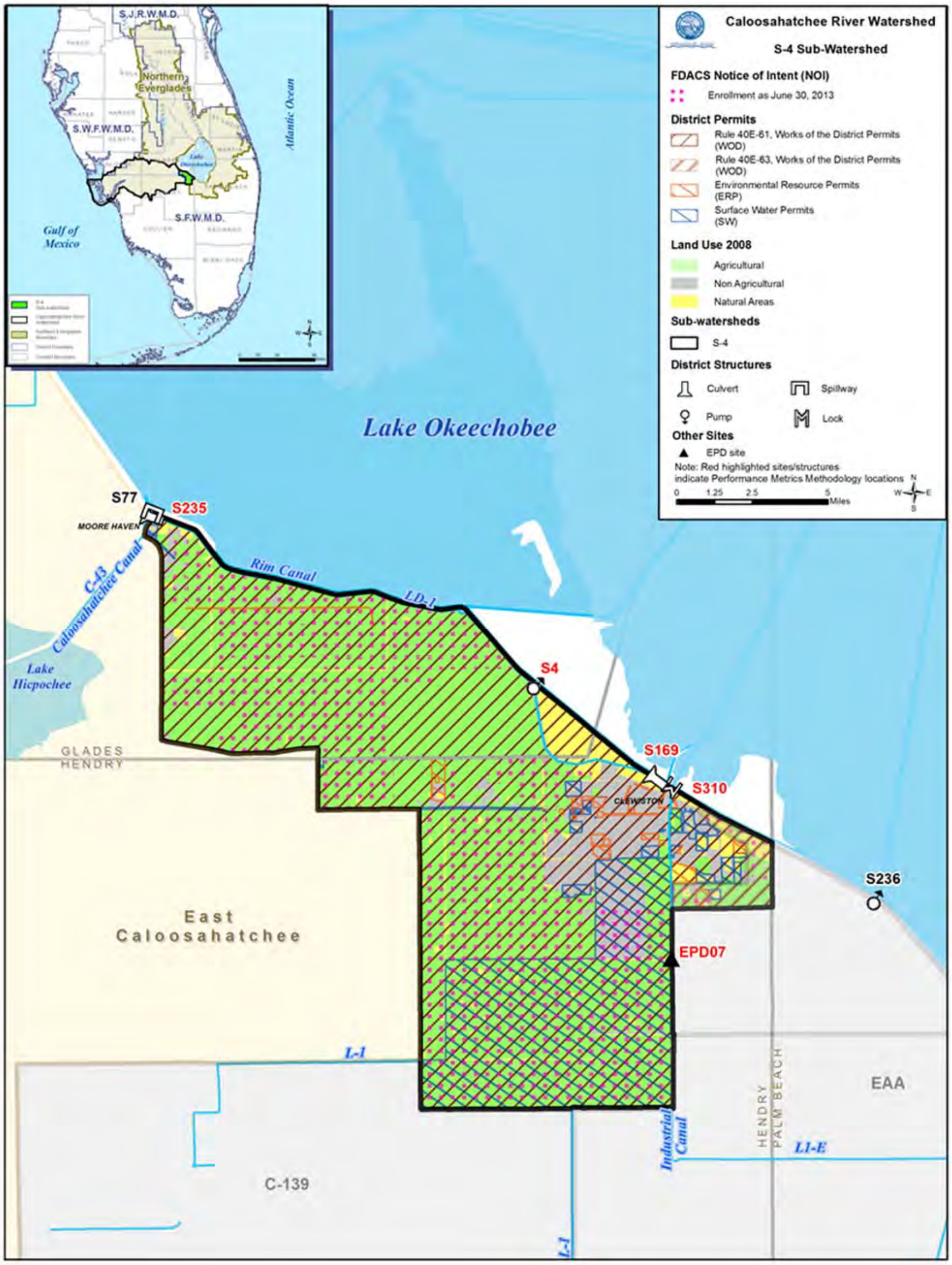
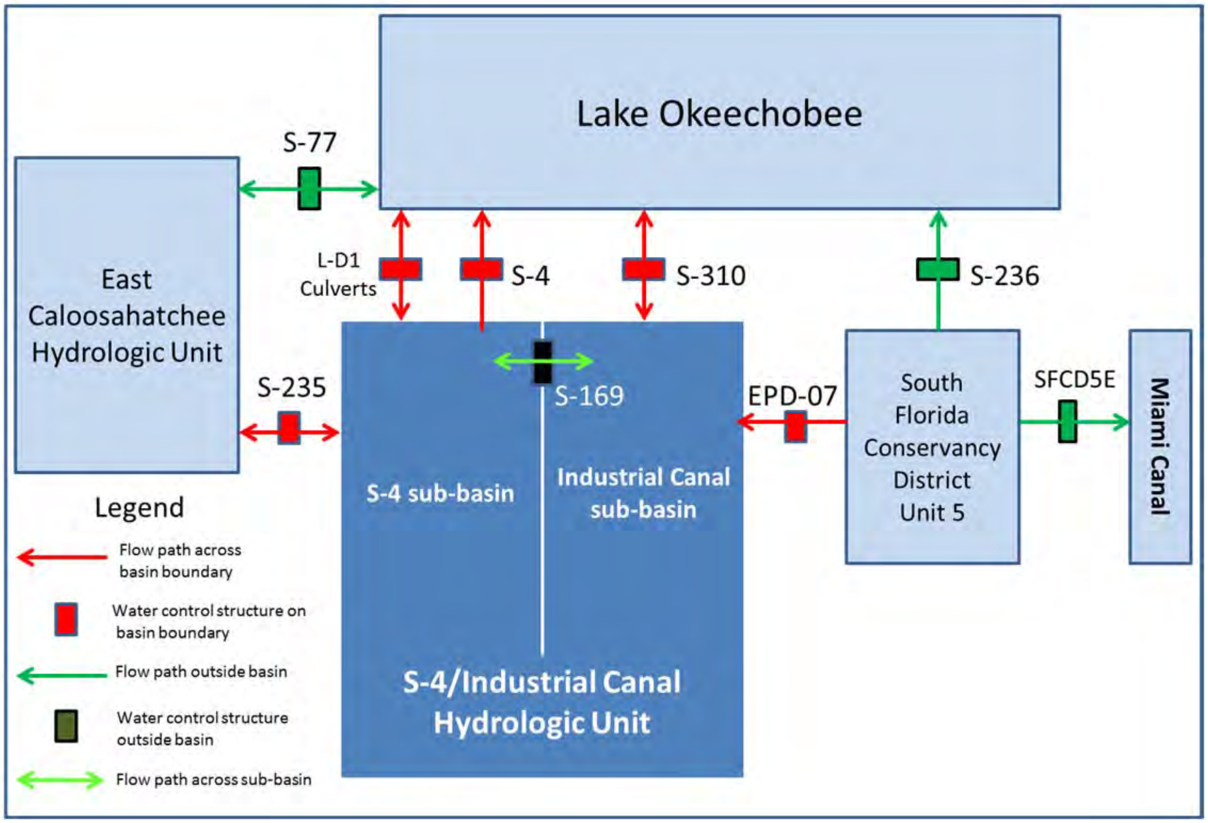

Caloosahatchee River Watershed
S-4 Sub-Watershed
FDACS Notice of Intent (NOI)
Enrollment as June 30, 2013
District Permits
Rule 40E-61, Works of the District Permits (WOD)
Rule 40E-63, Works of the District Permits (WOD)
Environmental Resource Permits (ERP)
Surface Water Permits (SW)
Land Use 2008
Agricultural
Non Agricultural
Natural Areas
Sub-watersheds
S-4
District Structures
Culvert
Spillway
Pump
Lock
Other Sites
EPD site
Note: Red highlighted sites/structures indicate Performance Metrics Methodology locations
0
1.25
2.5
5
Miles
S.J.R.W.M.D.
Northern Everglades
S.W.F.W.M.D.
S.F.W.M.D.
Atlantic Ocean
Gulf of Mexico
Lake Okeechobee
S77
S235
MOORE HAVEN
Rim Canal
LD-1
C-43 Caloosahatchee Canal
Lake Hicpochee
S4
GLADES
HENDRY
S169
S310
CLEWISTON
S236
EPD07
East Caloosahatchee
L-1
Industrial Canal
HENDRY
PALM BEACH
EAA
L1-E
C-139
L-1

Figure 3-2. S-4/Industrial Canal Sub-watershed Flow Schematic.



- S-310 is a boat lock that passes water in both directions between the S-4/Industrial Canal Sub-watershed and Lake Okeechobee when lake stages are below 15.5 feet, NGVD (the gate is closed when the lake stage is above 15.5 ft NGVD, from SFWMD Structure Books); and

- EPD-07 is a pump station that discharges excess water from the South Florida Conservancy District (SFCD) Unit 5 in the South Lake Okeechobee Sub-watershed to Industrial Canal[11]. In August 2005, new facilities became operational that enabled the

[11] Nitrogen species are not collected at this structure, so data from S-236, located on the same canal as EPD-07, is used as a surrogate.

diversion of a long-term average annual 80 percent of the SFCD Unit 5 drainage away from Lake Okeechobee as required by the Everglades Forever Act (Burns & McDonnell, 2008).

Flow and water quality data from these stations were used to calculate the annual nutrient loads used in the development of the performance metric (flow and nutrient monitoring sites are identified in **Tables B-1** and **B-2**).

Other structures that discharge to and from the S-4/Industrial Canal Sub-watershed are

- the LD-1 culverts (C-1, C-1A, and C-2 – discharge to/from Lake Okeechobee). The LD-1 Culverts normally remain closed. However, when Lake Okeechobee stages fall below 13.0 ft NGVD, they are opened to assist in equalizing water levels between the lake and the LD-1 Canal. Since S-310 is also fully opened during these conditions, it is likely that flow through these culverts is not significant.
- the Disston Island Conservancy District (DICD) Pump Station No. 3 (DICD3) - discharges to and from the East Caloosahatchee Sub-watershed. DICD3 has a rated capacity of only 178 cfs. According to Wayne Smith (Superintended of the DICD - personal communication July 1, 2010), the pump station services a small portion of the DICD and is not used frequently.

No discharge records are available for these structures. However, based on the above information, it is assumed that the nutrient loads discharged from these structures are not significant. S-235, S-4, S-310, and EPD-07 are the primary structures representing inflows and outflows of the sub-watershed, and therefore, the LD-1 Culverts and DICD3 are not addressed in this performance metric.

The historical data analysis for the S-4/Industrial Canal Sub-watershed summarized herein was initially prepared by HDR Engineering, Inc. as part of Contract No. ST061298 – WO08 (Data Analysis and Performance Measure Development for the St. Lucie and the Caloosahatchee River

Source Control Programs) with the District (HDR 2011) and was supplemented in collaboration with staff under this contract.

The performance metric methodology is based on flows and nutrient loads (TP, TN and TON) in runoff from the S-4/Industrial Canal Sub-watershed. Basin flows and loads, adjusted for pass-through flows and loads discharged from external sources, were calculated using algorithms provided in **Appendix A**. District staff identified the rainfall stations considered to be representative of the sub-watershed for the period WY1976-2010. Monthly rainfall data and weighting factors for the rainfall stations were developed and provided by the District. Annual basin flow and nutrient data for discharges from the S-4/Industrial Canal Sub-watershed for the WY1993-2010 period of record are summarized in **Tables 3-1** through **3-3**.

Table 3-1. Summary of historical TP data for the S-4/Industrial Canal Sub-watershed.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1992				38.80			-0.934	0.534	0.308
1993	106,756	17.622	134	46.54	30.40	0.92	5.558	1.235	2.175
1994	71,896	7.485	84	33.83	20.47	0.39	-0.994	0.576	0.302
1995	101,775	23.532	187	58.12	28.98	1.23	1.402	0.620	1.328
1996	129,326	23.440	147	53.38	36.82	1.23	-0.552	0.864	0.763
1997	88,818	10.278	94	38.13	25.29	0.54	-0.733	0.801	0.566
1998	114,857	16.179	114	54.22	32.70	0.85	1.039	0.763	1.007
1999	78,842	20.649	212	34.48	22.45	1.08	1.398	1.225	1.449
2000	131,064	28.655	177	58.34	37.32	1.50	3.871	1.133	1.733
2001	36,636	6.888	152	34.30	10.43	0.36	-0.615	1.006	0.803
2002	47,396	11.258	193	43.78	13.50	0.59	-1.095	0.783	0.660
2003	94,857	20.933	179	42.96	27.01	1.10	1.878	0.923	1.586
2004	88,864	15.699	143	36.98	25.30	0.82	-0.432	0.696	0.239
2005	110,534	22.510	165	40.47	31.47	1.18	0.269	0.927	1.109
2006	113,392	30.280	216	48.63	32.29	1.58	-0.372	0.930	0.786
2007	25,621	6.906	219	24.83	7.30	0.36	-0.052	1.079	1.130
2008	15,712	4.519	233	36.52	4.47	0.24	-1.578	0.683	0.255
2009	48,116	16.153	272	30.54	13.70	0.84	0.181	1.128	1.064
2010	109,247	21.455	159	56.29	31.11	1.12	-1.709	0.679	-0.137
Minimum	*15,712*	*4.519*	*84*	*24.83*	*4.47*	*0.24*	*-1.709*	*0.576*	*-0.137*
Average	*84,095*	*16.913*	*163*	*42.91*	*23.94*	*0.88*	*0.415*	*0.892*	*0.934*
Maximum	*131,064*	*30.280*	*272*	*58.34*	*37.32*	*1.58*	*5.558*	*1.235*	*2.175*
Std. Dev.	*35,596*	*7.697*	*49*	*10.13*	*10.14*	*0.40*	*1.887*	*0.208*	*0.588*
Skewness	*-0.618*	*-0.039*	*0.082*	*0.130*	*-0.618*	*-0.04*	*1.518*	*0.229*	*0.226*
Median	*91,861*	*16.901*	*171*	*41.72*	*26.16*	*0.88*	*-0.212*	*0.894*	*0.905*

Note: The FWM TP concentration was calculated by dividing the annual TP load by the annual flow.

Table 3-2. Summary of historical TN data for the S-4/Industrial Canal Sub-watershed.

Water Year	Flow AF	TN Load mt	FWM TN Conc µg/L	Rainfall inches	Unit Area Runoff inches	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1993	106,756	284.176	2,158	46.54	30.40	14.87	5.558	1.235	2.175
1994	71,896	192.678	2,173	33.83	20.47	10.08	-0.994	0.576	0.302
1995	101,775	353.531	2,816	58.12	28.98	18.49	1.402	0.620	1.328
1996	129,326	432.129	2,709	53.38	36.82	22.60	-0.552	0.864	0.763
1997	88,818	245.164	2,238	38.13	25.29	12.82	-0.733	0.801	0.566
1998	114,857	374.645	2,644	54.22	32.70	19.60	1.039	0.763	1.007
1999	78,842	261.203	2,686	34.48	22.45	13.66	1.398	1.225	1.449
2000	131,064	424.730	2,627	58.34	37.32	22.22	3.871	1.133	1.733
2001	36,636	108.764	2,407	34.30	10.43	5.69	-0.615	1.006	0.803
2002	47,396	160.680	2,748	43.78	13.50	8.41	-1.095	0.783	0.660
2003	94,857	298.533	2,551	42.96	27.01	15.62	1.878	0.923	1.586
2004	88,864	295.763	2,698	36.98	25.30	15.47	-0.432	0.696	0.239
2005	110,534	363.490	2,666	40.47	31.47	19.01	0.269	0.927	1.109
2006	113,392	333.888	2,387	48.63	32.29	17.47	-0.372	0.930	0.786
2007	25,621	81.387	2,575	24.83	7.30	4.26	-0.051	1.079	1.131
2008	15,712	51.394	2,652	36.52	4.47	2.69	-1.578	0.683	0.255
2009	48,116	174.291	2,937	30.54	13.70	9.12	0.181	1.128	1.064
2010	109,247	383.043	2,842	56.29	31.11	20.04	-1.709	0.679	-0.137
Minimum	***15,712***	***51.394***	***2,158***	***24.83***	***4.47***	***2.69***	***-1.709***	***0.576***	***-0.137***
Average	***84,095***	***267.749***	***2,581***	***42.91***	***23.94***	***14.01***	***0.415***	***0.892***	***0.934***
Maximum	***131,064***	***432.129***	***2,937***	***58.34***	***37.32***	***22.60***	***5.558***	***1.235***	***2.175***
Std. Dev.	***35,596***	***116.943***	***226***	***10.13***	***10.14***	***6.12***	***1.887***	***0.208***	***0.588***
Skewness	***-0.618***	***-0.421***	***-0.675***	***0.130***	***-0.618***	***-0.42***	***1.518***	***0.229***	***0.226***
Median	***91,861***	***289.970***	***2,648***	***41.72***	***26.16***	***15.17***	***-0.212***	***0.894***	***0.905***

Note: The FWM TN concentration was calculated by dividing the annual TN load by the annual flow.

Table 3-3. Summary of historical TON data for the S-4/Industrial Canal Sub-watershed.

Water Year	Flow AF	TON Load mt	FWM TON Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1993	106,756	187.585	1,425	46.54	30.40	9.81	5.558	1.235	2.175
1994	71,896	143.582	1,619	33.83	20.47	7.51	-0.994	0.576	0.302
1995	101,775	189.804	1,512	58.12	28.98	9.93	1.402	0.620	1.328
1996	129,326	311.660	1,954	53.38	36.82	16.30	-0.552	0.864	0.763
1997	88,818	207.894	1,898	38.13	25.29	10.87	-0.733	0.801	0.566
1998	114,857	280.749	1,982	54.22	32.70	14.69	1.039	0.763	1.007
1999	78,842	175.391	1,803	34.48	22.45	9.17	1.398	1.225	1.449
2000	131,064	278.060	1,720	58.34	37.32	14.55	3.871	1.133	1.733
2001	36,636	90.945	2,012	34.30	10.43	4.76	-0.615	1.006	0.803
2002	47,396	102.236	1,749	43.78	13.50	5.35	-1.095	0.783	0.660
2003	94,857	204.099	1,744	42.96	27.01	10.68	1.878	0.923	1.586
2004	88,864	189.629	1,730	36.98	25.30	9.92	-0.432	0.696	0.239
2005	110,534	198.858	1,459	40.47	31.47	10.40	0.269	0.927	1.109
2006	113,392	220.848	1,579	48.63	32.29	11.55	-0.372	0.930	0.786
2007	25,621	58.121	1,839	24.83	7.30	3.04	-0.052	1.079	1.130
2008	15,712	34.064	1,758	36.52	4.47	1.78	-1.578	0.683	0.255
2009	48,116	92.452	1,558	30.54	13.70	4.84	0.181	1.128	1.064
2010	109,247	249.561	1,852	56.29	31.11	13.05	-1.709	0.679	-0.137
Minimum	***15,712***	***34.064***	***1,425***	***24.83***	***4.47***	***1.78***	***-1.709***	***0.576***	***-0.137***
Average	***84,095***	***178.641***	***1,722***	***42.91***	***23.94***	***9.34***	***0.415***	***0.892***	***0.934***
Maximum	***131,064***	***311.660***	***2,012***	***58.34***	***37.32***	***16.30***	***5.558***	***1.235***	***2.175***
Std. Dev.	***35,596***	***78.470***	***177***	***10.13***	***10.14***	***4.10***	***1.887***	***0.208***	***0.588***
Skewness	***-0.618***	***-0.232***	***-0.182***	***0.130***	***-0.618***	***-0.23***	***1.518***	***0.229***	***0.226***
Median	***91,861***	***189.717***	***1,747***	***41.72***	***26.16***	***9.92***	***-0.212***	***0.894***	***0.905***

Note: The FWM TON concentration was calculated by dividing the annual TON load by the annual flow.

For the development of the TP and TN performance metric methodologies, a Base Period of WY1993-2001 was selected for the following reasons.

- Reliable water quality and flow data are available. Flow data from all stations were not available in previous water years.
- It represents a period of relatively constant land use practices.
- It contained a reasonably wide range of hydrologic conditions.
- A strong correlation exists between annual nutrient loads and rainfall, allowing for a performance metric methodology that explicitly incorporates hydrologic variability.

- It represents a period with initial implementation of source controls.

- The diversions from the adjacent Chapter 298 District into the sub-watershed that began in WY2006 had no noticeable effect on the sub-watershed runoff and nutrient runoff load due to the pass-through algorithm used to account for these external inflows.

The Base Period is compared to the historical period of record and WY2001-2010 in **Tables 3-4** through **3-6** for TP, TN and TON respectively**.** This comparison is provided to identify the differences between the Base Period annual rainfall, flows and nutrient levels compared to the entire period of record and compared to a recent ten-year period. The implementation of source controls in a basin subsequent to the Base Period should result in lower levels of nutrients when compared against both the period of record and recent ten-year period.

Table 3-4. Comparison of Base Period with period of record and WY2001-2010 TP data for the S-4/Industrial Canal Sub-watershed.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1993-2010					
Annual Minimum	15,712	4.519	84	24.83	0.24
Annual Average	84,095	16.919	163	42.91	0.89
Annual Median	91,861	16.901	171	41.72	0.88
Annual Maximum	131,064	30.280	272	58.34	1.58
Preliminary Base Period WY1993-2001					
Annual Minimum	36,636	6.888	84	33.83	0.36
Annual Average	95,552	17.192	146	45.70	0.90
Annual Median	101,775	17.622	147	46.54	0.92
Annual Maximum	131,064	28.655	212	58.34	1.50
Difference between Period of Record and Base Period					
Annual Minimum	-20,924	-2.369	0	-9.00	-0.12
Annual Average	-11,457	-0.273	17	-2.80	-0.01
Annual Median	-9,915	-0.721	24	-4.83	-0.04
Annual Maximum	0	1.625	60	0.00	0.09
Annual Minimum	-57%	-34%	0%	-27%	-34%
Annual Average	-12%	-2%	12%	-6%	-2%
Annual Median	-10%	-4%	16%	-10%	-4%
Annual Maximum	0%	6%	28%	0%	6%
WY2001-2010					
Annual Minimum	15,712	4.519	143	24.83	0.24
Annual Average	69,038	15.671	184	39.53	0.82
Annual Median	68,490	15.926	186	38.73	0.83
Annual Maximum	113,392	30.280	272	56.29	1.58
Difference between WY2001-2010 and Base Period					
Annual Minimum	-20,924	-2.369	59	-9.00	-0.12
Annual Average	-26,515	-1.522	38	-6.17	-0.08
Annual Median	-33,285	-1.696	39	-7.82	-0.09
Annual Maximum	-17,672	1.625	60	-2.05	0.09
Annual Minimum	-57%	-34%	70%	-27%	-34%
Annual Average	-28%	-9%	26%	-14%	-9%
Annual Median	-33%	-10%	27%	-17%	-10%
Annual Maximum	-13%	6%	28%	-4%	6%

Table 3-5. Comparison of Base Period with period of record and WY2001-2010 TN data for the S-4/Industrial Canal Sub-watershed.

Metric	Flow AF	TN Load mt	TN Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1993-2010					
Annual Minimum	15,712	51.394	2,158	24.83	2.69
Annual Average	84,095	267.749	2,581	42.91	14.01
Annual Median	91,861	289.970	2,648	41.72	15.17
Annual Maximum	131,064	432.129	2,937	58.34	22.60
Preliminary Base Period WY1993-2001					
Annual Minimum	36,636	108.764	2,158	33.83	5.69
Annual Average	95,552	297.447	2,524	45.70	15.56
Annual Median	101,775	284.176	2,627	46.54	14.87
Annual Maximum	131,064	432.129	2,816	58.34	22.60
Difference between Period of Record and Base Period					
Annual Minimum	-20,924	-57.370	0	-9.00	-3.00
Annual Average	-11,457	-29.697	58	-2.80	-1.55
Annual Median	-9,915	5.793	21	-4.83	0.30
Annual Maximum	0	0.000	121	0.00	0.00
Annual Minimum	-57%	-53%	0%	-27%	-53%
Annual Average	-12%	-10%	2%	-6%	-10%
Annual Median	-10%	2%	1%	-10%	2%
Annual Maximum	0%	0%	4%	0%	0%
WY2001-2010					
Annual Minimum	15,712	51.394	2,387	24.83	2.69
Annual Average	69,038	225.123	2,644	39.53	11.78
Annual Median	68,490	235.027	2,659	38.73	12.29
Annual Maximum	113,392	383.043	2,937	56.29	20.04
Difference between WY2001-2010 and Base Period					
Annual Minimum	-20,924	-57.370	229	-9.00	-3.00
Annual Average	-26,515	-72.323	120	-6.17	-3.78
Annual Median	-33,285	-49.149	32	-7.82	-2.57
Annual Maximum	-17,672	-49.086	121	-2.05	-2.57
Annual Minimum	-57%	-53%	11%	-27%	-53%
Annual Average	-28%	-24%	5%	-14%	-24%
Annual Median	-33%	-17%	1%	-17%	-17%
Annual Maximum	-13%	-11%	4%	-4%	-11%

Table 3-6. Comparison of Base Period with period of record and WY2001-2010 TON data for the S-4/Industrial Canal Sub-watershed.

Metric	Flow AF	TON Load mt	TON Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1993-2010					
Annual Minimum	15,712	34.064	1,425	24.83	1.78
Annual Average	84,095	178.641	1,722	42.91	9.34
Annual Median	91,861	189.717	1,747	41.72	9.92
Annual Maximum	131,064	311.660	2,012	58.34	16.30
Base Period WY1993-2001					
Annual Minimum	36,636	90.945	1,425	33.83	4.76
Annual Average	95,552	207.297	1,759	45.70	10.84
Annual Median	101,775	189.804	1,803	46.54	9.93
Annual Maximum	131,064	311.660	2,012	58.34	16.30
Difference between Period of Record and Base Period					
Annual Minimum	-20,924	-56.881	0	-9.00	-2.98
Annual Average	-11,457	-28.656	-37	-2.80	-1.50
Annual Median	-9,915	-0.088	-57	-4.83	0.00
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	-57%	-63%	0%	-27%	-63%
Annual Average	-12%	-14%	-2%	-6%	-14%
Annual Median	-10%	0%	-3%	-10%	0%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	15,712	34.064	1,459	24.83	1.78
Annual Average	69,038	144.081	1,692	39.53	7.54
Annual Median	68,490	145.933	1,747	38.73	7.63
Annual Maximum	113,392	249.561	2,012	56.29	13.05
Difference between WY2001-2010 and Base Period					
Annual Minimum	-20,924	-56.881	34	-9.00	-2.98
Annual Average	-26,515	-63.215	-67	-6.17	-3.31
Annual Median	-33,285	-43.872	-57	-7.82	-2.29
Annual Maximum	-17,672	-62.099	0	-2.05	-3.25
Annual Minimum	-57%	-63%	2%	-27%	-63%
Annual Average	-28%	-30%	-4%	-14%	-30%
Annual Median	-33%	-23%	-3%	-17%	-23%
Annual Maximum	-13%	-20%	0%	-4%	-20%

3.1.1.1 TP Trend. Using the approach described in Section 2.5.4, a series of regression equations were evaluated to determine which one best described the hydrologic variability of the Base Period annual TP load. The predicted annual TP loads derived from the Base Period data using a 0 percent load reduction were calculated according to the following equation and explanation.

$$\text{TP Annual Load} = -20.89832 + 0.59219\ X + 12.06646\ C$$

Explained Variance = 76.2%, Standard Error of Regression = 4.323 mt

Predictors (X and C) are calculated from the first two moments (m_1, m_2) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

$m_1 = \text{Sum}\ [\ r_i\ ]\ /\ 12$

$m_2 = \text{Sum}\ [\ r_i - m_1\ ]^2\ /\ 12$

X = the 12-month total rainfall (inches) = 12 m_1

C = coefficient of variation calculated from 12 monthly rainfall totals

$C = [\ (12/11)\ m_2]^{0.5}/m_1$

The first predictor (X) indicates that load increases with the total annual rainfall. The second predictor (C) indicates that the load resulting from a given annual rainfall is higher when the distribution of monthly rainfall has higher variability. For a given annual rainfall, the lowest load would be predicted when rainfall was evenly distributed across months and the highest load would be predicted when all of the rain fell in one month. Real cases are likely to fall in between.

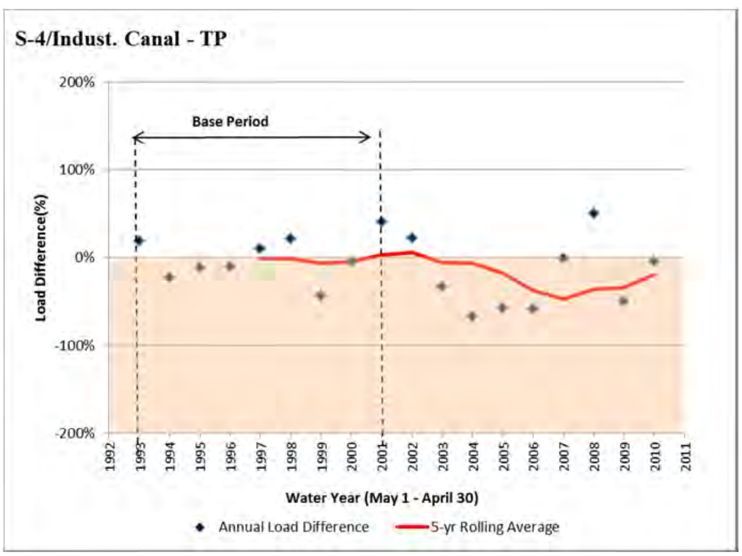
Table 3-7 presents the annual observed and predicted sub-watershed TP loads. The load trend is presented in **Figure 3-3**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-3** denotes a reduction in loads.

Table 3-7. WY1993 – WY2010 S-4/Industrial Canal Sub-watershed TP measurements and calculations. (Base Period: WY1993-2001).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1993	46.54	17.622	21.564	18%	
1994	33.83	7.485	6.086	-23%	
1995	58.12	23.532	21.001	-12%	
1996	53.38	23.44	21.138	-11%	
1997	38.13	10.278	11.347	9%	-2%
1998	54.22	16.179	20.417	21%	-1%
1999	34.48	20.649	14.302	-44%	-7%
2000	58.34	28.655	27.321	-5%	-5%
2001	34.30	6.888	11.553	40%	3%
2002	43.78	11.258	14.476	22%	5%
2003	42.96	20.933	15.679	-34%	-6%
2004	36.98	15.699	9.399	-67%	-6%
2005	40.47	22.51	14.253	-58%	-18%
2006	48.63	30.28	19.122	-58%	-38%
2007	24.83	6.906	6.825	-1%	-48%
2008	36.52	4.519	8.970	50%	-36%
2009	30.54	16.153	10.798	-50%	-34%
2010	56.29	21.559	20.629	-5%	-20%

Note: Predicted load represents the base period load adjusted for rainfall variability

Figure 3-3. S-4/Industrial Canal Sub-watershed TP load trend.



Note: A positive load difference denotes a reduction in load in comparison to the base period.
An upward trend in the solid line denotes a reduction in loads.

3.1.1.2 TN Trend. Using the approach described in Section 2.5.4, a series of regression equations were evaluated to determine which one best described the hydrologic variability of the Base Period annual TN load. The predicted annual TN loads derived from the Base Period data using a 0 percent load reduction were calculated according to the following equation and explanation.

$$\text{TN Annual Load} = -1251.25618 + 407.82192\ X$$

Explained Variance = 79.5%, Standard Error of Regression = 52.508 mt

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m_1 = Sum [r_i] / 12

X = the natural logarithm of the 12-month total rainfall (inches) = ln(12 m_1)

The predictor (X) indicates that TN load increases with total annual rainfall.

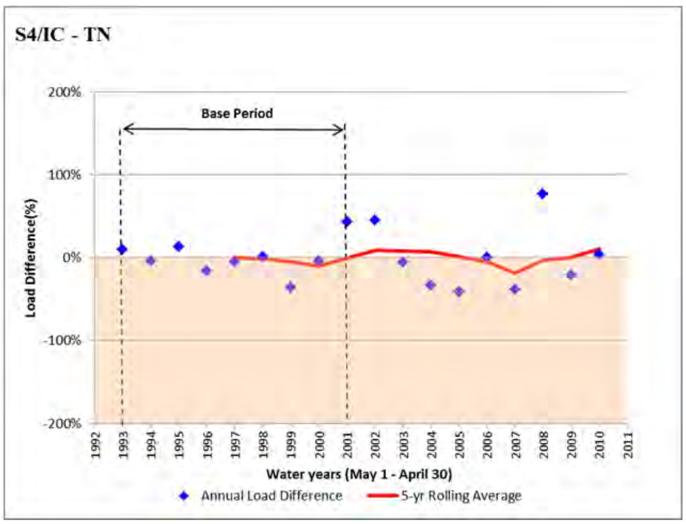
Table 3-8 presents the annual observed and predicted sub-watershed TN loads. The load trend is presented in **Figure 3-4**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-4** denotes a reduction in loads.

Table 3-8. WY1993 – WY2010 S-4/Industrial Canal Sub-watershed TN measurements and calculations. (Base Period: WY1993-2001).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1993	46.54	284.176	314.906	10%	
1994	33.83	192.678	184.828	-4%	
1995	58.12	353.531	405.524	13%	
1996	53.38	432.129	370.831	-17%	
1997	38.13	245.164	233.623	-5%	0%
1998	54.22	374.645	377.197	1%	-2%
1999	34.48	261.203	192.588	-36%	-6%
2000	58.34	424.73	407.066	-4%	-10%
2001	34.30	108.764	190.455	43%	-1%
2002	43.78	160.68	289.976	45%	9%
2003	42.96	298.533	282.264	-6%	8%
2004	36.98	295.763	221.136	-34%	7%
2005	40.47	363.49	257.913	-41%	1%
2006	48.63	333.888	332.822	0%	-5%
2007	24.83	81.387	58.688	-39%	-19%
2008	36.52	51.394	216.030	76%	-4%
2009	30.54	174.291	143.103	-22%	0%
2010	56.29	379.403	392.478	3%	11%

Note: Predicted load represents the base period load adjusted for rainfall variability

Figure 3-4. S-4/Industrial Canal Sub-watershed TN load trend.



Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

3.1.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the S-4/Industrial Canal Sub-watershed.

3.1.2.1 Total Phosphorus Performance Metric Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.5, the overall range of TP load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 30 percent was determined to be reasonable and appropriate. Details are provided in **Appendix C**.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 30 percent load reduction. The Annual Load Target and Annual Load Limit will be calculated according to the following equations and explanation:

TP Annual Load Target = -14.62787 + 0.41452 X + 8.44621 C

Explained Variance = 76.2%, Standard Error of Regression = 3.026 mt

Predictors (X and C) are calculated from the first two moments (m_1, m_2) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m_1 = Sum [r_i] / 12

m_2 = Sum [r_i - m_1]^2 / 12

X = 12 m_1

C = [(12/11) m_2] $^{0.5}$/m_1

TP Annual Load Limit = Target + 1.43976 SE

SE = standard error of the Target for May-April interval

$$SE = 3.02608 [1 + 1/9 + 0.00112 (X-X_m)^2 + 2.03794 (C–C_m)^2 + 0.00884 (X-X_m) (C–C_m)]^{0.5}$$

Where:

X = the 12-month total rainfall (inches)

C = coefficient of variation calculated from 12 monthly rainfall totals

X_m = average value of the predictor in base period = 45.704 inches

C_m = average value of the predictor in base period = 0.91367

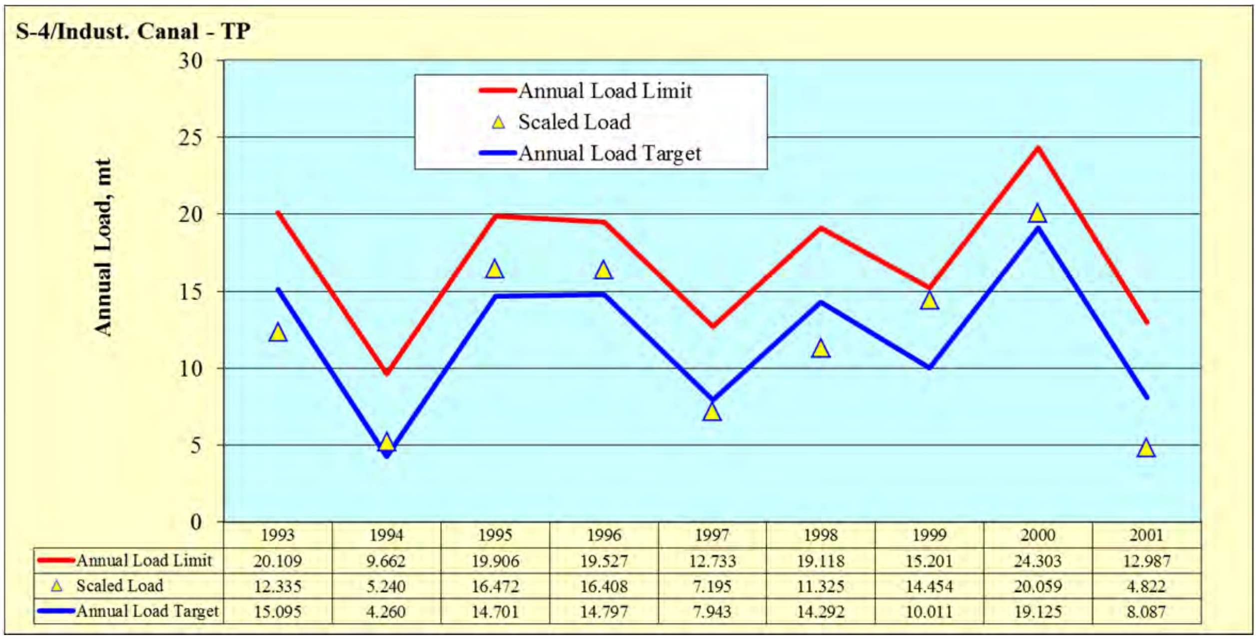
The first predictor (X) indicates that load increases with the total annual rainfall. The second predictor (C) indicates that the load resulting from a given annual rainfall is higher when the distribution of monthly rainfall has higher variability. For a given annual rainfall, the lowest load would be predicted when rainfall was evenly distributed across months and the highest load would be predicted when all of the rain fell in one month. Real cases are likely to fall in between.

A comparison of the scaled loads and the resulting Targets and Limits for the Base Period are presented in **Figure 3-5.** Annual TP loads at the sub-watershed outlet structures, adjusted to account for pass-through loads and regional projects (as applicable) as described in Appendices A and D, respectively, will be evaluated against the performance measure described above.

3.1.2.1.1 Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load, adjusted for regional projects (if present), from the basin exceeds the Annual Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (26.95 – 62.81 inches), as derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall amount which reflects the cumulative effect of the predictor variables of the Annual Load Target equation. The adjusted rainfall is the rainfall that would produce the equivalent annual load using the Annual Load Target equation by setting the value of C to its mean value for the calibration period.

$$\text{Adjusted Rain} = X + 20.37588\,(C - 0.91367)$$

Figure 3-5. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the S-4/Industrial Canal Sub-watershed.



The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1993-2010 period of record are summarized in **Table 3-9**. The performance determination for TP may be suspended for some water years when the TN performance determination is not suspended due to two reasons:

1. the suspension of the performance determination for TP is based on adjusted rainfall, where the TN performance determination is based on observed rainfall, and
2. there may be years when the observed TP load is below the TP Annual Load Target while the observed TN load may be above the TN Annual Load Target.

Since the performance determinations for the nutrients are carried out independently, the possibility of conflicting suspension decisions does not adversely affect the overall basin performance determination.

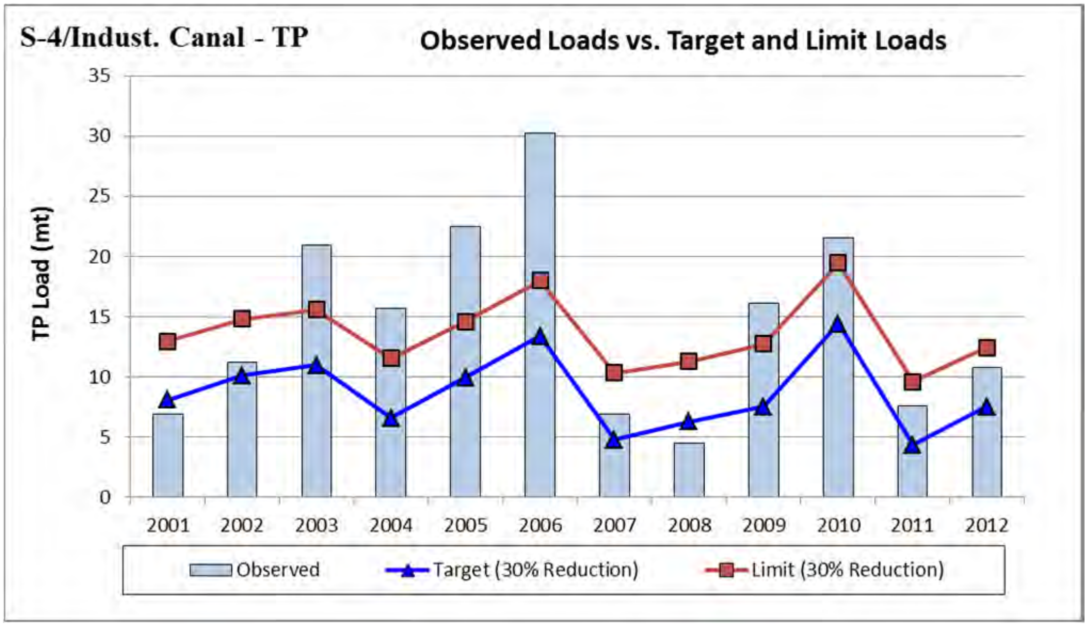
The annual performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

3.1.2.1.2 Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-6**.

Table 3-9. TP Annual Load Targets and Limits for the historical period of record for the S-4/Industrial Canal Sub-watershed (Base Period: WY1993-2001).

Water Year	Observed Load, mt	Rain in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1993	17.622	46.54	1.235	15.095	20.110	53.09
1994	7.485	33.83	0.576	4.260	9.661	26.95
1995	23.532	58.12	0.620	14.701	19.906	52.14
1996	23.440	53.38	0.864	14.797	19.527	52.37
1997	10.278	38.13	0.801	7.943	12.733	35.83
1998	16.179	54.22	0.763	14.292	19.119	51.15
1999	20.649	34.48	1.225	10.011	15.201	40.82
2000	28.655	58.34	1.133	19.125	24.303	62.81
2001	6.888	34.30	1.006	8.087	12.987	36.18
2002	11.258	43.78	0.783	10.133	14.810	41.12
2003	20.933	42.96	0.923	10.976	15.586	43.15
2004	15.699	36.98	0.696	6.580	11.566	32.54
2005	22.510	40.47	0.927	9.977	14.632	40.74
2006	30.280	48.63	0.930	13.385	17.999	48.96
2007	6.906	24.83	1.079	4.778	10.331	28.20
2008	4.519	36.52	0.683	6.279	11.309	31.82
2009	16.153	30.54	1.128	7.559	12.776	34.91
2010	21.559	56.29	0.679	14.440	19.459	51.51
2011	7.603	28.86	0.833	4.371	9.625	27.22
2012	10.818	33.94	0.960	7.549	12.451	34.88

Figure 3-6. Comparison of WY2001-2010 TP loads with Annual Load Targets and Limits for the S-4/Industrial Canal Sub-watershed.



Note: The Base Period extended from WY1993-2001.

3.1.2.1.3 Exceedance Frequency Analysis. As shown in **Figure 3-5,** although the scaled observed loads fall above the Annual Load Target roughly half the time (five out of nine years, or 55 percent), three of these exceedances occur in successive years. In accordance with the proposed performance determination process discussed in Section 2.5.12, three successive years when the observed load exceeds the Annual Load Target would prevent the basin from meeting its performance measure. In the case of the scaled Base Period data, this is an example of a Type I error[12], or "false positive" - when the performance method suggests a lack of compliance when the basin's load actually achieves the long-term reduction goals. The use of a three-year cycle for the Annual Load Target is consistent with the District's Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of 12.5 percent. Using the approach described in

[12] The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.

Section 2.5.11, an approximation of the cumulative exceedance frequency for the performance determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP loads of the Base Period (**Table 3-10**). Because the TP loads and rainfall statistics from the Base Period do not perfectly describe normal distributions (e.g., the medians are generally less than the means), the methodology includes conditional probabilities, and because the random number generator is imperfect, the exceedance frequencies deviate from the theoretical values shown in the second column. However, the results are determined to be reasonable and defensible since the cumulative exceedance frequency is less than the theoretical value of approximately 17.5 percent.

Table 3-10. Exceedance frequencies for the proposed TP performance determination methodology for the S-4/Industrial Canal Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if $Rain_{adj}$ is outside the range and Load > Annual Load Target	<20%	5.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.2%
Step 4. Load > Annual Load Limit?	<10%	3.0%
Cumulative Exceedance Frequency	**<17.5%**	**13.4%**

3.1.2.2 Total Nitrogen Performance Metric Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.5, the overall range of TN load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 35 percent was determined to be reasonable and appropriate. In addition, a threshold of 90 percent of the TON load was established to ensure that estimates of TN reductions do not go beyond what could be reasonably expected from source controls on anthropogenic activities. Details are provided in Appendix C and in Attachment 1.

3.1.2.2.1 TN-based Prediction Equations

A TN-based load prediction equation and an associated 90th percent upper confidence limit (UCL) were derived from the Base Period TN data using a 35 percent reduction.

TN-based Prediction = -813.31466 + 265.08379 X

Explained Variance = 80%, Standard Error of Regression = 34.131 mt

Predictor (X) is calculated from the first two moment (m_1) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m_1 = Sum [r_i] / 12

X = the natural logarithm of the 12-month total rainfall (inches) = 12 m_1

TN-based UCL = TN-based Prediction + 1.41492 SE

SE_{TN} = standard error of the TN-based Prediction

$SE_{TN} = 34.1305 [1 + 1/9 + (X-X_m)^2 / 0.45062]^{0.5}$

Where:

X_m = average value of the predictor in the base period = 3.79750

3.1.2.2.2 TON-based Prediction Equations

A TON-based TN load prediction equation and an associated UCL were derived from the Base Period TON data using a 10 percent reduction to represent 90 percent of the Base Period TON level.

TON-based Prediction = -593.98524 + 205.54389 X

Explained Variance = 58%, Standard Error of Regression = 44.484 mt

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m_1 = Sum [r_i] / 12

X = ln(12 m_1)

TON-based UCL = TON-based Prediction + 1.41492 SE

SE_{TON} = standard error of the TON-based Prediction for May-April interval

$SE_{TON} = 44.48377 [1 + 1/9 + (X-X_m)^2 / 0.45062]^{0.5}$

Where:

X = the natural logarithm of the 12-month total rainfall (inches)

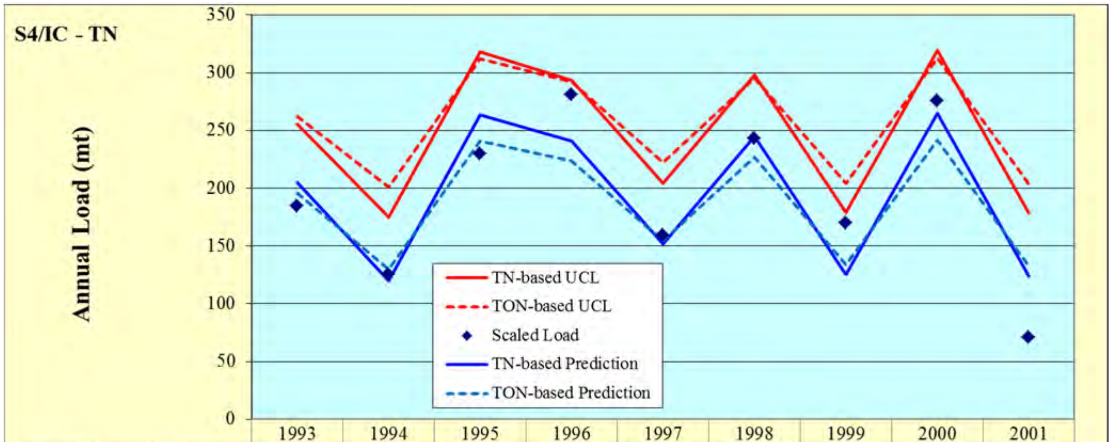
X_m = average value of the predictor in base period = 3.91295

A comparison of the Base Period TN loads, scaled to reflect the 35 percent load reduction goal, with the TN-based Prediction (and associated UCL) and the TON-based Prediction (and associated UCL) is presented in **Figure 3-7.**

3.1.2.2.3 TN Annual Load Target and Annual Load Limit

Each year, the equations above will be used to calculate the TN-based Prediction and the TON-based Prediction. The larger of the two predicted loads will become the TN Annual Load Target. The TN Annual Load Limit will be the predicted UCL associated with the prediction equation, so whichever prediction establishes the Annual Load Target will be the basis for the Annual Load Limit. Annual TN loads at the sub-watershed outlet structures, adjusted to account for pass-through loads and regional projects (as applicable) as described in Appendices A and D, will be evaluated against the performance measure described above.

Figure 3-7. Comparison of scaled annual TN loads with the Annual Load Targets and Limits for the S-4/Industrial Canal Sub-watershed.



	1993	1994	1995	1996	1997	1998	1999	2000	2001
TN-based UCL	255.687	174.781	317.948	293.565	203.990	297.991	179.343	319.046	178.087
TON-based UCL	261.834	201.026	311.885	292.010	222.349	295.595	204.308	312.787	203.402
Scaled Load	184.714	125.241	229.795	280.884	159.357	243.519	169.782	276.075	70.697
TN-based Prediction	204.689	120.138	263.591	241.040	151.855	245.178	125.183	264.593	123.796
TON-based Prediction	195.367	129.807	241.039	223.553	154.400	226.762	133.718	241.816	132.643

3.1.2.2.4. Suspension of Performance Determination. The TN performance determination will be suspended due to rainfall conditions if the observed annual TN load, adjusted for regional projects (if present) and pass-through loads, from the basin exceeds the TN Annual Load Target and the rainfall falls outside the range of rainfall values for the Base Period (33.83 – 58.34 inches). The rainfall values, Annual Load Targets and Annual Load Limits for the WY1993-2010 period of record are summarized in **Table 3-11**. The performance determination for TN may be suspended for some water years when the TP performance determination is not suspended due to two reasons:

1. the suspension of the performance determination for TP is based on adjusted rainfall, where the TN performance determination is based on observed rainfall, and
2. there may be years when the observed TP load is below the TP Annual Load Target while the observed TN load may be above the TN Annual Load Target.

Examples include the performance determinations for WY2007 and WY2009, which would have been suspended for TN but not for TP. Since the performance determinations for the nutrients are carried out independently, the possibility of conflicting suspension decisions does not adversely affect the overall basin performance determination.

3.1.2.2.5. Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-8**. The annual performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

Table 3-11. TN Annual Load Targets and Limits for the historical period of record for the S-4/Industrial Canal Sub-watershed (Base Period: WY1993-2001).

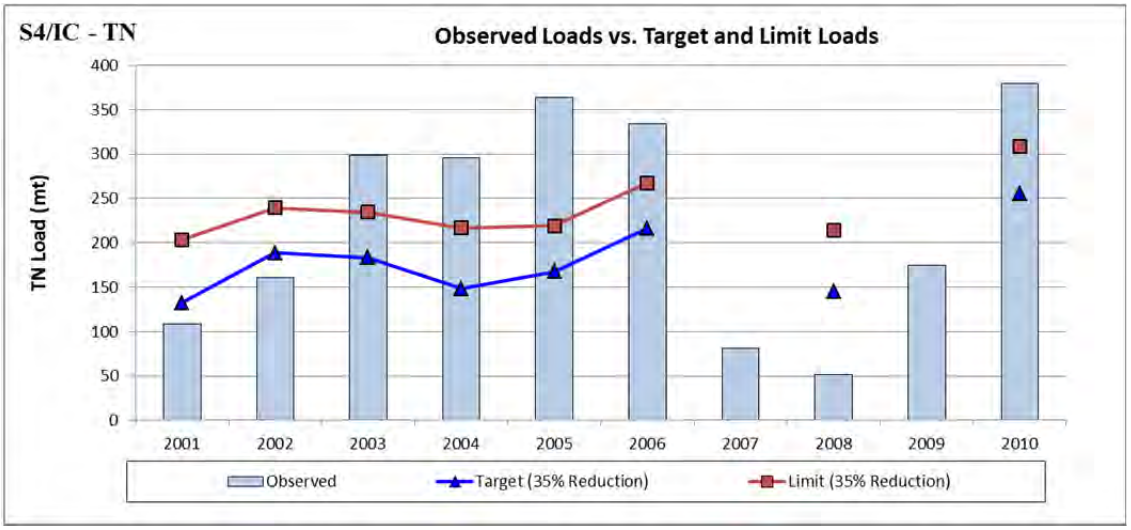
Water Year	Observed Rain, inches	Observed TN Load, mt	TN-based Prediction, mt	TN-based UCL mt	TON-based Prediction, mt	TON-based UCL mt
1993	46.54	284.176	204.690	255.687	195.367	261.834
1994	33.83	192.678	120.137	174.781	129.806	201.026
1995	58.12	353.531	263.591	317.948	241.039	311.885
1996	53.38	432.129	241.039	293.565	223.552	292.010
1997	38.13	245.164	151.856	203.990	154.400	222.349
1998	54.22	374.645	245.178	297.99	226.762	295.595
1999	34.48	261.203	125.182	179.343	133.718	204.308
2000	58.34	424.730	264.592	319.046	241.815	312.787
2001	34.30	108.764	123.795	178.087	132.642	203.402
2002	43.78	160.680	188.484	239.406	182.802	249.170
2003	42.96	298.533	183.472	234.447	178.915	245.352
2004	36.98	295.763	143.738	196.393	148.106	216.732
2005	40.47	363.490	167.644	219.023	166.642	233.607
2006	48.63	333.888	216.334	267.62	204.397	271.239
2007	24.83	81.387	38.148	104.216	66.233	152.342
2008	36.52	51.394	140.420	193.311	145.533	214.469
2009	30.54	174.291	93.016	150.745	108.777	184.017
2010	56.29	379.403	255.110	308.704	234.463	304.315

Indicates the TN Annual Load Target

Indicates the TN Annual Load Limit

Indicates the assessment would be suspended because the rainfall was below the Base Period minimum and the Target was exceeded.

Figure 3-8. Comparison of WY2001-2010 TN loads with Annual Load Targets and Limits for the S-4/Industrial Canal Sub-watershed.



Notes:

1. The Base Period extended from WY1993-2001.
2. The performance determination for WY2007 and WY2009 would have been suspended due to rainfall below the minimum value during the Base Period coupled with the observed load being greater than the Load Target.

3.1.2.2.6. Exceedance Frequency Analysis. Using the approach described in Section 2.5.11, an approximation of the cumulative exceedance frequency for the performance determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual TN loads of the Base Period. Separate approximations were prepared for the TN-based equations and the TON-based equations (**Tables 3-12** and **3-13**). Because the TN loads and rainfall statistics from the Base Period do not perfectly describe normal distributions (e.g., the medians are generally less than the means), the methodology includes conditional probabilities, and because the random number generator is imperfect, the exceedance frequencies deviate from the theoretical values shown in the second column. However, the results are determined to be reasonable and defensible since the cumulative exceedance frequency is less than the theoretical value of approximately 17.5 percent.

Table 3-12. Exceedance frequencies for the TN-based prediction and UCL for the S-4/Industrial Canal Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	12.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	8.8%
Step 4. Load > Annual Load Limit?	<10%	4.2%
Cumulative Exceedance Frequency	**<17.5%**	**11.9%**

Table 3-13. Exceedance frequencies for the TON-based prediction and UCL for the S-4/Industrial Canal Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	12.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	8.8%
Step 4. Load > Annual Load Limit?	<10%	4.2%
Cumulative Exceedance Frequency	**<17.5%**	**12.0%**

3.2 East Caloosahatchee Sub-watershed

The following sections present a description of the East Caloosahatchee Sub-watershed, a summary of historical flow and nutrient levels, nutrient reduction goals for the collective source control programs, and development of the performance metrics.

3.2.1 Background

The East Caloosahatchee Sub-watershed consists of 204,094 acres located adjacent to the southwest shoreline of Lake Okeechobee (**Figure 3-9**). It includes the area that drains to the C-43 Canal between S-77 and S-78. Flows are discharged to and from Lake Okeechobee at S-77; flows are also discharged to and from the S-4/Industrial Canal Sub-watershed at S-235. Flow and water quality data from S-77, S-78 and S-235 were used in the development of the performance metric (flow and nutrient monitoring sites are identified in **Tables B-1** and **B-2**). There are five additional locations where flows cross the boundaries of the East Caloosahatchee Sub-watershed (**Figure 3-10**), as described below.

- Disston Island Conservancy District Pump No. 3 (DICD3) discharges in both directions to and from the S-4/Industrial Canal Sub-watershed,
- S-342N discharges from Nicodemus Slough,
- G-135 discharges from the L-1 Borrow Canal (Flaghole Drainage District) to C-43,
- Canals 1, 2, and 3, with other tertiary canals, provide a connection with the West Caloosahatchee Sub-watershed (Hansing 2012), and
- Culvert 5A discharges both directions to and from Lake Okeechobee. Culvert 5A data were evaluated by District staff and it was concluded that the nutrient loads discharge from this structure are not significant (Hansing and Baker 2012).

The discharges at these locations are small and there are little or no flow or water quality data (HDR 2011b); hence, these flows and loads were not considered in the derivation of the performance measure methodology for the East Caloosahatchee Sub-watershed. Data from S-77, S-78 and S-235 are expected to be representative of the East Caloosahatchee Sub-watershed.

Figure 3-9. East Caloosahatchee Sub-watershed schematic (from SFWMD).

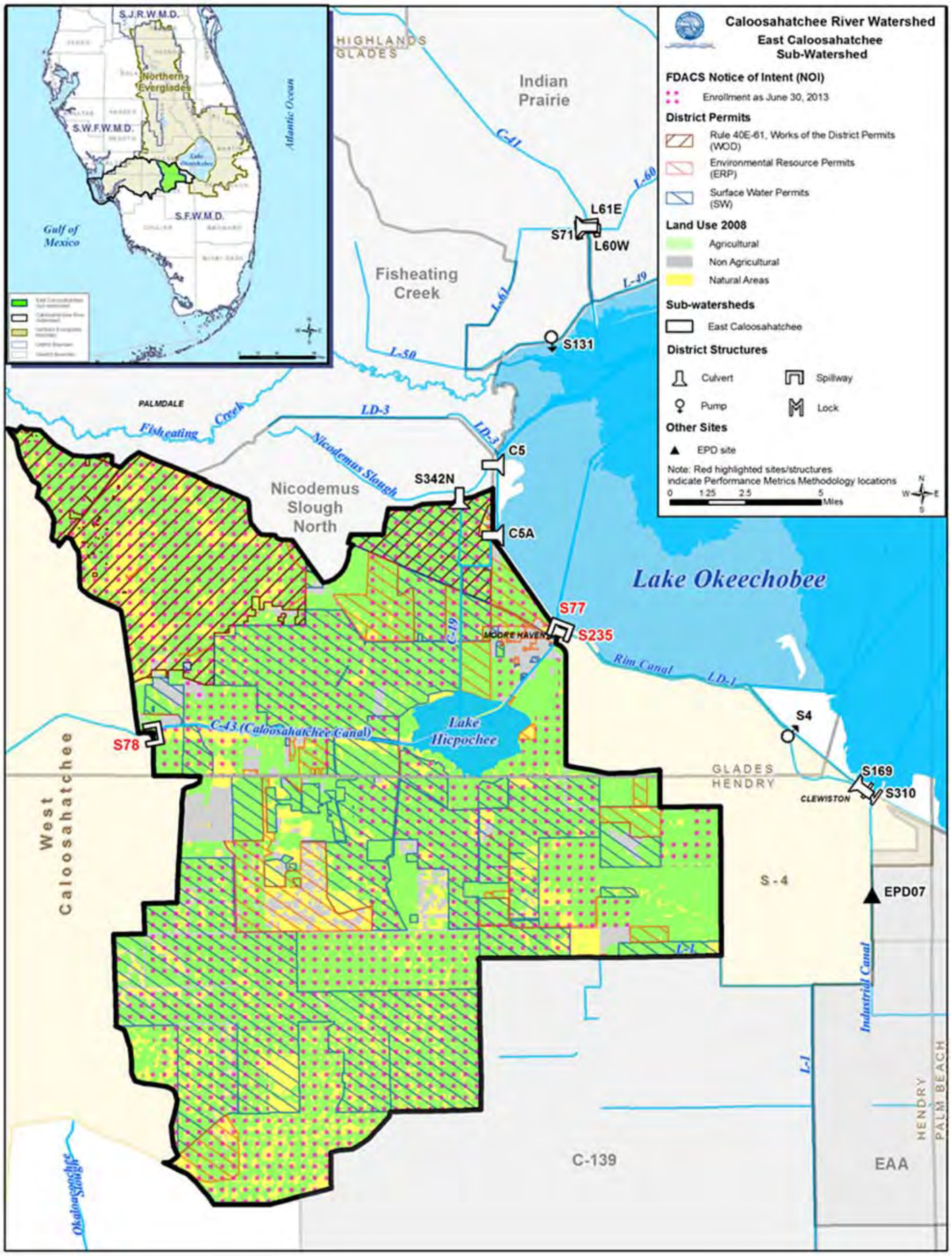
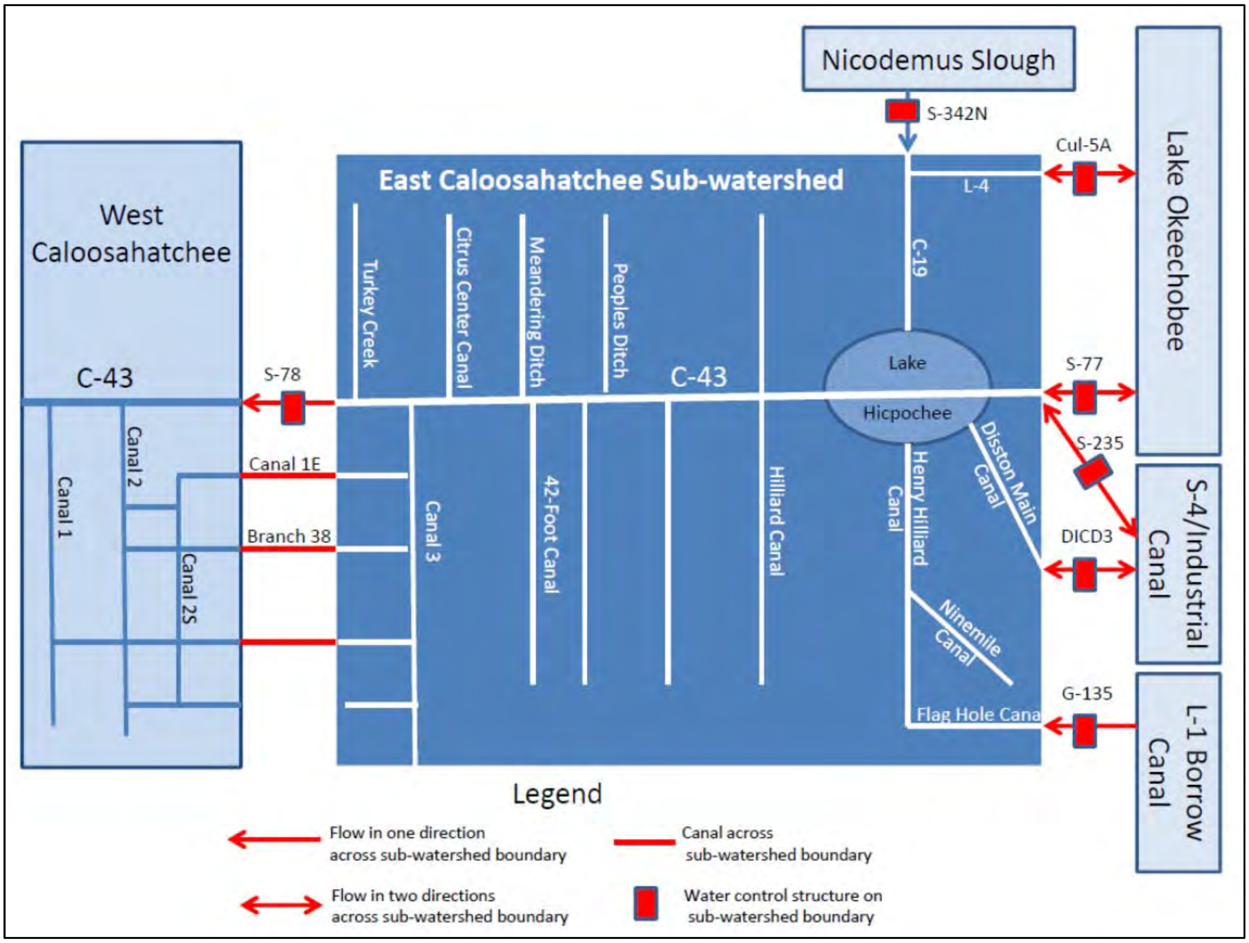


Figure 3-10. Flow diagram for East Caloosahatchee Sub-watershed.



The historical data analysis for the East Caloosahatchee Sub-watershed summarized herein was initially prepared by HDR Engineering, Inc., as part of Contract No. ST061298 – WO08 (Data Analysis and Performance Measure Development for the St. Lucie and the Caloosahatchee River Source Control Programs) with the District (HDR 2011) and was supplemented in collaboration with staff under this contract.

The performance measure methodology is based on flows and nutrient loads (TP and TN) resulting from rainfall and runoff from the East Caloosahatchee Sub-watershed. Basin flows and loads, adjusted for pass through flows and loads discharged from external sources, were calculated using algorithms provided in **Appendix A**. District staff identified the rainfall stations considered to be representative of the sub-watershed for the period WY1976-2010. Monthly rainfall data and weighting factors for the rainfall stations were developed and provided by the District. Annual flow and nutrient data for discharges from the East Caloosahatchee Sub-watersheds are summarized in **Tables 3-14** through **3-16**.

For the development of the TP and TN performance metrics, a Base Period of WY1982-1990 was selected for the following reasons.

- it represents a period with minimal prior implementation of source controls. With the selection of the Base Period to precede significant source control implementation, no additional calculation is necessary in the performance measure methodology to account for prior source control implementation,
- it represents a period of relatively uniform water management,
- it traversed a wide range of hydrologic conditions (i.e., wet and dry years),
- reliable water quality and hydrologic data are available, and
- a strong correlation exists between annual nutrient loads and rainfall, allowing for a performance measure methodology that explicitly incorporates hydrologic variability.

The Base Period is compared to the historical period of record and WY2001-2010 in **Tables 3-17** through **3-19** for TP, TN and TON, respectively**.**

Table 3-14. Summary of historical TP data for the East Caloosahatchee Sub-watershed.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff inches	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1981				32.31			2.043	0.887	1.348
1982	89,153	23.524	214	42.29	5.24	0.25	3.411	0.840	1.538
1983	588,703	191.171	263	72.47	34.61	2.07	0.128	0.664	0.382
1984	211,215	23.375	90	52.22	12.42	0.25	1.338	0.620	0.673
1985	267,350	110.464	335	47.99	15.72	1.19	-0.694	0.890	0.584
1986	199,891	54.941	223	46.57	11.75	0.59	-1.014	0.724	0.556
1987	343,358	77.371	183	56.21	20.19	0.84	-0.388	0.772	0.687
1988	254,651	61.200	195	48.58	14.97	0.66	1.105	0.617	0.830
1989	145,877	28.799	160	46.03	8.58	0.31	1.480	0.912	1.319
1990	112,163	23.186	168	43.81	6.59	0.25	-1.113	0.787	0.650
1991	156,204	35.225	183	52.85	9.18	0.38	-0.175	0.791	0.718
1992	238,943	63.450	215	59.68	14.05	0.69	0.294	0.714	0.859
1993	275,410	68.620	202	52.67	16.19	0.74	3.817	1.009	1.823
1994	205,552	37.435	148	47.73	12.09	0.40	-1.252	0.520	0.013
1995	295,839	61.034	167	57.57	17.39	0.66	0.018	0.449	0.924
1996	317,530	64.932	166	57.42	18.67	0.70	-1.614	0.839	0.367
1997	139,355	21.436	125	47.75	8.19	0.23	-0.276	0.814	0.587
1998	237,053	57.393	196	62.17	13.94	0.62	-0.421	0.578	-0.031
1999	287,114	52.254	148	42.46	16.88	0.56	-0.573	0.823	0.686
2000	364,314	53.367	119	60.47	21.42	0.58	2.354	1.078	1.506
2001	120,427	-3.249	-22	34.44	7.08	-0.04	-0.851	0.915	0.590
2002	226,842	71.868	257	54.89	13.34	0.78	-1.389	0.893	0.602
2003	462,008	101.838	179	61.45	27.16	1.10	2.209	0.805	1.395
2004	349,932	92.883	215	54.29	20.57	1.00	-1.524	0.748	0.251
2005	300,291	7.730	21	52.49	17.66	0.08	1.054	0.893	1.137
2006	575,220	93.531	132	57.97	33.82	1.01	0.026	0.947	0.881
2007	243,725	54.036	180	37.94	14.33	0.58	0.720	1.151	1.225
2008	108,808	18.112	135	51.49	6.40	0.20	2.054	0.766	1.267
2009	248,322	89.048	291	46.30	14.60	0.96	1.268	1.253	1.399
2010	334,902	66.316	161	63.32	19.69	0.72	-1.279	0.667	0.009
Minimum	***89,153***	***7.730***	***21***	***37.94***	***5.24***	***0.08***	***-1.614***	***0.449***	***-0.031***
Average	***270,704***	***60.876***	***182***	***52.75***	***15.92***	***0.66***	***0.342***	***0.806***	***0.816***
Maximum	***588,703***	***191.171***	***335***	***72.47***	***34.61***	***2.07***	***3.817***	***1.253***	***1.823***
Std. Dev.	***122,851***	***37.216***	***62***	***7.69***	***7.22***	***0.40***	***1.487***	***0.181***	***0.489***
Skewness	***1.045***	***1.537***	***0.096***	***0.360***	***1.045***	***1.54***	***0.710***	***0.432***	***0.129***
Median	***251,487***	***59.214***	***180***	***52.58***	***14.79***	***0.64***	***0.022***	***0.798***	***0.703***

Notes:

1. The FWM TP concentration was calculated by dividing the annual TP load by the annual flow.
2. In WY2001, the observed load was negative due to more TP load entering the basin than leaving the basin, thus resulting in a negative TP concentration. Since the negative TP concentration is not physically possible, these data were excluded from the summary statistics.

Table 3-15. Summary of historical TN data for the East Caloosahatchee Sub-watershed.

Water Year	Flow AF	TN Load mt	FWM TN Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1982	89,153	245.516	2,233	42.29	5.24	2.65	3.411	0.840	1.538
1983	588,703	1,430.413	1,970	72.47	34.61	15.45	0.128	0.664	0.382
1984	211,215	760.549	2,919	52.22	12.42	8.22	1.338	0.620	0.673
1985	267,350	413.785	1,255	47.99	15.72	4.47	-0.694	0.890	0.584
1986	199,891	537.945	2,182	46.57	11.75	5.81	-1.014	0.724	0.556
1987	343,358	842.317	1,989	56.21	20.19	9.10	-0.388	0.772	0.687
1988	254,651	430.907	1,372	48.58	14.97	4.65	1.105	0.617	0.830
1989	145,877	261.992	1,456	46.03	8.58	2.83	1.480	0.912	1.319
1990	112,163	202.599	1,464	43.81	6.59	2.19	-1.113	0.787	0.650
1991	156,204	352.475	1,829	52.85	9.18	3.81	-0.175	0.791	0.718
1992	238,943	522.124	1,771	59.68	14.05	5.64	0.294	0.714	0.859
1993	275,410	-284.060	-836	52.67	16.19	-3.07	3.817	1.009	1.823
1994	205,552	416.512	1,643	47.73	12.09	4.50	-1.252	0.520	0.013
1995	295,839	454.268	1,245	57.57	17.39	4.91	0.018	0.449	0.924
1996	317,530	-857.701	-2,190	57.42	18.67	-9.26	-1.614	0.839	0.367
1997	139,355	149.833	872	47.75	8.19	1.62	-0.276	0.814	0.587
1998	237,053	212.449	727	62.17	13.94	2.29	-0.421	0.578	-0.031
1999	287,114	527.246	1,489	42.46	16.88	5.70	-0.573	0.823	0.686
2000	364,314	387.696	863	60.47	21.42	4.19	2.354	1.078	1.506
2001	120,427	-235.139	-1,583	34.44	7.08	-2.54	-0.851	0.915	0.590
2002	226,842	553.677	1,979	54.89	13.34	5.98	-1.389	0.893	0.602
2003	462,008	901.921	1,583	61.45	27.16	9.74	2.209	0.805	1.395
2004	349,932	601.546	1,394	54.29	20.57	6.50	-1.524	0.748	0.251
2005	300,291	10.901	29	52.49	17.66	0.12	1.054	0.893	1.137
2006	575,220	1,221.004	1,721	57.97	33.82	13.19	0.026	0.947	0.881
2007	243,725	426.600	1,419	37.94	14.33	4.61	0.720	1.151	1.225
2008	108,808	197.117	1,469	51.49	6.40	2.13	2.054	0.766	1.267
2009	248,322	677.713	2,213	46.30	14.60	7.32	1.268	1.253	1.399
2010	334,902	596.033	1,443	63.32	19.69	6.44	-1.279	0.667	0.009
Minimum	***89,153***	***10.901***	***29***	***37.94***	***5.24***	***0.12***	***-1.524***	***0.449***	***-0.031***
Average	***268,723***	***512.890***	***1,547***	***52.58***	***15.80***	***5.54***	***0.283***	***0.797***	***0.794***
Maximum	***588,703***	***1,430.413***	***2,919***	***72.47***	***34.61***	***15.45***	***3.411***	***1.253***	***1.538***
Std. Dev.	***127,307***	***321.970***	***570***	***7.93***	***7.49***	***3.48***	***1.322***	***0.183***	***0.458***
Skewness	***1.068***	***1.215***	***-0.303***	***0.419***	***1.068***	***1.22***	***0.594***	***0.554***	***-0.097***
Median	***246,024***	***442.588***	***1,479***	***52.36***	***14.47***	***4.78***	***0.022***	***0.789***	***0.703***

Notes:

1. The FWM TN concentration was calculated by dividing the annual TN load by the annual flow.
2. In WY1993, WY1996 and WY2001 the observed load was negative due to more TN load entering the basin than leaving the basin, thus resulting in a negative TN concentration. Since the negative TN concentration is not physically possible, these data were excluded from the summary statistics.

Table 3-16. Summary of historical TON data for the East Caloosahatchee Sub-watershed.

Water Year	Flow AF	TON Load mt	FWM TON Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1982	89,153	219.229	1,994	42.29	5.24	2.37	3.411	0.840	1.538
1983	588,703	1,226.343	1,689	72.47	34.61	13.25	0.128	0.664	0.382
1984	211,215	944.436	3,625	52.22	12.42	10.20	1.338	0.620	0.673
1985	267,350	376.041	1,140	47.99	15.72	4.06	-0.694	0.890	0.584
1986	199,891	453.931	1,841	46.57	11.75	4.90	-1.014	0.724	0.556
1987	343,358	750.155	1,771	56.21	20.19	8.10	-0.388	0.772	0.687
1988	254,651	369.601	1,177	48.58	14.97	3.99	1.105	0.617	0.830
1989	145,877	206.581	1,148	46.03	8.58	2.23	1.480	0.912	1.319
1990	112,163	164.029	1,186	43.81	6.59	1.77	-1.113	0.787	0.650
1991	156,204	276.601	1,436	52.85	9.18	2.99	-0.175	0.791	0.718
1992	238,943	429.719	1,458	59.68	14.05	4.64	0.294	0.714	0.859
1993	275,410	-338.646	-997	52.67	16.19	-3.66	3.817	1.009	1.823
1994	205,552	357.852	1,411	47.73	12.09	3.87	-1.252	0.520	0.013
1995	295,839	452.736	1,241	57.57	17.39	4.89	0.018	0.449	0.924
1996	317,530	-757.975	-1,935	57.42	18.67	-8.19	-1.614	0.839	0.367
1997	139,355	69.879	407	47.75	8.19	0.75	-0.276	0.814	0.587
1998	237,053	121.509	416	62.17	13.94	1.31	-0.421	0.578	-0.031
1999	287,114	429.255	1,212	42.46	16.88	4.64	-0.573	0.823	0.686
2000	364,314	146.136	325	60.47	21.42	1.58	2.354	1.078	1.506
2001	120,427	-277.998	-1,871	34.44	7.08	-3.00	-0.851	0.915	0.590
2002	226,842	497.114	1,777	54.89	13.34	5.37	-1.389	0.893	0.602
2003	462,008	612.580	1,075	61.45	27.16	6.62	2.209	0.805	1.395
2004	349,932	520.686	1,206	54.29	20.57	5.62	-1.524	0.748	0.251
2005	300,291	68.465	185	52.49	17.66	0.74	1.054	0.893	1.137
2006	575,220	922.988	1,301	57.97	33.82	9.97	0.026	0.947	0.881
2007	243,725	364.573	1,213	37.94	14.33	3.94	0.720	1.151	1.225
2008	108,808	163.464	1,218	51.49	6.40	1.77	2.054	0.766	1.267
2009	248,322	564.991	1,845	46.30	14.60	6.10	1.268	1.253	1.399
2010	334,902	486.603	1,178	63.32	19.69	5.26	-1.279	0.667	0.009
Minimum	***89,153***	***68.465***	***185***	***37.94***	***5.24***	***0.74***	***-1.524***	***0.449***	***-0.031***
Average	***268,723***	***430.596***	***1,299***	***52.58***	***15.80***	***4.65***	***0.283***	***0.797***	***0.794***
Maximum	***588,703***	***1,226.343***	***3,625***	***72.47***	***34.61***	***13.25***	***3.411***	***1.253***	***1.538***
Std. Dev.	***127,307***	***284.588***	***665***	***7.93***	***7.49***	***3.07***	***1.322***	***0.183***	***0.458***
Skewness	***1.068***	***1.111***	***1.309***	***0.419***	***1.068***	***1.11***	***0.594***	***0.554***	***-0.097***
Median	***246,024***	***402.648***	***1,216***	***52.36***	***14.47***	***4.35***	***0.022***	***0.789***	***0.703***

Notes:

1. The FWM TON concentration was calculated by dividing the annual TON load by the annual flow.
2. In WY1993, WY1996 and WY2001 the observed load was negative due to more TON load entering the basin than leaving the basin, thus resulting in a negative TON concentration. Since the negative TON concentration is not physically possible, these data were excluded from the summary statistics.

Table 3-17. Comparison of Base Period with period of record and WY2001-2010 data for the East Caloosahatchee Sub-watershed: TP.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	89,153	7.730	21	37.94	0.08
Annual Average	270,704	60.876	182	52.75	0.66
Annual Median	251,487	59.214	180	52.58	0.64
Annual Maximum	588,703	191.171	335	72.47	2.07
Preliminary Base Period WY1982-1990					
Annual Minimum	89,153	23.186	90	42.29	0.25
Annual Average	245,818	66.003	218	50.69	0.71
Annual Median	211,215	54.941	195	47.99	0.59
Annual Maximum	588,703	191.171	335	72.47	2.07
Difference between Period of Record and Base Period					
Annual Minimum	0	-15.456	-69	-4.35	-0.17
Annual Average	24,887	-5.127	-35	2.07	-0.06
Annual Median	40,272	4.272	-16	4.59	0.05
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	-67%	-77%	-10%	-67%
Annual Average	10%	-8%	-16%	4%	-8%
Annual Median	19%	8%	-8%	10%	8%
Annual Maximum	0%	0%	0%	0%	0%
WY2002-2010					
Annual Minimum	108,808	7.730	21	37.94	0.08
Annual Average	316,672	66.151	169	53.35	0.71
Annual Median	300,291	71.868	179	54.29	0.78
Annual Maximum	575,220	101.838	291	63.32	1.10
Difference between WY2002-2010 and Base Period					
Annual Minimum	19,655	-15.456	-69	-4.35	-0.17
Annual Average	70,854	0.148	-48	2.66	0.00
Annual Median	89,076	16.927	-16	6.30	0.18
Annual Maximum	-13,483	-89.333	-44	-9.15	-0.96
Annual Minimum	22%	-67%	-77%	-10%	-67%
Annual Average	29%	0%	-22%	5%	0%
Annual Median	42%	31%	-8%	13%	31%
Annual Maximum	-2%	-47%	-13%	-13%	-47%

Note: Since negative TP concentrations are not physically possible,
a water year with these data (WY2001) was excluded from the summary statistics.

Table 3-18. Comparison of Base Period with period of record and WY2001-2010 data for the East Caloosahatchee Sub-watershed: TN.

Metric	Flow AF	TN Load mt	TN Conc µg/L	Rainfall inches	UAL lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	89,153	10.901	29	37.94	0.12
Annual Average	268,723	512.890	1,547	52.58	5.54
Annual Median	246,024	442.588	1,479	52.36	4.78
Annual Maximum	588,703	1,430.413	2,919	72.47	15.45
Preliminary Base Period WY1982-1990					
Annual Minimum	89,153	202.599	1,255	42.29	2.19
Annual Average	245,818	569.558	1,878	50.69	6.15
Annual Median	211,215	430.907	1,970	47.99	4.65
Annual Maximum	588,703	1,430.413	2,919	72.47	15.45
Difference between Period of Record and Base Period					
Annual Minimum	0	-191.698	-1,226	-4.35	-2.07
Annual Average	22,905	-56.668	-331	1.89	-0.61
Annual Median	34,809	11.681	-491	4.37	0.13
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	-95%	-98%	-10%	-95%
Annual Average	9%	-10%	-18%	4%	-10%
Annual Median	16%	3%	-25%	9%	3%
Annual Maximum	0%	0%	0%	0%	0%
WY2002-2010					
Annual Minimum	108,808	10.901	29	37.94	0.12
Annual Average	316,672	576.279	1,475	53.35	6.22
Annual Median	300,291	596.033	1,469	54.29	6.44
Annual Maximum	575,220	1,221.004	2,213	63.32	13.19
Difference between WY2002-2010 and Base Period					
Annual Minimum	19,655	-191.698	-1,226	-4.35	-2.07
Annual Average	70,854	6.721	-403	2.66	0.07
Annual Median	89,076	165.126	-501	6.30	1.78
Annual Maximum	-13,483	-209.409	-706	-9.15	-2.26
Annual Minimum	22%	-95%	-98%	-10%	-95%
Annual Average	29%	1%	-21%	5%	1%
Annual Median	42%	38%	-25%	13%	38%
Annual Maximum	-2%	-15%	-24%	-13%	-15%

Note: Since negative TN concentrations are not physically possible, a water year with these data (WY2001) was excluded from the summary statistics.

Table 3-19. Comparison of Base Period with period of record and WY2001-2010 data for the East Caloosahatchee Sub-watershed: TON.

Metric	Flow AF	TON Load mt	TON Conc µg/L	Rainfall inches	UAL lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	89,153	68.465	185	37.94	0.74
Annual Average	268,723	430.596	1,299	52.58	4.65
Annual Median	246,024	402.648	1,216	52.36	4.35
Annual Maximum	588,703	1,226.343	3,625	72.47	13.25
Preliminary Base Period WY1982-1990					
Annual Minimum	89,153	164.029	1,140	42.29	1.77
Annual Average	245,818	523.372	1,726	50.69	5.65
Annual Median	211,215	376.041	1,689	47.99	4.06
Annual Maximum	588,703	1,226.343	3,625	72.47	13.25
Difference between Period of Record and Base Period					
Annual Minimum	0	-95.564	-955	-4.35	-1.03
Annual Average	22,905	-92.776	-427	1.89	-1.00
Annual Median	34,809	26.607	-474	4.37	0.29
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	-58%	-84%	-10%	-58%
Annual Average	9%	-18%	-25%	4%	-18%
Annual Median	16%	7%	-28%	9%	7%
Annual Maximum	0%	0%	0%	0%	0%
WY2002-2010					
Annual Minimum	108,808	68.465	185	37.94	0.74
Annual Average	316,672	466.829	1,195	53.35	5.04
Annual Median	300,291	497.114	1,213	54.29	5.37
Annual Maximum	575,220	922.988	1,845	63.32	9.97
Difference between WY2002-2010 and Base Period					
Annual Minimum	19,655	-95.564	-955	-4.35	-1.03
Annual Average	70,854	-56.542	-531	2.66	-0.61
Annual Median	89,076	121.073	-476	6.30	1.31
Annual Maximum	-13,483	-303.355	-1,780	-9.15	-3.28
Annual Minimum	22%	-58%	-84%	-10%	-58%
Annual Average	29%	-11%	-31%	5%	-11%
Annual Median	42%	32%	-28%	13%	32%
Annual Maximum	-2%	-25%	-49%	-13%	-25%

Note: Since negative TON concentrations are not physically possible,
a water year with these data (WY2001) was excluded from the summary statistics.

3.2.1.1 TP Trend. Using the approach described in Section 2.5.4, a series of regression equations were evaluated to determine which one best described the hydrologic variability of the Base Period annual TP load. The predicted annual TP loads derived from the Base Period data using a 0 percent load reduction were calculated according to the following equation and explanation.

TP Annual Load = -195.42288 + 5.15781 X

Explained Variance = 72.6% , Standard Error of Regression = 31.138 mtons

Predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m_1 = Sum [r_1] / 12

X = the 12-month total rainfall (inches) = 12 m_1

The regression equation predicts that load increases with the total annual rainfall.

Table 3-20 presents the annual observed and predicted sub-watershed TP loads. The load trend is presented in **Figure 3-11**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-11** denotes a reduction in loads.

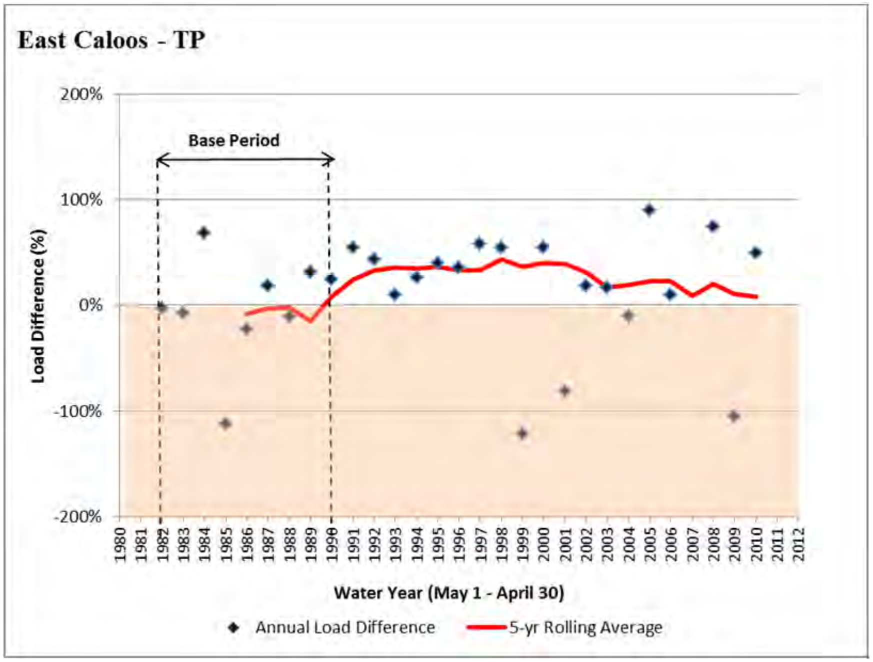
Table 3-20. WY1982 – WY2010 East Caloosahatchee Sub-watershed TP measurements and calculations. (Base Period: WY1982-1990).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1982	42.29	23.524	22.701	-4%	
1983	72.47	191.171	178.363	-7%	
1984	52.22	23.375	73.918	68%	
1985	47.99	110.464	52.100	-112%	
1986	46.57	54.941	44.776	-23%	-9%
1987	56.21	77.371	94.497	18%	-3%
1988	48.58	61.200	55.143	-11%	-2%
1989	46.03	28.799	41.991	31%	-15%
1990	43.81	23.186	30.540	24%	8%
1991	52.85	35.225	77.167	54%	25%
1992	59.68	63.450	112.395	44%	33%
1993	52.67	68.620	76.239	10%	35%
1994	47.73	37.435	50.759	26%	34%
1995	57.57	61.034	101.512	40%	36%
1996	57.42	64.932	100.738	36%	33%
1997	47.75	21.436	50.862	58%	33%
1998	62.17	57.393	125.238	54%	44%
1999	42.46	52.254	23.577	-122%	36%
2000	60.47	53.367	116.469	54%	40%
2001	34.44	-3.249	-17.788	-82%	39%
2002	54.89	71.868	87.689	18%	31%
2003	61.45	101.838	121.524	16%	17%
2004	54.29	92.883	84.594	-10%	19%
2005	52.49	7.730	75.310	90%	23%
2006	57.97	93.531	103.575	10%	22%
2007	37.94	54.036	0.264	-20361%	9%
2008	51.49	18.112	70.152	74%	20%
2009	46.30	89.048	43.383	-105%	10%
2010	63.32	66.316	131.169	49%	8%

Notes:

1. Predicted load represents the base period load adjusted for rainfall variability.
2. Steps for addressing negative loads are described in Section 2.5.12.

Figure 3-11. East Caloosahatchee Sub-watershed TP load trend.



Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

3.2.1.2 TN Trend. Using the approach described in Section 2.5.4, a series of regression equations were evaluated to determine which one best described the hydrologic variability of the Base Period annual TN load. The predicted annual TN loads derived from the Base Period data using a 0 percent load reduction were calculated according to the following equation and explanation.

$$\text{TN Annual Load} = -8615.30879 + 2347.29717\ X$$

Explained Variance = 95.5%, Standard Error of Regression = 89.193 mt

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m_1 = Sum [r_i] / 12

X = the natural logarithm of the 12-month total rainfall (inches) = ln(12 m_1)

The regression equation predicts that TN load increases with total annual rainfall.

Table 3-21 presents the annual observed and predicted sub-watershed TN loads. The load trend is presented in **Figure 3-12.** The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-12** denotes a reduction in loads.

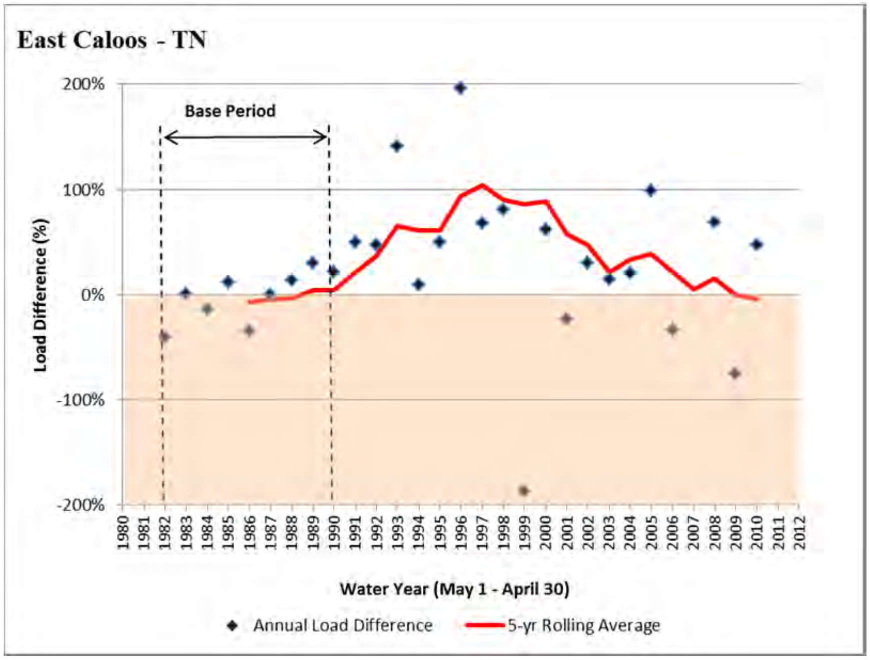
Table 3-21. WY1982 – WY2010 East Caloosahatchee Sub-watershed TN measurements and calculations. (Base Period: WY1982-1990).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1982	42.29	245.516	174.263	-41%	
1983	72.47	1430.413	1438.564	1%	
1984	52.22	760.549	669.355	-14%	
1985	47.99	413.785	471.055	12%	
1986	46.57	537.945	400.566	-34%	-7%
1987	56.21	842.317	842.163	0%	-4%
1988	48.58	430.907	499.739	14%	-4%
1989	46.03	261.992	373.173	30%	4%
1990	43.81	202.599	257.146	21%	4%
1991	52.85	352.475	697.499	49%	22%
1992	59.68	522.124	982.789	47%	37%
1993	52.67	-284.060	689.495	141%	65%
1994	47.73	416.512	458.309	9%	61%
1995	57.57	454.268	898.287	49%	61%
1996	57.42	-857.701	892.160	196%	94%
1997	47.75	149.833	459.295	67%	104%
1998	62.17	212.449	1078.723	80%	90%
1999	42.46	527.246	183.676	-187%	86%
2000	60.47	387.696	1013.656	62%	88%
2001	34.44	-235.139	-307.708	-24%	57%
2002	54.89	553.677	786.391	30%	48%
2003	61.45	901.921	1051.377	14%	22%
2004	54.29	601.546	760.594	21%	33%
2005	52.49	10.901	681.443	98%	38%
2006	57.97	1221.004	914.554	-34%	22%
2007	37.94	426.600	-80.513	-630%	5%
2008	51.49	197.117	636.305	69%	16%
2009	46.30	677.713	386.905	-75%	0%
2010	63.32	596.033	1121.749	47%	-5%

Notes:

1. Predicted load represents the base period load adjusted for rainfall variability.
2. Steps for addressing negative loads are described in Section 2.5.12.

Figure 3-12. East Caloosahatchee Sub-watershed TN load trend.



Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

3.2.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the East Caloosahatchee Sub-watershed.

3.2.2.1 Total Phosphorus Performance Metric Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.5, the overall range of TP load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 30 percent was determined to be reasonable and appropriate. Details are provided in Appendix C and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 30 percent load reduction. The Annual Load Target and Annual Load Limit will be calculated according to the following equations and explanation:

TP Annual Load Target = -136.79649 + 3.61048 X

Explained Variance = 72.6%, Standard Error of Regression = 21.797 mtons

Predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m_1 = Sum [r_1] / 12

X = 12 m_1

TP Annual Load Limit = Target + 1.41492 SE

SE = standard error of the Target for May-April interval

SE = 21.79661 $[1 + 1/9 + (X-X_m)^2 / 675.50602]^{0.5}$

Where:

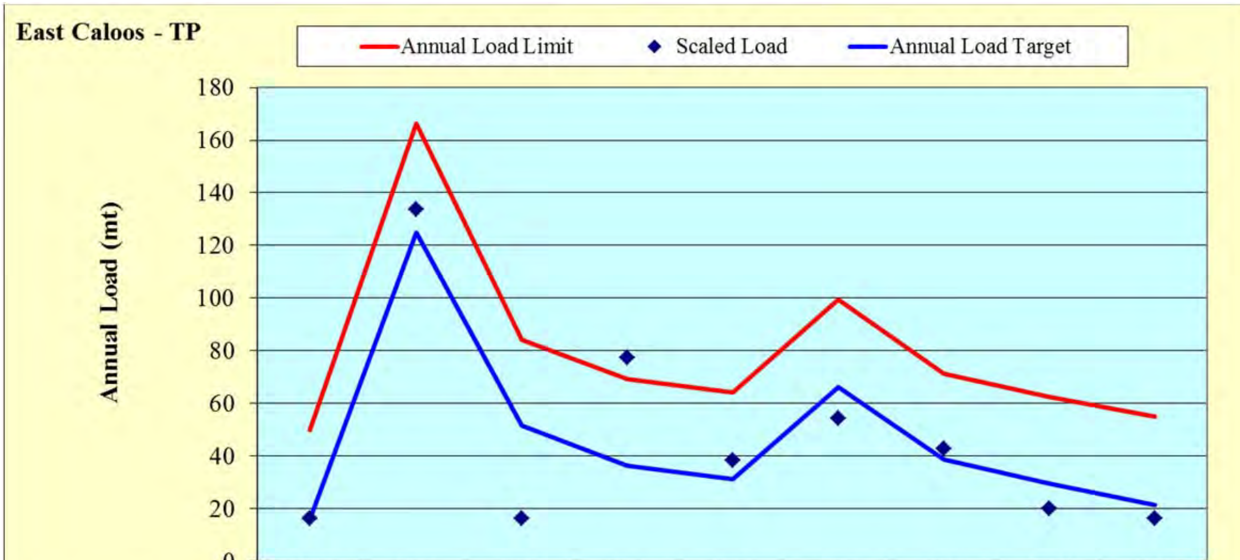
X = the 12-month total rainfall (inches)

X_m = average value of the predictor in base period = 50.686 inches

The regression equation predicts that load increases with the total annual rainfall.

A comparison of the scaled loads and the resulting Targets and Limits for the Base Period are presented in **Figure 3-13**. Annual TP loads at the sub-watershed outlet structures, adjusted to account for pass-through loads and regional projects (as applicable) as described in Appendices A and D, respectively, will be evaluated against the performance measure described above.

Figure 3-13. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the East Caloosahatchee Sub-watershed.



	1982	1983	1984	1985	1986	1987	1988	1989	1990
Annual Load Limit	49.892	166.388	84.302	69.136	64.217	99.311	71.205	62.369	54.895
Scaled Load	16.467	133.820	16.363	77.325	38.459	54.160	42.840	20.159	16.230
Annual Load Target	15.891	124.855	51.743	36.470	31.343	66.148	38.600	29.394	21.379

3.2.2.1.1 Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load, adjusted for regional projects (if present), from the basin exceeds the Annual Load Target and the rainfall falls outside the range of rainfall values for the Base Period (42.29 – 72.47 inches). The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the WY1982-2010 period of record are summarized in **Table 3-22**. The annual performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart **Figure 1-2**.

3.2.2.1.2 Comparison to WY2001-2010. A comparison of the WY2001-2010 observed TP loads to the Annual Load Targets and Limits is presented in **Figure 3-14**.

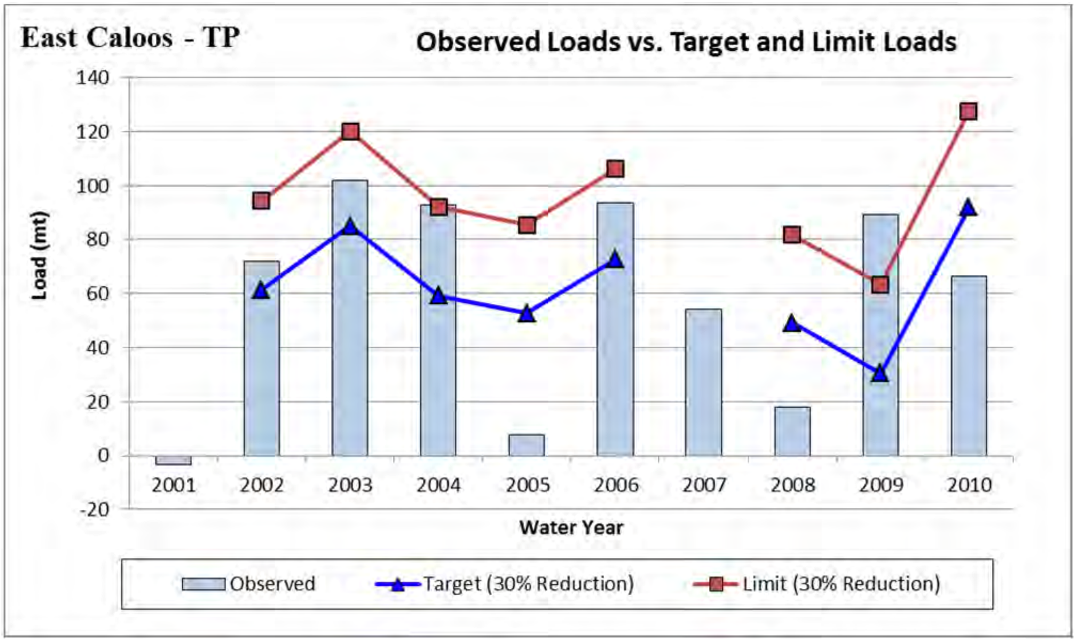
Table 3-22. TP Annual Load Targets and Limits for the historical period of record for the East Caloosahatchee Sub-watershed (Base Period: WY1982-1990).

Water Year	Observed Load, mt	Rain inches	Target Load, mt	Limit Load, mt
1982	23.524	42.29	15.890	49.891
1983	191.171	72.47	124.855	166.388
1984	23.375	52.22	51.742	84.302
1985	110.464	47.99	36.470	69.136
1986	54.941	46.57	31.343	64.217
1987	77.371	56.21	66.148	99.311
1988	61.200	48.58	38.600	71.205
1989	28.799	46.03	29.394	62.368
1990	23.186	43.81	21.378	54.895
1991	35.225	52.85	54.017	86.627
1992	63.450	59.68	78.677	112.892
1993	68.620	52.67	53.367	85.961
1994	37.435	47.73	35.531	68.229
1995	61.034	57.57	71.059	104.578
1996	64.932	57.42	70.517	103.993
1997	21.436	47.75	35.604	68.298
1998	57.393	62.17	87.667	122.916
1999	52.254	42.46	16.504	50.447
2000	53.367	60.47	81.529	116.049
2001	-3.249	34.44	-12.452	25.343
2002	71.868	54.89	61.382	94.272
2003	101.838	61.45	85.067	119.995
2004	92.883	54.29	59.216	92.005
2005	7.730	52.49	52.717	85.296
2006	93.531	57.97	72.503	106.141
2007	54.036	37.94	0.185	36.039
2008	18.112	51.49	49.107	81.630
2009	89.048	46.30	30.368	63.291
2010	66.316	63.32	91.819	127.618

Notes:

1. Shaded water years indicate the performance determination would have been suspended due to anomalous rainfall coupled with the observed load being greater than the Load Target.
2. Steps for addressing negative loads are described in Section 2.5.12.

Figure 3-14. Comparison of WY2001-2010 TP loads with Annual Load Targets and Limits for the East Caloosahatchee Sub-watershed.



Notes:

1. The performance determination for WY2001 and WY2007 would have been suspended due to rainfall below the minimum value during the Base Period coupled with the observed load being greater than the Load Target.
2. Steps for addressing negative loads are described in Section 2.5.12.

3.2.2.1.3 Exceedance Frequency Analysis. As shown in **Figure 3-13**, although the scaled observed loads fall above the Annual Load Target roughly half the time (five out of nine years, or 55 percent), only the scaled observed load for WY1985 exceeded the calculated Annual Load Limit during the base period. In accordance with the proposed performance determination process discussed in Section 2.5.12, having the observed load exceed the Annual Load Limit would prevent the basin from meeting its performance measure for that year. In the case of the scaled Base Period data, this is an example of a Type I error, or “false positive” – when the performance method suggests a lack of compliance when the basin’s load actually achieves the long-term reduction goals. While this occurrence is not common, it is statistically possible. The use of the upper 90 percent confidence limit for the Annual Load is consistent with the District’s

Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of approximately ten percent. Using the approach described in Section 2.5.11, an approximation of the cumulative exceedance frequency for the performance determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP load of the Base Period (**Table 3-23**). Because the TP loads and rainfall statistics from the Base Period do not perfectly describe normal distributions (e.g., the medians are generally less than the means), the methodology includes conditional probabilities, and because the random number generator is imperfect, the exceedance frequencies deviate from the theoretical values shown in the second column. However, the results are determined to be reasonable and defensible since the cumulative exceedance frequency is less than the theoretical value of approximately 17.5 percent.

Table 3-23. Exceedance frequencies for the proposed TP determination methodology for the East Caloosahatchee Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain is outside the range and Load > Annual Load Target	<20%	9.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.9%
Step 4. Load > Annual Load Limit?	<10%	4.3%
Cumulative Exceedance Frequency	**<17.5%**	**13.1%**

3.2.2.2 Total Nitrogen Performance Metric Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.5, the overall range of TN load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 30 percent was determined to be reasonable and appropriate. In addition, a threshold of 90 percent of the TON load was established to ensure that estimates of TN reductions do not go beyond what could be reasonably expected from source controls on anthropogenic activities. Details are provided in Appendix C and in Attachment 1.

3.2.2.2.1 TN-based Prediction Equations

A TN-based load prediction equation and an associated 90^{th} percent upper confidence limit (UCL) were derived from the Base Period TN data using a 30 percent reduction.

TN-based Prediction = -6030.71633 + 1643.10806 X

Explained Variance = 95.5%, Standard Error of Regression = 62.435 mt

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m_1 = Sum [r_i] / 12

X = the natural logarithm of the 12-month total rainfall (inches) = ln(12 m_1)

Where:

X = the natural logarithm of the 12-month total rainfall (inches)

TN-based UCL = TN-based Prediction + 1.41492 SE

SE_{TN} = standard error of the TN-based Prediction

$SE_{TN} = 62.43487 [1 + 1/9 + (X-X_m)^2 / 0.21326]^{0.5}$

Where:

X_m = average value of the predictor in the base period = 3.91295

3.2.2.2.2 TON-based Prediction Equations

A TON-based TN load prediction equation and an associated UCL were derived from the Base Period TON data using a 10 percent reduction to represent 90 percent of the Base Period TON level.

TON-based Prediction = -6890.68249 + 1881.37053 X

Explained Variance = 85.1%, Standard Error of Regression = 137.403 mt

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

$m_1 = Sum [r_i] / 12$

$X = \ln(12\ m_1)$

TON-based UCL = TON-based Prediction + 1.41492 SE

SE_{TON} = standard error of the TON-based Prediction for May-April interval

$SE_{TON} = 137.40342 [1 + 1/9 + (X-X_m)^2 / 0.21326]^{0.5}$

Where:

X = the natural logarithm of the 12-month total rainfall (inches)

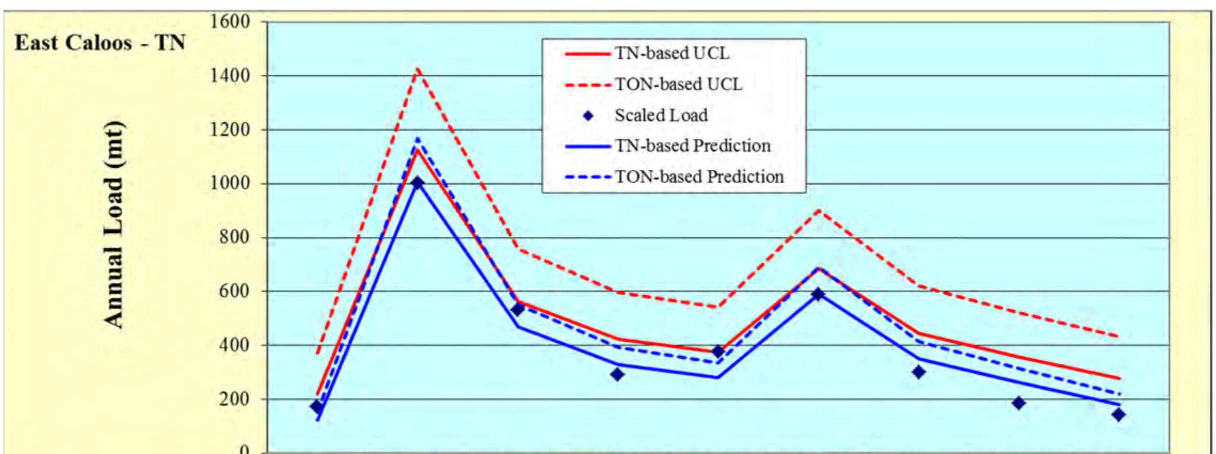
X_m = average value of the predictor in base period = 3.91295

A comparison of the Base Period TN loads, scaled to reflect the 30 percent load reduction goal, with the TN-based Prediction (and associated UCL) and the TON-based Prediction (and associated UCL) is presented in **Figure 3-15.**

3.2.2.2.3 TN Annual Load Target and Annual Load Limit

Each year, the equations above will be used to calculate the TN-based Prediction and the TON-based Prediction. The larger of the two predicted loads will become the TN Annual Load Target. The TN Annual Load Limit will be the predicted UCL associated with the prediction equation, so whichever prediction establishes the Annual Load Target will be the basis for the Annual Load Limit. Annual TN loads at the sub-watershed outlet structures, adjusted to account for pass-through loads and regional projects (as applicable) as described in Appendices A and D, will be evaluated against the performance measure described above.

Figure 3-15. Comparison of scaled annual TN loads with the Annual Load Targets and Limits for the East Caloosahatchee Sub-watershed.

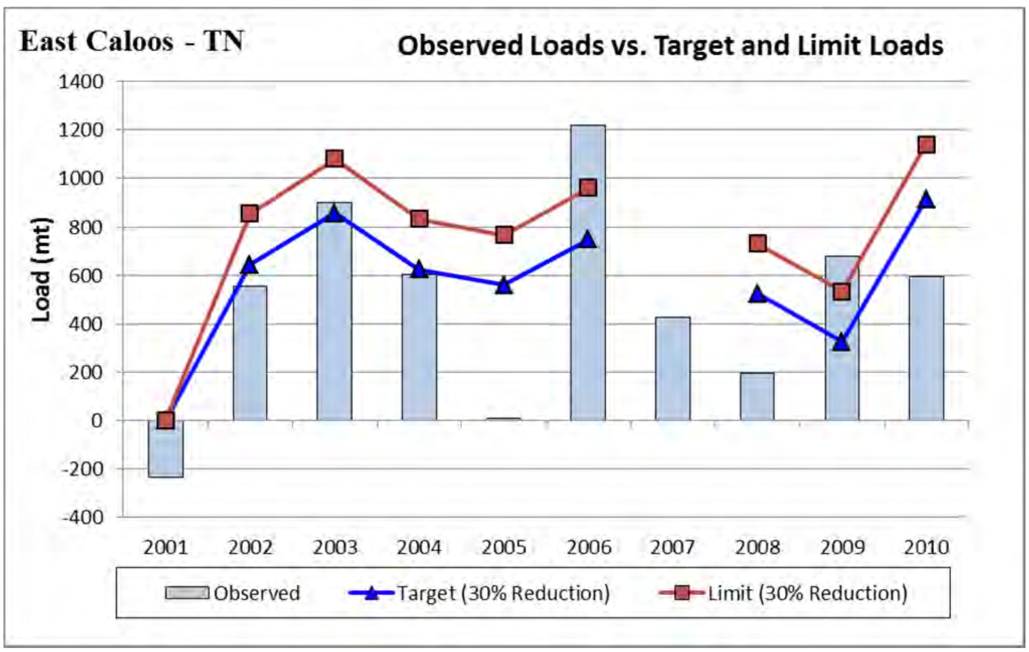


	1982	1983	1984	1985	1986	1987	1988	1989	1990
TN-based UCL	220.518	1123.985	562.022	423.203	374.528	685.246	443.110	355.705	276.539
TON-based UCL	371.052	1425.014	756.734	597.775	542.747	900.212	620.388	521.567	433.088
Scaled Load	171.861	1001.289	532.384	289.650	376.562	589.622	301.635	183.394	141.819
TN-based Prediction	121.984	1006.995	468.548	329.739	280.396	589.514	349.817	261.221	180.002
TON-based Prediction	154.204	1167.547	551.022	392.084	335.587	689.529	415.074	313.631	220.635

3.2.2.2.4 Suspension of Performance Determination. The TN performance determination will be suspended due to rainfall conditions if the observed annual TN load, adjusted for regional projects (if present) and pass-through loads, from the basin exceeds the Annual Load Target and the rainfall falls outside the range of rainfall values for the Base Period (42.29 – 72.47 inches). The rainfall values, Annual Load Targets and Annual Load Limits for the WY1982-2010 period of record are summarized in **Table 3-24**. The annual performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

3.2.2.2.5 Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-16**.

Figure 3-16. Comparison of WY2001-2010 TN loads with Annual Load Targets and Limits for the East Caloosahatchee Sub-watershed.



Notes:

1. The performance determination for WY2007 would have been suspended due to rainfall below the minimum value during the Base Period coupled with the observed load being greater than the Load Target.
2. Steps for addressing negative loads are described in Section 2.5.12.

Table 3-24. TN Annual Load Targets and Limits for the historical period of record for the East Caloosahatchee Sub-watershed (Base Period: WY1982-1990).

Water Year	Observed Rain, inches	Observed Load, mt	TN-based Prediction, mt	TN-based UCL mt	TON-based Prediction, mt	TON-based UCL mt
1982	42.29	245.516	121.985	220.518	154.205	371.052
1983	72.47	1,430.413	1006.999	1123.985	1167.552	1425.014
1984	52.22	760.549	468.541	562.022	551.014	756.734
1985	47.99	413.785	329.743	423.203	392.089	597.775
1986	46.57	537.945	280.390	374.528	335.580	542.747
1987	56.21	842.317	589.522	685.246	689.537	900.212
1988	48.58	430.907	349.821	443.110	415.078	620.388
1989	46.03	261.992	261.226	355.705	313.637	521.567
1990	43.81	202.599	180.006	276.539	220.639	433.088
1991	52.85	352.475	488.245	581.950	573.576	779.792
1992	59.68	522.124	687.948	786.974	802.236	1020.163
1993	52.67	-284.060	482.640	576.277	567.157	773.222
1994	47.73	416.512	320.817	414.376	381.868	587.769
1995	57.57	454.268	628.803	725.697	734.515	947.756
1996	57.42	-857.701	624.517	721.271	729.607	942.545
1997	47.75	149.833	321.505	415.058	382.657	588.542
1998	62.17	212.449	755.111	857.052	879.138	1103.491
1999	42.46	527.246	128.577	226.859	161.752	378.050
2000	60.47	387.696	709.555	809.465	826.977	1046.848
2001	34.44	-235.139	-215.398	-97.996	-232.101	26.267
2002	54.89	553.677	550.476	645.255	644.830	853.416
2003	61.45	901.921	735.970	837.024	857.222	1079.622
2004	54.29	601.546	532.416	626.827	624.151	831.927
2005	52.49	10.901	477.015	570.575	560.716	766.623
2006	57.97	1,221.004	640.180	737.458	747.542	961.619
2007	37.94	426.600	-56.366	50.776	-50.008	185.776
2008	51.49	197.117	445.409	538.691	524.528	729.813
2009	46.30	677.713	270.836	365.134	324.641	532.170
2010	63.32	596.033	785.227	888.647	913.621	1141.226

(pink)	Indicates the Annual TN Target
(blue)	Indicates the Annual TN Limit
(yellow)	Indicates the assessment would be suspended because the rainfall was below the Base Period minimum and the Target was exceeded.

Steps for addressing negative loads are described in Section 2.5.12.

3.2.2.2.6 Exceedance Frequency Analysis. Using the approach described in Section 2.5.11, an approximation of the cumulative exceedance frequency for the performance determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual TN loads of the Base Period. Separate approximations were prepared for the TN-based equations and the TON-based equations (**Tables 3-25** and **3-26**). Because the TN loads and rainfall statistics from the Base Period do not perfectly describe normal distributions (e.g., the medians are generally less than the means), the methodology includes conditional probabilities, and because the random number generator is imperfect, the exceedance frequencies deviate from the theoretical values shown in the second column. However, the results are determined to be reasonable and defensible since the cumulative exceedance frequency is less than the theoretical value of approximately 17.5 percent.

Table 3-25. Exceedance frequencies for the proposed TN-based prediction and UCL for the East Caloosahatchee Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	7.8%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.3%
Step 4. Load > Annual Load Limit?	<10%	4.4%
Cumulative Exceedance Frequency	**<17.5%**	**13.6%**

Table 3-26. Exceedance frequencies for the proposed TON-based prediction and UCL for the East Caloosahatchee Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	7.8%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.3%
Step 4. Load > Annual Load Limit?	<10%	4.4%
Cumulative Exceedance Frequency	**<17.5%**	**13.6%**

3.3 West Caloosahatchee Sub-watershed

The following sections present a description of the West Caloosahatchee Sub-watershed, a summary of historical flow and nutrient levels, nutrient reduction goals for the collective source control programs, and development of the performance metrics.

3.3.1 Background

The West Caloosahatchee Sub-watershed is about 350,114 acres in size and is composed of the area that drains to C-43 Canal (Caloosahatchee River) between S-78 and S-79 (**Figure 3-17**). The primary source of inflows to the West Caloosahatchee Sub-watershed is S-78 on C-43 which discharges from the East Caloosahatchee Sub-watershed. Outflows from the West Caloosahatchee Sub-watershed are discharged at S-79 on C-43 to the Tidal Caloosahatchee Sub-watershed. Flow and water quality data are available for S-78 and S-79 for the period from WY1982 to the present and were used in the development of the performance metric (flow and nutrient monitoring sites are identified in **Tables B-1** and **B-2**).

Inflows can also be discharged at the following canals (see **Figure 3-18**):

- There are three hydraulic connections that move water between Canal 3 in the East Caloosahatchee Sub-watershed and Canals 1 and 2 in the West Caloosahatchee Sub-watershed. District staff conducted hydrological evaluation of the flows that cross the sub-watershed boundary to (1) identify the 298 Water Control Districts (WCDs), and (2) review WCD plans and regulatory permits for flow distribution, structures, and operating procedures (Hansing 2012).

Figure 3-17. West Caloosahatchee Sub-watershed schematic (from SFWMD).

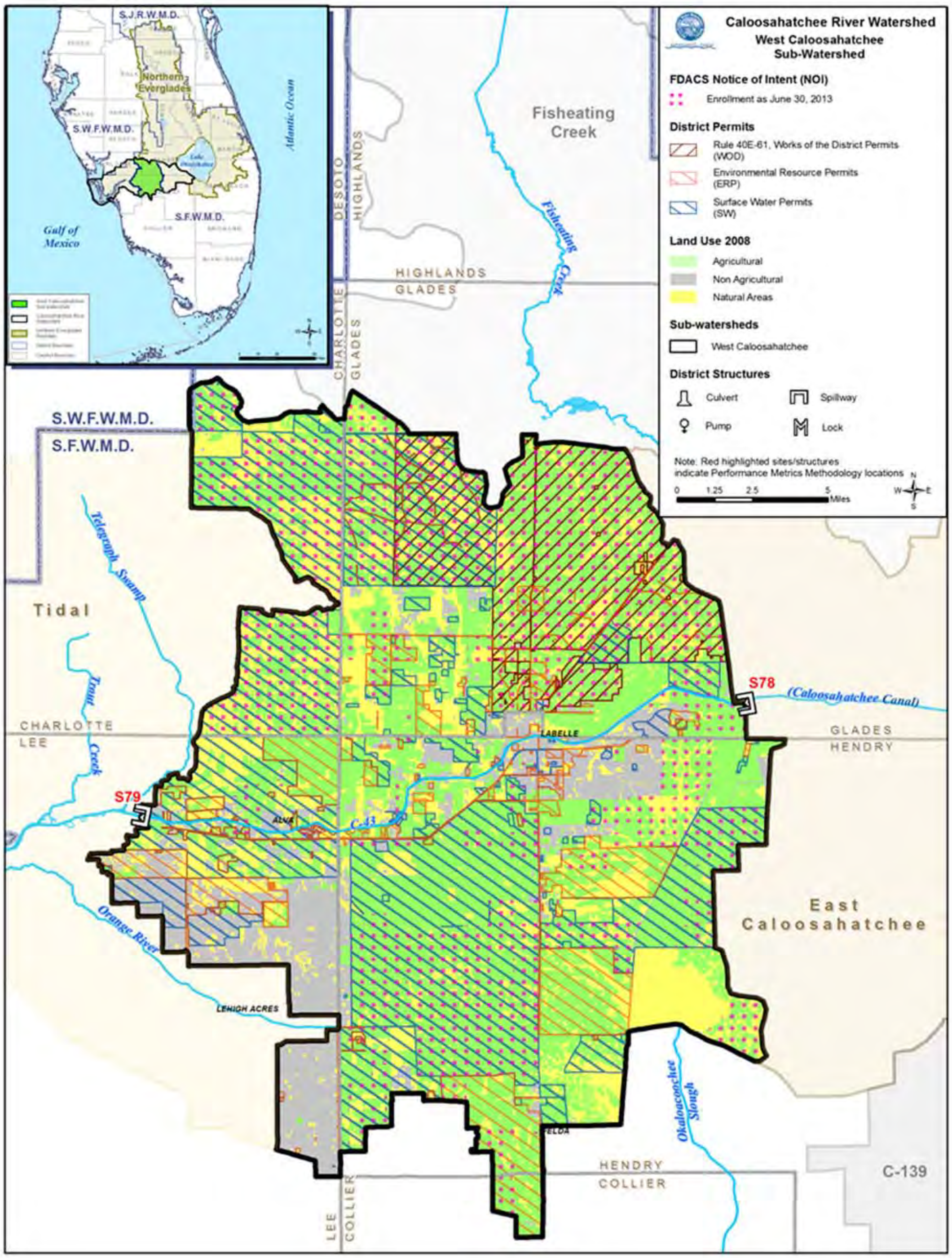
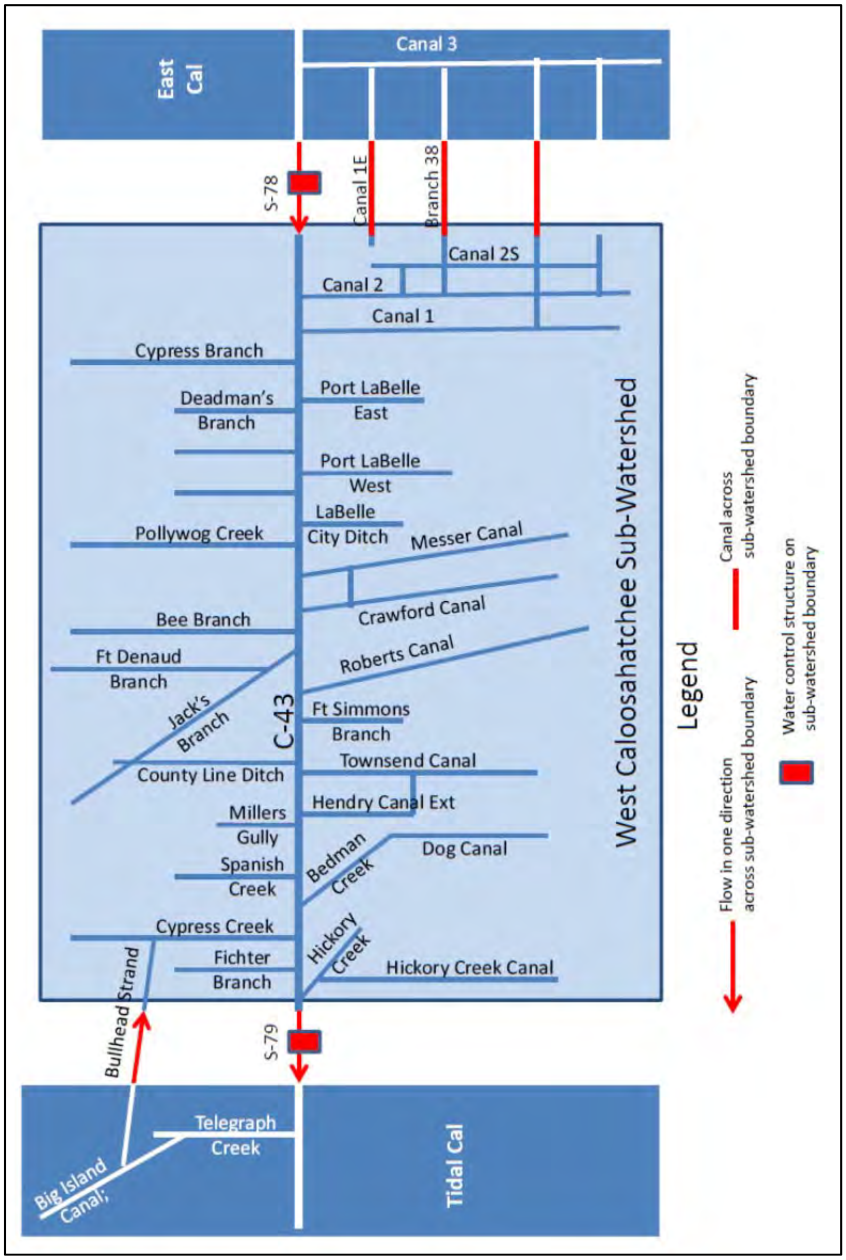


Figure 3-18. Flow Schematic of West Caloosahatchee Sub-watershed.



- Flows from the Tidal Caloosahatchee Sub-watershed can be discharged from Telegraph Swamp into the West Caloosahatchee Sub-watershed via Bullhead Strand which flows to Cypress Creek and then into the C-43 Canal. Four broad crested weirs maintain water levels in Telegraph Creek/Telegraph Swamp. One of the four, discharges to Bullhead Strand – the other three discharge to Telegraph Creek and then to the C-43 Canal downstream of S-79.

No discharge records are available for these structures. For the purposes of this analysis, it is assumed that the nutrient loads discharged from these structures are not significant. S-78 and S-79 are the primary structures representing inflow and outflows of the West Caloosahatchee Sub-watershed.

The historical data analysis for the West Caloosahatchee Sub-watershed summarized herein was initially prepared by HDR Engineering, Inc., as part of Contract No. ST061298 – WO08 (Data Analysis and Performance Measure Development for the St. Lucie and Caloosahatchee River Source Control Programs) with the District and was supplemented in collaboration with staff under this contract (HDR, 2011).

The performance metric methodologies are based on flows and nutrient (TP and TN) loads resulting from rainfall and runoff from the West Caloosahatchee Sub-watershed. Basin flows and loads, adjusted for pass-through flows and loads discharged from external sources, were calculated using algorithms provided in Appendix A.

District staff identified the rainfall stations considered to be representative of the sub-watershed for the period WY1976-2010. Monthly rainfall data and weighting factors for the rainfall stations were developed and provided by the District. **Tables 3-27** through **3-29** present the period of record flow and load data for the West Caloosahatchee Sub-watershed.

Table 3-27. Summary of historical data for the West Caloosahatchee Sub-watershed for the WY 1982-2010 period of record: TP data.

Water Year	Flow AF	TP Load mt	TP FWM Conc, µg/L	Rainfall inches	Unit Area Runoff, inches	Unit Area TP Load, lbs/ac	Rainfall Characteristics		
							Kurtosis	Coef. Of Var.	Skewness
1982	457,363	98.946	175	43.69	15.68	0.62	2.151	0.977	1.422
1983	1,058,478	216.426	166	73.64	36.28	1.36	-0.247	0.694	0.450
1984	910,660	122.168	109	53.22	31.21	0.77	3.058	0.778	1.377
1985	575,755	120.394	170	50.24	19.73	0.76	-0.007	0.858	0.738
1986	523,350	120.472	187	46.61	17.94	0.76	-1.601	0.756	0.471
1987	772,081	150.298	158	57.09	26.46	0.95	-0.860	0.769	0.511
1988	681,078	111.464	133	57.32	23.34	0.70	-0.998	0.601	0.195
1989	309,607	83.368	218	42.94	10.61	0.52	1.080	0.795	0.990
1990	294,720	80.380	221	49.15	10.10	0.51	-1.431	0.872	0.517
1991	325,420	83.050	207	51.00	11.15	0.52	-0.958	0.831	0.576
1992	657,374	130.271	161	61.77	22.53	0.82	-1.139	0.622	0.235
1993	647,329	330.552	414	53.39	22.19	2.08	6.193	1.048	2.209
1994	519,743	97.720	152	50.53	17.81	0.62	-1.434	0.663	0.310
1995	606,950	112.804	151	53.51	20.80	0.71	-0.724	0.595	0.797
1996	965,629	111.681	94	65.26	33.10	0.70	-1.406	0.907	0.542
1997	350,371	66.414	154	50.76	12.01	0.42	-0.390	0.850	0.663
1998	772,686	78.477	82	69.15	26.48	0.49	-0.380	0.532	0.136
1999	419,917	78.656	152	43.87	14.39	0.50	0.145	0.829	0.879
2000	675,884	105.388	126	55.30	23.17	0.66	2.157	1.172	1.558
2001	189,533	69.545	297	37.18	6.50	0.44	-0.236	1.002	0.825
2002	702,698	142.543	164	53.90	24.08	0.90	-1.387	0.965	0.661
2003	699,566	127.863	148	64.95	23.98	0.81	0.296	0.666	0.814
2004	822,969	139.058	137	61.99	28.21	0.88	-1.365	0.774	0.380
2005	625,286	100.857	131	53.01	21.43	0.64	0.199	1.004	0.934
2006	997,639	212.099	172	54.77	34.19	1.34	1.957	1.147	1.413
2007	418,013	96.898	188	40.39	14.33	0.61	-1.445	0.937	0.626
2008	80,523	23.017	232	49.90	2.76	0.14	0.137	0.686	0.552
2009	570,118	149.324	212	52.28	19.54	0.94	2.912	1.257	1.652
2010	606,614	124.693	167	71.92	20.79	0.79	-0.633	0.619	0.200
Minimum	***80,523***	***23.017***	***82***	***37.18***	***2.76***	***0.14***	***-1.601***	***0.532***	***0.136***
Average	***594,392***	***120.166***	***164***	***54.09***	***20.37***	***0.76***	***0.126***	***0.835***	***0.780***
Maximum	***1,058,478***	***330.552***	***414***	***73.64***	***36.28***	***2.08***	***6.193***	***1.257***	***2.209***
Std. Dev.	***238,976***	***56.611***	***63***	***9.01***	***8.19***	***0.36***	***1.793***	***0.185***	***0.499***
Median	***606,950***	***111.681***	***164***	***53.22***	***20.80***	***0.70***	***-0.380***	***0.829***	***0.661***
Skewness	***-0.069***	***2.008***	***2.083***	***0.442***	***-0.07***	***2.01***	***1.730***	***0.476***	***1.126***

Note: The FWM TP concentration was calculated by dividing the annual TP load by the annual flow.

Table 3-28. Summary of historical data for the West Caloosahatchee Sub-watershed for the WY 1982-2010 period of record: TN data.

Water Year	Flow AF	TN Load mt	TN FWM Conc, µg/L	Rainfall inches	Unit Area Runoff, in/yr	Unit Area TN Load, lbs/ac	Rainfall Characteristics		
							Kurtosis	Coef. Of Var.	Skewness
1982	457,363	1,065.355	1,888	43.69	15.68	6.71	2.151	0.977	1.422
1983	1,058,478	1,338.364	1,025	73.64	36.28	8.43	-0.247	0.694	0.450
1984	910,660	385.123	343	53.22	31.21	2.43	3.058	0.778	1.377
1985	575,755	935.819	1,318	50.24	19.73	5.89	-0.007	0.858	0.738
1986	523,350	1,614.219	2,501	46.61	17.94	10.16	-1.601	0.756	0.471
1987	772,081	2,507.268	2,633	57.09	26.46	15.79	-0.860	0.769	0.511
1988	681,078	1,279.367	1,523	57.32	23.34	8.06	-0.998	0.601	0.195
1989	309,607	628.011	1,644	42.94	10.61	3.95	1.080	0.795	0.990
1990	294,720	583.983	1,606	49.15	10.10	3.68	-1.431	0.872	0.517
1991	325,420	763.899	1,903	51.00	11.15	4.81	-0.958	0.831	0.576
1992	657,374	1,187.829	1,465	61.77	22.53	7.48	-1.139	0.622	0.235
1993	647,329	1,885.544	2,361	53.39	22.19	11.87	6.193	1.048	2.209
1994	519,743	1,110.724	1,733	50.53	17.81	6.99	-1.434	0.663	0.310
1995	606,950	1,579.759	2,110	53.51	20.80	9.95	-0.724	0.595	0.797
1996	965,629	1,570.234	1,318	65.26	33.10	9.89	-1.406	0.907	0.542
1997	350,371	792.257	1,833	50.76	12.01	4.99	-0.390	0.850	0.663
1998	772,686	967.679	1,015	69.15	26.48	6.09	-0.380	0.532	0.136
1999	419,917	747.362	1,443	43.87	14.39	4.71	0.145	0.829	0.879
2000	675,884	1,072.855	1,287	55.30	23.17	6.76	2.157	1.172	1.558
2001	189,533	142.824	611	37.18	6.50	0.90	-0.236	1.002	0.825
2002	702,698	1,327.594	1,532	53.90	24.08	8.36	-1.387	0.965	0.661
2003	699,566	1,136.426	1,317	64.95	23.98	7.16	0.296	0.666	0.814
2004	822,969	1,115.304	1,099	61.99	28.21	7.02	-1.365	0.774	0.380
2005	625,286	1,423.086	1,845	53.01	21.43	8.96	0.199	1.004	0.934
2006	997,639	1,418.567	1,153	54.77	34.19	8.93	1.957	1.147	1.413
2007	418,013	888.826	1,724	40.39	14.33	5.60	-1.445	0.937	0.626
2008	80,523	137.100	1,380	49.90	2.76	0.86	0.137	0.686	0.552
2009	570,118	882.239	1,255	52.28	19.54	5.56	2.912	1.257	1.652
2010	606,614	1,012.478	1,353	71.92	20.79	6.38	-0.633	0.619	0.200
Minimum	***80,523***	***137.100***	***343***	***37.18***	***2.76***	***0.86***	***-1.601***	***0.532***	***0.136***
Average	***594,392***	***1,086.210***	***1,482***	***54.09***	***20.37***	***6.84***	***0.126***	***0.835***	***0.780***
Maximum	***1,058,478***	***2,507.268***	***2,633***	***73.64***	***36.28***	***15.79***	***6.193***	***1.257***	***2.209***
Std. Dev.	***238,976***	***499.474***	***506***	***9.01***	***8.19***	***3.15***	***1.793***	***0.185***	***0.499***
Median	***606,950***	***1,072.855***	***1,465***	***53.22***	***20.80***	***6.76***	***-0.380***	***0.829***	***0.661***
Skewness	***-0.069***	***0.460***	***0.116***	***0.442***	***-0.07***	***0.46***	***1.730***	***0.476***	***1.126***

Note: The FWM TN concentration was calculated by dividing the annual TN load by the annual flow.

Table 3-29. Summary of historical data for the West Caloosahatchee Sub-watershed for the WY 1982-2010 period of record: TON data.

Water Year	Flow AF	TON Load mt	TON FWM Conc, µg/L	Rainfall inches	Unit Area Runoff, in/yr	Unit Area TON Load, lbs/ac	Rainfall Characteristics Kurtosis	Coef. Of Var.	Skewness
1982	457,363	889.623	1,577	43.69	15.68	5.60	2.151	0.977	1.422
1983	1,058,478	983.113	753	73.64	36.28	6.19	-0.247	0.694	0.450
1984	910,660	48.627	43	53.22	31.21	0.31	3.058	0.778	1.377
1985	575,755	653.080	920	50.24	19.73	4.11	-0.007	0.858	0.738
1986	523,350	1,383.046	2,142	46.61	17.94	8.71	-1.601	0.756	0.471
1987	772,081	2,040.091	2,142	57.09	26.46	12.85	-0.860	0.769	0.511
1988	681,078	942.573	1,122	57.32	23.34	5.94	-0.998	0.601	0.195
1989	309,607	427.824	1,120	42.94	10.61	2.69	1.080	0.795	0.990
1990	294,720	411.803	1,133	49.15	10.10	2.59	-1.431	0.872	0.517
1991	325,420	662.928	1,652	51.00	11.15	4.17	-0.958	0.831	0.576
1992	657,374	880.203	1,086	61.77	22.53	5.54	-1.139	0.622	0.235
1993	647,329	1,614.723	2,022	53.39	22.19	10.17	6.193	1.048	2.209
1994	519,743	819.336	1,278	50.53	17.81	5.16	-1.434	0.663	0.310
1995	606,950	1,300.988	1,738	53.51	20.80	8.19	-0.724	0.595	0.797
1996	965,629	1,056.697	887	65.26	33.10	6.65	-1.406	0.907	0.542
1997	350,371	631.363	1,461	50.76	12.01	3.98	-0.390	0.850	0.663
1998	772,686	647.222	679	69.15	26.48	4.08	-0.380	0.532	0.136
1999	419,917	500.743	967	43.87	14.39	3.15	0.145	0.829	0.879
2000	675,884	726.234	871	55.30	23.17	4.57	2.157	1.172	1.558
2001	189,533	13.108	56	37.18	6.50	0.08	-0.236	1.002	0.825
2002	702,698	965.020	1,113	53.90	24.08	6.08	-1.387	0.965	0.661
2003	699,566	736.303	853	64.95	23.98	4.64	0.296	0.666	0.814
2004	822,969	599.537	591	61.99	28.21	3.78	-1.365	0.774	0.380
2005	625,286	979.055	1,269	53.01	21.43	6.16	0.199	1.004	0.934
2006	997,639	871.219	708	54.77	34.19	5.49	1.957	1.147	1.413
2007	418,013	748.559	1,452	40.39	14.33	4.71	-1.445	0.937	0.626
2008	80,523	111.596	1,124	49.90	2.76	0.70	0.137	0.686	0.552
2009	570,118	644.150	916	52.28	19.54	4.06	2.912	1.257	1.652
2010	606,614	809.938	1,082	71.92	20.79	5.10	-0.633	0.619	0.200
Minimum	***80,523***	***13.108***	***43***	***37.18***	***2.76***	***0.08***	***-1.601***	***0.532***	***0.136***
Average	***594,392***	***796.507***	***1,086***	***54.09***	***20.37***	***5.02***	***0.126***	***0.835***	***0.780***
Maximum	***1,058,478***	***2,040.091***	***2,142***	***73.64***	***36.28***	***12.85***	***6.193***	***1.257***	***2.209***
Std. Dev.	***238,976***	***430.798***	***515***	***9.01***	***8.19***	***2.71***	***1.793***	***0.185***	***0.499***
Median	***606,950***	***748.559***	***1,113***	***53.22***	***20.80***	***4.71***	***-0.380***	***0.829***	***0.661***
Skewness	***-0.069***	***0.702***	***0.098***	***0.442***	***-0.07***	***0.70***	***1.730***	***0.476***	***1.126***

Note: The FWM TON concentration was calculated by dividing the annual TON load by the annual flow.

The Base Period of WY 1988-1997 is recommended because:

- This period represents a period with minimal impacts prior to implementation of source controls. With the selection of the Base Period to precede significant source control implementation, no additional calculation is necessary in the performance measure methodology to account for prior source control implementation,
- There is a strong relationship between rainfall and nutrient loading,
- No changes were detected in the annual rainfall and flow since the base period,
- Rainfall patterns during this period are representative of long-term conditions,
- No significant annual trends were detected in the data, and
- Although a potential outlier was detected in the data, after examination, evaluations concluded that the values were representative of the physical conditions that existed and they were retained in the analysis.

Tables 3-30 through **3-32** compare hydrologic and nutrient data for the period of record and Base Period and for the WY2001-2010 period. Additional information is provided in Appendix A.

Table 3-30. Comparisons of Base Period with period of record and WY2001-2010 data for the West Caloosahatchee Sub-watershed: TP.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	80,523	23.017	82	37.18	0.14
Annual Average	594,392	120.166	164	54.09	0.76
Annual Median	606,950	111.681	164	53.22	0.70
Annual Maximum	1,058,478	330.552	414	73.64	2.08
Base Period WY1988-1997					
Annual Minimum	294,720	66.414	94	42.94	0.42
Annual Average	535,822	120.770	183	53.56	0.76
Annual Median	563,347	104.592	158	52.20	0.66
Annual Maximum	965,629	330.552	414	65.26	2.08
Difference between Period of Record and Base Period					
Annual Minimum	-214,197	-43.397	-12	-5.76	-0.27
Annual Average	58,569	-0.604	-19	0.53	0.00
Annual Median	43,604	7.089	7	1.03	0.04
Annual Maximum	92,849	0.000	0	8.38	0.00
Annual Minimum	-73%	-65%	-13%	-13%	-65%
Annual Average	11%	-1%	-10%	1%	-1%
Annual Median	8%	7%	4%	2%	7%
Annual Maximum	10%	0%	0%	13%	0%
WY2001-2010					
Annual Minimum	80,523	23.017	131	37.18	0.14
Annual Average	571,296	118.590	168	54.03	0.75
Annual Median	615,950	126.278	170	53.46	0.80
Annual Maximum	997,639	212.099	297	71.92	1.34
Difference between WY2001-2010 and Base Period					
Annual Minimum	-214,197	-43.397	37	-5.76	-0.27
Annual Average	35,474	-2.181	-14	0.47	-0.01
Annual Median	52,604	21.686	12	1.26	0.14
Annual Maximum	32,010	-118.453	-117	6.66	-0.75
Annual Minimum	-73%	-65%	39%	-13%	-65%
Annual Average	7%	-2%	-8%	1%	-2%
Annual Median	9%	21%	8%	2%	21%
Annual Maximum	3%	-36%	-28%	10%	-36%

Table 3-31. Comparisons of Base Period with period of record and WY2001-2010 data for the West Caloosahatchee Sub-watershed: TN.

Metric	Flow AF	TN Load mt	TN Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	80,523	137.100	343	37.18	0.86
Annual Average	594,392	1,086.210	1,482	54.09	6.84
Annual Median	606,950	1,072.855	1,465	53.22	6.76
Annual Maximum	1,058,478	2,507.268	2,633	73.64	15.79
Base Period WY1988-1997					
Annual Minimum	294,720	583.983	1,318	42.94	3.68
Annual Average	535,822	1,138.161	1,722	53.56	7.17
Annual Median	563,347	1,149.277	1,689	52.20	7.24
Annual Maximum	965,629	1,885.544	2,361	65.26	11.87
Difference between Period of Record and Base Period					
Annual Minimum	-214,197	-446.883	-975	-5.76	-2.81
Annual Average	58,569	-51.951	-241	0.53	-0.33
Annual Median	43,604	-76.421	-224	1.03	-0.48
Annual Maximum	92,849	621.724	272	8.38	3.91
Annual Minimum	-73%	-77%	-74%	-13%	-77%
Annual Average	11%	-5%	-14%	1%	-5%
Annual Median	8%	-7%	-13%	2%	-7%
Annual Maximum	10%	33%	12%	13%	33%
WY2001-2010					
Annual Minimum	80,523	137.100	611	37.18	0.86
Annual Average	571,296	948.444	1,346	54.03	5.97
Annual Median	615,950	1,063.891	1,335	53.46	6.70
Annual Maximum	997,639	1,423.086	1,845	71.92	8.96
Difference between WY2001-2010 and Base Period					
Annual Minimum	-214,197	-446.883	-707	-5.76	-2.81
Annual Average	35,474	-189.716	-376	0.47	-1.19
Annual Median	52,604	-85.385	-354	1.26	-0.54
Annual Maximum	32,010	-462.458	-516	6.66	-2.91
Annual Minimum	-73%	-77%	-54%	-13%	-77%
Annual Average	7%	-17%	-22%	1%	-17%
Annual Median	9%	-7%	-21%	2%	-7%
Annual Maximum	3%	-25%	-22%	10%	-25%

Table 3-32. Comparisons of Base Period with period of record and WY2001-2010 data for the West Caloosahatchee Sub-watershed: TON.

Metric	Flow AF	TON Load mt	TON Conc µg/L	Rainfall inches	UAL lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	80,523	13.108	43	37.18	0.08
Annual Average	594,392	796.507	1,086	54.09	5.02
Annual Median	606,950	748.559	1,113	53.22	4.71
Annual Maximum	1,058,478	2,040.091	2,142	73.64	12.85
Preliminary Base Period WY1988-1997					
Annual Minimum	294,720	411.803	887	42.94	2.59
Annual Average	535,822	874.844	1,324	53.56	5.51
Annual Median	563,347	849.770	1,206	52.20	5.35
Annual Maximum	965,629	1,614.723	2,022	65.26	10.17
Difference between Period of Record and Base Period					
Annual Minimum	-214,197	-398.695	-844	-5.76	-2.51
Annual Average	58,569	-78.337	-237	0.53	-0.49
Annual Median	43,604	-101.211	-93	1.03	-0.64
Annual Maximum	92,849	425.368	120	8.38	2.68
Annual Minimum	-73%	-97%	-95%	-13%	-97%
Annual Average	11%	-9%	-18%	1%	-9%
Annual Median	8%	-12%	-8%	2%	-12%
Annual Maximum	10%	26%	6%	13%	26%
WY2001-2010					
Annual Minimum	80,523	13.108	56	37.18	0.08
Annual Average	571,296	647.849	919	54.03	4.08
Annual Median	615,950	742.431	999	53.46	4.67
Annual Maximum	997,639	979.055	1,452	71.92	6.16
Difference between WY2001-2010 and Base Period					
Annual Minimum	-214,197	-398.695	-831	-5.76	-2.51
Annual Average	35,474	-226.995	-404	0.47	-1.43
Annual Median	52,604	-107.339	-207	1.26	-0.68
Annual Maximum	32,010	-635.668	-570	6.66	-4.00
Annual Minimum	-73%	-97%	-94%	-13%	-97%
Annual Average	7%	-26%	-31%	1%	-26%
Annual Median	9%	-13%	-17%	2%	-13%
Annual Maximum	3%	-39%	-28%	10%	-39%

3.3.1.1 TP Trend. Using the approach described in Section 2.5.4, a series of regression equations were evaluated to determine which one best described the hydrologic variability of the Base Period annual TP load. The predicted annual TP loads derived from the Base Period data using a 0 percent load reduction were calculated according to the following equation and explanation.

$$\text{TP Annual Load} = [\ -37.66394 + 11.39314\ X + 4.32389\ S\ ]^2$$

Explained Variance = 82.2%, Standard Error of Regression = 29.216 mt

Predictors (X and S) are calculated from the first three moments (m_1, m_2, and m_3) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

X = natural logarithm of the 12-month total rainfall (inches) = $12m_1$

S = skewness calculated from 12 monthly rainfall totals = $[\ (12/11)\ m_3]^{1.5} / m_2$

$m_1 = \text{Sum}\ [\ r_i\ ] / 12$

$m_2 = \text{Sum}\ [\ r_i - m_1\ ]^2 / 12$

$m_3 = \text{Sum}\ [\ r_i - m_1\ ]^3 / 12$

The first predictor (X) indicates that load increases with the square of the total annual rainfall. The second predictor (S) indicates that the load resulting from a given annual rainfall is higher when the distribution of monthly rainfall is skewed to the right. For a given annual rainfall, the lowest load would be predicted when rainfall is evenly distributed across months and the highest load would be predicted when all of the rain falls in one month. Real cases are likely to fall in between.

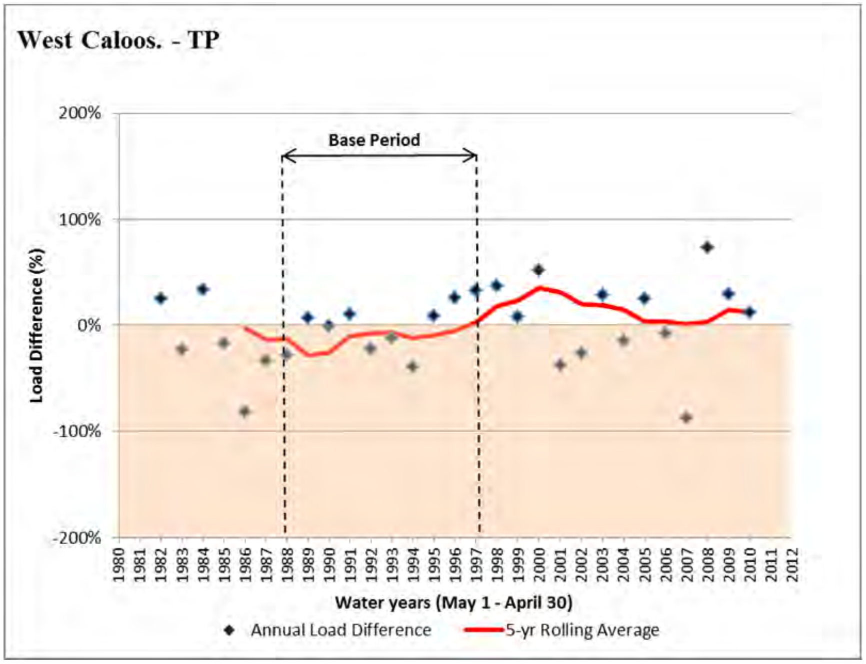
Table 3-33 presents the annual observed and predicted sub-watershed TP loads. The load trend is presented in **Figure 3-19**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-19** denotes a reduction in loads.

Table 3-33. WY1982 – WY2010 West Caloosahatchee Sub-watershed TP measurements and calculations. (Base Period: WY1988-1997).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1982	43.69	98.946	132.662	25%	
1983	73.64	216.426	175.910	-23%	
1984	53.22	122.168	184.180	34%	
1985	50.24	120.394	103.060	-17%	
1986	46.61	120.472	66.309	-82%	-2%
1987	57.09	150.298	112.925	-33%	-14%
1988	57.32	111.464	86.603	-29%	-13%
1989	42.94	83.368	89.352	7%	-28%
1990	49.15	80.38	80.039	0%	-25%
1991	51.00	83.05	92.593	10%	-10%
1992	61.77	130.271	106.727	-22%	-7%
1993	53.39	330.552	296.016	-12%	-6%
1994	50.53	97.72	70.004	-40%	-12%
1995	53.51	112.804	123.775	9%	-9%
1996	65.26	111.681	150.908	26%	-5%
1997	50.76	66.414	98.901	33%	3%
1998	69.15	78.477	125.186	37%	18%
1999	43.87	78.656	84.950	7%	23%
2000	55.3	105.388	218.766	52%	35%
2001	37.18	69.545	50.385	-38%	31%
2002	53.9	142.543	112.786	-26%	20%
2003	64.95	127.863	179.730	29%	19%
2004	61.99	139.058	120.962	-15%	14%
2005	53.01	100.857	134.811	25%	3%
2006	54.77	212.099	197.516	-7%	3%
2007	40.39	96.898	51.570	-88%	1%
2008	49.9	23.017	85.938	73%	3%
2009	52.28	149.324	211.916	30%	15%
2010	71.92	124.693	141.914	12%	12%

Note: Predicted load represents the base period load adjusted for rainfall variability

Figure 3-19. West Caloosahatchee Sub-watershed TP load trend.



Notes: A positive load difference denotes a reduction in load in comparison to the base period.
An upward trend in the solid line denotes a reduction in loads.

3.3.1.2 TN Trend. Using the approach described in Section 2.5.4, a series of regression equations were evaluated to determine which one best described the hydrologic variability of the Base Period annual TN load. The predicted annual TN loads derived from the Base Period data using a 0 percent load reduction were calculated according to the following equation and explanation.

TN Annual Load = -11169.78874 + 2893.29644 X + 725.02823 S + -1115.41479 C)

Explained Variance = 90.1%, Standard Error of Regression = 172.169 mt

The predictors X, S and C are calculated from the first three moments (m_1, m_2, and m_3) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

X = natural logarithm of the 12-month total rainfall (inches) = $\ln\{12m_1\}$

S = skewness calculated from 12 monthly rainfall totals = $[(12/11)\ m_3]^{1.5} / m_2$

C = natural logarithm of the coefficient of variation calculated from 12 monthly rainfall totals

$C = \ln\{[(12/11)\ m_2]^{0.5}/m_1\}$

$m_1 = \text{Sum} [r_i] / 12$

$m_2 = \text{Sum} [r_i - m_1]^2 / 12$

$m_3 = \text{Sum} [r_i - m_1]^3 / 12$

The predictor (X) indicates that TN load increases with the total annual rainfall. The second and third predictors (S and C) indicate that the load resulting from a given annual rainfall is higher when the distribution of monthly rainfall has higher variability. For a given annual rainfall, the lowest load would be predicted when rainfall is evenly distributed across months and the highest load would be predicted when all of the rain falls in one month. Real cases fall in between.

Table 3-34 presents the annual observed and predicted sub-watershed TN loads. The load trend is presented in **Figure 3-20**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-20** denotes a reduction in loads.

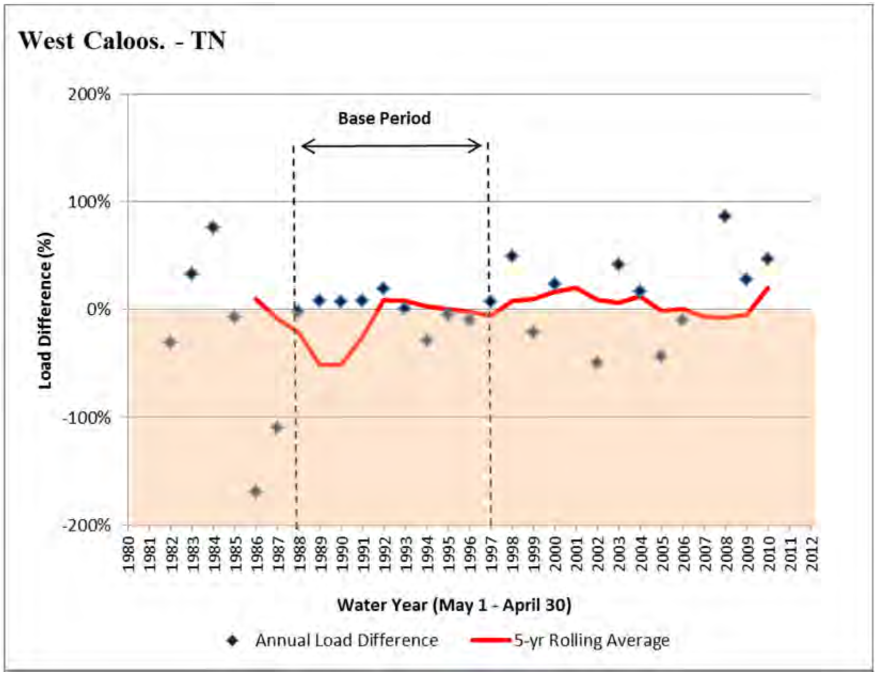
Table 3-34. WY1982 – WY2010 West Caloosahatchee Sub-watershed TN measurements and calculations. (Base Period: WY1988-1997).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1982	43.69	1,065.355	815.481	-31%	
1983	73.64	1,338.364	2002.743	33%	
1984	53.22	385.123	1607.793	76%	
1985	50.24	935.819	868.606	-8%	
1986	46.61	1,614.219	599.207	-169%	9%
1987	57.09	2,507.268	1195.991	-110%	-8%
1988	57.32	1,279.367	1253.460	-2%	-22%
1989	42.94	628.011	682.107	8%	-51%
1990	49.15	583.983	626.858	7%	-52%
1991	51.00	763.899	830.256	8%	-26%
1992	61.77	1,187.829	1460.479	19%	8%
1993	53.39	1,885.544	1887.948	0%	8%
1994	50.53	1,110.724	862.533	-29%	2%
1995	53.51	1,579.759	1502.115	-5%	0%
1996	65.26	1,570.234	1421.345	-10%	-3%
1997	50.76	792.257	854.470	7%	-6%
1998	69.15	967.679	1889.575	49%	8%
1999	43.87	747.362	616.912	-21%	10%
2000	55.30	1,072.855	1392.917	23%	17%
2001	37.18	142.824	-112.372	-227%	20%
2002	53.90	1,327.594	885.144	-50%	9%
2003	64.95	1,136.426	1949.275	42%	6%
2004	61.99	1,115.304	1332.029	16%	12%
2005	53.01	1,423.086	990.712	-44%	-2%
2006	54.77	1,418.567	1283.975	-10%	0%
2007	40.39	888.826	57.756	-1439%	-7%
2008	49.90	137.100	963.652	86%	-8%
2009	52.28	882.239	1220.488	28%	-5%
2010	71.92	1,012.478	1880.672	46%	20%

Notes:

1. Predicted load represents the base period load adjusted for rainfall variability.
2. Steps for addressing negative loads are described in Section 2.5.12.

Figure 3-20. West Caloosahatchee Sub-watershed TN load trend.



Notes:
1. A positive load difference denotes a reduction in load in comparison to the base period.
2. An upward trend in the solid line denotes a reduction in loads.

3.3.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the West Caloosahatchee Sub-watershed.

3.3.2.1 Total Phosphorus Performance Metric Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.5, the overall range of TP load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 30 percent was determined to be reasonable and appropriate. Details are provided in Appendix C and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 30 percent load reduction, and will be calculated according to the following equations and explanation.

TP Annual Load Target = $[-31.51187 + 9.53218\ X + 3.61761\ S]^2$

Explained Variance = 82.2%, Standard Error of Regression = 20.451 mt

Predictors (X and S) are calculated from the first three moments (m_1, m_2, and m_3) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

X = natural logarithm of the 12-month total rainfall (inches) = $12m_1$

S = skewness calculated from 12 monthly rainfall totals = $[\ (12/11)\ m_3]^{1.5} / m_2$

m_1 = Sum $[\ r_i\ ] / 12$

m_2 = Sum $[\ r_i - m_1\ ]^2 / 12$

m_3 = Sum $[\ r_i - m_1\ ]^3 / 12$

TP Annual Load Limit = $[\text{sqrt(Target)} + (1.41492 * SE)]^2$

SE = standard error of the Target for May-April interval

$$SE = 1.13072\ [\ 1 + 1/10 + 8.28187\ (X-X_m)^2 + 0.3467\ (S-S_m)^2 + 0.83154\ (X-X_m)\ (S-S_m)\ ]^{0.5}$$

Where:

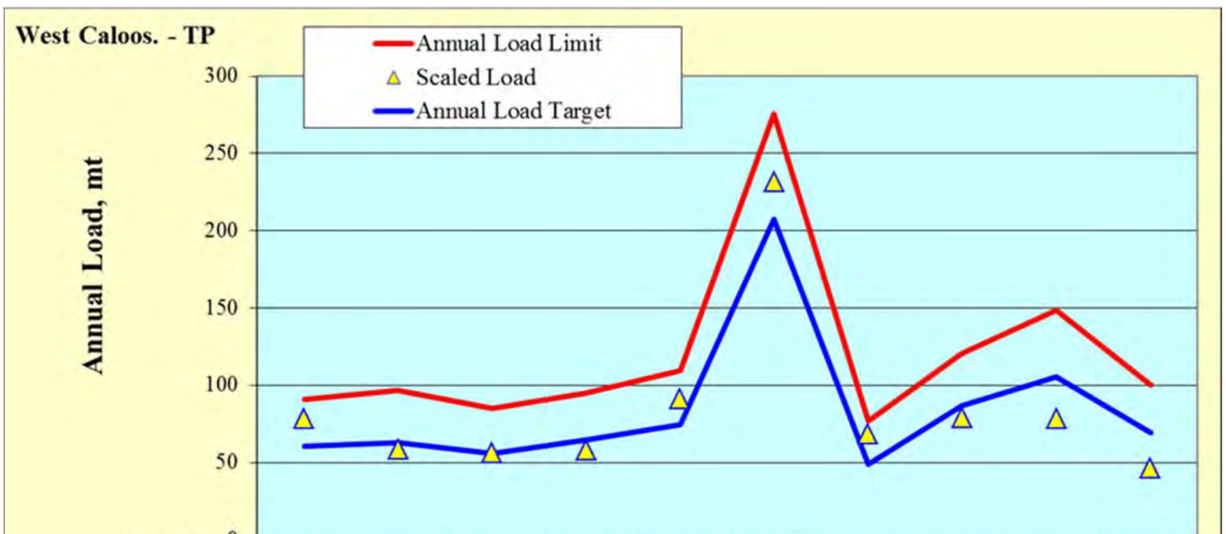
X_m = average value of the predictor in base period = 3.97441

S_m = average value of the predictor in base period = 0.70340

The first predictor (X) indicates that load increases with the square of the total annual rainfall. The second predictor (S) indicates that the load resulting from a given annual rainfall is higher when the distribution of monthly rainfall is skewed to the right. For a given annual rainfall, the lowest load would be predicted when rainfall is evenly distributed across months and the highest load would be predicted when all of the rain falls in one month. Real cases are likely to fall in between.

A comparison of the Base Period loads, scaled to reflect the 30 percent reduction goal, and the resulting Targets and Limits for are presented in **Figure 3-21.** Annual TP loads at the sub-watershed outlet structures, adjusted to account for pass-through loads and regional projects (as applicable) as described in Appendices A and D, respectively, will be evaluated against the performance measure described above.

Figure 3-21. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the West Caloosahatchee Sub-watershed.



Water Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Annual Load Limit	91.039	96.845	85.020	95.020	109.598	275.371	76.520	120.758	148.561	100.284
Scaled Load	78.025	58.358	56.266	58.135	91.190	231.386	68.404	78.963	78.177	46.490
Annual Load Target	60.622	62.547	56.027	64.815	74.709	207.211	49.003	86.643	105.636	69.231

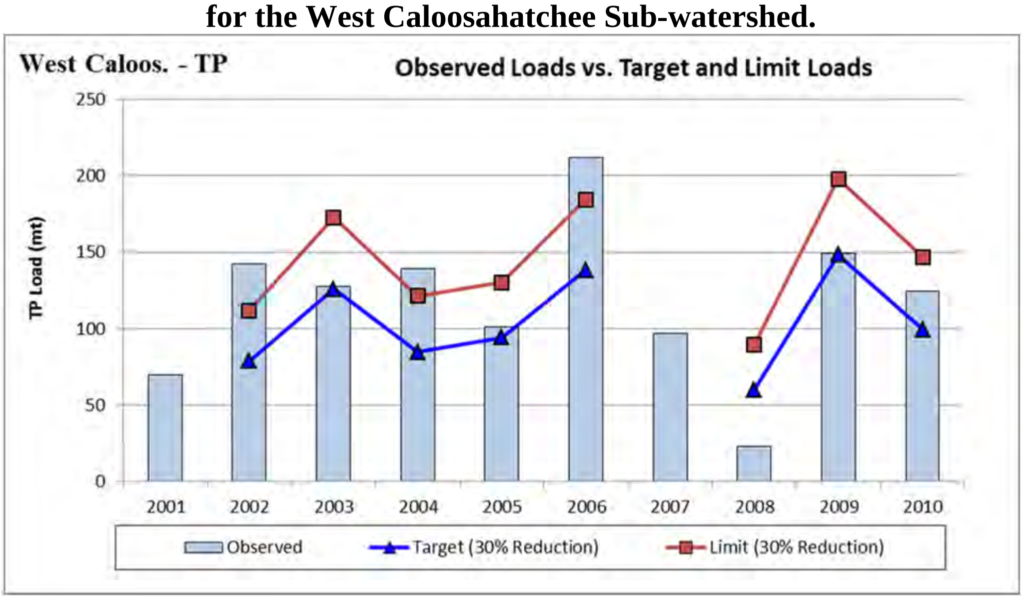
3.3.2.1.1 Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load, adjusted for regional projects (if present), from the basin exceeds the Annual Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (43.52 – 94.54 inches), as described below. Extreme rainfall conditions will be assessed by calculating an adjusted rainfall amount which reflects the cumulative effect of the predictor variables of the Annual Load Target equation. The adjusted rainfall is the rainfall that would produce the equivalent annual load using the Annual Load Target equation by setting the value of S to its mean value for the calibration period.

$$\text{Adjusted Rain} = \exp\left[X + 0.37952\,(S - 0.70340)\right]$$

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1982-2010 period of record are summarized in **Table 3-35**. The annual TP performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

3.3.2.1.2 Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-22**.

Figure 3-22. Comparison of WY2001-2010 TP loads with Annual Load Targets and Limits for the West Caloosahatchee Sub-watershed.



Note: The performance determinations for WY2001 and WY2007 would have been suspended due to rainfall below the minimum value during the Base Period coupled with the observed load being greater than the Load Target.

Table 3-35. TP Annual Load Targets and Limits for the historical period of record for the West Caloosahatchee Sub-watershed (Base Period: WY1988-1997).

Water Year	Observed Load, mt	Target Load, mt	Limit Load, mt	Observed Rain, in	Adjusted Rain, in
1982	98.946	92.863	134.217	43.69	57.39
1983	216.426	123.137	177.364	73.64	66.89
1984	122.168	128.926	172.883	53.22	68.72
1985	120.394	72.142	103.867	50.24	50.90
1986	120.472	46.416	74.477	46.61	42.68
1987	150.298	79.048	112.379	57.09	53.07
1988	111.464	60.622	91.039	57.32	47.26
1989	83.368	62.547	96.845	42.94	47.87
1990	80.380	56.027	85.020	49.15	45.79
1991	83.050	64.815	95.020	51.00	48.59
1992	130.271	74.709	109.598	61.77	51.71
1993	330.552	207.211	275.371	53.39	94.54
1994	97.720	49.003	76.520	50.53	43.52
1995	112.804	86.643	120.758	53.51	55.45
1996	111.681	105.636	148.561	65.26	61.38
1997	66.414	69.231	100.284	50.76	49.99
1998	78.477	87.630	130.414	69.15	55.75
1999	78.656	59.465	92.134	43.87	46.89
2000	105.388	153.136	203.429	55.30	76.49
2001	69.545	35.270	68.493	37.18	38.94
2002	142.543	78.950	111.609	53.90	53.04
2003	127.863	125.811	172.761	64.95	67.73
2004	139.058	84.674	121.386	61.99	54.83
2005	100.857	94.368	130.092	53.01	57.86
2006	212.099	138.261	184.456	54.77	71.70
2007	96.898	36.099	66.011	40.39	39.22
2008	23.017	60.157	89.719	49.90	47.11
2009	149.324	148.341	198.047	52.28	74.93
2010	124.693	99.340	146.920	71.92	59.41

Notes:

1. Shaded water years indicate the performance determination would have been suspended due to adjusted rainfall below the Base Period range coupled with the observed load being greater than the Load Target.
2. Steps for addressing negative loads are described in Section 2.5.12.

3.3.2.1.3 Exceedance Frequency Analysis. Using the approach described in Section 1.6, an approximation of the cumulative exceedance frequency for the performance determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP loads of the Base Period (**Table 3-36**). Because the TP loads and rainfall statistics from the Base Period do not perfectly describe normal distributions (e.g., the medians are generally less than the means), the methodology includes conditional probabilities, and because the random number generator is imperfect, the exceedance frequencies deviate from the theoretical values shown in the second column. However, the results are determined to be reasonable and defensible since the cumulative exceedance frequency is less than the theoretical value of approximately 17.5 percent.

Table 3-36. Exceedance frequencies for the proposed TP performance determination methodology for the West Caloosahatchee sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if $Rain_{adj}$ is outside the range and Load > Annual Load Target	<20%	4.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.3%
Step 4. Load > Annual Load Limit?	<10%	3.5%
Cumulative Exceedance Frequency	**<17.5%**	**13.7%**

3.3.2.2 Total Nitrogen Performance Metric Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.5, the overall range of TN load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 25 percent was determined to be reasonable and appropriate. In addition, a threshold of 90 percent of the TON load was established to ensure that estimates of TN reductions do not go beyond what could be reasonably expected from source controls on anthropogenic activities. Details are provided in Appendix C and in Attachment 1.

3.3.2.2.1 TN-based Prediction Equations

A TN-based load prediction equation and an associated 90th percent upper confidence limit (UCL) were derived from the Base Period TN data using a 25 percent reduction.

TN-based Prediction = -8377.34747 + 2169.97388 X - 836.56039 C + 543.77106 S

Explained Variance = 90.1%, Standard Error of Regression = 129.127 mt

The predictors X, S and C are calculated from the first three moments (m1, m2, and m3) of the 12 monthly rainfall totals (ri, i=1 to 12, inches) for the Evaluation Year:

$m_1 = \text{Sum} [r_i] / 12$

$m_2 = \text{Sum} [r_i - m_1]^2 / 12$

$m_3 = \text{Sum} [r_i - m_1]^3 / 12$

$X = \ln (12 m_1)$

$C = \ln \{[(12/11) m_2]^{0.5}/m_1\}$

$S = (12/11) m_3 / m_2^{1.5}$

TN-based UCL = TN-based Prediction + 1.43976 SE

SE_{TN} = standard error of the TN-based Prediction for May-April interval

$$SE_{TN} = 129.12707 [1 + 1/10 + 8.28199 (X-X_m)^2 + 0.58177 (S-S_m)^2 + 4.93178 (C-C_m)^2 + 0.82314 (X-X_m) (S-S_m) + 0.03844 (X-X_m) (C-C_m) - 2.15336 (S-S_m) (C-C_m)]^{0.5}$$

Where:

X = the natural logarithm of the 12-month total rainfall (inches)

C = the natural logarithm of the coefficient of variation calculated from 12 monthly rainfall totals

S = skewness coefficient calculated from 12 monthly rainfall totals

X_m = average value of the predictor in calibration period = 3.97441

C_m = average value of the predictor in calibration period = -0.26789

S_m = average value of the predictor in calibration period = 0.70340

The predictor (X) indicates that TN load increases with the total annual rainfall. The second and third predictors (S and C) indicate that the load resulting from a given annual rainfall is higher when the distribution of monthly rainfall has higher variability. For a given annual rainfall, the lowest load would be predicted when rainfall is evenly distributed across months and the highest load would be predicted when all of the rain falls in one month. Real cases fall in between.

3.3.2.2.2 TON-based Prediction Equations

A TON-based TN load prediction equation and an associated UCL were derived from the Base Period TON data using a 10 percent reduction to represent 90 percent of the Base Period TON level.

TON-based Prediction = -7574.28708 + 1928.62129 X - 950.18979 C + 628.32211 S

Explained Variance = 91.6%, Standard Error of Regression = 120.837 mt

The predictors X, S and C are calculated from the first three moments (m_1, m_2, and m_3) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

$m_1 = \text{Sum} [r_i] / 12$

$m_2 = \text{Sum} [r_i - m_1]^2 / 12$

$m_3 = \text{Sum} [r_i - m_1]^3 / 12$

$X = \ln (12\ m_1)$

$C = \ln \{ [(12/11)\ m_2]^{0.5}/m_1 \}$

$S = (12/11)\ m_3 / m_2^{\ 1.5}$

TON-based UCL = TON-based Prediction + 1.43976 SE

SE_{TON} = standard error of the TON-based Prediction for May-April interval

$SE_{TON} = 120.8371 [1 + 1/10 + 8.28199 (X\text{-}X_m)^2 + 0.58177 (S–S_m)^2 + 4.93178 (C\text{-}C_m)^2 + 0.82314 (X\text{-}X_m) (S–S_m) + 0.03844 (X\text{-}X_m) (C\text{-}C_m) - 2.15336 (S\text{-}S_m) (C\text{-}C_m)]^{0.5}$

Where:

X = the natural logarithm of the 12-month total rainfall (inches)

C = the natural logarithm of the coefficient of variation calculated from 12 monthly rainfall totals

S = skewness coefficient calculated from 12 monthly rainfall totals

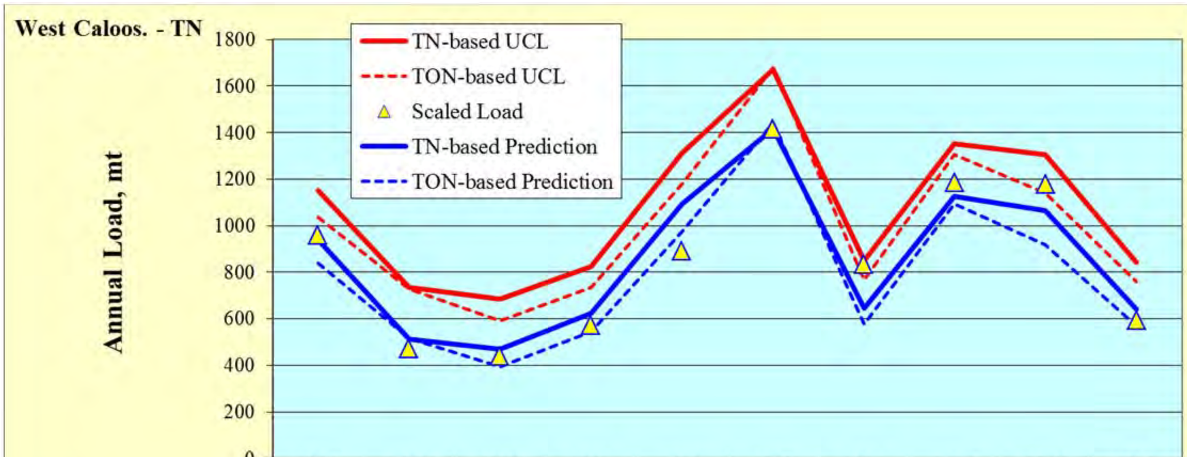
X_m = average value of the predictor in calibration period = 3.97441

C_m = average value of the predictor in calibration period = -0.26789

S_m = average value of the predictor in calibration period = 0.70340

A comparison of the Base Period TN loads, scaled to reflect the 25 percent load reduction goal, with the TN-based Prediction (and associated UCL) and the TON-based Prediction (and associated UCL) is presented in **Figure 3-23.**

Figure 3-23. Comparison of scaled annual TN loads with the Annual Load Targets and Limits for the West Caloosahatchee Sub-watershed.



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
TN-based UCL	1151.022	736.350	683.871	825.108	1311.806	1671.610	851.335	1351.824	1303.811	843.218
TON-based UCL	1037.731	727.324	592.438	735.943	1179.586	1679.698	767.454	1306.256	1140.060	759.990
Scaled Load	959.525	471.008	437.987	572.924	890.872	1414.158	833.043	1184.819	1177.676	594.193
TN-based Prediction	940.096	511.569	470.154	622.705	1095.368	1415.956	646.906	1126.586	1066.009	640.857
TON-based Prediction	840.346	516.975	392.441	546.533	977.045	1440.457	576.149	1095.478	917.525	570.620

3.3.2.2.3 TN Annual Load Target and Annual Load Limit. Each year, the equations above will be used to calculate the TN-based Prediction and the TON-based Prediction. The larger of the two loads will become the TN Annual Load Target. The TN Annual Load Limit will be the predicted UCL associated with the prediction equation, so whichever prediction establishes the Annual Load Target will be the basis for the Annual Load Limit. Annual TN loads at the sub-watershed outlet structures, adjusted to account for pass-through loads and regional projects (as applicable) as described in Appendices A and D, will be evaluated against the performance measure described above.

3.3.2.2.4 Suspension of Performance Determination. The TN performance determination will be suspended due to rainfall conditions if the observed annual TN load, adjusted for regional projects (if present) and pass-through loads, from the basin exceeds the Annual TN Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (for the TN-based prediction: 44.60 – 68.96 inches; and for the TON-based prediction: 43.36 – 74.67 inches), as described below. Extreme rainfall conditions will be assessed by calculating an adjusted rainfall amount which reflects the cumulative effect of the predictor variables of the Annual Load Target equation. The adjusted rainfall is the rainfall that would produce the equivalent annual load using the Annual Load Target equation by setting the value of S and C to their mean value for the calibration period.

TN-based Adjusted Rainfall = exp [X + 0.25059 (S - 0.7034) - 0.38552 (C + 0.26789)]

TON-based Adjusted Rainfall = exp [X + 0.32579 (S- 0.7034) - 0.49268 (C + 0.26789)]

The adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1982-2010 period of record are summarized in **Table 3-37**.

The annual performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

3.3.2.2.5 Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-24**.

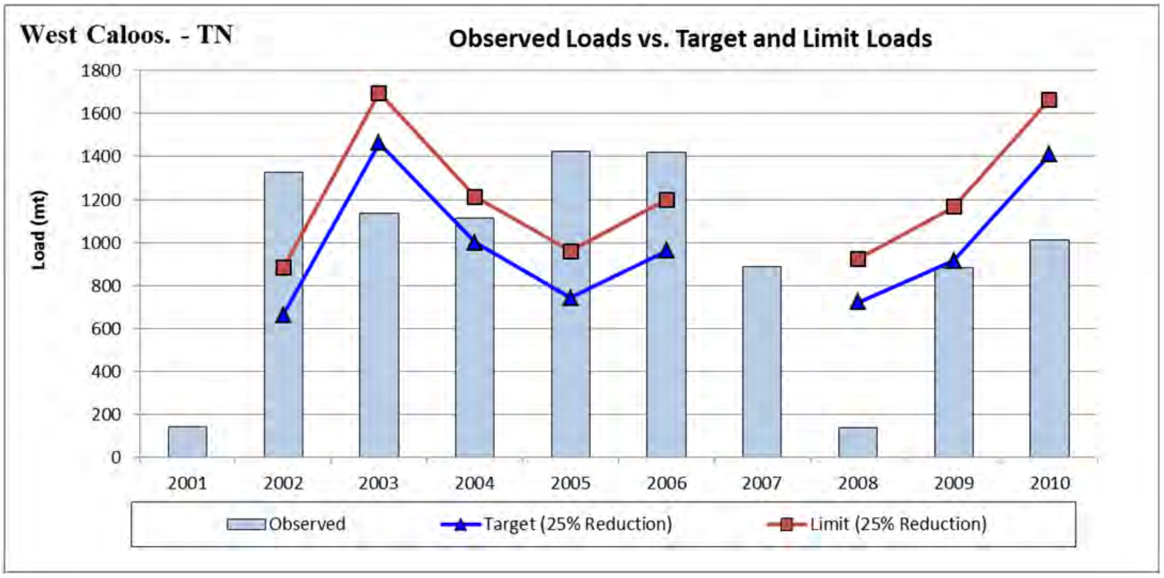
Table 3-37. TN Annual Targets and Limits for the historical period of record for the West Caloosahatchee Sub-watershed (Base Period: WY1988-1997).

Water Year	Observed Rain, inches	Observed TN Load, mt	TN-based Prediction, mt	TN-based UCL mt	TON-based Prediction, mt	TON-based UCL mt	TN-based Adjusted Rain, in	TON-based Adjusted Rain, in
1982	43.69	1,065.355	611.611	840.880	625.929	840.480	47.60	48.95
1983	73.64	1,338.364	1502.058	1760.710	1347.053	1589.099	71.75	71.14
1984	53.22	385.123	1205.845	1421.127	1194.616	1396.078	62.60	65.73
1985	50.24	935.819	651.454	853.634	588.983	778.183	48.48	48.02
1986	46.61	1,614.219	449.405	661.151	396.840	594.993	44.17	43.46
1987	57.09	2,507.268	896.993	1096.670	796.924	983.782	54.29	53.48
1988	57.32	1,279.367	940.095	1151.022	840.346	1037.731	55.38	54.70
1989	42.94	628.011	511.580	736.360	516.975	727.324	45.46	46.26
1990	49.15	583.983	470.143	683.861	392.441	592.438	44.60	43.36
1991	51.00	763.899	622.692	825.096	546.533	735.943	47.85	46.97
1992	61.77	1,187.829	1095.359	1311.796	977.045	1179.586	59.49	58.72
1993	53.39	1,885.544	1415.961	1671.614	1440.457	1679.698	68.96	74.67
1994	50.53	1,110.724	646.900	851.330	576.149	767.454	48.38	47.70
1995	53.51	1,579.759	1126.586	1351.825	1095.478	1306.256	60.35	62.44
1996	65.26	1,570.234	1066.009	1303.811	917.525	1140.060	58.69	56.93
1997	50.76	792.257	640.853	843.214	570.620	759.990	48.25	47.56
1998	69.15	967.679	1417.181	1675.867	1281.017	1523.095	69.00	68.74
1999	43.87	747.362	462.684	682.654	448.764	654.613	44.45	44.65
2000	55.30	1,072.855	1044.688	1285.454	992.952	1218.260	58.12	59.21
2001	37.18	142.824	-84.279	205.100	-84.367	186.434	34.54	33.87
2002	53.90	1,327.594	663.858	882.991	564.551	769.616	48.76	47.41
2003	64.95	1,136.426	1461.957	1695.685	1372.715	1591.438	70.44	72.09
2004	61.99	1,115.304	999.022	1212.772	867.266	1067.293	56.91	55.47
2005	53.01	1,423.086	743.034	959.829	666.326	869.203	50.57	49.98
2006	54.77	1,418.567	962.982	1198.671	903.760	1124.318	55.97	56.53
2007	40.39	888.826	43.317	305.294	14.038	259.196	36.63	35.64
2008	49.90	137.100	722.739	924.607	671.602	860.510	50.10	50.12
2009	52.28	882.239	915.366	1165.746	877.176	1111.481	54.75	55.76
2010	71.92	1,012.478	1410.504	1664.249	1253.061	1490.515	68.79	67.75

(pink)	Indicates the Annual TN Target
(blue)	Indicates the Annual TN Limit
(yellow)	Indicates the assessment would be suspended because the rainfall was below the Base Period minimum and the Target was exceeded.

Steps for addressing negative loads are described in Section 2.5.12.

Figure 3-24. Comparison of WY2001-2010 TN loads with Annual Load Targets and Limits for the West Caloosahatchee Sub-watershed.



Note: The performance determinations forWY2001 and WY2007 would have been suspended due to rainfall below the minimum value during the Base Period coupled with the observed load being greater than the Load Target.

3.3.2.2.6 Exceedance Frequency Analysis. Using the approach described in Section 2.5.11, an approximation of the cumulative exceedance frequency for the performance determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual TN loads of the Base Period. Separate approximations were prepared for the TN-based equations and the TON-based equations (**Tables 3-38** and **3-39**). Because the TN loads and rainfall statistics from the Base Period do not perfectly describe normal distributions (e.g., the medians are generally less than the means), the methodology includes conditional probabilities, and because the random number generator is imperfect, the exceedance frequencies deviate from the theoretical values shown in the second column. However, the results are determined to be reasonable and defensible since the cumulative exceedance frequency is less than the theoretical value of approximately 17.5 percent.

Table 3-38. Exceedance frequencies for the proposed TN-based prediction and UCL for the West Caloosahatchee Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	10.8%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	8.8%
Step 4. Load > Annual Load Limit?	<10%	2.0%
Cumulative Exceedance Frequency	**<17.5%**	**10.2%**

Table 3-39. Exceedance frequencies for the proposed TON-based prediction and UCL for the West Caloosahatchee Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	9.8%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.2%
Step 4. Load > Annual Load Limit?	<10%	2.1%
Cumulative Exceedance Frequency	**<17.5%**	**10.7%**

3.4 Tidal Caloosahatchee Sub-watershed

The following sections present a description of the Tidal Caloosahatchee Sub-watershed, a summary of historical flow and nutrient levels, nutrient reduction goals for the collective source control programs, and development of the performance metrics.

3.4.1 Background

The Tidal Caloosahatchee Sub-watershed consists of 264,705 acres located adjacent to the Caloosahatchee Estuary and west of the West Caloosahatchee Sub-watershed. The Tidal Caloosahatchee Sub-watershed contains 32 tributaries, of which eighteen (18) tributaries, representing 86 percent of the sub-watershed area, are monitored for water quality, including phosphorus and nitrogen (**Figure 3-25** and **Table 3-40**).

Historical data analyses for the sub-watershed were initially conducted by HDR Engineering, Inc. as part of Contract No. ST061298 – WO08 (Data Analysis and Performance Measure Development for the St Lucie and the Caloosahatchee River Source Control Programs) with the District (HDR 2011). At that time the focus was on annual nutrient loads, and many of the tributaries were not fully analyzed due to lack of flow data. However, under the current contract, performance metrics based on nutrient concentrations were developed, and additional historical data analyses were conducted.

District staff compiled available monthly nutrient concentration data for the tributaries within the sub-watershed. Water quality data in the sub-watershed are collected by multiple agencies, and the stations included data for different periods of record (**Table 3-41**). Uncertainty is inherent in any data collection program, and the historical data for the Tidal Caloosahatchee Sub-watershed include the following three significant components of uncertainty:

Figure 3-25. Tidal Caloosahatchee Sub-watershed schematic showing tributaries (from SFWMD).

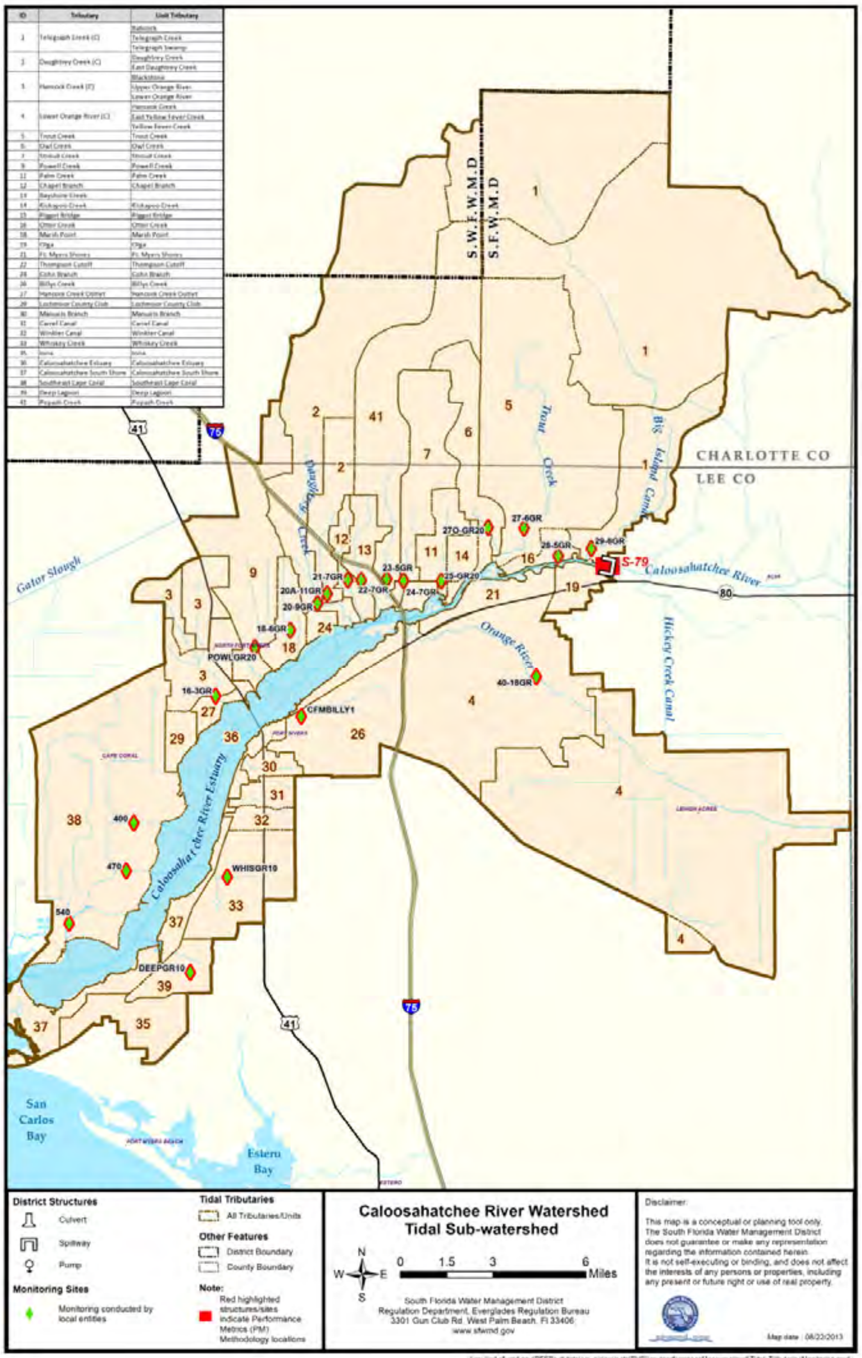


Table 3-40. Areas of the Tidal Caloosahatchee Sub-watershed tributaries (from SFWMD).

Basin	Area (acres)
Monitored Tributaries	
Bayshore Creek	2,067
Billy Creek	6,778
Chapel Branch	1,366
Daughtrey Creek	23,330
Deep Lagoon	2,073
Hancock Creek	6,645
Lower Orange River	51,380
Marsh Point	1,957
Otter Creek	1,030
Owl Creek	3,870
Palm Creek	1,966
Popash Creek	11,341
Powell Creek	8,541
SE Cape Coral	20,152
Stroud Creek	5,591
Telegraph Creek	53,806
Trout Creek	19,869
Whiskey Creek	5,417
Sub-total	**227,178**
Unmonitored Tributaries	
Caloosahatchee South Shores	6,720
Caloosahatchee River/Estuary	16,407
Carrel Canal	1,107
Cohn Branch	470
Ft. Myers Shores	2,047
Hancock Creek Outlet	828
Iona	3,515
Kickapoo Creek	956
Lochmoor Country Club	1,041
Manuels Branch	888
Olga Creek	1,418
Piggot Bridge	582
Thompson Cutoff	569
Winkler Canal	982
Sub-total	**37,527**
Sub-watershed Total	***264,705***

- the data do not distinguish between basin stormwater runoff flow and the influence of twice daily tidal cycles,
- flow estimates are not available for all monitoring stations, and
- the Reference Period contains less than eight years of data, the minimum required for a performance measure.

3.4.1.1 Selection of representative stations. Monitoring stations that sample water quality from common tributaries were identified, and sub-basins were combined as appropriate. This resulted in five combinations of tributaries as explained below:

1. Monthly water quality data for East Daughtrey Creek were combined with Daughtrey Creek data; data were combined by flow-weighting, using the unit area runoff coefficients and areas for the basins developed for the 2012 update for the CRWPP.
2. Yellow Fever Creek and East Yellow Fever Creek are tributary to Hancock Creek, so the Hancock Creek water quality data were used to represent the discharge from the three sub-basins.

Table 3-41. Water quality data sources in the Tidal Caloosahatchee Sub-watershed.

Basin	Monitoring Site	Agency Collecting Data	Period of Record
Bayshore Creek	22-7GR	Lee County	WY2006-2013
Billy Creek	CFMBILLY1	Lee County	WY2006-2010
Chapel Branch	21-7GR	Lee County	WY2006-2013
Daughtrey Creek	20-9GR & 20A11-GR	Lee County	WY2006-2013
Deep Lagoon	DEEPGR10	Lee County	WY2005-2013
Hancock Creek	16-3GR	Lee County	WY2006-2013
Lower Orange River	40-18GR	Lee County	WY2005-2013
Marsh Point	18-6GR	Lee County	WY2006-2013
Otter Creek	28-5GR	Lee County	WY2006-2013
Owl Creek	270-GR20	Lee County	WY2006-2013
Palm Creek	25-GR20	Lee County	WY2005-2013
Popash Creek	23-5GR	Lee County	WY2006-2013
Powell Creek	POWLGR20	Lee County	WY2004-2013
SE Cape Coral	400, 470, 540	Cape Coral	WY2003-2013
Stroud Creek	24-7GR	Lee County	WY2006-2013
Telegraph Creek	29-8GR	Lee County	WY2006-2013
Trout Creek	27-6GR	Lee County	WY2006-2013
Whiskey Creek	WHISGR10	Lee County	WY2005-2013

3. Babcock and Telegraph Swamp are tributary to Telegraph Creek, so the Telegraph Creek water quality data were used to represent the discharge from the three basins.
4. Blackstone and Upper Orange River are tributary to Lower Orange River, so the Lower Orange River water quality data were used to represent the discharge from the three basins.
5. Monthly water quality data for three Southeast Cape Coral stations, 400, 470 and 540, were combined by taking the arithmetic average of the samples' concentrations.

Basic synoptic statistics were calculated for TP and TN for each tributary (**Table 3-42**; additional details provided in **Appendix A**). Potential outliers were identified using the Maximum Normed Residual Outlier Analysis (Snedecor 1989), and District staff reviewed the comments and other information associated with the data in order to assess whether the value should be retained in future analyses[13]. In addition to statistical outliers, agency staff screened the data to exclude samples collected during periods of atypical basin runoff conditions, e.g., construction, incoming tides and large amounts of floating aquatic vegetation. Based on the review of individual tributary periods of record, a common Reference Period of WY2006-WY2012 (May 2005 – April 2012) was selected for the Tidal Caloosahatchee Sub-watershed.

3.4.1.2 Nutrient Concentration Analyses. Spatially composite sub-watershed nutrient concentrations were calculated from the individual tributary concentrations for each month of the WY2006-2012 Reference Period using the following algorithm.

Composite monthly value = sum (tributary conc * tributary runoff) / sum (tributary runoff)
Where tributary runoff = tributary unit area runoff * tributary area
tributary unit area runoff = sum (land use unit area runoff coefficient * land use area)

[13] A TP concentration of 3,020 µg/L for Chapel Brach collected in February 2006 was discarded as a result of this review.

Table 3-42. Summary of Reference Period monthly data for the Tidal Caloosahatchee Sub-watershed and its tributaries.

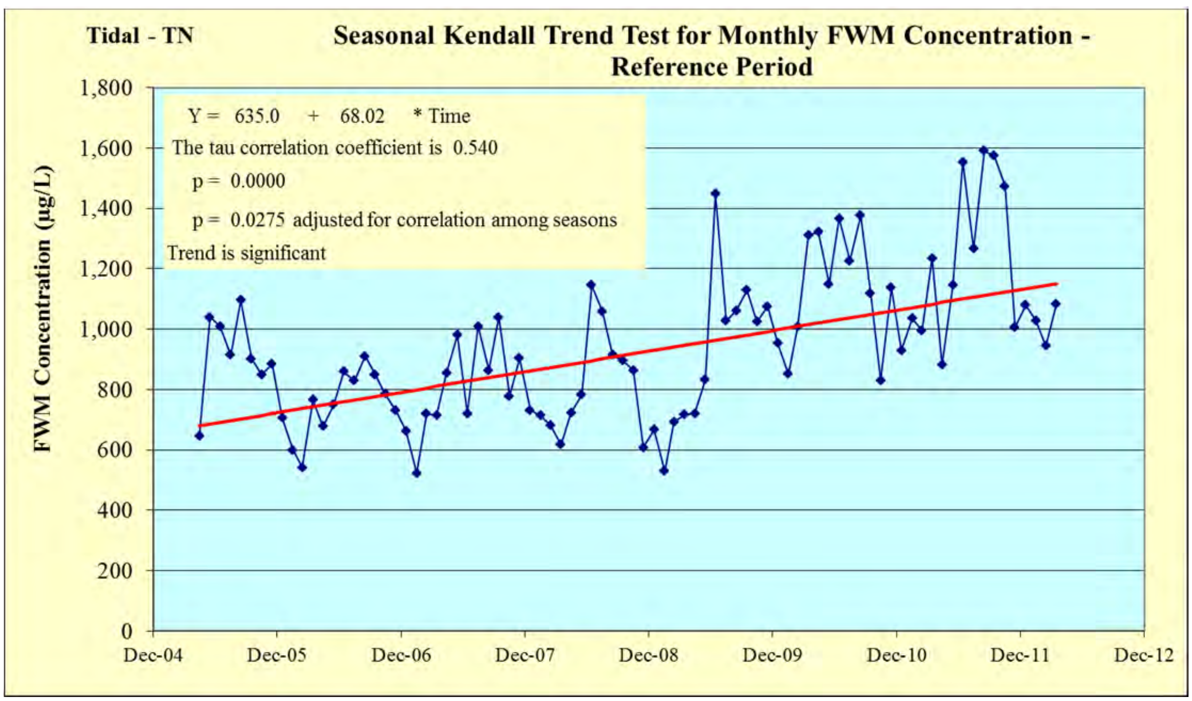
Tributary	WY2006 - WY2012 Reference Period Summary									
	Total Phosphorus					Total Nitrogen				
	Begin	End	Missing Data	Median µg/L	Maximum µg/L	Begin	End	Missing Data	Median µg/L	Maximum µg/L
Bayshore Creek	2006	2012	14%	110	390	2006	2012	14%	1,138	1,910
Billy Creek	2006	2010	38%	245	490	2006	2010	38%	935	2,380
Chapel Branch	2006	2012	2%	90	910	2006	2012	2%	1,220	3,715
Daughtrey Creek	2006	2012	1%	92	665	2006	2012	1%	950	2,021
Deep Lagoon	2006	2012	2%	110	270	2006	2012	2%	1,005	1,910
Hancock Creek	2006	2012	1%	150	360	2006	2012	1%	920	1,915
Lower Orange River	2006	2012	1%	32	170	2006	2012	1%	780	1,510
Marsh Point	2006	2012	6%	170	880	2006	2012	6%	880	1,517
Otter Creek	2006	2012	12%	160	740	2006	2012	12%	1,075	2,525
Owl Creek	2006	2012	4%	74	240	2006	2012	4%	930	2,830
Palm Creek	2006	2012	2%	94	410	2006	2012	2%	1,165	2,440
Popash Creek	2006	2012	2%	160	540	2006	2012	2%	1,085	2,010
Powell Creek	2006	2012	50%	105	1300	2006	2012	50%	852	2,210
Southeast Cape Coral	2006	2012	1%	53	180	2006	2012	1%	718	1,648
Stroud Creek	2006	2012	2%	71	940	2006	2012	2%	1,040	2,340
Telegraph Creek	2006	2012	5%	69	440	2006	2012	5%	1,070	2,654
Trout Creek	2006	2012	4%	52	250	2006	2012	4%	870	2,430
Whiskey Creek	2006	2012	5%	40	170	2006	2012	5%	625	1,210
Sub-watershed	***2006***	***2012***	***0%***	***83***	***269***	***2006***	***2012***	***0%***	***907***	***1,591***

The land use unit area runoff coefficients and areas for each land use were obtained from the 2012 Caloosahatchee River Watershed Protection Plan (SFWMD 2012; Attachment 1; Appendix A). This algorithm properly takes into account missing data in that both the numerator and denominator include "0" if a tributary is missing data for any individual month. Annual summaries of the sub-watershed composite nutrient data are presented in **Table 3-43**. A statistically significant increasing trend was observed in TN concentrations for the composite area (**Figure 3-26**). Similarly, a statistically significant increasing trend was observed in TON concentrations for the composite area (additional information is contained in Appendix A).

Table 3-43. Annual summary of median composite concentrations for the Tidal Caloosahatchee Sub-watershed.

Water Year	TP	TN	TON
	Median µg/L	Median µg/L	Median µg/L
2006	65	867	675
2007	84	740	592
2008	95	818	672
2009	92	753	622
2010	97	1,026	871
2011	70	1,143	1,018
2012	69	1,114	1,012
2013	65	1,247	1,137
WY2006-2012 monthly median	83	907	779

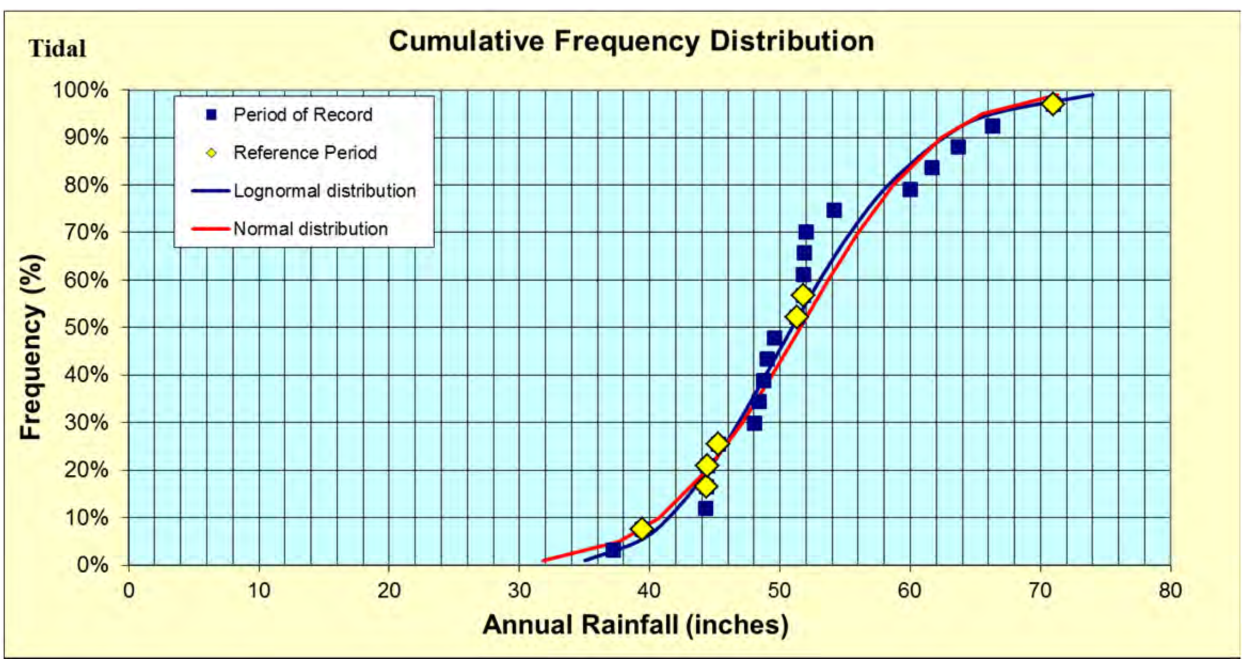
Figure 3-26. Trend analysis for monthly TN concentrations for the Tidal Caloosahatchee Sub-watershed.



3.4.1.3 Rainfall Analyses. The performance indicators for the Tidal Caloosahatchee Sub-watershed were based on the monthly data for TP, TN and TON without an explicit adjustment for hydrologic variability. As such, it is helpful to understand the hydrologic conditions that existed during the time of water quality data collection. Since flow data are not available for the sub-watershed, rainfall data were analyzed as a measure of the hydrologic variability. Daily rainfall data at four representative stations were compiled by the District using the Thiessen polygon weights shown in **Appendix A**.

The cumulative frequency distribution for WY1991-2012 annual rainfall is shown in **Figure 3-27**. Annual rainfall during the WY2006-WY2012 Reference Period (39.46 to 70.96 inches) ranged from 5 percent to 100 percent of the range observed during the WY1991-2012 period (37.21 to 70.96 inches).

Figure 3-27. Frequency distribution for annual Tidal Caloosahatchee Sub-watershed rainfall.



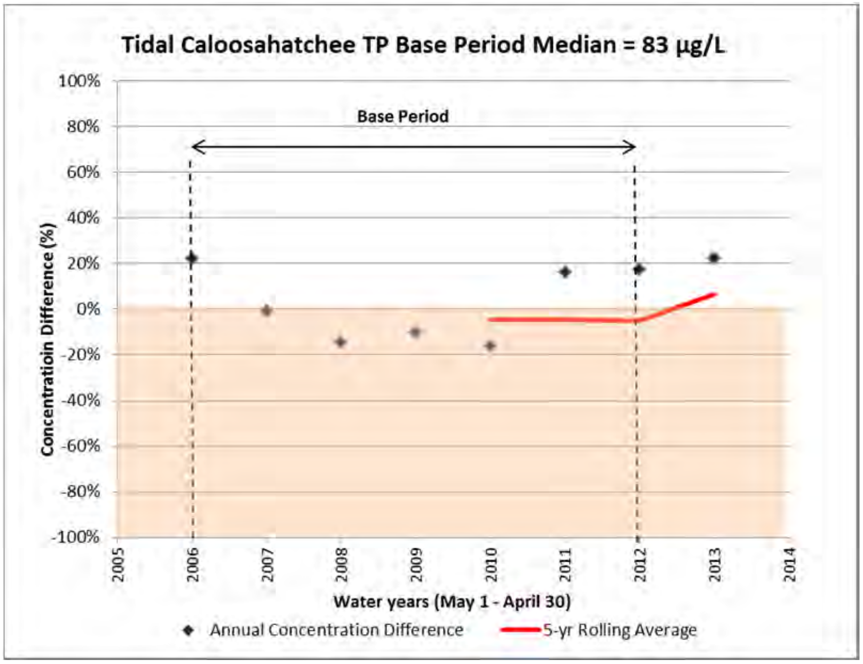
3.4.1.4 TP Trend. Table 3-44 presents the observed annual median and 60-month median TP concentrations and differences from the reference period median concentration. The sub-watershed TP concentration trend is presented in **Figure 3-28**. The solid line shows the five-year trend of load differences. The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-28** denotes a reduction in loads.

Table 3-44. WY2006-2013 Tidal Caloosahatchee Sub-watershed TP measurements and calculations. (Reference Period: WY2006-2012).

Water Year	Annual TP Median, µg/L	Annual Difference	TP 60-month Median, µg/L	5-yr Rolling Average Difference
2006	65	22%		
2007	84	-1%		
2008	95	-14%		
2009	92	-10%		
2010	97	-16%	87	-5%
2011	70	16%	87	-5%
2012	69	17%	87	-5%
2013	65	22%	78	7%

Notes
1. Reference period median = 83 µg/L
2. Annual difference values are calculated as [1 – (annual median / reference period median)].
3. 5-year rolling average difference values are calculated as [1 – (60-month median concentration) / (the reference period median)].

Figure 3-28. Tidal Caloosahatchee Sub-watershed TP concentration trend.



Notes: A positive concentration difference denotes a reduction in concentration in comparison to the base period. An upward trend in the solid line denotes a reduction in concentrations.

3.4.1.5 TN Trend. Table 3-45 presents the observed annual median and 60-month median TN concentrations and differences from the reference period median concentration. The sub-watershed TN concentration trend is presented in **Figure 3-29**. The solid line shows the five-year trend of load differences. The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-29** denotes a reduction in loads.

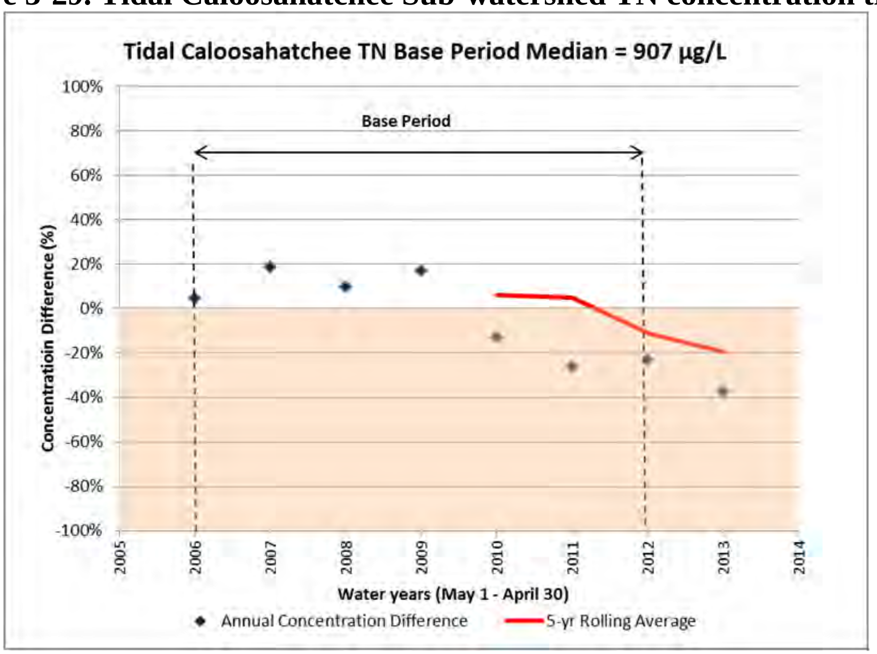
Table 3-45. WY2006-2013 Tidal Caloosahatchee Sub-watershed TN measurements and calculations. (Reference Period: WY2006-2012).

Water Year	Annual TN Median, µg/L	Annual Difference	TN 60-month Median, µg/L	5-yr Rolling Average Reduction
2006	867	4%		
2007	740	18%		
2008	818	10%		
2009	753	17%		
2010	1,026	-13%	850	6%
2011	1,143	-26%	863	5%
2012	1,114	-23%	1,007	-11%
2013	1,247	-37%	1,082	-19%

Notes

1. Reference period median = 907 µg/L
2. Annual difference values are calculated as [1 – (annual median / reference period median)].
3. 5-year rolling average difference values are calculated as [1 – (60-month median concentration) / (the reference period median)].

Figure 3-29. Tidal Caloosahatchee Sub-watershed TN concentration trend.



Notes: A positive concentration difference denotes a reduction in concentration in comparison to the base period. An upward trend in the solid line denotes a reduction in concentrations.

3.4.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the Tidal Caloosahatchee Sub-watershed.

Based on a review of multiple analyses, estimates were generated for basin-specific nutrient reductions anticipated as a result of implementation of collective source controls within the sub-watershed. These analyses included the following.

- Evaluation of individual land use source control effectiveness ranges described in Section 2.5 and Appendix C.
- Review of the nutrient reduction estimates for BMPs reported in the CRWPP.
- For TN, there was an assumption that a TN level equal to 90 percent of the reference period TON is a reasonable approximation of the natural background TN, and that the remaining ten percent is attributable to anthropogenic activities (e.g., use of organic fertilizers and cycling of inorganic nitrogen into TON) which could potentially be reduced through source controls.
- Best professional judgment.

Additional details are presented in **Appendix C**.

3.4.2.1 Total Phosphorus Performance Metric Methodology

The proposed TP performance indicators consist of two parts:

1. Part 1: An Annual Concentration Target component; and
2. Part 2: An Annual Concentration Limit component.

The Annual Concentration Target was based on the historical monthly concentrations for the Reference Periods, reduced by basin-specific source control reduction goals. The Annual Concentration Limit was based on the Reference Periods' maximum observed monthly concentration, reduced by basin-specific source control reduction goals. The two components of the TP performance metric for the Tidal Caloosahatchee Sub-watershed are described in the following sections. The associated TP performance determination process is presented as a flowchart in **Figure 1-3**.

3.4.2.1.1 The Annual Concentration Target Performance Determination for TP

The objective of the Annual Concentration Target component is to annually determine whether or not a basin's nutrient levels are meeting the desired long-term nutrient goals established for the basin. The Annual Concentration Target is a distribution of monthly concentrations, represented by the median concentration of the distribution. A summary of the Annual Concentration Targets for TP for the Tidal Caloosahatchee Sub-watershed and its tributaries is presented in **Table 3-46**.

If the performance determination could compare annual nutrient levels to long-term annual median (or mean) levels of the Reference Period, as was done for Chapter 40E-63, F.A.C, and proposed for the eastern CRW sub-watersheds, the comparison would be based on a common time frame (annual). For the Tidal Caloosahatchee Sub-watershed and its tributaries, long-term median annual concentrations could not be estimated for the Reference Period due to lack of available data over a sufficiently long period. However, long-term median monthly concentrations can be calculated. A direct comparison of median monthly concentrations for the Evaluation Year to median monthly concentrations for the Reference Period would not be appropriate because of the different time scales involved. Therefore, as the initial step in evaluating the Annual Concentration Target component, a correction for the difference in time scales is proposed by using an appropriate hypothesis test to determine if the Evaluation Year's monthly concentrations are systematically larger than the Reference Period's monthly concentrations, adjusted by the source control reduction goal.

Table 3-46. TP Annual Concentration Targets for the Tidal Caloosahatchee Sub-watershed and its tributaries.

Basin	TP Source Control Target Reduction Goal	Reference Period Median Concentration, µg/L	Annual TP Concentration Target - Median Concentration, µg/L
Tidal Sub-watershed	***10%***	***83***	***75***
Bayshore Creek	24%	110	84
Billy Creek	7%	245	227
Chapel Branch	11%	90	80
Daughtrey Creek	11%	92	82
Deep Lagoon	5%	110	104
Hancock Creek	6%	150	141
Lower Orange River	0%	32	32
Marsh Point	6%	170	160
Otter Creek	20%	160	128
Owl Creek	23%	74	57
Palm Creek	20%	94	75
Popash Creek	12%	160	141
Powell Creek	9%	105	96
Southeast Cape Coral	0%	53	53
Stroud Creek	18%	71	58
Telegraph Creek	19%	69	56
Trout Creek	0%	52	52
Whiskey Creek	0%	40	40

Note: The Annual Concentration Target is a distribution of monthly concentrations, represented by the median concentration adjusted by the source control reduction goal.

The most common hypothesis test for two populations is the Student's t-test, however, a number of assumptions and requirements apply to the t-test, including the assumption that both data sets are normally distributed. Because the monthly water quality data are not always normally or log-normally distributed, the most appropriate hypothesis test is the nonparametric rank-sum test (also known as the Wilcoxon rank-sum, or Mann-Whitney test). While the shapes of the two density distributions need to be the same in order to use the rank-sum test to compare the medians (or any other interval) of two populations, that shape assumption is not necessary in order to apply the rank-sum test as proposed, that is, to compare the general hypotheses that “the distributions are the same” (the null hypothesis) and whether “one distribution has values that are systematically larger than the other distribution” (the alternative hypothesis). The rank-sum test does not depend on the assumption that the data are normally distributed, or the other requirements of the t-test. In general, the rank-sum test is appropriate for evaluating whether one group tends to produce larger or smaller observations than a second group. For the application to the Tidal Caloosahatchee Sub-watershed, the rank-sum test will be used to determine whether or not the monthly concentrations of the Evaluation Year are systematically larger than the Reference Period’s monthly concentrations, adjusted by the source control reduction goal, collectively referred to as the Annual Concentration Target, or the “desired distribution”.

The rank-sum test evaluates the relative magnitude and variance (i.e., “spread”) in the two data sets and determines if the monthly concentrations of the Evaluation Year are systematically different (i.e., larger or smaller) than those of the Annual Concentration Target at a given significance level. The significance level of the rank-sum test can be selected, e.g., a significance level of from 1 to 10 percent is commonly used (USGS 2002). Because of the uncertainty in the historical data, a significance level of 5 percent is recommended here. This significance level is also equal to the probability of a Type I Error. The probability of a Type I error is the risk of rejecting the null hypothesis that the populations are the same and instead concluding that the Evaluation Year’s concentrations are significantly larger than the desired concentrations, that is, a “false positive”. Similar to the performance determination of the other sub-watersheds with performance metrics, a one-in-three year test is proposed, i.e., if the monthly concentrations of the Evaluation Year are not significantly greater than the Reference Period’s monthly concentrations, adjusted by the source control reduction goal, for one in three successive years, then the basin will have achieved the performance indicator, subject to the Annual Concentration Limit test results.

The null hypothesis, H_0, for the proposed rank-sum test is

H_0: Probability (x > y) = 50 percent the 2 distributions are the same, i.e., the data from one distribution is not systematically larger or smaller than data from the other distribution where x is the data set for the Evaluation Year and y is the data set for the Reference Period adjusted by the nutrient reduction goal.

With three possible alternative hypotheses:

H_1: Probability (x > y) ≠ 50 percent the data of the smaller data set are systematically different (larger or smaller) from the data of the larger data set, i.e., a 2-tailed test

H_2: Probability (x > y) > 50 percent the data of the smaller data set are systematically larger than the data of the larger data set, i.e., a 1-tailed test

H_3: Probability (x < y) > 50 percent the data of the smaller data set are lower than the data of the larger data set, i.e., a 1-tailed test

For use as the initial test of the performance indicator, if the null hypothesis cannot be rejected, then it isn't necessary to distinguish between the alternative hypotheses. However, if the null hypothesis is rejected, the performance metric methodology will evaluate H_2 in order to evaluate whether or not the data for the Evaluation Year is systematically larger than the data set for the Reference Period adjusted by the source control reduction goal (the "desired distribution"). In summary, if the evaluation year distribution is not significantly larger than the reference period distribution, then the evaluation year is deemed to achieve the performance metric.

To illustrate the use of a rank-sum test, each water year within the Reference Period was compared to the Reference Period using the rank-sum test to determine whether or not the Evaluation Year data were significantly greater than the Reference Period data. It is helpful to present the Reference Period monthly data in a box plot format in order to compare the median and the spread of the data sets (**Figure 3-30**).

The null hypothesis is that the Evaluation Year data are the same (i.e., not systematically larger or smaller than) as the data of the Reference Period, written as

H_0: probability [x > y] = 0.5

Where x are data from the Evaluation Year, and

y are data from the Reference Period

The alternative hypotheses could take one of three forms, depending on the desired evaluation:

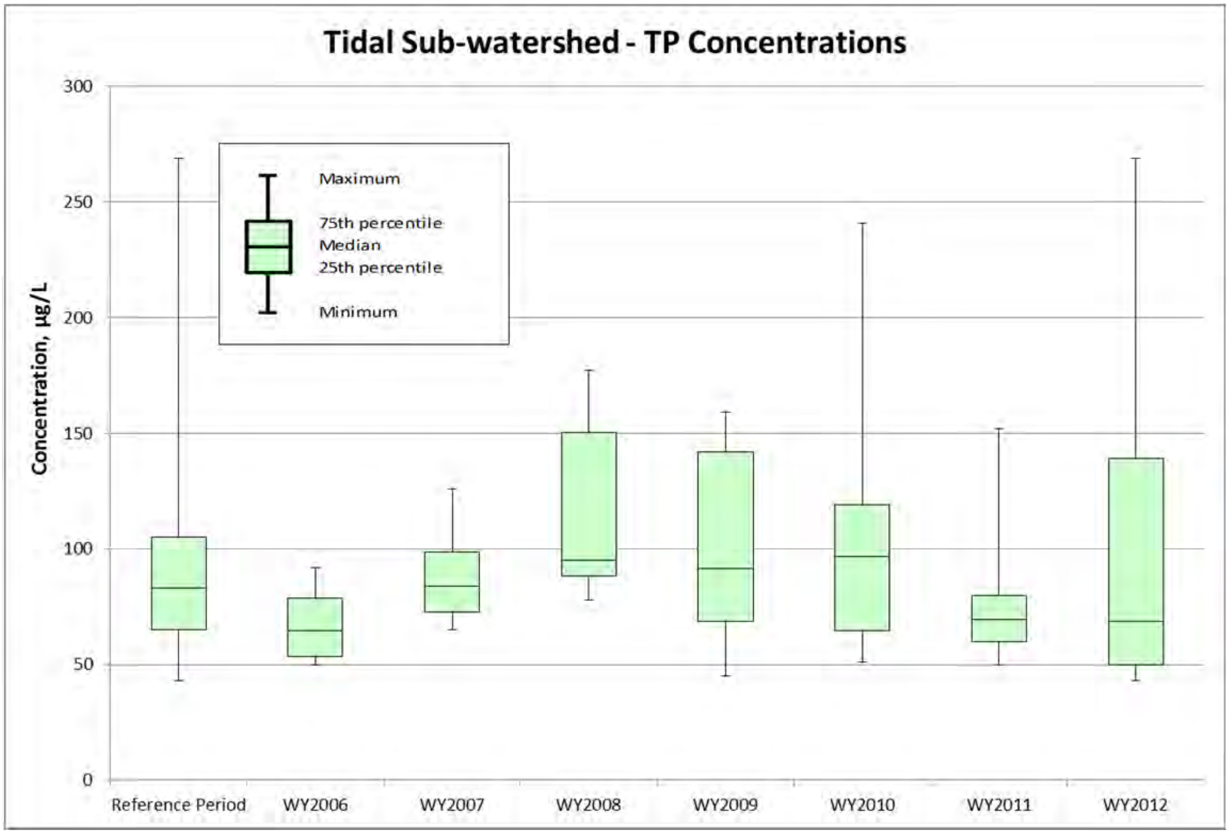
H_1: probability [x > y] ≠ 50 percent the given percentile of the Evaluation Year data set is different (larger or smaller) from the same percentile of the Reference Period data set (a 2-tailed test)

H_2: probability [x > y] > 50 percent the given percentile of the Evaluation Year data is significantly greater than the same percentile of the Reference Period data set (a 1-tailed test)

H_3: probability [x < y] > 50 percent the given percentile of the Evaluation Year data is significantly less than the same percentile of the Reference Period data set (a 1-tailed test)

For the Annual Concentration Target component, the desired alternative hypothesis is H_2 – whether the monthly concentrations of the Evaluation Year are significantly greater than the desired distribution.

Figure 3-30. Comparison of Reference Period (WY2006-2012) TP data to annual data for the Tidal Caloosahatchee Sub-watershed.



The steps for applying the Wilcoxon rank-sum test are described below.

1. Each of the monthly sample concentrations of the Reference Period and Evaluation Year is assigned a rank, ranging from 1 for the smallest value to N for the largest, where
   a. r = rank
   b. n = the number of monthly values for the Evaluation Year,
   c. m = the number of monthly values for the Reference Period, and
   d. N = n + m
   e. In case of ties, an average rank is used for each of the tied months

2. The test statistic, W_{rs}, is calculated as the sum of the ranks for the Evaluation Year:
   a. $W_{rs} = \sum r$ from 1 to n

3. The mean and standard deviation of the test statistic for the Evaluation Year are calculated. For the rank-sum test, the distribution of the test statistic W_{rs} closely approximates a normal distribution when the sample size for each group is 10 or above, allowing the "large sample approximation" (USGS 2002). This approximation does not imply that the data are, or must be, normally distributed; rather, it is based on the near normality of the test statistic at large sample sizes (USGS 2002). If there are no ties, when H_0 is true, W_{rs} has a mean (μ_W) and standard deviation (σ_W) of

   $\mu_W = n * (N + 1) / 2$

   $\sigma_W =$ square root [n*m*(N + 1) / 12]

   The formula below for σ_{Wt} is used for computing the large sample approximation rather than σ_W when more than a few ties occur.

σ_{Wt} = square root { [(n * m) / (N * (N – 1))] * $\sum R_k^2$ - [(n * m) * $(N + 1)^2$ /(4 * (N - 1))] }

   where $\sum R_k^2$ is the sum of the square of the ranks for k = 1 to N

4. The standardized test statistic, Z_{rs}, is calculated. The test statistic for the large sample approximation is computed by standardizing W_{rs} and making a continuity correction. Z_{rs}, the standardized form of the test statistic, is computed as

   $Z_{rs} = (W_{rs} – 0.5 – m_W) / s_{Wt}$ if $W_{rs} > m_W$

   $Z_{rs} = 0$ if $W_{rs} = m_W$

   $Z_{rs} = (W_{rs} + 0.5 – m_W) / s_{Wt}$ if $W_{rs} < m_W$

   Where m_W represents the mean of the statistic W_{rs} for the combined distributions.

5. The results of the test are evaluated.
   a. If the statistic W_{rs} for the Evaluation Year is less than or equal to the mean of Wrs for the combined distributions (m_W) then we cannot reject H_0, and therefore we

can conclude that the monthly concentrations for the Evaluation Year are not significantly greater than the desired distribution, and the basin has achieved the Annual Concentration Target.

b. If W_{rs} for the Evaluation Year is greater than the mean of W_{rs} for the combined distributions (m_W) then we need to evaluate whether or not the Evaluation Year's data are significantly greater than the Reference Period, i.e., to investigate the 2nd alternative hypothesis, H_2: probability [x > y] > 50 percent, using a 1-tailed test. Z_{rs} is compared to a table of the standard normal distribution for evaluation of the test results at the desired significance level using a 1-tailed test, Z_{crit}.

   i. If $Z_{rs} \leq -Z_{crit}$ we cannot reject H_0, and therefore we can conclude that the monthly concentrations for the Evaluation Year are not significantly greater than the desired distribution, and the basin has achieved the Annual Concentration Target.

   ii. If $Z_{rs} > -Z_{crit}$ we can reject H_0, and therefore we can conclude that the monthly concentrations for the Evaluation Year are significantly greater than the desired distribution, and the basin has not achieved the Annual Concentration Target.

Ideally twelve monthly samples will be available during the Evaluation Year for the annual performance determination. In light of the seasonality of the monthly data (see **Appendix A**), a minimum of at least one monthly sample each quarter per tributary, for at least 75 percent of the tributaries, during the Evaluation Year is recommended for using the rank-sum test.

As an example of the rank-sum algorithm applied to monthly data for an Evaluation Year, the monthly data for WY2009 is compared to the Reference Period data in **Figure 3-31**.

Figure 3-31. Example application of the rank-sum test to the Tidal Caloosahatchee Sub-watershed for TP.

Month	TP	Compared against WY2009			
	Conc, µg/L	Initial Rank	Occurrences	Final rank, r	r2
200505	80	44	1	44.00	1936.00
200506	92	61	1	61.00	3721.00
200507	63	19	2	19.50	380.25
200508	64	21	1	21.00	441.00
200509	74	37	2	37.50	1406.25
200510	53	10	3	10.67	113.78
200511	50	6	2	6.50	42.25
200512	72	33	2	33.50	1122.25
200601	65	22	4	22.75	517.56
200602	53	10	3	10.67	113.78
200603	55	13	3	13.67	186.78
200604	85	48	1	48.00	2304.00

… (continues for intermediate months) …

Month	TP	Compared against WY2009			
	Conc, µg/L	Initial Rank	Occurrences	Final rank, r	r2
201105	178	94	1	94.00	8836.00
201106	269	96	1	96.00	9216.00
201107	144	82	3	82.67	6833.78
201108	124	77	1	77.00	5929.00
201109	67	26	3	26.67	711.11
201110	55	13	3	13.67	186.78
201111	45	2	3	2.67	7.11
201112	49	5	1	5.00	25.00
201201	53	10	3	10.67	113.78
201202	43	1	1	1.00	1.00
201203	70	30	2	30.50	930.25
201204	104	68	3	68.67	4715.11
Evaluation Year - WY2009					
May	144	82	3	82.67	6833.78
June	152	85	3	85.67	7338.78
July	136	80	2	80.50	6480.25
August	109	73	2	73.50	5402.25
September	93	62	3	62.67	3927.11
October	90	59	2	59.50	3540.25
November	73	35	2	35.50	1260.25
December	65	22	4	22.75	517.56
January	67	26	3	26.67	711.11
February	45	2	3	2.67	7.11
March	87	52	3	52.67	2773.78
April	159	90	2	90.50	8190.25

Reference Period median = 83 µg/L
WY2009 median = 92 µg/L
WY2009 W_{rs} = 675.3
$sum[(R_k)^2]$ = 298,302
Reference Period mean, m_W = 582
s_{wt} = 89.507
Since $W_{rs} > m_W$, $Z_{rs} = (W_{rs} – 0.5 – m_W) / s_{Wt}$
Z_{rs} = 1.036 p-value = 0.150
$-Z_{5\%}$ = 1.645

Decision: Even though the test statistic W_{rs} for WY2009 is greater than the Reference Period mean, m_W, since $Z_{rs} < -Z_{5\%}$, we cannot reject the null hypothesis, and therefore we can conclude at a significance level of 5 percent that the WY2009 distribution <u>is not significantly greater</u> than the Reference Period distribution.

For the second step in evaluating the Annual Concentration Target component, the methodology will apply a "one-in-three-year test" as was done in Chapter 40E-63, F.A.C., and as proposed in the other CRW sub-watersheds. Specifically, if the results of the rank-sum test indicate that the Evaluation Year's data are significantly larger than the desired distribution for three successive years, there is an 87.5 percent confidence that the basin's concentration data are not achieving the source control nutrient reduction goals. Stated another way, for the annual target test of the proposed performance determination, the basin would achieve its performance indicator if the Evaluation Year concentrations are not significantly greater than the desired distribution, as determined by the rank-sum test, at least once in three successive years.

The annual performance determination will be suspended if the Annual Concentration Target is exceeded for the Evaluation Year, and the annual rainfall falls outside the range observed in the Reference Period (39.46 to 70.96 inches). Even though there was no explicit relationship between annual rainfall and the nutrient concentrations, this condition for suspension is recommended to ensure that the performance determination is conducted during evaluation years with similar environmental conditions (specifically annual rainfall) that existed during the collection of the data used to develop the Targets and Limits.

A comparison of the monthly TP concentrations for each of the individual water years to the WY2006-2012 Reference Period data using the Wilcoxon rank-sum test and the one in three year algorithm, with no reduction for source controls in this example, is shown in **Table 3-47**. While the monthly median concentrations for four water years were greater than the Reference Period median (WY2007-2010), only WY2008 was systematically larger than the Reference Period's distribution. Consequently, each of the water years of the Reference Period met the one-in-three year annual test.

Table 3-47. Summary of the rank-sum tests for the Tidal Caloosahatchee Sub-watershed Reference Period for TP; significance level of 5 percent.

Water Year	WY Median less than or equal to RP Median?	WY data significantly greater than RP data?	WY data less than or equal to RP data 1 in 3 years?
2006	Yes	No	Yes
2007	No	No	Yes
2008	No	Yes	Yes
2009	No	No	Yes
2010	No	No	Yes
2011	Yes	No	Yes
2012	Yes	No	Yes
All	***43%***	***14%***	***100%***

Note: “WY” = Water Year and “RP” = Reference Period

3.4.2.1.2 The Annual Concentration Limit performance determination for TP

For the Tidal Caloosahatchee Sub-watershed and its tributaries, the second part of the performance metric methodology will compare monthly concentrations during the Evaluation Year to an Annual Concentration Limit. The maximum monthly concentrations observed during the WY2006-2012 Reference Period, reduced by the basin-specific source control nutrient reduction goals, are recommended as the Annual Concentration Limits for the Tidal Caloosahatchee Sub-watershed and its tributaries (**Table 3-48**). The proposed performance metric methodology will compare the monthly concentrations during the Evaluation Year to the Annual Concentration Limit, and if a single monthly concentration is above the Annual Concentration Limit, then the basin will have not achieved its performance indicator.

Table 3-48. TP Annual Concentration Limits for the Tidal Caloosahatchee Sub-watershed and its tributaries.

Basin	TP Source Control Limit Reduction Goal	Reference Period Maximum Concentration, µg/L	Annual TP Concentration Limit, µg/L
Tidal Sub-watershed	***15%***	***269***	***228***
Bayshore Creek	24%	390	296
Billy Creek	10%	490	442
Chapel Branch	13%	910	788
Daughtrey Creek	13%	665	578
Deep Lagoon	9%	270	246
Hancock Creek	9%	360	328
Lower Orange River	13%	170	148
Marsh Point	9%	880	803
Otter Creek	21%	740	585
Owl Creek	23%	240	184
Palm Creek	20%	410	326
Popash Creek	14%	540	467
Powell Creek	11%	1,300	1,160
Southeast Cape Coral	9%	180	164
Stroud Creek	20%	940	755
Telegraph Creek	20%	440	353
Trout Creek	25%	250	188
Whiskey Creek	12%	170	150

Note: The Annual Concentration Limit was rounded off to three significant digits.

The annual performance determination will be suspended if the Annual Concentration Limit is exceeded for the Evaluation Year, and the annual rainfall falls outside the range observed in the Reference Period (39.46 to 70.96 inches). Even though there was no explicit relationship between annual rainfall and the nutrient concentrations, this condition for suspension is recommended to ensure that the performance determination is conducted during evaluation years with similar environmental conditions (specifically annual rainfall) that existed during the collection of the data used to develop the Targets and Limits.

3.4.2.2 Total Nitrogen Performance Metric Methodology

The proposed performance indicators consist of two parts:

1. Part 1: An Annual Concentration Target component; and
2. Part 2: An Annual Concentration Limit component.

The Annual Concentration Target was based on the historical monthly concentrations for the Reference Periods, reduced by the basin-specific source control reduction goals. The Annual Concentration Limit was based on the Reference Periods' maximum observed monthly concentration, reduced by the basin-specific source control reduction goals. The two components of the TN performance metric for the Tidal Caloosahatchee Sub-watershed are described in the following sections. The TN performance determination process is presented as a flowchart in **Figure 1-3**.

3.4.2.2.1 The Annual Concentration Target Performance Determination for TN

The objective of the Annual Concentration Target component is to annually determine whether or not a basin's nutrient levels are meeting the desired long-term nutrient goals established for the basin. The Annual Concentration Target is a distribution of monthly concentrations, represented by the median concentration of the distribution. A summary of the Annual Concentration Targets for TN for the Tidal Caloosahatchee Sub-watershed and its tributaries is presented in **Table 3-49**.

Table 3-49. TN Annual Concentration Targets for the Tidal Caloosahatchee Sub-watershed and its tributaries.

Basin	TN Source Control Target Reduction Goal	Reference Period Median Concentration, µg/L	Annual TN Concentration Target - Median Concentration, µg/L
Tidal Sub-watershed	***10%***	***907***	***816***
Bayshore Creek	16%	1,138	952
Billy Creek	25%	935	701
Chapel Branch	18%	1,220	999
Daughtrey Creek	5%	950	902
Deep Lagoon	16%	1,005	845
Hancock Creek	10%	920	827
Lower Orange River	11%	780	693
Marsh Point	21%	880	693
Otter Creek	9%	1,075	976
Owl Creek	9%	930	848
Palm Creek	17%	1,165	966
Popash Creek	5%	1,085	1,030
Powell Creek	16%	852	719
Southeast Cape Coral	3%	718	693
Stroud Creek	16%	1,040	875
Telegraph Creek	8%	1,070	986
Trout Creek	17%	870	719
Whiskey Creek	0%	625	625

Notes:

1. The Annual Concentration Target is a distribution of monthly concentrations, represented by the median concentration adjusted by the source control reduction goal.
2. The Annual Concentration Target was rounded off to three significant digits.

The initial step in evaluating the Annual Concentration Target component will be to use the Wilcoxon rank-sum test to determine if the Evaluation Year's monthly concentrations are systematically larger than the Reference Period's monthly concentrations, adjusted by the basin-specific source control reduction goal, collectively referred to as the "desired distribution" and the Annual Concentration Target. The steps for applying the Wilcoxon rank-sum test were described above in Section 2.3.1. Ideally twelve monthly samples will be available during the Evaluation Year for the annual performance determination. In light of the seasonality of the monthly data (see **Appendix A**), a minimum of at least one monthly sample each quarter per tributary for 75 percent of the tributaries during the Evaluation Year is recommended for using the rank-sum test.

As the second step in evaluating the Annual Concentration Target component, the methodology will apply a "one-in-three-year test" as was done in Chapter 40E-63, F.A.C., and as proposed in the other CRW sub-watersheds. Specifically, if the results of the rank-sum test indicate that the Evaluation Year's data are significantly larger than the desired distribution for three successive years, there is an 87.5 percent confidence that the basin's concentration data are not achieving the source control nutrient reduction goals. Stated another way, for the annual target test of the proposed performance determination, the basin would achieve its performance indicator if the Evaluation Year concentrations are not significantly greater than the desired distribution, as determined by the rank-sum test, at least once in three successive years.

The annual performance determination will be suspended if the Annual Concentration Target is exceeded for the evaluation year, and the annual rainfall falls outside the range observed in the Reference Period (39.46 to 70.96 inches). Even though there was no explicit relationship between annual rainfall and the nutrient concentrations, this condition for suspension is recommended to ensure that the performance determination is conducted during evaluation years with similar environmental conditions (specifically annual rainfall) that existed during the collection of the data used to develop the Targets and Limits.

To illustrate the use of a Wilcoxon rank-sum test, each water year within the Reference Period was compared to the Reference Period using the test to determine whether or not the Evaluation Year data were significantly greater than the Reference Period data (**Table 3-50**). It is helpful to present the Reference Period monthly data in a box plot format in order to compare the median and the spread of the data sets (**Figure 3-32**). While the monthly median concentrations for three water years were greater than the Reference Period median, only the WY2011 and

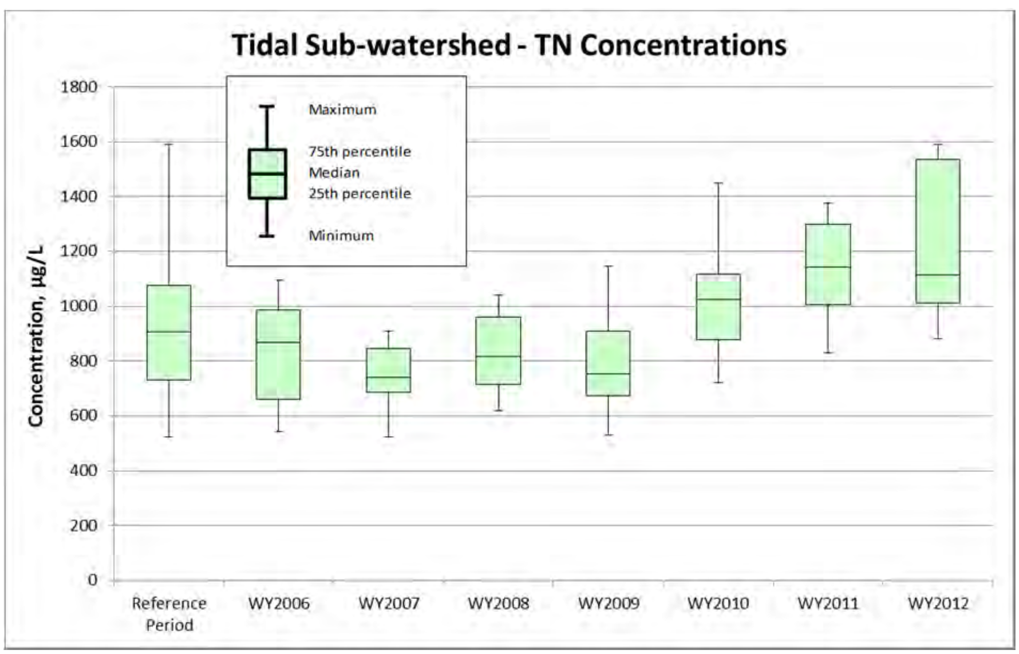
WY2012 distributions were systematically larger than the Reference Period distribution. However, each of the water years of the Reference Period met the one-in-three year annual test.

Table 3-50. Summary of the rank-sum tests for the Tidal Caloosahatchee Sub-watershed Reference Period for TN; significance level of 5 percent.

Water Year	WY Median less than or equal to RP Median?	WY data significantly greater than RP data?	WY data less than or equal to RP data 1 in 3 years?
2006	Yes	No	Yes
2007	Yes	No	Yes
2008	Yes	No	Yes
2009	Yes	No	Yes
2010	No	No	Yes
2011	No	Yes	Yes
2012	No	Yes	Yes
All	57%	29%	100%

Note: "WY" = Water Year and "RP" = Reference Period

Figure 3-32. Comparison of Reference Period (WY2006-2012) TN data to annual data for the Tidal Caloosahatchee Sub-watershed.



3.4.2.2.2 The Annual Concentration Limit Performance Determination for TN

For the Tidal Caloosahatchee Sub-watershed and its tributaries, the second part of the performance metric methodology will compare monthly concentrations during the Evaluation Year to an Annual Concentration Limit. The maximum monthly concentration observed during the WY2006-2012 Reference Period, reduced by the basin-specific source control nutrient reduction goals, is recommended as the Annual Concentration Limit for the Tidal Caloosahatchee Sub-watershed and its tributaries (**Table 3-51**). The proposed performance metric methodology will compare the monthly concentrations during the Evaluation Year to the Annual Concentration Limit, and if a single monthly concentration is above the Annual Concentration Limit, then the basin will have not achieved its performance indicator.

Table 3-51. TN Annual Concentration Limits for the Tidal Caloosahatchee Sub-watershed and its tributaries.

Basin	TN Source Control Limit Reduction Goal	Reference Period Maximum Concentration, µg/L	Annual TN Concentration Limit, µg/L
Tidal Sub-watershed	***15%***	***1,591***	***1,350***
Bayshore Creek	19%	1,910	1,550
Billy Creek	11%	2,380	2,120
Chapel Branch	15%	3,715	3,150
Daughtrey Creek	12%	2,021	1,780
Deep Lagoon	11%	1,910	1,700
Hancock Creek	19%	1,915	1,550
Lower Orange River	14%	1,510	1,300
Marsh Point	14%	1,517	1,310
Otter Creek	12%	2,525	2,220
Owl Creek	22%	2,830	2,200
Palm Creek	14%	2,440	2,100
Popash Creek	11%	2,010	1,790
Powell Creek	18%	2,210	1,810
Southeast Cape Coral	24%	1,648	1,260
Stroud Creek	12%	2,340	2,050
Telegraph Creek	14%	2,654	2,270
Trout Creek	13%	2,430	2,120
Whiskey Creek	33%	1,210	806

Note: The Annual Concentration Limit was rounded off to three significant digits.

The annual performance determination will be suspended if the Annual Concentration Limit is exceeded for the Evaluation Year, and the annual rainfall falls outside the range observed in the Reference Period (39.46 to 70.96 inches). Even though there was no explicit relationship between annual rainfall and the nutrient concentrations, this condition for suspension is recommended to ensure that the performance determination is conducted during evaluation years with similar environmental conditions (specifically annual rainfall) that existed during the collection of the data used to develop the Targets and Limits.

3.4.3 Relationship Between Sub-watershed Performance Determination and Tributary Performance Determination

If the sub-watershed performance metrics are not achieved, a determination of the tributary-specific performance metrics shown in **Tables 3-46, 3-48, 3-49** and **3-51** above, using the same methodology as described in Section 3.4.2, would be warranted, and could assist in prioritizing any necessary follow-up actions.

3.5 Coastal Caloosahatchee Sub-watershed

The following sections present a description of the Coastal Caloosahatchee Sub-watershed, a summary of historical flow and nutrient levels, nutrient reduction goals for the collective source control programs, and development of the performance metrics.

3.5.1 Background

The Coastal Caloosahatchee Sub-watershed consists of 229,317 acres located along the western border of the Caloosahatchee Watershed (**Figure 3-33** and **Table 3-52**). The Sub-watershed does not discharge into the Caloosahatchee Estuary, but rather, discharges directly to the adjacent waters of southern Charlotte Harbor (Pine Island Sound, San Carlos Bay and Matlacha Pass).

The Coastal Caloosahatchee Sub-watershed contains 13 tributaries, of which four (4) tributaries, representing 48 percent of the sub-watershed area, are monitored for water quality, including phosphorus and nitrogen. The majority of the unmonitored area is open water, including the various bays and tidal bodies of water (86 percent).

Historical data analyses for the sub-watershed were initially conducted by HDR Engineering, Inc. as part of Contract No. ST061298 – WO08 (Data Analysis and Performance Measure Development for the St Lucie and the Caloosahatchee River Source Control Programs) with the District (HDR 2011). At that time the focus was on annual nutrient loads, and many of the tributaries were not fully analyzed due to lack of flow data. However, under the current contract, performance metrics based on nutrient concentrations were developed, and additional historical data analyses were conducted.

Figure 3-33. Coastal Caloosahatchee Sub-watershed schematic showing tributaries (from SFWMD).

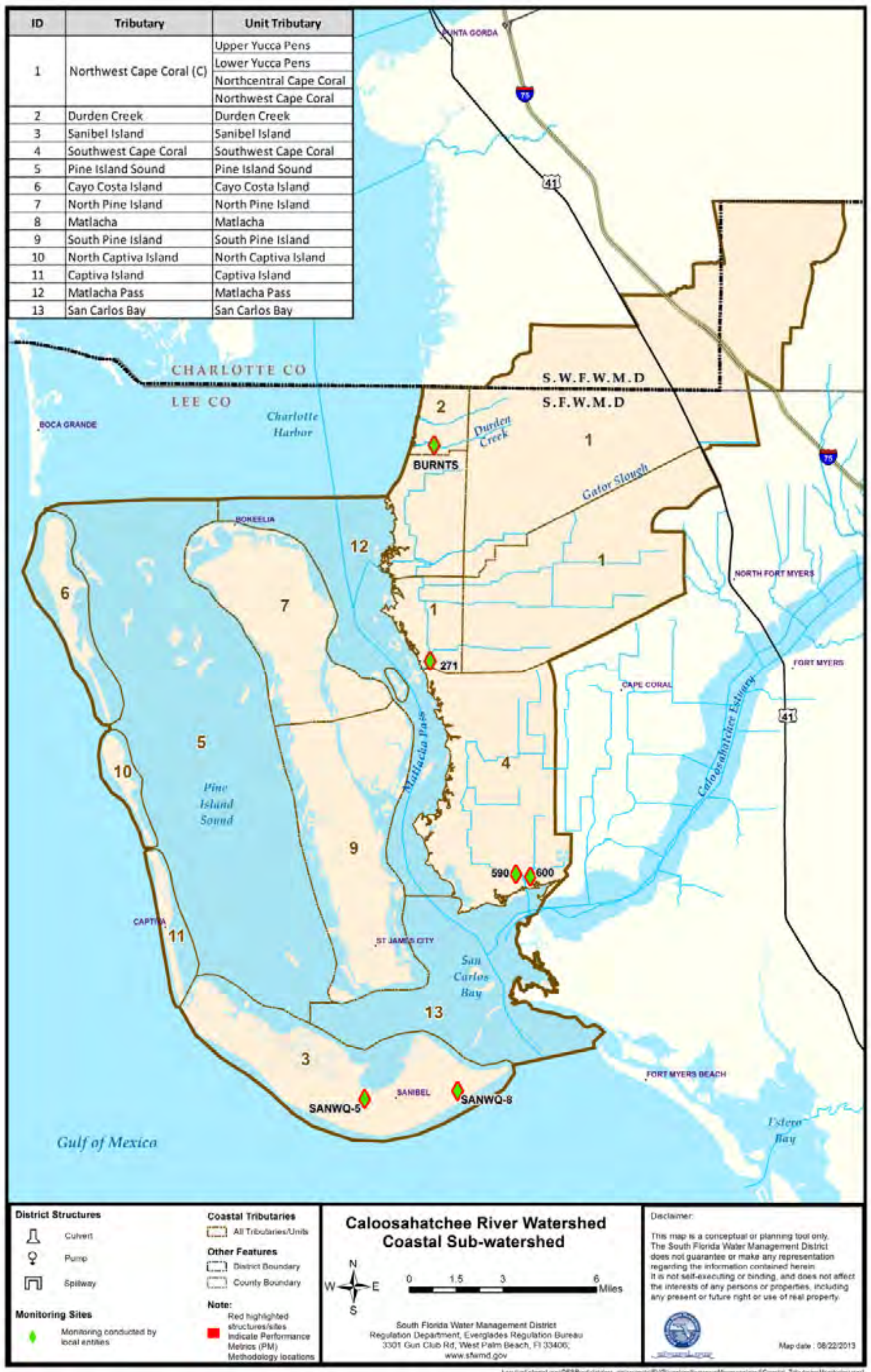


Table 3-52. Areas of the Coastal Caloosahatchee Sub-watershed tributaries (from SFWMD).

Basin	Area (acres)
Monitored Tributaries	
Durden Creek	2,241
NW Cape Coral (1)	71,471
Sanibel Island	17,296
SW Cape Coral	17,940
Sub-total	***108,948***
Unmonitored Tributaries	
Captiva Island	2,416
Cayo Costa Island	5,427
Matlacha	287
Matlacha Pass	16,093
North Captiva Island	1,899
North Pine Island	13,582
Pine Island Sound	46,142
San Carlos Bay	16,460
South Pine Island	18,063
Sub-total	120,369
Sub-watershed Total	***229,317***

Note: (1) indicates the basin includes multiple tributaries as described in the text.

District staff compiled available monthly nutrient concentration data for the tributaries within the sub-watershed. Water quality data in the sub-watershed are collected by multiple agencies, and the stations included data for different periods of record (**Table 3-53**). Uncertainty is inherent in any data collection program, and the historical data for the Tidal Caloosahatchee Sub-watershed include the following three significant components of uncertainty:

- the data do not distinguish between basin stormwater runoff flow and the influence of twice daily tidal cycles,
- flow estimates are not available for all monitoring stations, and
- the Reference Period contains less than eight years of data, the minimum required for a performance measure.

Table 3-53. Water quality data sources in the Coastal Caloosahatchee Sub-watershed.

Basin	Monitoring Site	Agency Collecting Data	Period of Record
Durden Creek	BURNTS	Lee County	WY2008-2013
NW Cape Coral	271	Cape Coral	WY2009-2013
Sanibel Island	SANWQ5, SANWQ8	Sanibel Island	WY2002-2013
SW Cape Coral	590, 600	Cape Coral	WY2003-2013

3.5.1.1 Selection of representative stations. Monitoring stations that sample water quality from common tributaries were identified, and sub-basins were combined as appropriate. This resulted in three combinations of tributaries.

1. The Upper Yucca Pens, Lower Yucca Pens, and north central Cape Coral are tributary to the Northwest Cape Coral basin; water quality data at station 271 are considered representative of discharges from those areas into Charlotte Harbor.
2. Monthly water quality data for two Sanibel Island stations, SANWQ5 and SANWQ8, were combined by taking the arithmetic average of the monthly samples' concentrations.
3. Monthly water quality data for two Southwest Cape Coral stations, 590 and 600, were combined by taking the arithmetic average of the monthly samples' concentrations.

Basic synoptic statistics were calculated for TP and TN for each tributary (**Table 3-54**; additional details are provided in **Appendix A**). A single potential outlier was identified using the Maximum Normed Residual Outlier Analysis (Snedecor 1989), and after reviewing the comments and other information associated with the data, District staff determined the value should be retained in the analyses. In addition to statistical outliers, agency staff screened the data to exclude samples collected during periods of atypical basin runoff conditions, e.g., construction, incoming tides and large amounts of floating aquatic vegetation.

Table 3-54. Summary of Reference Period monthly data for the Coastal Caloosahatchee Sub-watershed and its tributaries.

Basin	WY2009-2012 Reference Period Annual Water Year Summary									
	Total Phosphorus					Total Nitrogen				
	Begin	End	Missing Data	Median µg/L	Maximum µg/L	Begin	End	Missing Data	Median µg/L	Maximum µg/L
Durden Creek	2009	2012	15%	9	22	2009	2012	15%	1,111	2,010
NW Cape Coral	2009	2012	23%	30	70	2009	2012	29%	650	1,450
Sanibel Island	2009	2012	0%	84	221	2009	2012	0%	1,843	2,292
SW Cape Coral	2009	2012	2%	43	243	2009	2012	10%	731	1,250
Sub-watershed	2009	2012	0%	47	171	2009	2012	0%	991	1,982

Based on the review of individual tributary periods of record, a common Reference Period of WY2009-WY2012 (May 2008 – April 2012) was selected for the Coastal Caloosahatchee Sub-watershed. While this period is shorter than normally used, the exception was warranted due to the limited availability of data at the time of the analyses.

3.5.1.2 Nutrient Concentration Analyses. Spatially composite sub-watershed nutrient concentrations were calculated from the individual tributary concentrations for each month of the WY2009-2012 Reference Period using the following algorithm.

Composite monthly value = sum (tributary conc * tributary runoff) / sum (tributary runoff)
Where tributary runoff = tributary unit area runoff * tributary area
tributary unit area runoff = sum (land use unit area runoff coefficient * land use area)

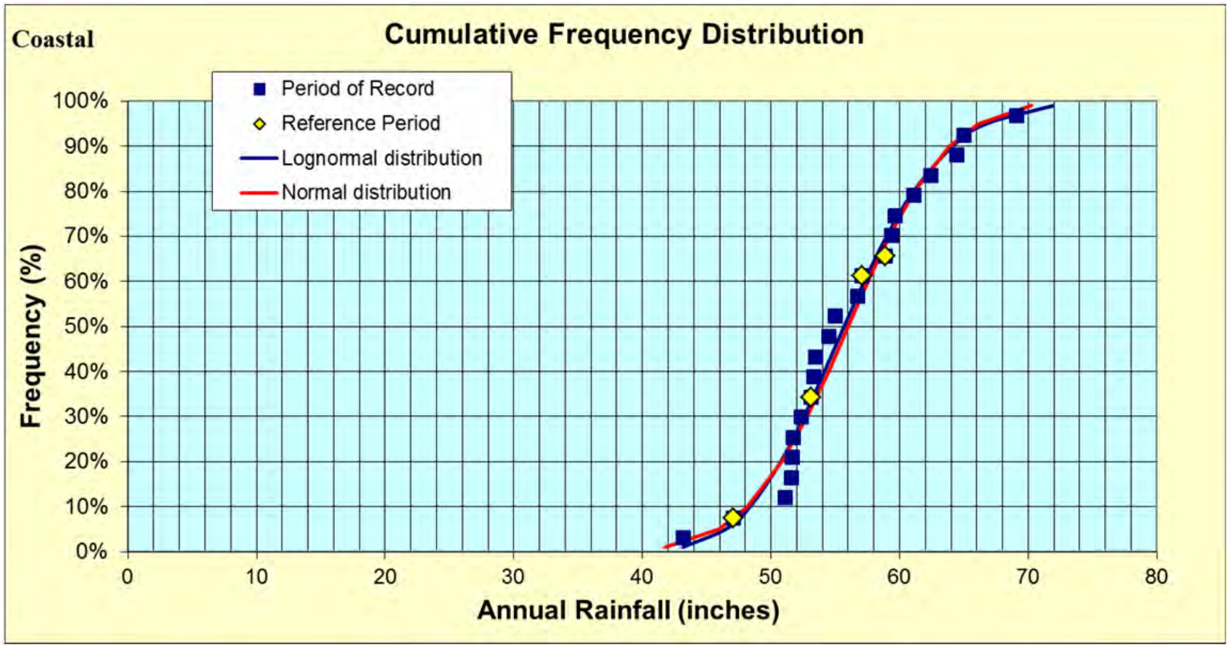
The land use unit area runoff coefficients and areas for each land use were obtained from the 2012 Caloosahatchee River Watershed Protection Plan (SFWMD 2012; Attachment 1; Appendix A). This algorithm properly takes into account missing data in that both the numerator and denominator include "0" if a tributary is missing data for any individual month. Annual summaries of the sub-watershed composite nutrient data are presented in **Table 3-55**. There were no statistically significant trends observed in the monthly TP, TN and TON concentrations; additional information is contained in **Appendix A**.

Table 3-55. Annual summary of median composite concentrations for the Coastal Caloosahatchee Sub-watershed.

Water Year	TP Median µg/L	TN Median µg/L	TON Median µg/L
2009	52	1028	896
2010	46	756	600
2011	40	898	742
2012	47	1117	976
2013	43	1028	847
WY2009-2012 monthly median	47	991	844

3.5.1.3 Rainfall Analysis. The performance indicators for the Coastal Caloosahatchee Sub-watershed were based on the monthly data for TP, TN and TON without an explicit adjustment for hydrologic variability. As such, it is helpful to understand the hydrologic conditions that existed during the time of water quality data collection. Since flow data are not available for the sub-watershed, rainfall data were analyzed as a measure of the hydrologic variability. Daily rainfall data at two representative stations were compiled by the District using the Thiessen polygon weights shown in **Appendix A**. The cumulative frequency distribution for WY1991-2012 annual rainfall is shown in **Figure 3-34**. Annual rainfall during the WY2009-WY2012 Reference Period ranged from 5 percent to 66 percent (47.10 to 58.86 inches) of the range observed during the WY1991-2012 period (43.20 to 69.10 inches).

Figure 3-34. Frequency distribution for annual Coastal Caloosahatchee Sub-watershed rainfall.



3.5.1.4 TP Trend. Table 3-56 presents the observed annual median and 60-month median TP concentrations and differences from the reference period median concentration. The sub-watershed TP concentration trend is presented in **Figure 3-35**. The solid line shows the five-year trend of load differences. The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-35** denotes a reduction in loads.

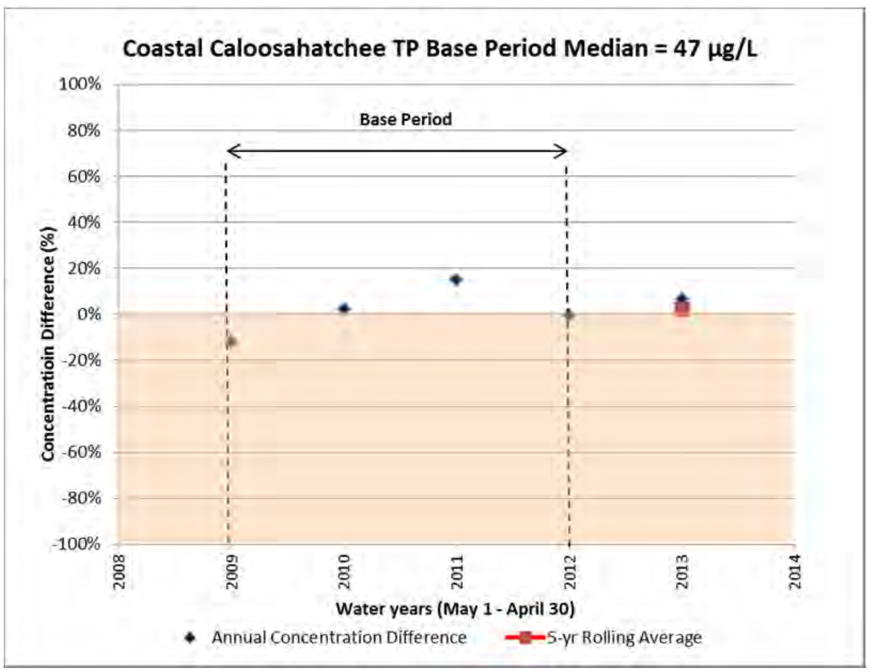
3.5.1.5 TN Trend. Table 3-57 presents the observed annual median and 60-month median TN concentrations and differences from the reference period median concentration. The sub-watershed TN concentration trend is presented in **Figure 3-36**. The solid line shows the five-year trend of load differences. The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-36** denotes a reduction in loads.

Table 3-56. WY2009-2013 Coastal Caloosahatchee Sub-watershed TP measurements and calculations. (Reference Period: WY2009-2012).

Water Year	Annual TP Median, µg/L	Annual Difference	TP 60-month Median, µg/L	5-yr Rolling Average Difference
2009	52	-12%		
2010	46	2%		
2011	40	15%		
2012	47	-1%		
2013	43	7%	46	2%

Notes
1. Reference period median = 47 µg/L
2. Annual difference values are calculated as [1 – (annual median / reference period median)].
3. 5-year rolling average difference values are calculated as [1 – (60-month median concentration) / (the reference period median)].

Figure 3-35. Coastal Caloosahatchee Sub-watershed TP concentration trend.



Notes:
1. A positive concentration difference denotes a reduction in concentration in comparison to the base period.
2. Due to limited duration of the data set the 5-year rolling average trend is just one point.

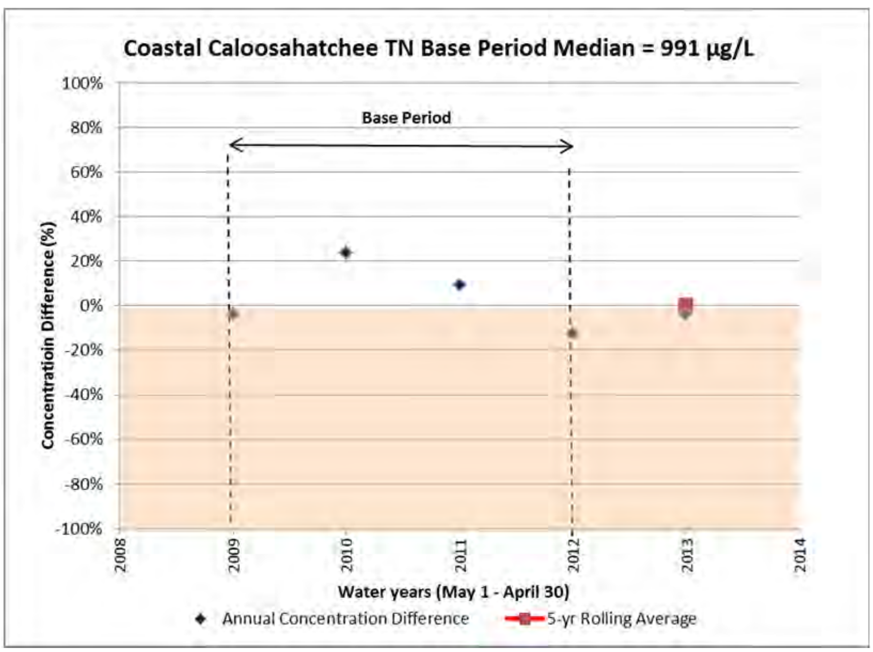
Table 3-57. WY2009-2013 Coastal Caloosahatchee Sub-watershed TN measurements and calculations. (Reference Period: WY2009-2012).

Water Year	Annual TN Median, µg/L	Annual Difference	TN 60-month Median, µg/L	5-yr Rolling Average Reduction
2009	1,028	-4%		
2010	756	24%		
2011	898	9%		
2012	1,117	-13%		
2013	1,028	-4%	991	0%

Notes

1. Reference period median = 991 µg/L
2. Annual difference values are calculated as [1 – (annual median / reference period median)].
3. 5-year rolling average difference values are calculated as [1 – (60-month median concentration) / (the reference period median)].

Figure 3-36. Coastal Caloosahatchee Sub-watershed TN concentration trend.



Notes: A positive concentration difference denotes a reduction in concentration in comparison to the base period. Due to limited duration of the data set the 5-year rolling average trend is just one point (WY2013).

3.5.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the Coastal Caloosahatchee Sub-watershed.

Based on a review of multiple analyses, estimates were generated for basin-specific nutrient reductions anticipated as a result of implementation of collective source controls within the sub-watershed. These analyses included the following.

- Evaluation of individual land use source control effectiveness ranges described in Section 2.5 and Appendix C.
- Review of the nutrient reduction estimates for BMPs reported in the CRWPP.
- For TN, there was an assumption that a TN level equal to 90 percent of the reference period TON is a reasonable approximation of the natural background TN, and that the remaining ten percent is attributable to anthropogenic activities (e.g., use of organic fertilizers and cycling of inorganic nitrogen into TON) which could potentially be reduced through source controls.
- Best professional judgment.

Additional details are presented in **Appendix C**.

3.5.2.1 Total Phosphorus Performance Metric Methodology

The proposed TP performance indicators consist of two parts:

1. Part 1: An Annual Concentration Target component; and
2. Part 2: An Annual Concentration Limit component.

The Annual Concentration Target was based on the historical monthly concentrations for the Reference Periods, reduced by basin-specific source control reduction goals. The Annual Concentration Limit was based on the Reference Periods' maximum observed monthly concentration, reduced by basin-specific source control reduction goals. The two components of the TP performance metric for the Coastal Caloosahatchee Sub-watershed are described in the following sections. The associated TP performance determination process is presented as a flowchart in **Figure 1-3**.

3.5.2.1.1 The Annual Concentration Target Performance Determination for TP

The objective of the Annual Concentration Target component is to annually determine whether or not a basin's nutrient levels are meeting the desired long-term nutrient goals established for the basin. The nutrient reduction goal established by District staff was to not exceed existing conditions, i.e., a reduction goal of 0 percent. The Annual Concentration Target is a distribution of monthly concentrations, represented by the median concentration of the distribution. A summary of the Annual Concentration Target for TP for the Coastal Caloosahatchee Sub-watershed and its tributaries is presented in **Table 3-58**.

The initial step in evaluating the Annual Concentration Target component will be to use the Wilcoxon rank-sum test to determine if the Evaluation Year's monthly concentrations are systematically larger than the Reference Period's monthly concentrations, adjusted by the basin-specific source control reduction goal, collectively referred to as the "desired distribution" and the Annual Concentration Target. The steps for applying the Wilcoxon rank-sum test were described above in Section 3.4.2.1. Ideally twelve monthly samples will be available during the Evaluation Year for the annual performance determination. In light of the seasonality of the monthly data (see **Appendix A**), a minimum of at least one monthly sample each quarter per tributary for 75 percent of the tributaries during the Evaluation Year is recommended for using the rank-sum test.

Table 3-58. TP Annual Concentration Targets for the Coastal Caloosahatchee Sub-watershed and its tributaries.

Basin	TP Source Control Target Reduction Goal	Reference Period Median Concentration, µg/L	Annual TP Concentration Target - Median Concentration, µg/L
Coastal Sub-watershed	***0%***	***47***	***47***
Durden Creek	0%	9	9
Northwest Cape Coral	0%	30	30
Sanibel Island	0%	84	84
Southwest Cape Coral	0%	43	43

Note: The Annual Concentration Target is a distribution of monthly concentrations, represented here by the median concentration.

As the second step in evaluating the Annual Concentration Target component, the methodology will apply a "one-in-three-year test" as was done in Chapter 40E-63, F.A.C., and as proposed in the other CRW sub-watersheds. Specifically, if the results of the rank-sum test indicate that the Evaluation Year's data are significantly larger than the desired distribution for three successive years, there is an 87.5 percent confidence that the basin's concentration data are not achieving the source control nutrient reduction goals. Stated another way, for the annual target test of the proposed performance determination, the basin would achieve its performance indicator if the Evaluation Year concentrations are not significantly greater than the desired distribution, as determined by the rank-sum test, at least once in three successive years.

The annual performance determination will be suspended if the Annual Concentration Target is exceeded for the Evaluation Year, and the annual rainfall falls outside the range observed in the Reference Period (47.10 to 58.86 inches). Even though there was no explicit relationship between annual rainfall and the nutrient concentrations, this condition for suspension is recommended to ensure that the performance determination is conducted during evaluation years with similar environmental conditions (specifically annual rainfall) that existed during the collection of the data used to develop the Targets and Limits.

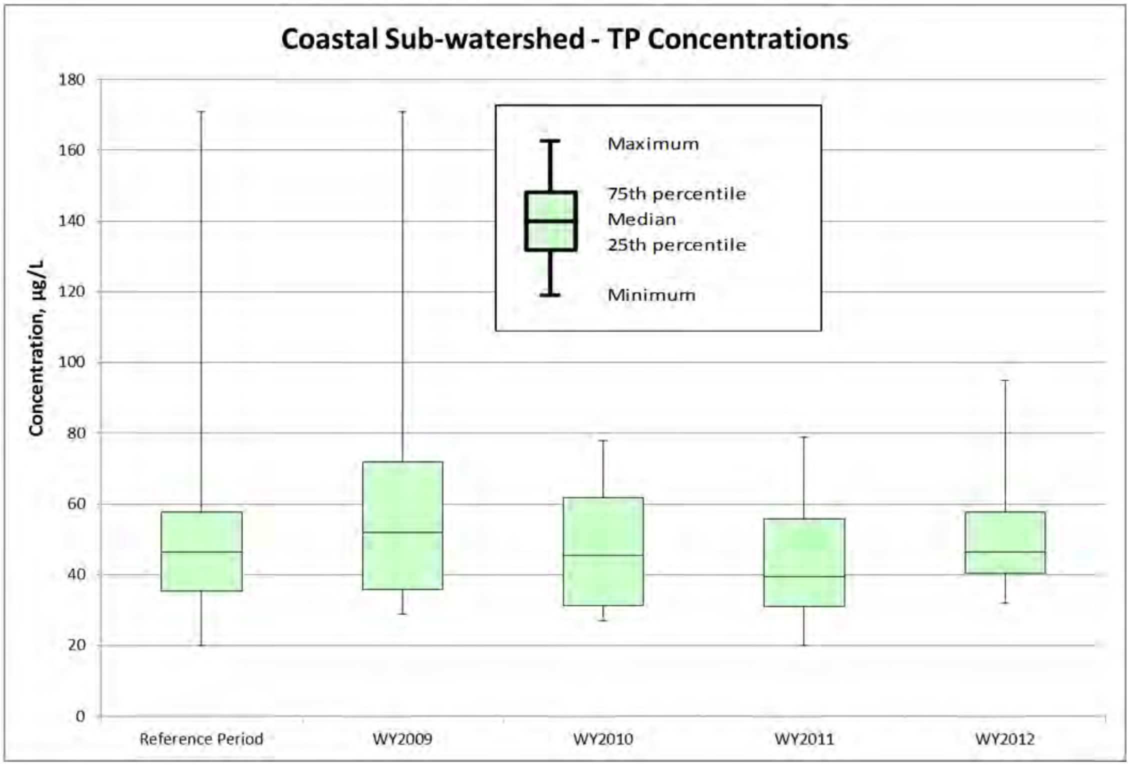
The comparison of the monthly TP concentrations for each of the individual water years to the WY2009-2012 Reference Period data using the Wilcoxon rank-sum test and the one in three year algorithm, with no reduction for source controls in this example, is shown in **Table 3-59.** It is helpful to present the Reference Period monthly data in a box plot format in order to compare the median and the spread of the data sets (**Figure 3-37**). While the monthly median concentration for WY2009 was greater than the Reference Period median, the water year's distribution was not systematically larger than the Reference Period's distribution. Consequently, each of the water years of the Reference Period met the one-in-three year annual test.

Table 3-59. Summary of the rank-sum tests for the Coastal Caloosahatchee Sub-watershed Reference Period for TP; significance level of 5 percent.

Water Year	WY Median less than or equal to RP Median?	WY data significantly greater than RP data	WY data less than or equal to RP data 1 in 3 years?
2009	No	No	Yes
2010	Yes	No	Yes
2011	Yes	No	Yes
2012	Yes	No	Yes
All	***75%***	***0%***	***100%***

Note: "WY" = Water Year and "RP" = Reference Period

Figure 3-37. Comparison of Reference Period (WY2009-2012) TP data to annual data for the Coastal Caloosahatchee Sub-watershed.



3.5.2.1.2 The Annual Concentration Limit Performance Determination for TP

For the Coastal Caloosahatchee Sub-watershed and its tributaries, the performance metric methodology will compare monthly concentrations during the Evaluation Year to an Annual Concentration Limit. The maximum monthly concentration observed during the WY2009-2012 Reference Period, reduced by the basin-specific source control nutrient reduction goals, is recommended as the Annual Concentration Limit for the Coastal Caloosahatchee Sub-watershed and its tributaries (**Table 3-60**). The nutrient reduction goal established by District staff was to not exceed existing conditions, i.e., a reduction goal of 0 percent. The proposed performance metric methodology will compare the monthly concentrations during the Evaluation Year to the Annual Concentration Limit, and if a single monthly concentration is above the Annual Concentration Limit, then the basin will have not achieved its performance indicator.

Table 3-60. TP Annual Concentration Limits for the Coastal Caloosahatchee Sub-watershed and its tributaries.

Basin	TP Source Control Limit Reduction Goal	Reference Period Maximum Concentration, µg/L	Annual TP Concentration Limit, µg/L
Coastal Sub-watershed	***0%***	***171***	***171***
Durden Creek	0%	22	22
Northwest Cape Coral	0%	70	70
Sanibel Island	0%	221	221
Southwest Cape Coral	0%	243	243

The annual performance determination will be suspended if the Annual Concentration Limit is exceeded for the Evaluation Year, and the annual rainfall falls outside the range observed in the Reference Period (47.10 to 58.86 inches). Even though there was no explicit relationship between annual rainfall and the nutrient concentrations, this condition for suspension is recommended to ensure that the performance determination is conducted during evaluation years with similar environmental conditions (specifically annual rainfall) that existed during the collection of the data used to develop the Targets and Limits.

3.5.2.2 Total Nitrogen Performance Metric Methodology

The proposed performance indicators consist of two parts:

1. Part 1: An Annual Concentration Target component; and
2. Part 2: An Annual Concentration Limit component.

The Annual Concentration Target was based on the historical monthly concentrations for the Reference Periods, reduced by the basin-specific source control reduction goals. The Annual Concentration Limit was based on the Reference Periods' maximum observed monthly concentration, reduced by the basin-specific source control reduction goals. The two components of the TN performance metric for the Coastal Caloosahatchee Sub-watershed are described in the following sections. The TN performance determination process is presented as a flowchart in **Figure 1-3**.

3.5.2.2.1 The Annual Concentration Target Performance Determination for TN

The objective of the Annual Concentration Target component is to annually determine whether or not a basin's nutrient levels are meeting the desired long-term nutrient goals established for the basin. The Annual Concentration Target is a distribution of monthly concentrations, represented by the median concentration of the distribution. A summary of the Annual Concentration Targets for TN for the Coastal Caloosahatchee Sub-watershed and its tributaries is presented in **Table 3-61**.

Table 3-61. TN Annual Concentration Targets for the Coastal Caloosahatchee Sub-watershed and its tributaries.

Basin	TN Source Control Target Reduction Goal	Reference Period Median Concentration, µg/L	Annual TN Concentration Target - Median Concentration, µg/L
Coastal Sub-watershed	***15%***	***991***	***842***
Durden Creek	6%	1,111	1,040
Northwest Cape Coral	17%	650	540
Sanibel Island	11%	1,843	1,640
Southwest Cape Coral	17%	731	607

Notes:

1. The Annual Concentration Target is a distribution of monthly concentrations, represented here by the median concentration adjusted by the source control reduction goal.
2. The Annual Concentration Target was rounded off to three significant digits.

The initial step in evaluating the Annual Concentration Target component will be to use the Wilcoxon rank-sum test to determine if the Evaluation Year's monthly concentrations are systematically larger than the Reference Period's monthly concentrations, adjusted by the basin-specific source control reduction goal, collectively referred to as the "desired distribution" and the Annual Concentration Target. The steps for applying the Wilcoxon rank-sum test were described above in Section 3.4.2.1. Ideally twelve monthly samples will be available during the Evaluation Year for the annual performance determination. A minimum of at least one monthly sample each quarter per tributary for 75 percent of the tributaries during the Evaluation Year is recommended for using the rank-sum test.

As the second step in evaluating the Annual Concentration Target component, the methodology will apply a "one-in-three-year test" as was done in 40E-63, and as proposed in the other CRW sub-watersheds. Specifically, if the results of the rank-sum test indicate that the Evaluation Year's data are significantly larger than the desired distribution for three successive years, there is an 87.5 percent confidence that the basin's concentration data are not achieving the source control nutrient reduction goals. Stated another way, for the annual target test of the proposed performance determination, the basin would achieve its performance indicator if the Evaluation Year concentrations are not significantly greater than the desired distribution, as determined by the rank-sum test, at least once in three successive years.

The annual performance determination will be suspended if the Annual Concentration Target is exceeded for the evaluation year, and the annual rainfall falls outside the range observed in the Reference Period (47.10 to 58.86 inches). Even though there was no explicit relationship between annual rainfall and the nutrient concentrations, this condition for suspension is recommended to ensure that the performance determination is conducted during evaluation years with similar environmental conditions (specifically annual rainfall) that existed during the collection of the data used to develop the Targets and Limits.

To illustrate the use of a Wilcoxon rank-sum test, each water year within the Reference Period was compared to the Reference Period using the test to determine whether or not the Evaluation

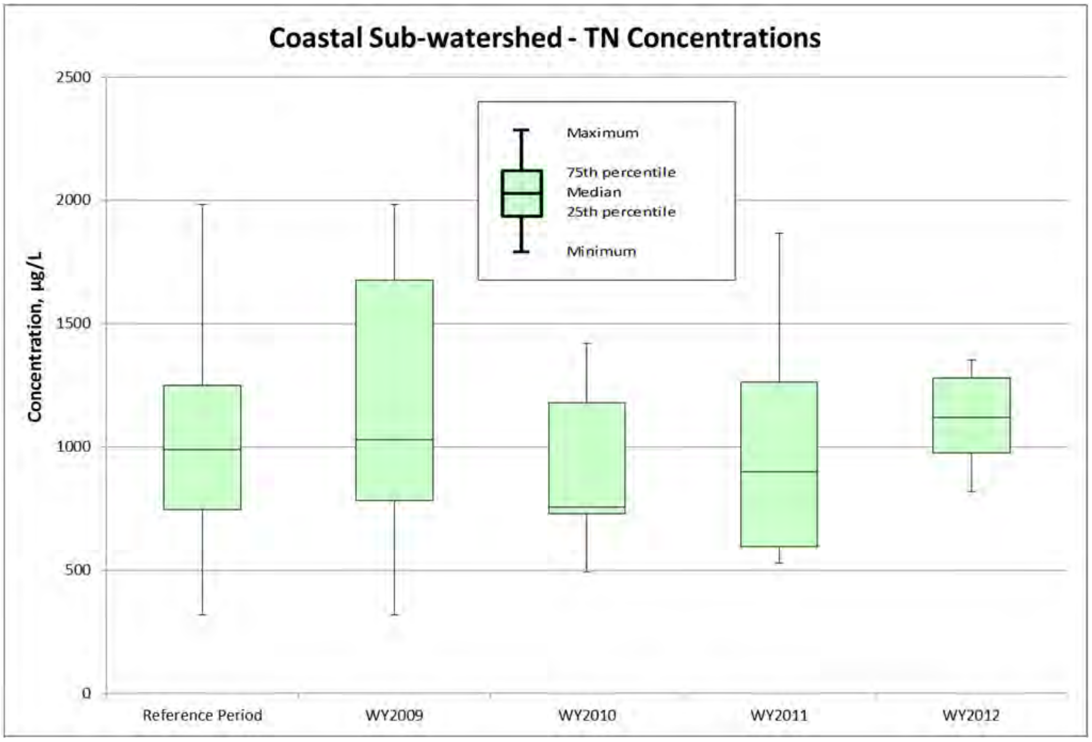
Year data were significantly greater than the Reference Period data (**Table 3-62**). It is helpful to present the Reference Period monthly data in a box plot format in order to compare the median and the spread of the data sets (**Figure 3-38**). While the monthly median concentration for WY2009 was greater than the Reference Period median, the WY2009 data distribution was not systematically larger than the Reference Period distribution. Hence, each of the water years of the Reference Period met the one-in-three year annual test.

Table 3-62. Summary of the rank-sum tests for the Coastal Caloosahatchee Sub-watershed Reference Period for TN; significance level of 5 percent.

Water Year	WY Median less than or equal to RP Median?	WY data significantly greater than RP data	WY data less than or equal to RP data 1 in 3 years?
2009	No	No	Yes
2010	Yes	No	Yes
2011	Yes	No	Yes
2012	No	No	Yes
All	***50%***	***0%***	***100%***

Note: "WY" = Water Year and "RP" = Reference Period

Figure 3-38. Comparison of Reference Period (WY2009-2012) TN data to annual data for the Coastal Caloosahatchee Sub-watershed.



3.5.2.2.2 The Annual Concentration Limit Performance Determination for TN

For the Coastal Caloosahatchee Sub-watershed and its tributaries, the performance metric methodology will compare monthly concentrations during the Evaluation Year to an Annual Concentration Limit. The maximum monthly concentration observed during the WY2009-2012 Reference Period, reduced by the basin-specific source control nutrient reduction goals, is recommended as the Annual Concentration Limit for the Coastal Caloosahatchee Sub-watershed and its tributaries (**Table 3-63**). The proposed performance metric methodology will compare the monthly concentrations during the Evaluation Year to the Annual Concentration Limit, and if a single monthly concentration is above the Annual Concentration Limit, then the basin will have not achieved its performance indicator.

Table 3-63. TN Annual Concentration Limits for the Coastal Caloosahatchee Sub-watershed and its tributaries.

Basin	TN Source Control Limit Reduction Goal	Reference Period Maximum Concentration, µg/L	Annual TN Concentration Limit, µg/L
Coastal Sub-watershed	***14%***	***1,982***	***1,710***
Durden Creek	12%	2,010	1,770
Northwest Cape Coral	14%	1,450	1,250
Sanibel Island	14%	2,292	1,980
Southwest Cape Coral	14%	1,250	1,080

Note: The Annual Concentration Limit was rounded off to three significant digits.

The annual performance determination will be suspended if the Annual Concentration Limit is exceeded for the Evaluation Year, and the annual rainfall falls outside the range observed in the Reference Period (47.10 to 58.86 inches). Even though there was no explicit relationship between annual rainfall and the nutrient concentrations, this condition for suspension is recommended to ensure that the performance determination is conducted during evaluation years with similar environmental conditions (specifically annual rainfall) that existed during the collection of the data used to develop the Targets and Limits.

3.5.3 Relationship Between Sub-watershed Performance Determination and Tributary Performance Determination

If the sub-watershed performance metrics are not achieved, a determination of the tributary-specific performance metrics shown in **Tables 3-58, 3-60, 3-61** and **3-63** above, using the same methodology as described in Section 3.5.2, would be warranted, and could assist in prioritizing any necessary follow-up actions.

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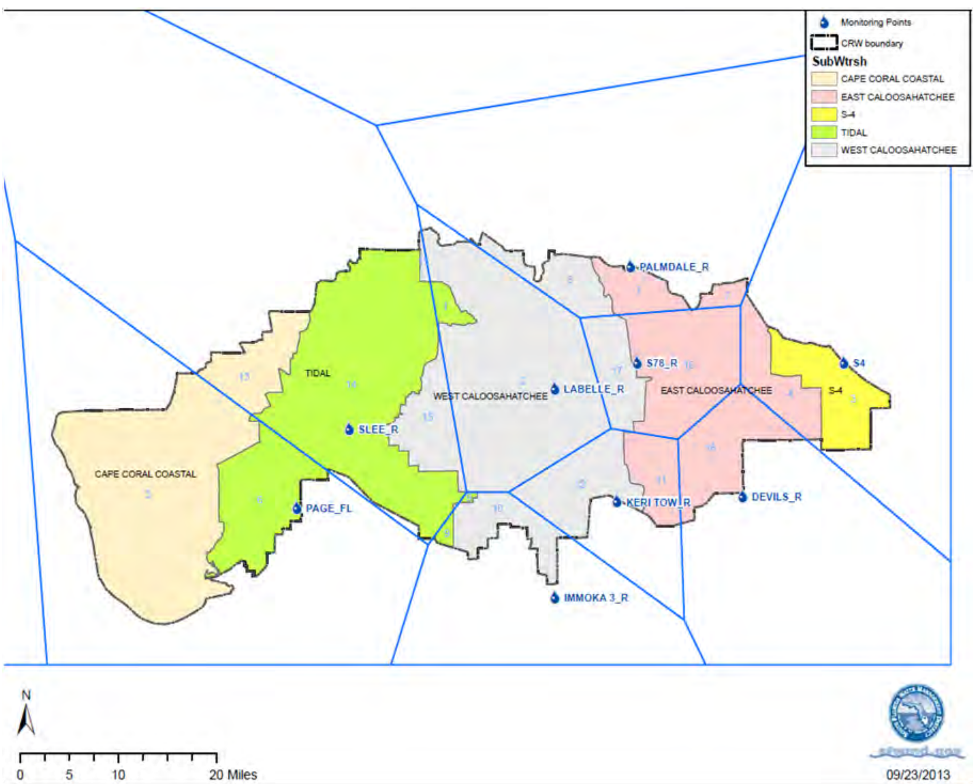
APPENDIX A - SUPPLEMENTAL INFORMATION FOR THE DERIVATION OF THE PERFORMANCE METRIC METHODOLOGIES FOR THE BASINS OF THE CALOOSAHATCHEE RIVER WATERSHED

Unit area runoff coefficients (from SFWMD 2012) for various land use types

CRWPP Land Use	Runoff, in in/yr
Residential Low Density	25.18
Residential Medium Density	29.76
Residential High Density	36.62
Other Urban	33.88
Improved Pasture	27.47
Unimproved Pasture	22.89
Rangeland, Woodland Pasture	20.60
Row Crops	32.05
Sugar Cane	27.47
Citrus	27.47
Sod	27.47
Ornamentals	27.47
Horse Farms	22.89
Dairies	22.89
Other Agriculture	24.49
Tree Plantations	13.73
Water	4.58
Natural Areas	19.46
Transportation	45.78
Communication, Utilities	25.18

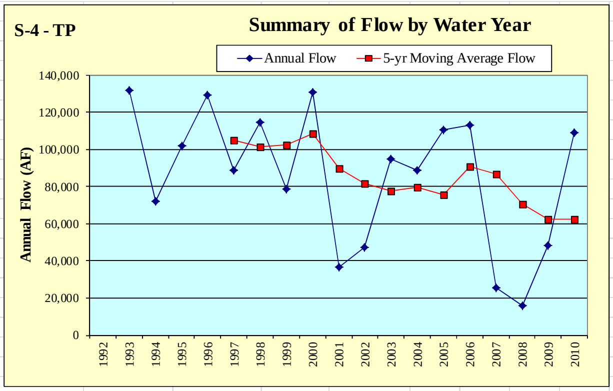
Rainfall stations and weights for the sub-watersheds

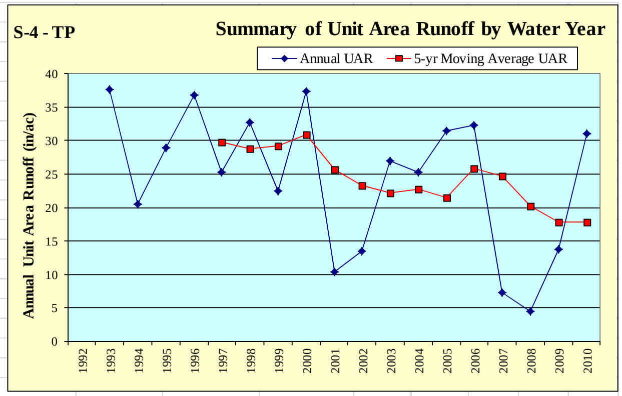
STATION	Sub-watershed	Weighting Factor
S4_R	S-4/Industrial Canal	1.0000
DEVILS_R	East Caloosahatchee	0.23490
PALMDALE_R	East Caloosahatchee	0.12646
S78_R	East Caloosahatchee	0.35985
S4_R	East Caloosahatchee	0.15638
KERI TOW_R	East Caloosahatchee	0.12241
SLEE_R	West Caloosahatchee	0.10269
PALMDALE_R	West Caloosahatchee	0.07763
LABELLE_R	West Caloosahatchee	0.52341
IMMOKA 3_R	West Caloosahatchee	0.08542
S78_R	West Caloosahatchee	0.08401
KERI TOW_R	West Caloosahatchee	0.12685
SLEE_R	Tidal Caloosahatchee	0.72763
PAGE_FL (NOAA)	Tidal Caloosahatchee	0.23403
LABELLE_R	Tidal Caloosahatchee	0.02551
IMMOKA 3_R	Tidal Caloosahatchee	0.01282
SLEE_R	Coastal Caloosahatchee	0.14632
PAGE_FL (NOAA)	Coastal Caloosahatchee	0.85368

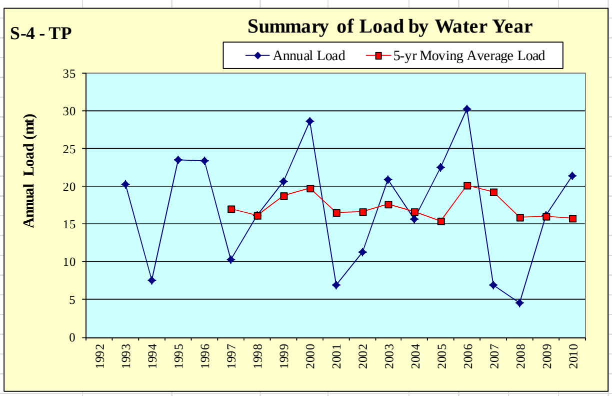


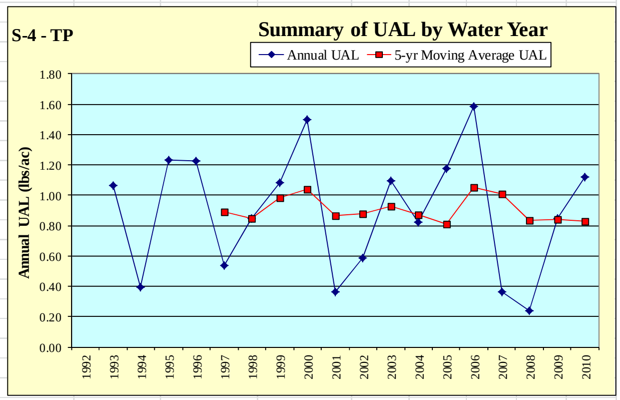
S-4/INDUSTRIAL CANAL SUB-WATERSHED

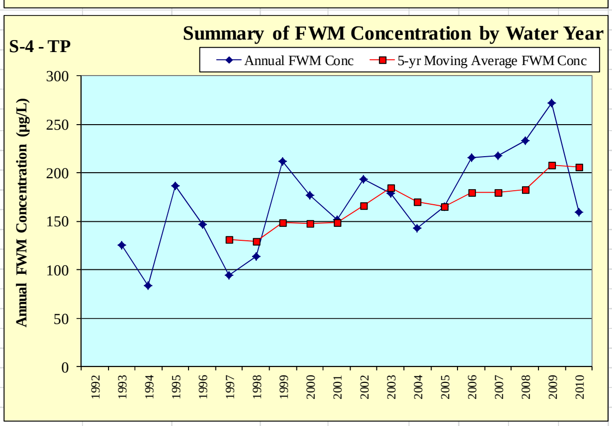
Annual Flow and Nutrient Levels

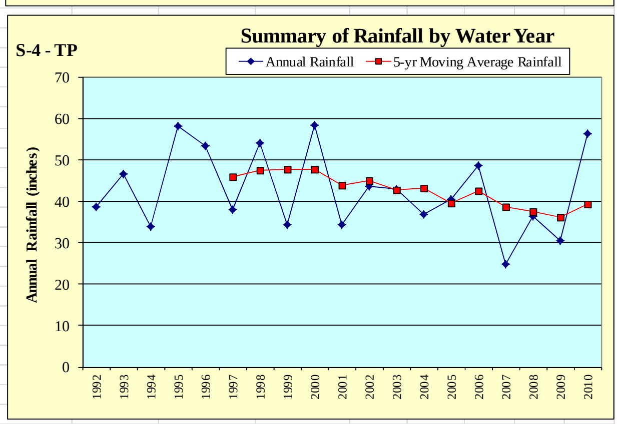


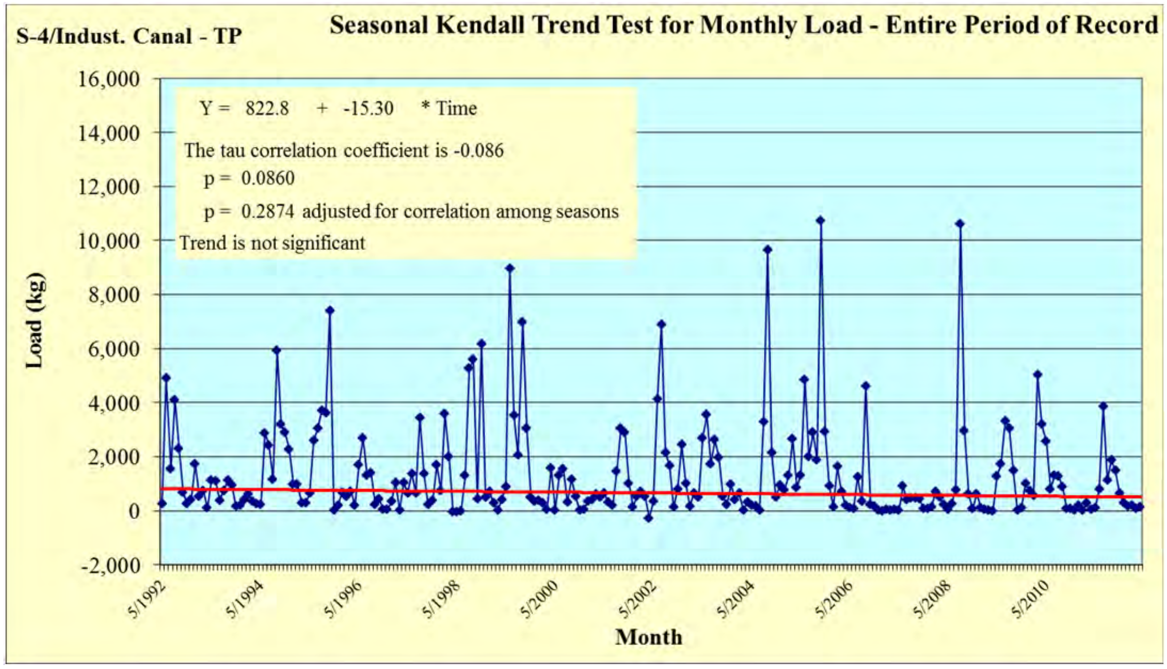


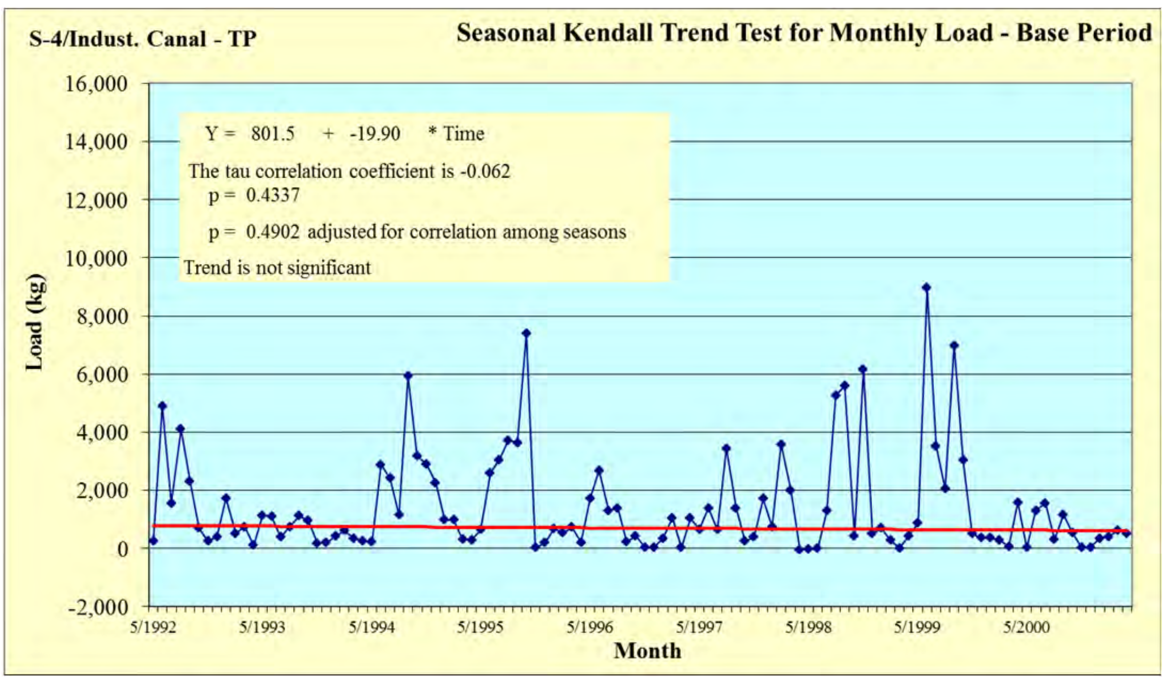


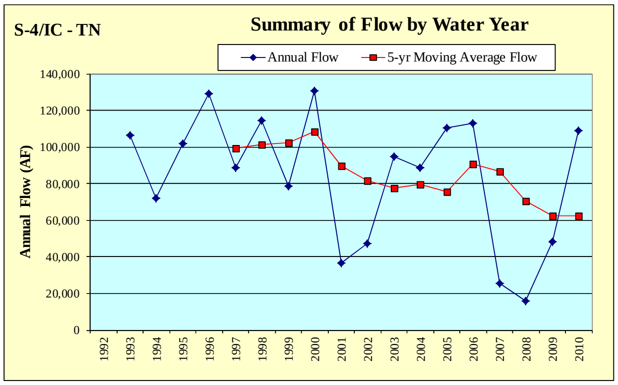


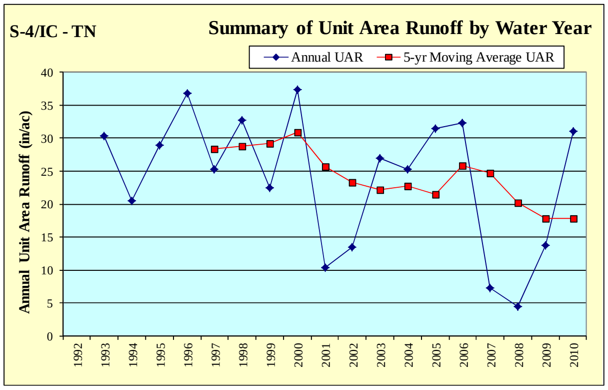


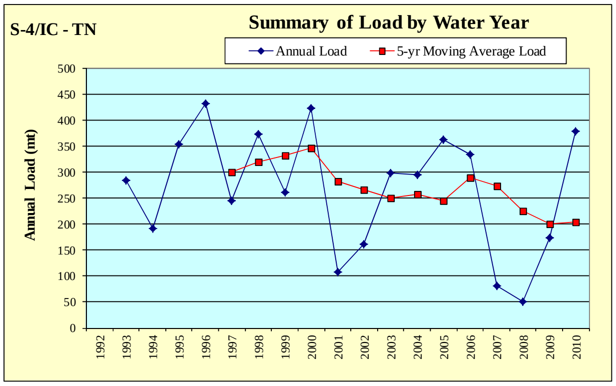


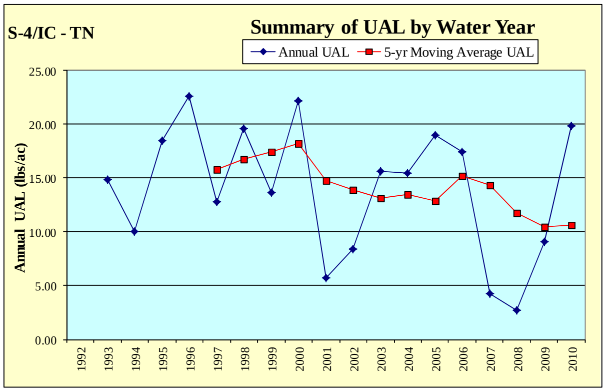

S-4/Indust. Canal - TP
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 822.8 + -15.30 * Time
The tau correlation coefficient is -0.086
p = 0.0860
p = 0.2874 adjusted for correlation among seasons
Trend is not significant
Load (kg)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
5/1992
5/1994
5/1996
5/1998
5/2000
5/2002
5/2004
5/2006
5/2008
5/2010
Month

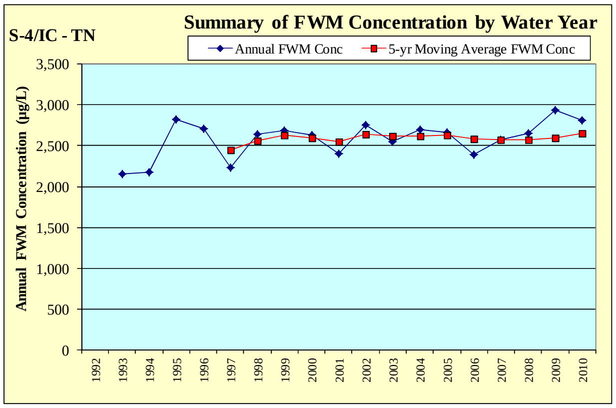

S-4/Indust. Canal - TP
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 801.5 + -19.90 * Time
The tau correlation coefficient is -0.062
p = 0.4337
p = 0.4902 adjusted for correlation among seasons
Trend is not significant
Load (kg)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
5/1992
5/1993
5/1994
5/1995
5/1996
5/1997
5/1998
5/1999
5/2000
Month

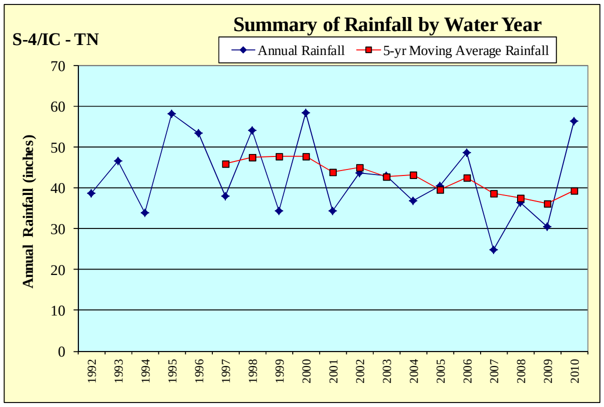

S-4/IC - TN
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

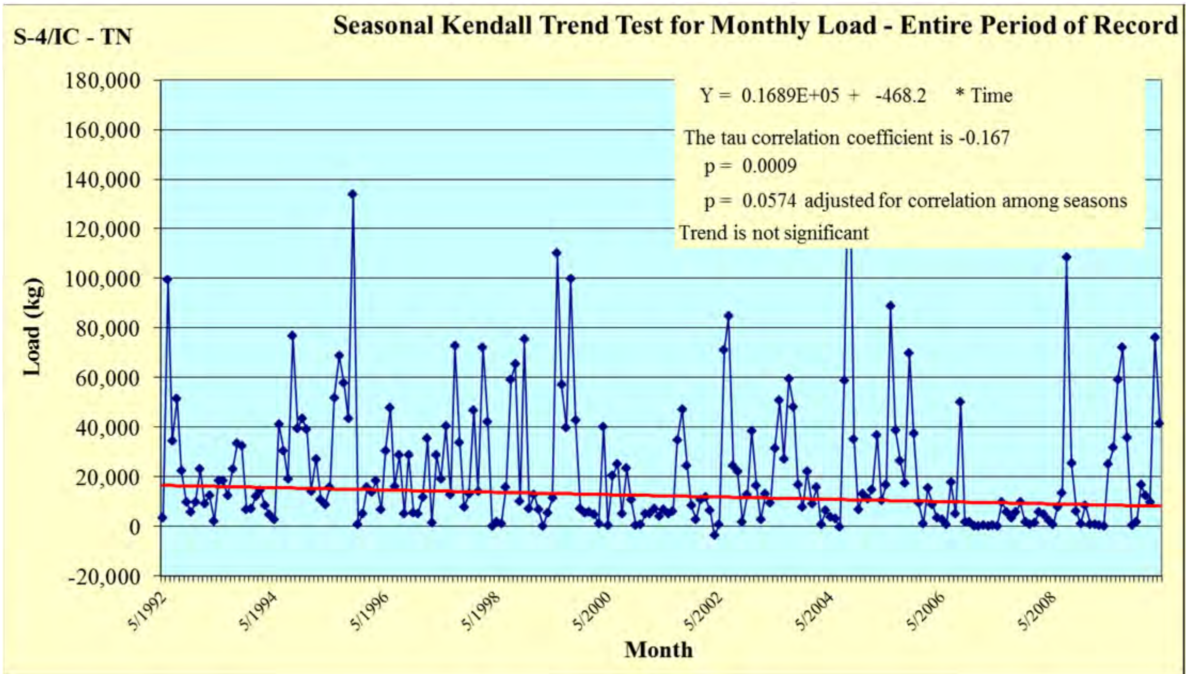

S-4/IC - TN
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in/ac)

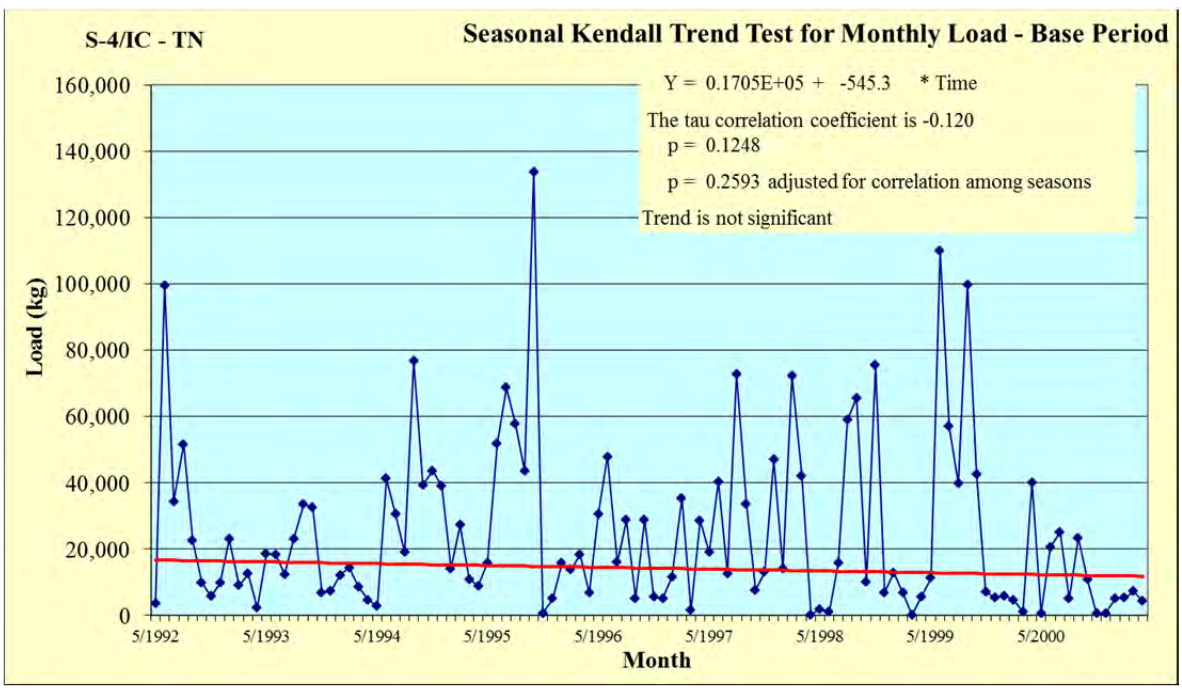

S-4/IC - TN
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)

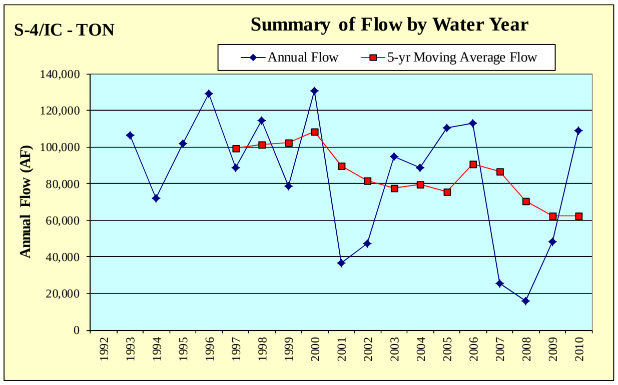

S-4/IC - TN
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)

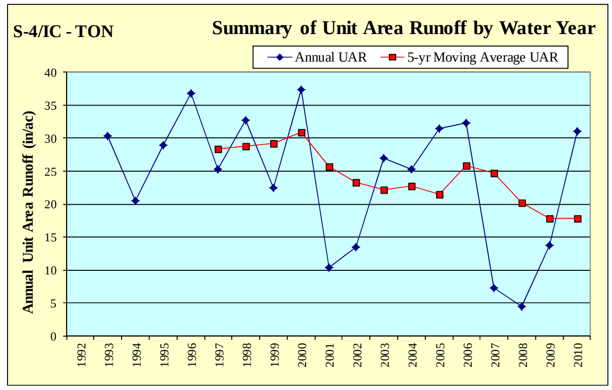

S-4/IC - TN
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)

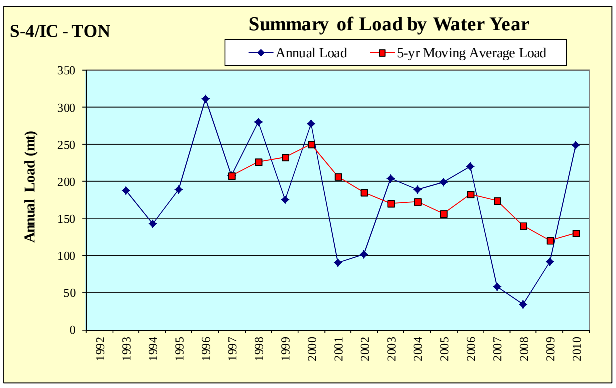

S-4/IC - TN
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

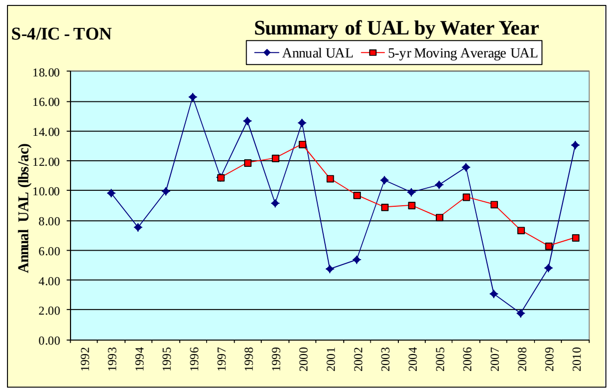

S-4/IC - TN
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 0.1689E+05 + -468.2 * Time
The tau correlation coefficient is -0.167
p = 0.0009
p = 0.0574 adjusted for correlation among seasons
Trend is not significant
Load (kg)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
-20,000
5/1992
5/1994
5/1996
5/1998
5/2000
5/2002
5/2004
5/2006
5/2008
Month

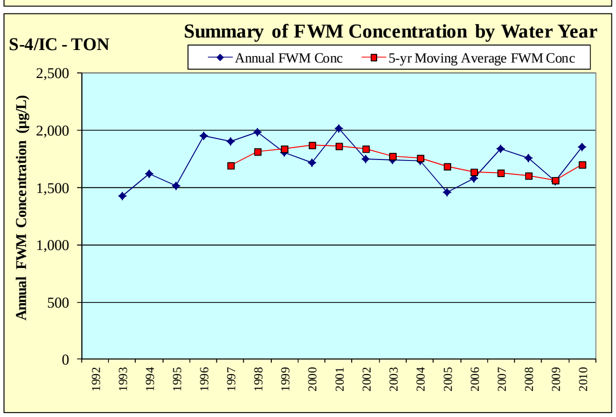

S-4/IC - TN
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 0.1705E+05 + -545.3 * Time
The tau correlation coefficient is -0.120
p = 0.1248
p = 0.2593 adjusted for correlation among seasons
Trend is not significant
Load (kg)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1992
5/1993
5/1994
5/1995
5/1996
5/1997
5/1998
5/1999
5/2000
Month

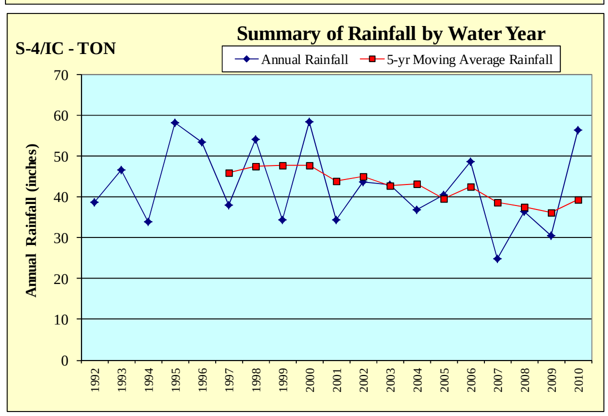

S-4/IC - TON
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)


S-4/IC - TON
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in/ac)


S-4/IC - TON
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)


S-4/IC - TON
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)


S-4/IC - TON
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)


S-4/IC - TON
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

Calculation of Net Basin Nutrient Loads for the S-4/Industrial Canal Sub-watershed

The S-4/Industrial Canal Sub-watershed receives inflows from Lake Okeechobee, the East Caloosahatchee Sub-watershed, and from Unit 5 of the South Florida Conservancy District (EPD-07 of the SFCD). The S-4/Industrial Canal Sub-watershed discharges to Lake Okeechobee and the East Caloosahatchee Sub-watershed. Some or all of the total inflows to the S-4/Industrial Canal Sub-watershed may be retained in the basin as a result of meeting agricultural and urban water supply demands, evapotranspiration, groundwater infiltration, or increasing internal storage. Pass-through flows and loads are the portion of the total inflows that are discharged from the Sub-watershed. Because S-169 controls flow between the S-4 Sub-basin and the Industrial Canal Sub-basin, flow through S-169 must be considered in the calculation of the Sub-watershed's pass-through flows and loads. Failure to do so will result in overestimates of pass through, e.g., on days when S-169 is closed, inflows to the Sub-watershed through S-310 cannot physically reach S-235 and therefore, cannot contribute to pass through at that structure. Basin flows and loads result from rainfall and runoff from the Sub-watershed and do not include pass-through flows and loads.

In order to properly account for the S-169 operations, it's necessary to make a minor modification to the standard algorithm for calculating pass-through flows and loads. Pass-through flows are calculated using applicable algorithms for four operational conditions:

1. On days when the total inflows or total outflows are zero;
2. On days when the total inflows and total outflows are nonzero and S-169 is closed;
3. On days when the total inflows and total outflows are nonzero and S-169 is discharging from the Industrial Canal Sub-basin to the S-4 Sub-basin (positive flow values in DBHYDRO);
4. On days when the total inflows and total outflows are nonzero and S-169 is discharging from the S-4 Sub-basin to the Industrial Canal Sub-basin (negative flow values in DBHYDRO);

The following equations describe how pass-through flows are calculated for each of these conditions.

1. If

$$\text{Total Inflow} = Q_{S310In} + Q_{EPD07} + Q_{S235In} = 0$$

or

$$\text{Total Outflow} = Q_{S310Out} + Q_{S4} + Q_{S235Out} = 0$$

then

$$PT_{S4IC} = \text{pass-through flow} = 0$$

where Q_{S310In} = Discharges at S-310 from Lake Okeechobee to the Industrial Canal

$Q_{S310Out}$ = Discharges at S-310 from the Industrial Canal to Lake Okeechobee

Q_{S235In} = Discharges at S-235 from the East Caloosahatchee Sub-watershed to the S-4 Sub-basin

$Q_{S235Out}$ = Discharges at S-235 from the S-4 Sub-basin to the East Caloosahatchee Sub-watershed
Q_{EPD07} = Discharges at pump station EPD-07 from SFCD to the Industrial Canal
Q_{S4} = Discharges at S-4 from the S-4 Sub-basin to Lake Okeechobee
PT_{S4IC} = Portion of the total inflow to the S-4/Industrial Canal Sub-watershed that is discharged from the Sub-watershed
Notes: $Q_{S4}$is unidirectional out of the Sub-watershed
Q_{EPD07} is unidirectional into the Sub-watershed

2. If

$$\text{Total Inflow} > 0$$

and

$$\text{Total Outflow} > 0$$

and

$$Q_{S169West} = 0$$

and

$$Q_{S169East} = 0$$

then

$$PT_{S4} = \text{minimum}\ (Q_{S235In}\ ,\ Q_{S4})$$
$$PT_{IC} = \text{minimum}\ (Q_{EPD07},\ Q_{S310Out})$$
$$PT_{S4IC} = PT_{S4} + PT_{IC}$$

where $Q_{S169West}$ = Discharges at S-169 from the Industrial Canal to the S-4 Sub-basin
$Q_{S169East}$ = Discharges at S-169 from the S-4 Sub-basin to the Industrial Canal Sub-basin
PT_{S4} = Portion of the total inflow to the S-4 Sub-basin that is discharged from the Sub-basin
PT_{IC} = Portion of the total inflow to the Industrial Canal Sub-basin that is discharged from the Sub-basin

3. If

$$\text{Total Inflow} > 0$$

and

$$\text{Total Outflow} > 0$$

and

$$Q_{S169West} > 0$$

then

$$PT_{IC} = \text{minimum}\ (Q_{S310In} + Q_{EPD07}\ ,\ Q_{S310Out})$$
$$PT_{S4} = \text{minimum}\ (Q_{S235In} + \text{minimum}\ (Q_{S169West}\ ,\ (Q_{S310In} + Q_{EPD07} - PT_{IC}))\ ,\ (Q_{S4} + Q_{S235Out}))$$
$$PT_{S4IC} = PT_{S4} + PT_{IC}$$

4. If

$$\text{Total Inflow} > 0$$

and

$$\text{Total Outflow} > 0$$

and

$$Q_{S169East} > 0$$

then

$$PT_{S4} = \text{minimum}\,(Q_{S235In}\,,\, Q_{S4} + Q_{S235Out}\,)$$
$$PT_{IC} = \text{minimum}\,(Q_{S310In} + Q_{EPD07} + \text{minimum}\,(Q_{S169East}\,,\,(Q_{S235In} - PT_{S4}),\, Q_{S310Out})$$
$$PT_{S4IC} = PT_{S4} + PT_{IC}$$

For all conditions,

B_{S4IC} = net basin flow produced by local rainfall and runoff
= $O_{S4IC} – PT_{S4IC}$

All calculations were performed on a daily time step and then summed to monthly and annual totals.

Pass through nutrient loads are calculated using the appropriate Sub-watershed flow weighted inflow concentrations, based on the applicable algorithms for the following three S-169 flow conditions:

1. On days when S-169 is closed;
2. On days when S-169 discharges to the west, from the Industrial Canal to the S-4 Sub-basin; and
3. On days when S-169 discharges to the east, from the S-4 Sub-basin to the Industrial Canal.

The following algorithms are used for the three conditions described above:

1. If

$$Q_{S169West} = Q_{S169East} = 0$$

Then

$$PTL_{IC} = PT_{IC} * C_{EPD07}$$
$$PTL_{S4} = PT_{S4} * C_{S235In}$$
$$PTL_{S4IC} = PTL_{IC} + PTL_{S4}$$

where PTL_{IC} = Portion of the total inflow load to the Industrial Canal Sub-basin that is discharged from the Sub-basin

C_{EPD07} = Concentration of discharges at pump station EPD-07[14]

PTL_{S4} = Portion of the total inflow load to the S-4 Sub-basin that is discharged from the Sub-basin

C_{S235In} = Concentration of S-235 discharges from the East Caloosahatchee Sub-watershed to the S-4 Sub-basin

[14] The TN concentration at nearby S-236 is currently used as a surrogate for the TN concentration at EPD-07.

PTL_{S4IC} = Portion of the total inflow load to the S-4/Industrial Canal Sub-watershed that is discharged from the Sub-watershed

2. If

$$Q_{S169West} > 0$$

Then

$$PTL_{IC} = PT_{IC} * C_{EPD07}$$

$$PTC_{S4} = (Q_{S235In} * C_{S235In} + Q_{EPD07} * C_{EPD07} + Q_{S310In} * C_{S310In}) / (Q_{S235In} + Q_{EPD07} + Q_{S310In})$$

$$PTL_{S4} = PT_{S4} * PTC_{S4}$$

$$PTL_{S4IC} = PTL_{IC} + PTL_{S4}$$

where PTC_{S4} = Flow weighted inflow concentration of S-4 Sub-basin

C_{S235In} = Concentration of flows at S-235 from East Caloosahatchee Sub-watershed to the S-4 Sub-basin

C_{EPDO7} = Concentration discharged at pump station EPD-07 into the Industrial Canal Sub-basin

C_{S310In} = Concentration discharged at S-310 from Lake Okeechobee into the Industrial Canal Sub-basin

3. If

$$Q_{S169East} > 0$$

Then

$$PTL_{IC}=PT_{IC} * (Q_{S235In} * C_{S235In} + Q_{EPD07} * C_{EPD07}) / (Q_{S235In} + Q_{EPD07})$$

$$PTL_{S4} = PT_{S4} * C_{S235In}$$

$$PTL_{S4IC} = PTL_{IC} + PTL_{S4}$$

Once the pass-through loads are calculated, the Sub-watershed's net basin loads are calculated by subtracting pass-through loads from the total outflow loads as follows:

BL_{S4IC} = net basin load produced by local rainfall and runoff
= $OL_{S4IC} – PTL_{S4IC}$

OL_{S4IC} = $OL_{S235} + OL_{S4} + OL_{S310Out}$

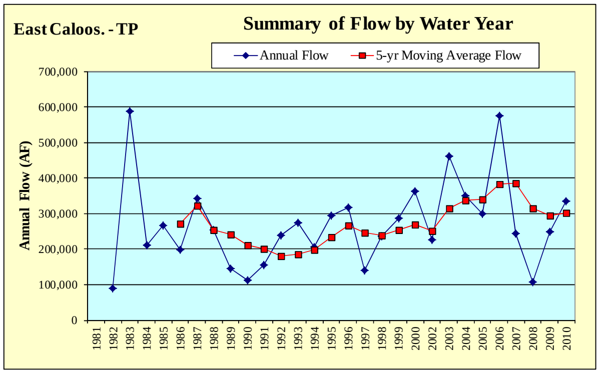
OL_{S235} = load discharged at S-235 to the East Caloosahatchee Hydrologic Unit

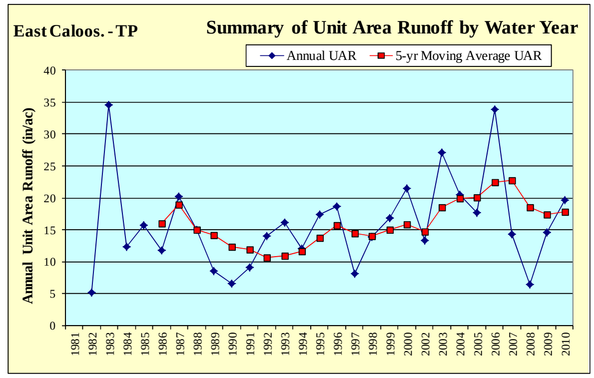
OL_{S4} = load discharged at S-4 to Lake Okeechobee

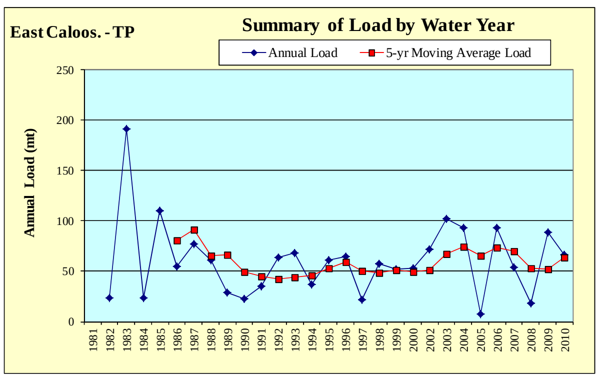
$OL_{S310Out}$ = load discharged at S-310 to Lake Okeechobee

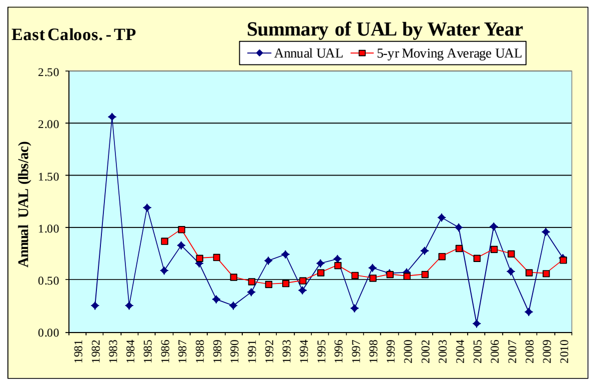
EAST CALOOSAHATCHEE SUB-WATERSHED

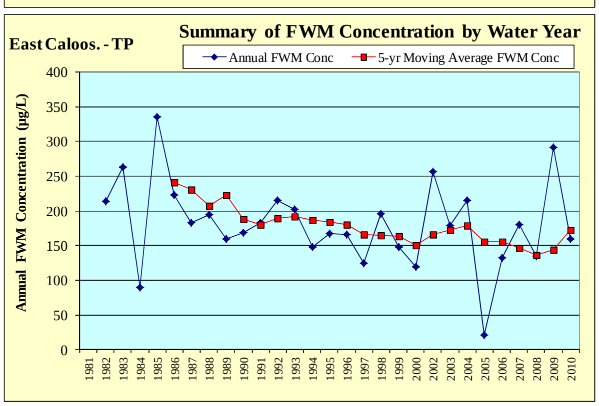
Annual Flow and Nutrient Levels

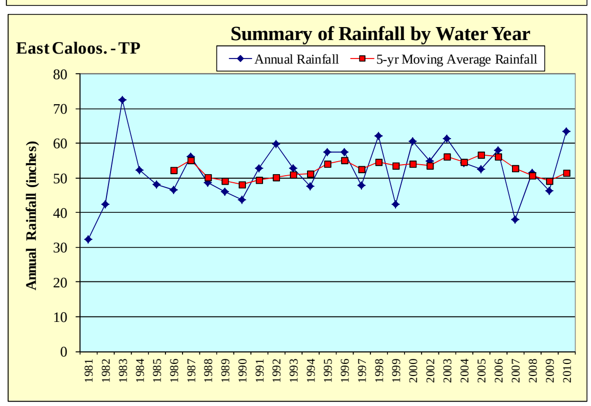


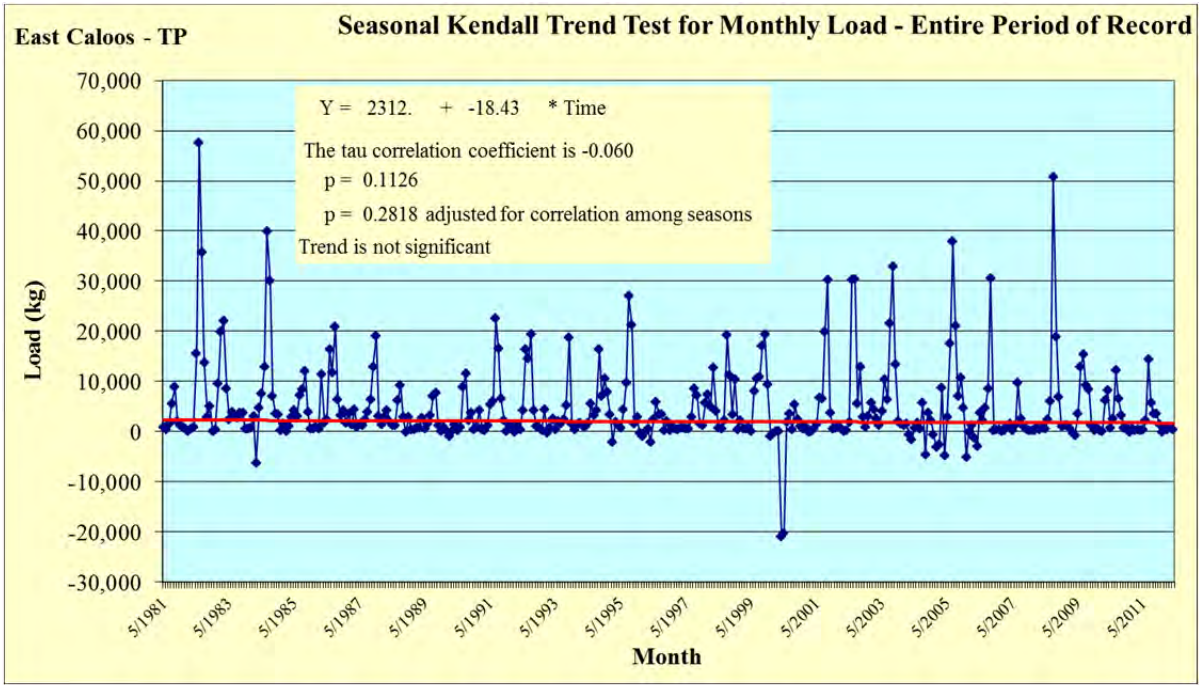


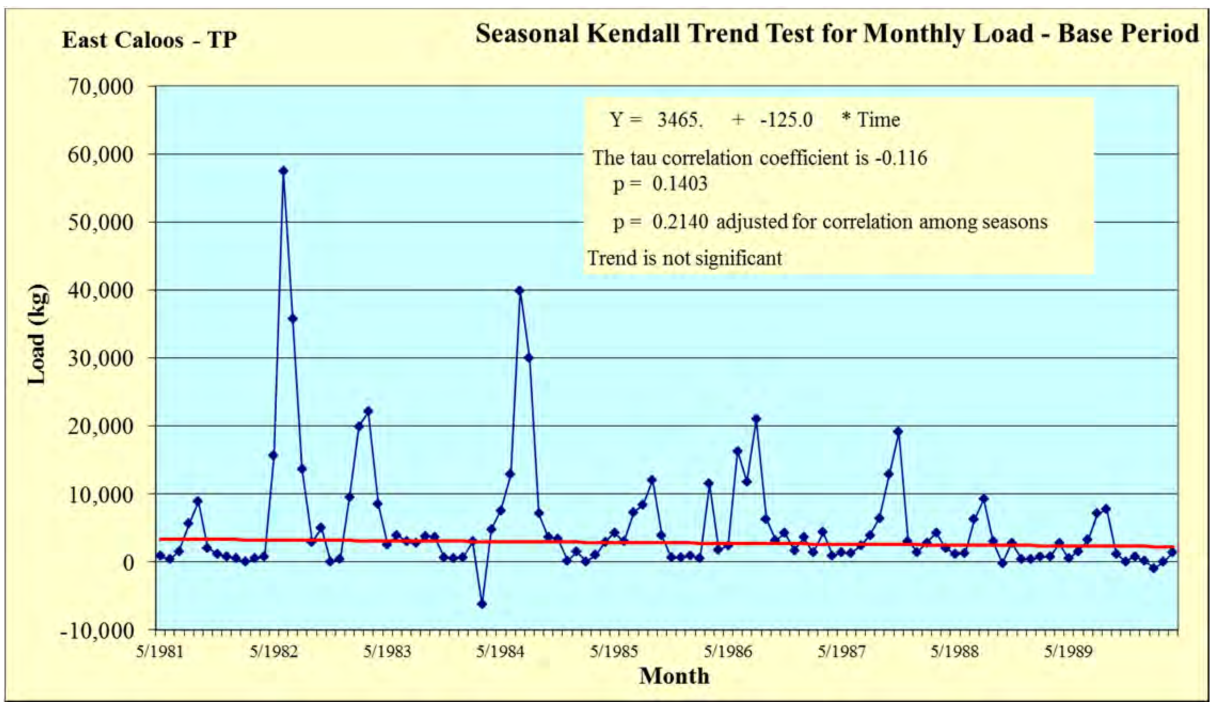


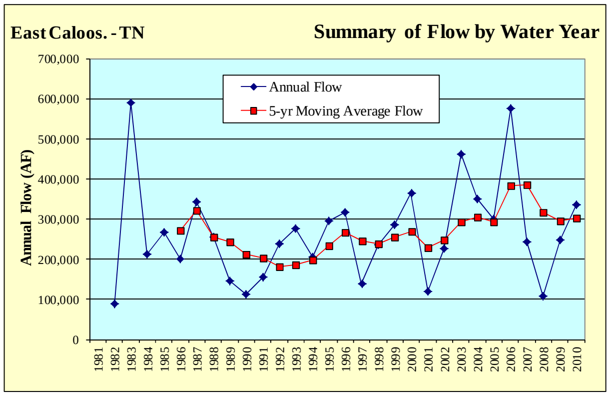


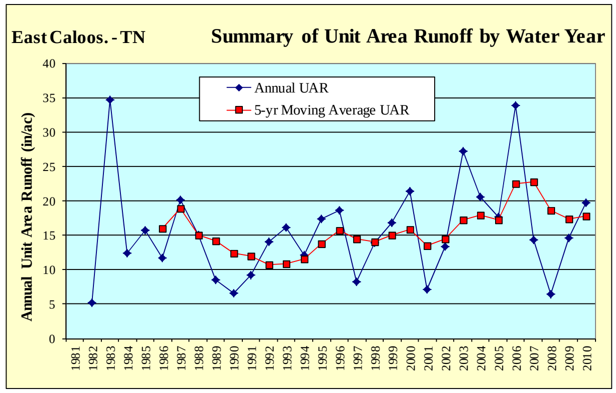


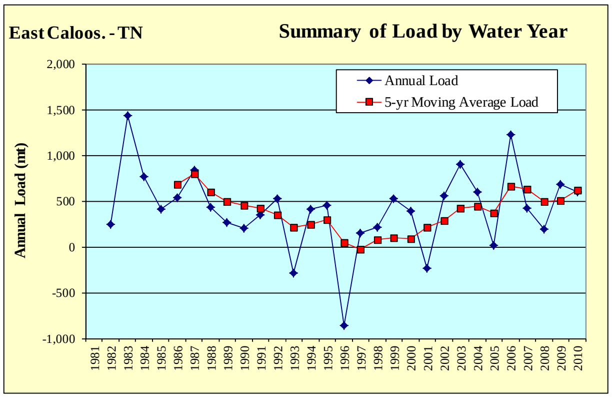


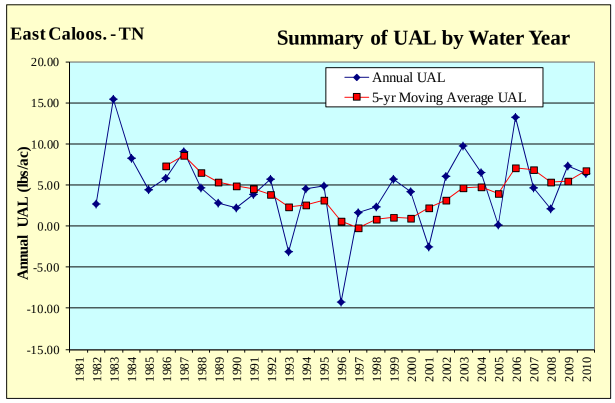

East Caloos - TP
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 2312. + -18.43 * Time
The tau correlation coefficient is -0.060
p = 0.1126
p = 0.2818 adjusted for correlation among seasons
Trend is not significant
Load (kg)
Month
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
5/1981
5/1983
5/1985
5/1987
5/1989
5/1991
5/1993
5/1995
5/1997
5/1999
5/2001
5/2003
5/2005
5/2007
5/2009
5/2011

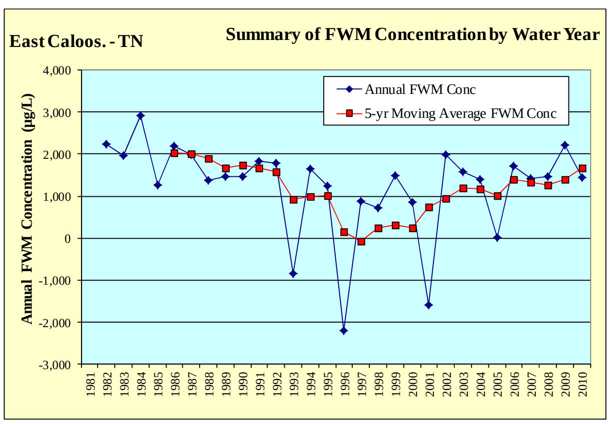

East Caloos - TP
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 3465. + -125.0 * Time
The tau correlation coefficient is -0.116
p = 0.1403
p = 0.2140 adjusted for correlation among seasons
Trend is not significant
Load (kg)
Month
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
5/1981
5/1982
5/1983
5/1984
5/1985
5/1986
5/1987
5/1988
5/1989

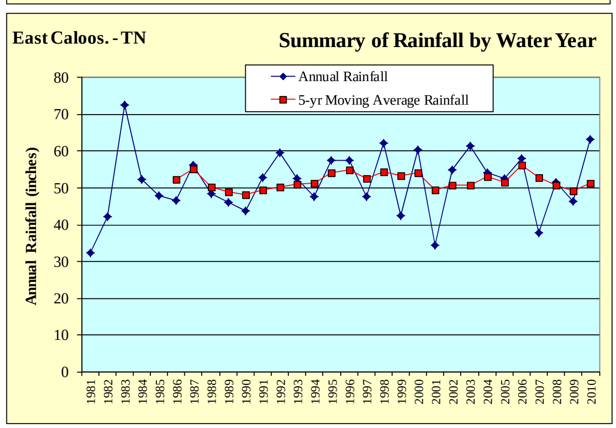

East Caloos. - TN
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

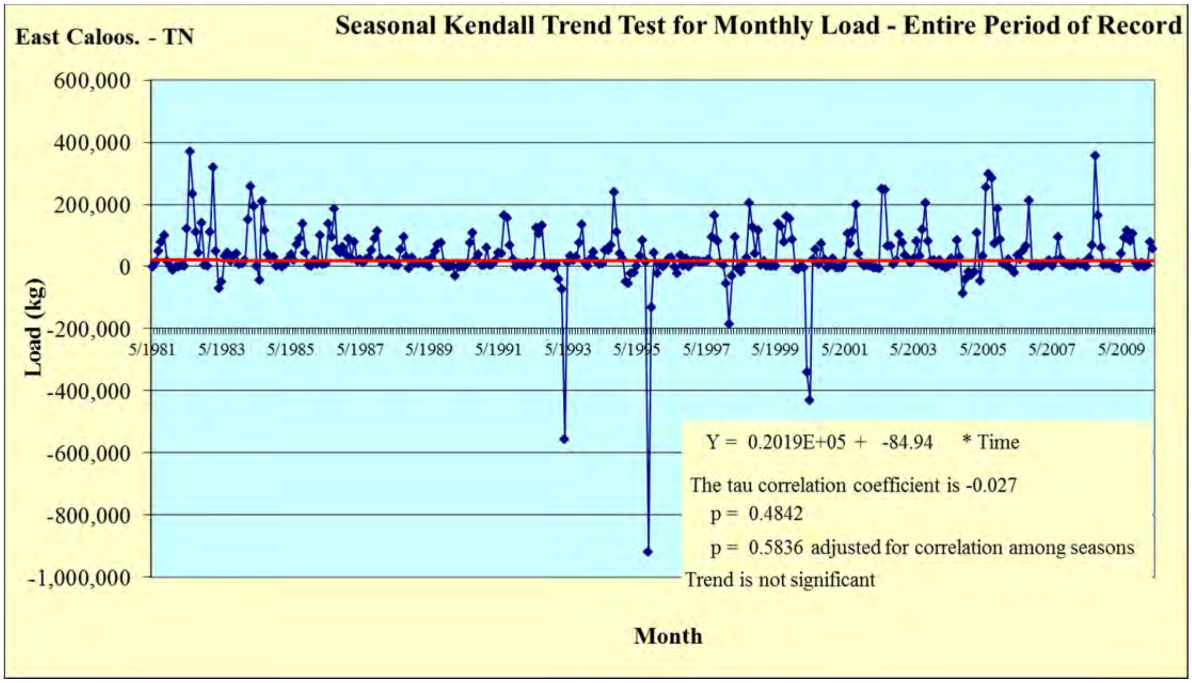

East Caloos. - TN
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in/ac)

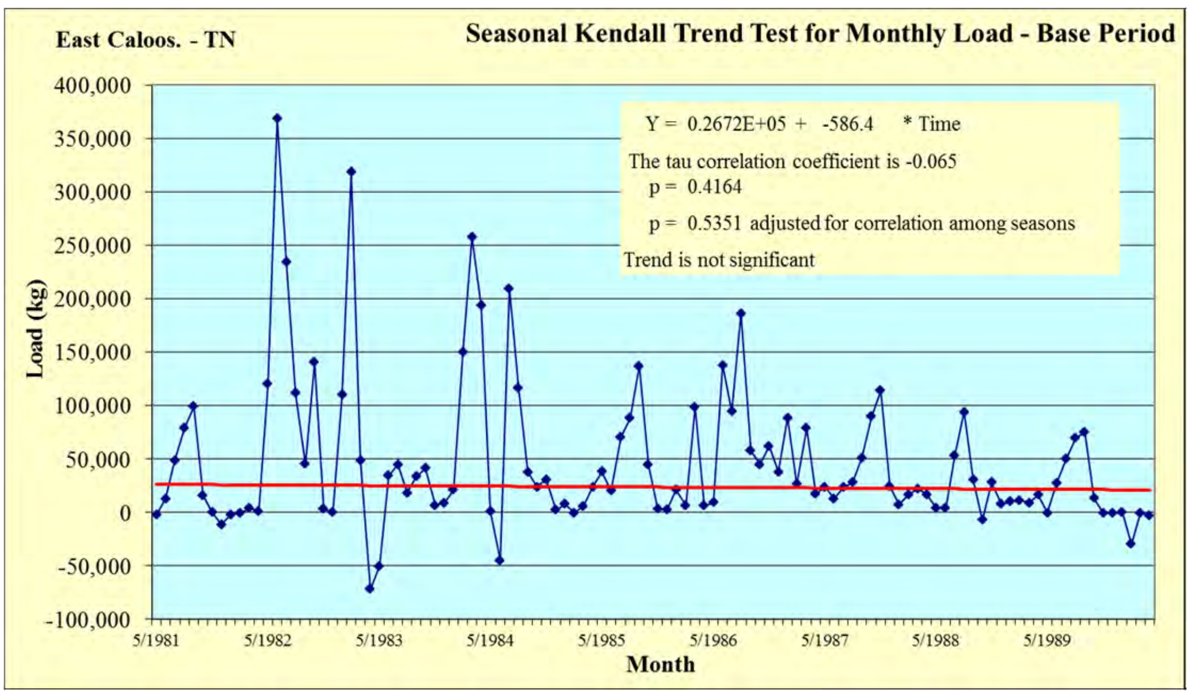

East Caloos. - TN
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)

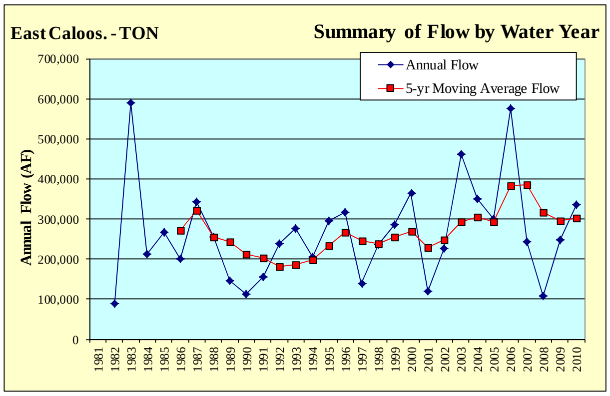

East Caloos. - TN
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)

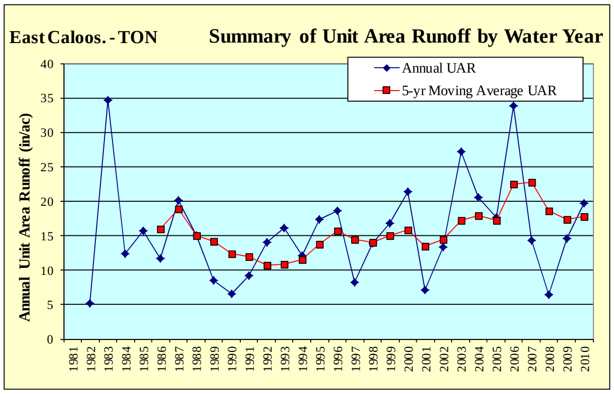

East Caloos. - TN
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)

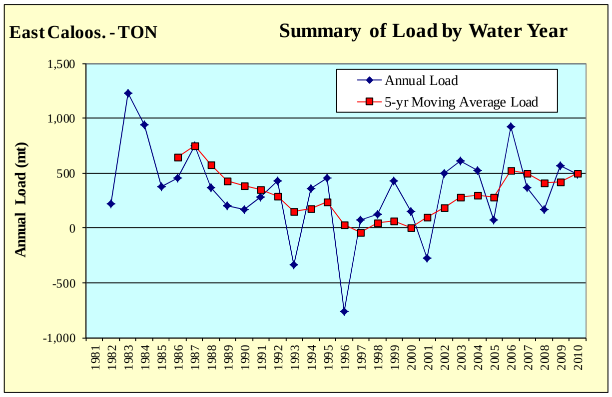

East Caloos. - TN
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

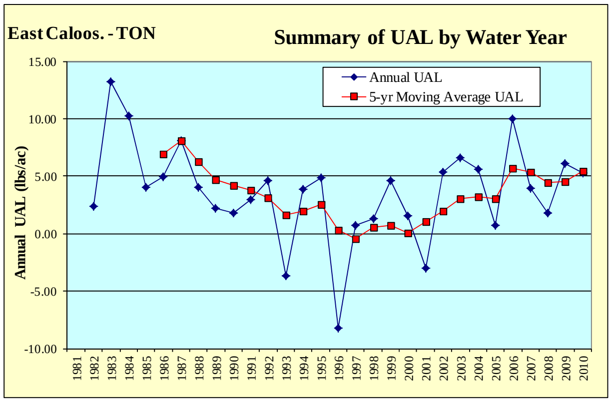

East Caloos. - TN
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Load (kg)
Month
600,000
400,000
200,000
0
-200,000
-400,000
-600,000
-800,000
-1,000,000
5/1981 5/1983 5/1985 5/1987 5/1989 5/1991 5/1993 5/1995 5/1997 5/1999 5/2001 5/2003 5/2005 5/2007 5/2009
Y = 0.2019E+05 + -84.94 * Time
The tau correlation coefficient is -0.027
p = 0.4842
p = 0.5836 adjusted for correlation among seasons
Trend is not significant

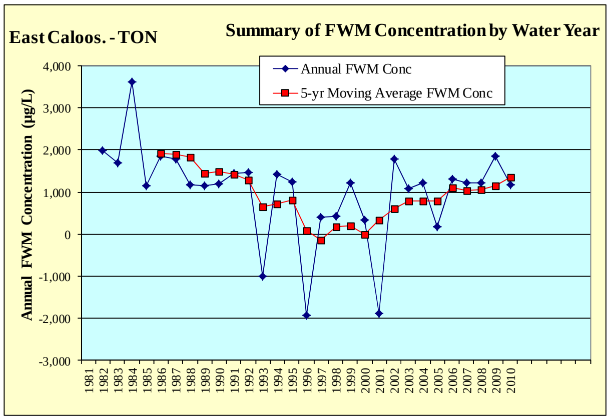

East Caloos. - TN
Seasonal Kendall Trend Test for Monthly Load - Base Period
Load (kg)
Month
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
5/1981 5/1982 5/1983 5/1984 5/1985 5/1986 5/1987 5/1988 5/1989
Y = 0.2672E+05 + -586.4 * Time
The tau correlation coefficient is -0.065
p = 0.4164
p = 0.5351 adjusted for correlation among seasons
Trend is not significant

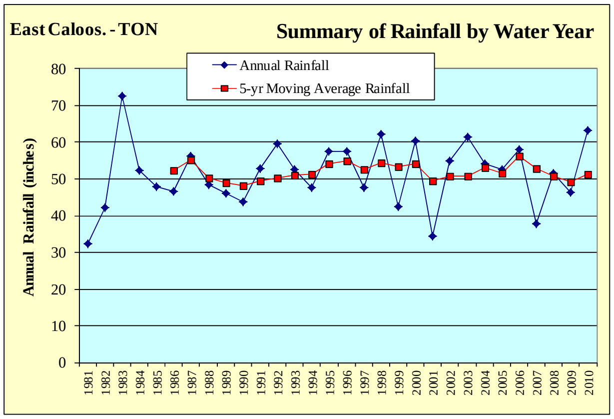

East Caloos. - TON
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)


East Caloos. - TON
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in/ac)


East Caloos. - TON
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)


East Caloos. - TON
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)


East Caloos. - TON
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)


East Caloos. - TON
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

Calculation of Net Basin Nutrient Loads for the East Caloosahatchee Sub-watershed

East Caloosahatchee Sub-watershed Flows

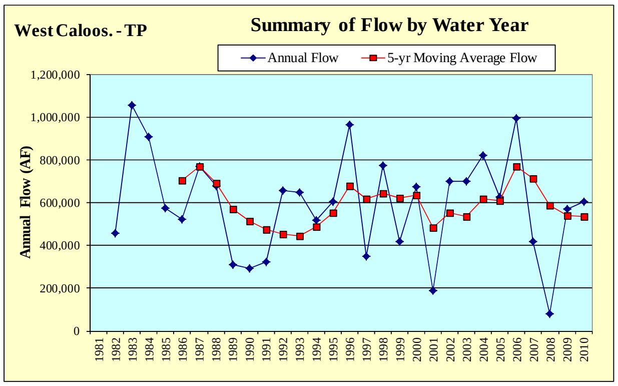
I_{EC}	= total inflow to the East Caloosahatchee Sub-watershed
	= $Q_{S77In} + Q_{S235In}$
$QS77_{In}$	= S-77 discharges from Lake Okeechobee into C-43
$QS235_{In}$	= S-235 discharges from the L-D3 Canal into C-43
O_{EC}	= total outflow from the East Caloosahatchee Sub-watershed
	= $Q_{S77Out} + Q_{S235Out} + Q_{S78}$
Q_{S77Out}	= S-77 discharges from C-43 into Lake Okeechobee
$Q_{S235Out}$	= S-235 discharges from C-43 into the L-D3 Canal
Q_{S78}	= S-78 discharges
PT_{EC}	= pass through flow
	= minimum (I_{EC} , O_{EC})
B_{EC}	= net basin flow produced by local rainfall and runoff
	= $O_{EC} - PT_{EC}$

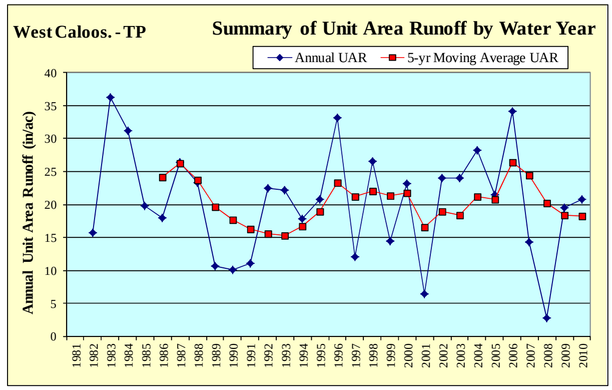
East Caloosahatchee Sub-watershed Loads

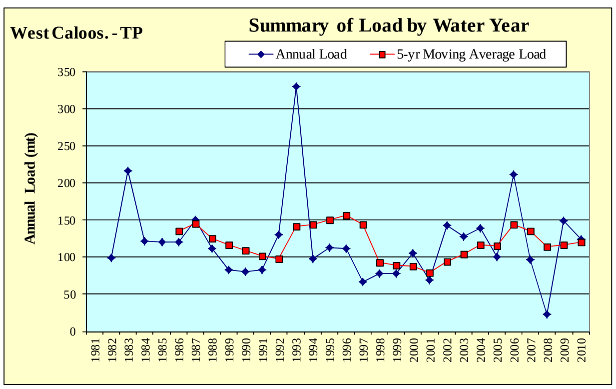
OL_{EC}	= total outflow nutrient load
	= $Q_{S77Out} * C_{S77Out} + Q_{S235Out} * C_{S235Out} + Q_{S78} * C_{S78}$
C_{S77Out}	= S-77 nutrient outflow concentration
$C_{S235Out}$	= S-235 nutrient outflow concentration
C_{S78}	= S-78 nutrient concentration
PTL_{EC}	= pass through nutrient load
	= $PT_{EC} * C_{In}$
C_{In}	= cumulative flow weighted mean inflow concentration
	= $(Q_{S77In} * C_{S77In} + Q_{S235In} * C_{S235In}) / I_{EC}$
BL_{EC}	= net basin load produced by local rainfall and runoff
	= $OL_{EC} - PTL_{EC}$
C_{S77In}	= S-77 nutrient inflow concentration
C_{S235In}	= S-235 nutrient inflow concentration

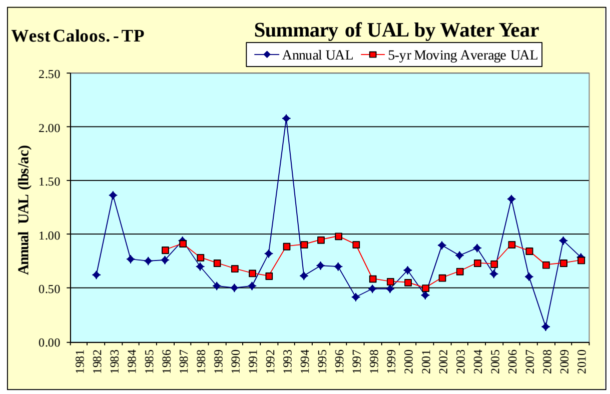
WEST CALOOSAHATCHEE SUB-WATERSHED

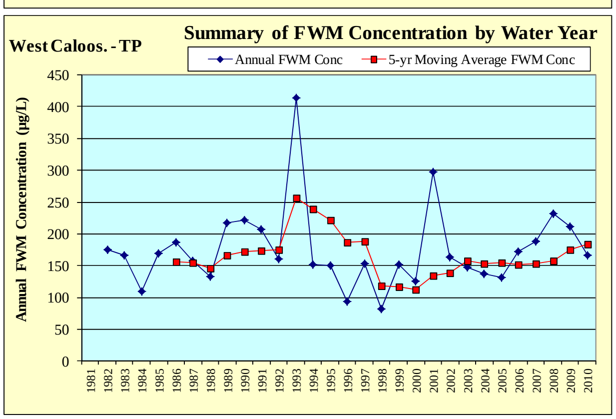
Annual Flow and Nutrient Levels

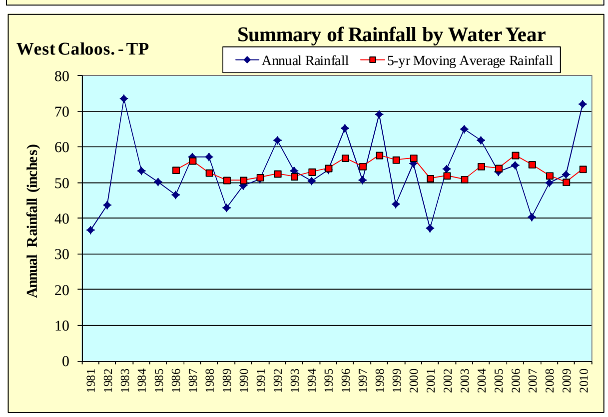


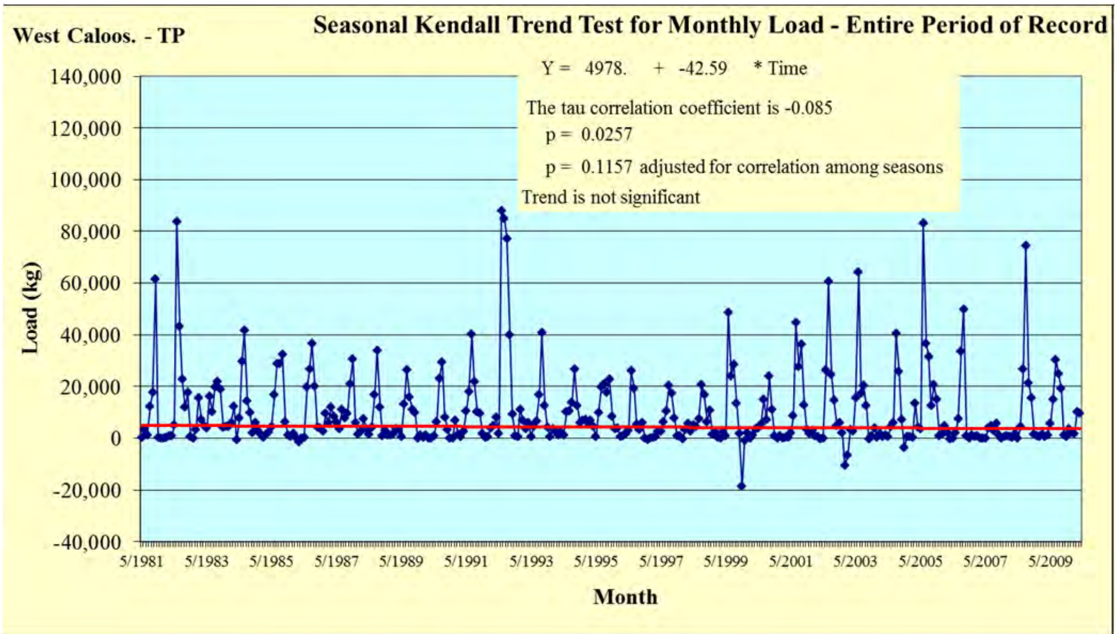


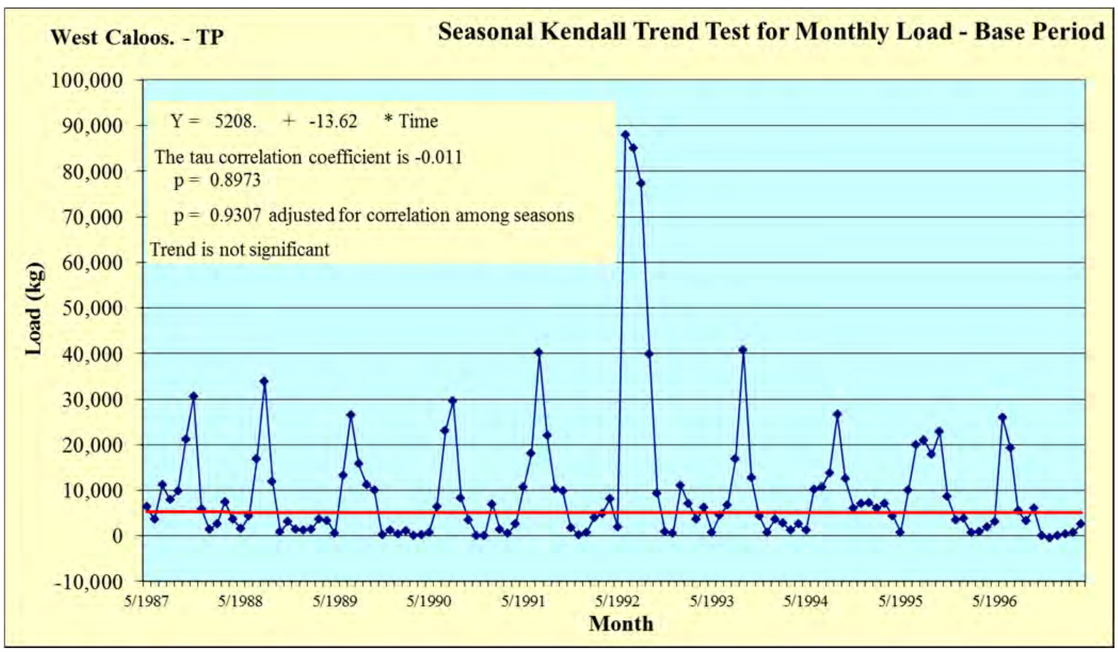


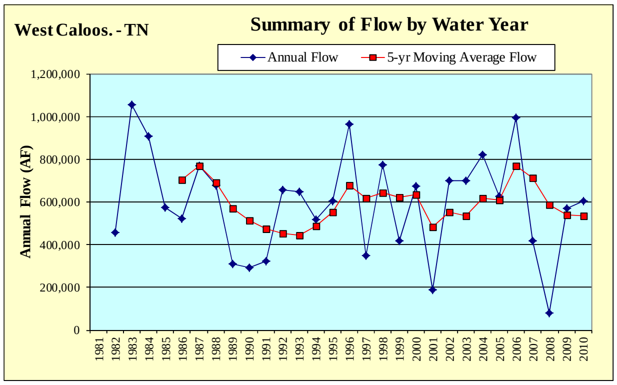


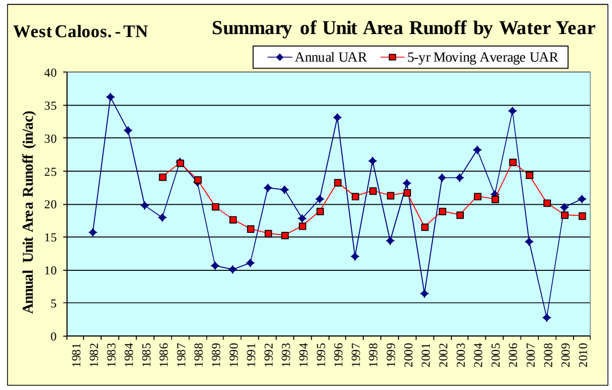


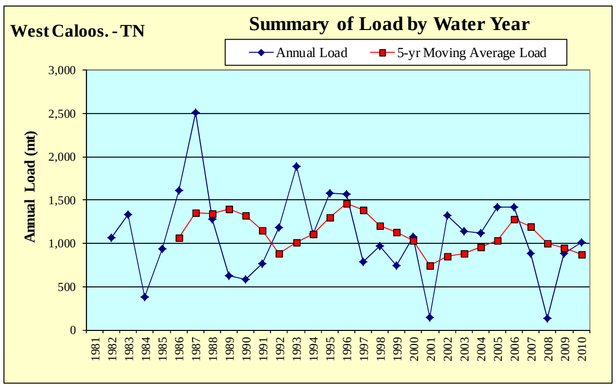


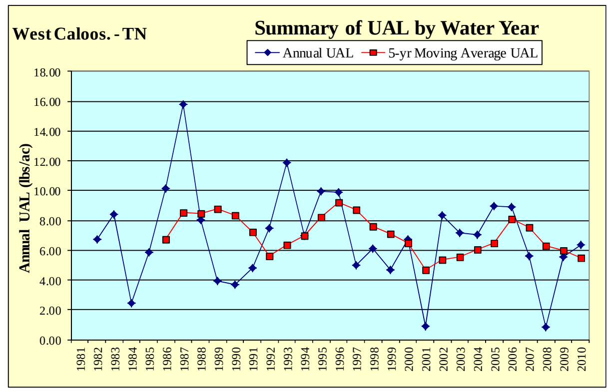

West Caloos. - TP
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 4978. + -42.59 * Time
The tau correlation coefficient is -0.085
p = 0.0257
p = 0.1157 adjusted for correlation among seasons
Trend is not significant
Load (kg)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
-20,000
-40,000
5/1981 5/1983 5/1985 5/1987 5/1989 5/1991 5/1993 5/1995 5/1997 5/1999 5/2001 5/2003 5/2005 5/2007 5/2009
Month

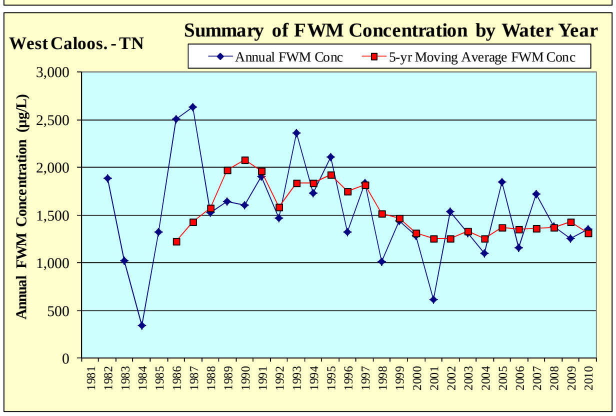

West Caloos. - TP
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 5208. + -13.62 * Time
The tau correlation coefficient is -0.011
p = 0.8973
p = 0.9307 adjusted for correlation among seasons
Trend is not significant
Load (kg)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
5/1987 5/1988 5/1989 5/1990 5/1991 5/1992 5/1993 5/1994 5/1995 5/1996
Month

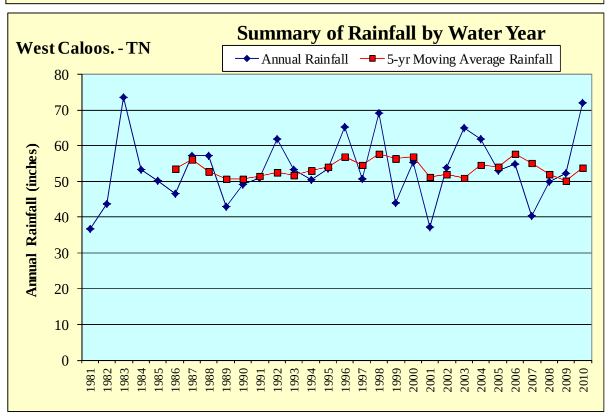

West Caloos. - TN
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

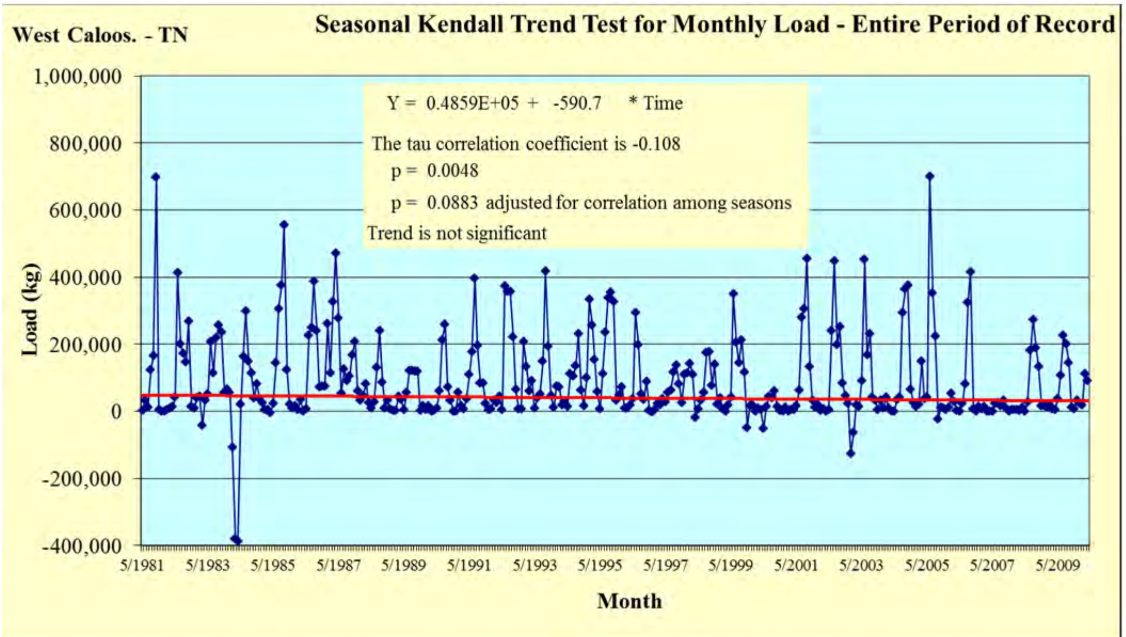

West Caloos. - TN
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in/ac)

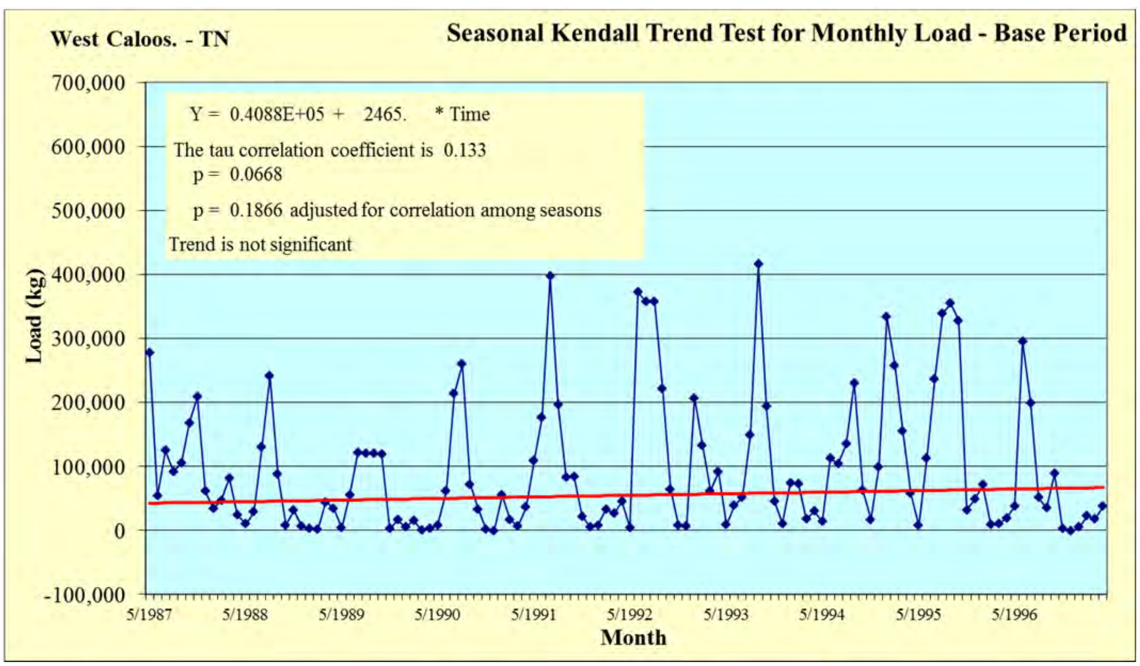

West Caloos. - TN
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)

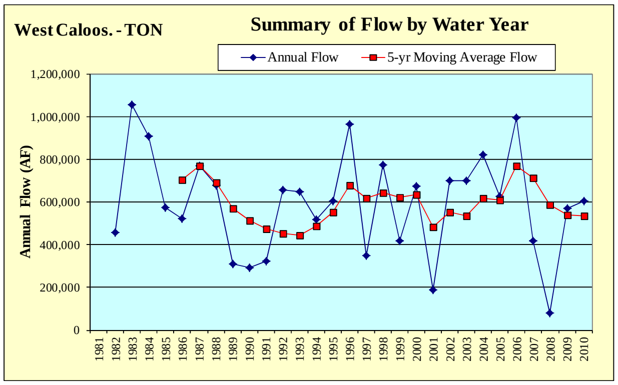

West Caloos. - TN
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)

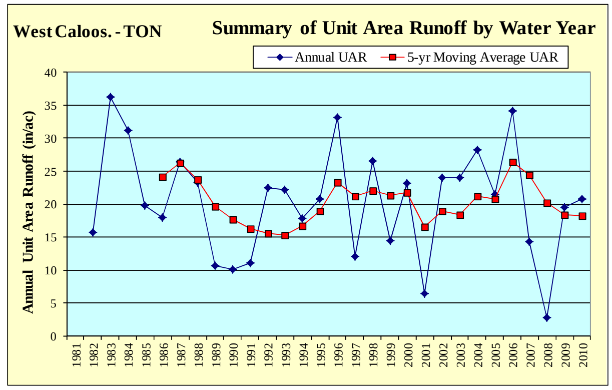

West Caloos. - TN
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)

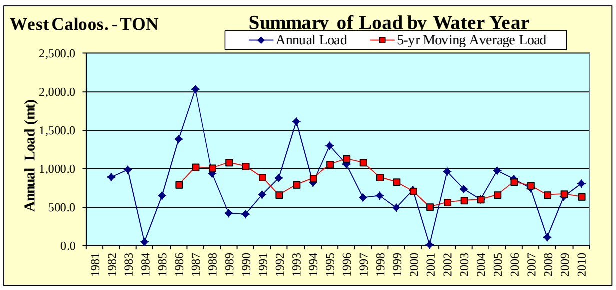

West Caloos. - TN
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

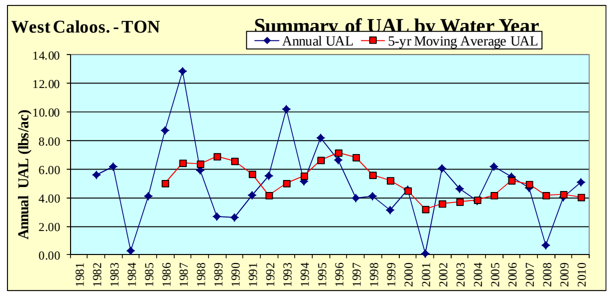

West Caloos. - TN
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 0.4859E+05 + -590.7 * Time
The tau correlation coefficient is -0.108
p = 0.0048
p = 0.0883 adjusted for correlation among seasons
Trend is not significant
Load (kg)
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
-400,000
5/1981
5/1983
5/1985
5/1987
5/1989
5/1991
5/1993
5/1995
5/1997
5/1999
5/2001
5/2003
5/2005
5/2007
5/2009
Month

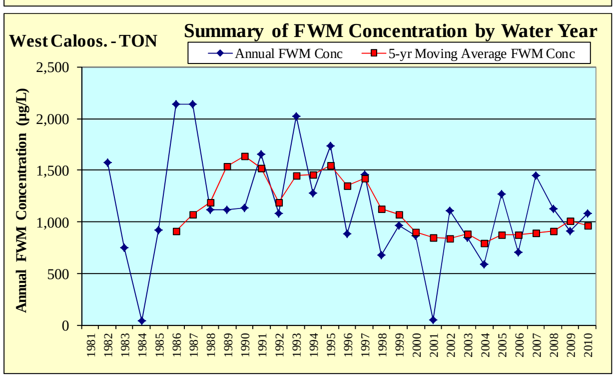

West Caloos. - TN
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 0.4088E+05 + 2465. * Time
The tau correlation coefficient is 0.133
p = 0.0668
p = 0.1866 adjusted for correlation among seasons
Trend is not significant
Load (kg)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
-100,000
5/1987
5/1988
5/1989
5/1990
5/1991
5/1992
5/1993
5/1994
5/1995
5/1996
Month

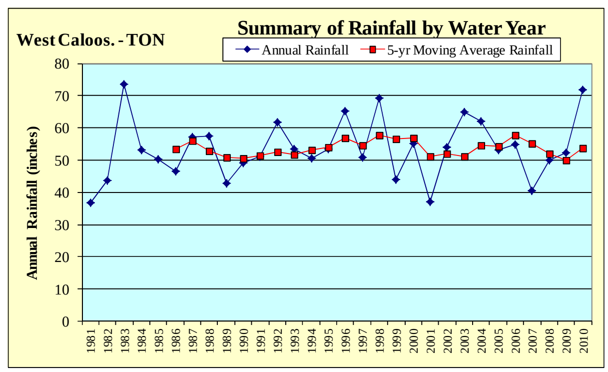

West Caloos. - TON
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)


West Caloos. - TON
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in/ac)


West Caloos. - TON
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)


West Caloos. - TON
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)


West Caloos. - TON
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)


West Caloos. - TON
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

Calculation of Net Basin Nutrient Loads for the West Caloosahatchee Sub-watershed

West Caloosahatchee Sub-watershed Flows

I_{WC}	= total inflow to the West Caloosahatchee Sub-watershed
	= Q_{S78In}
$QS78_{In}$	= S-78 discharges from THE C-43
O_{WC}	= total outflow from the West Caloosahatchee Sub-watershed
	= Q_{S79Out}
Q_{S79}	= S-79 discharges
PT_{WC}	= pass through flow
	= minimum (I_{WC} , O_{WC})
B_{WC}	= net basin flow produced by local rainfall and runoff
	= $O_{WC} – PT_{WC}$

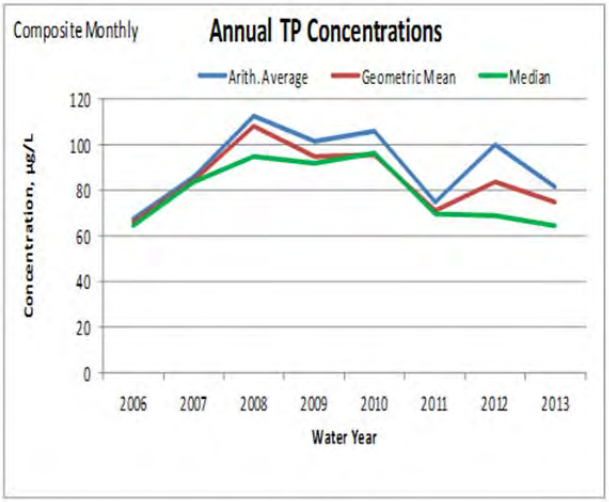
West Caloosahatchee Sub-watershed Loads

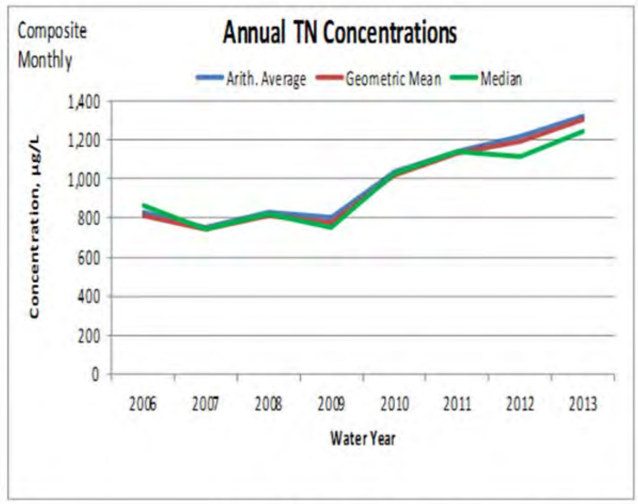
OL_{WC}	= total outflow nutrient load
	= $Q_{S79} * C_{S79}$
C_{S79}	= S-79 nutrient concentration
PTL_{WC}	= pass through nutrient load
	= $PT_{WC} * C_{In}$
C_{In}	= cumulative flow weighted mean inflow concentration
	= C_{S78}
C_{S78}	= S-78 nutrient concentration
BL_{WC}	= net basin load produced by local rainfall and runoff
	= $OL_{WC} – PTL_{WC}$

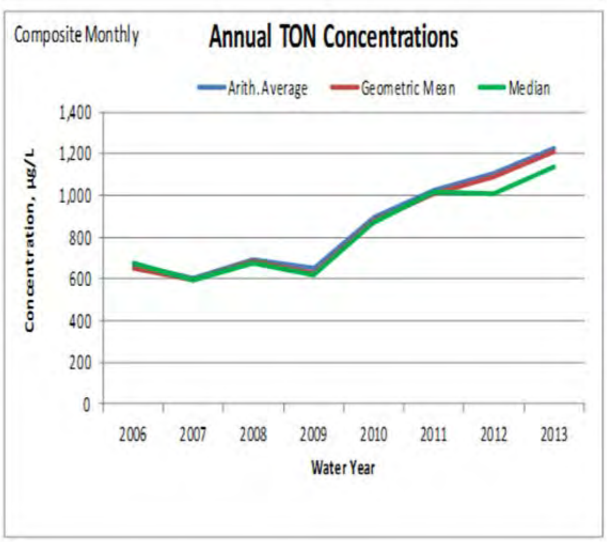
TIDAL CALOOSAHATCHEE SUB-WATERSHED

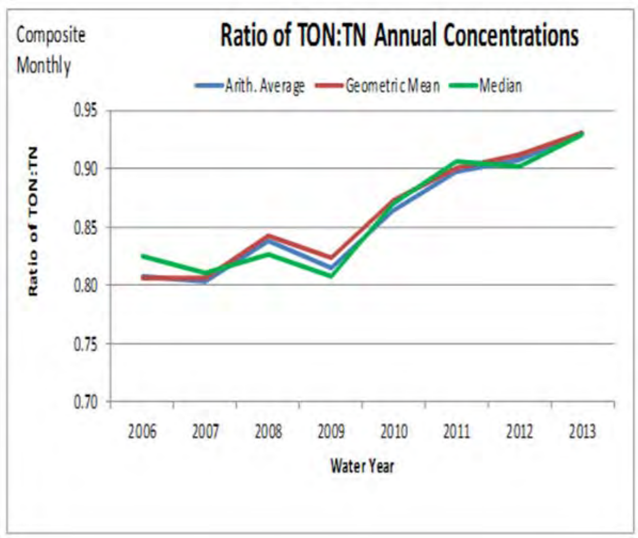
Annual Flow and Nutrient Levels

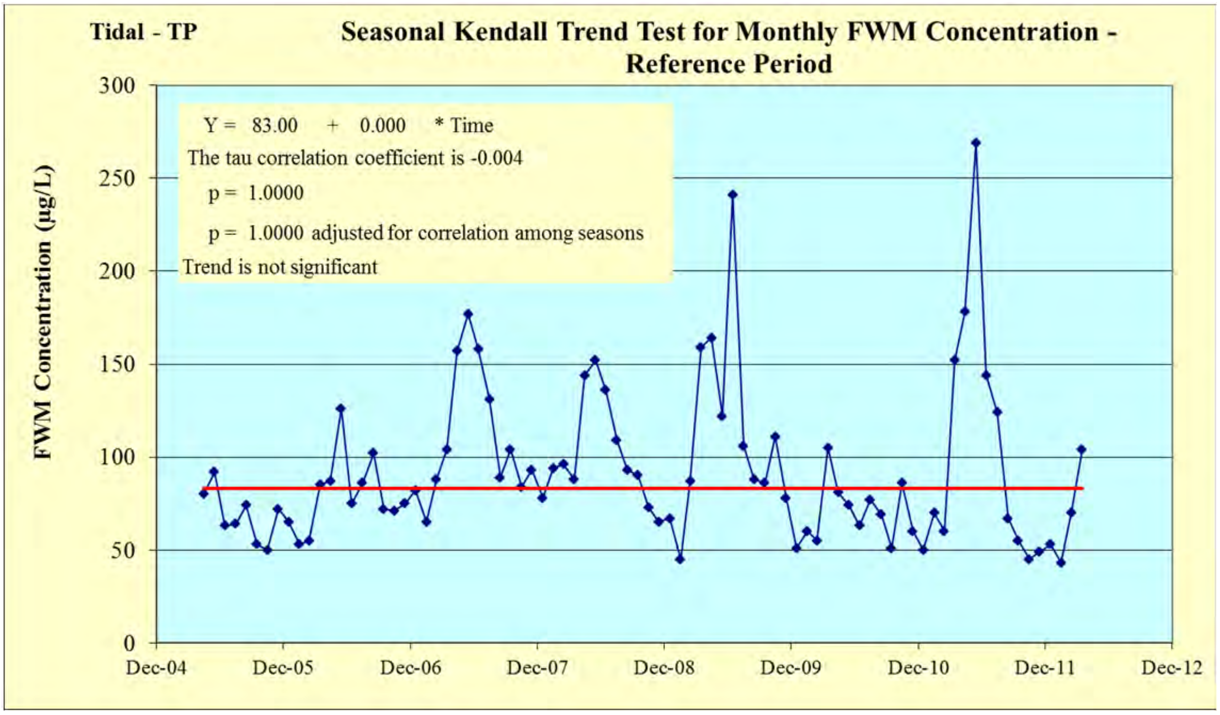
Annual summaries of Tidal Caloosahatchee Sub-watershed composite concentrations.

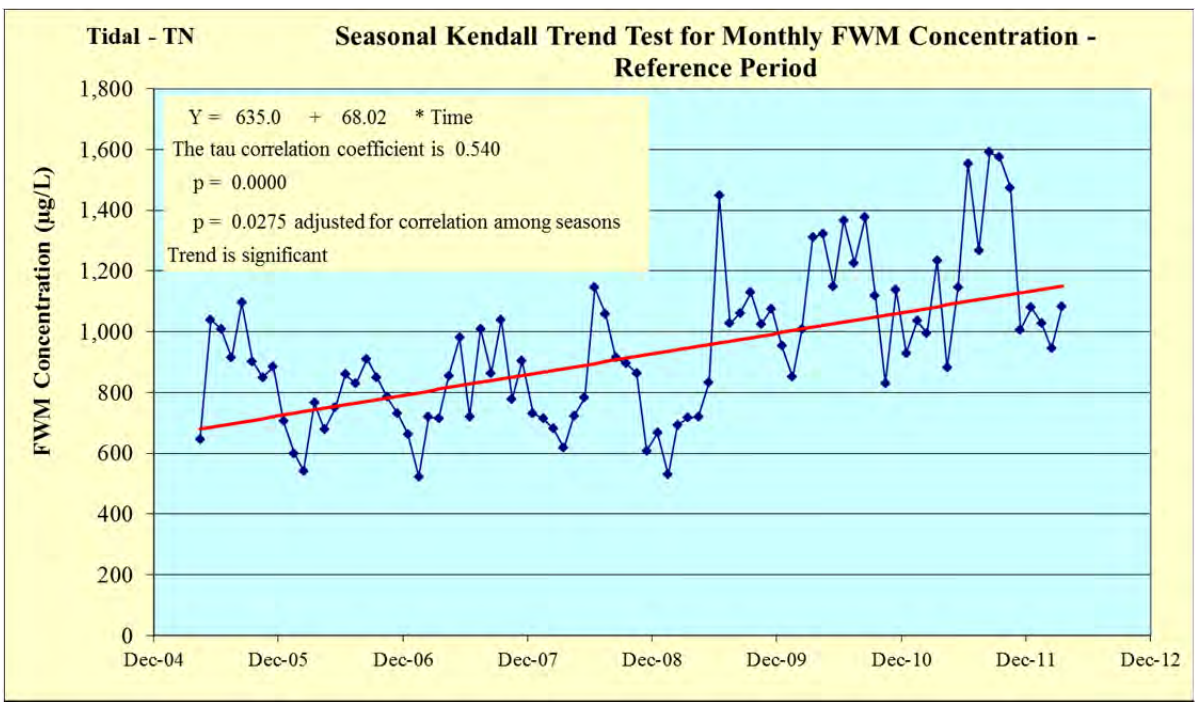


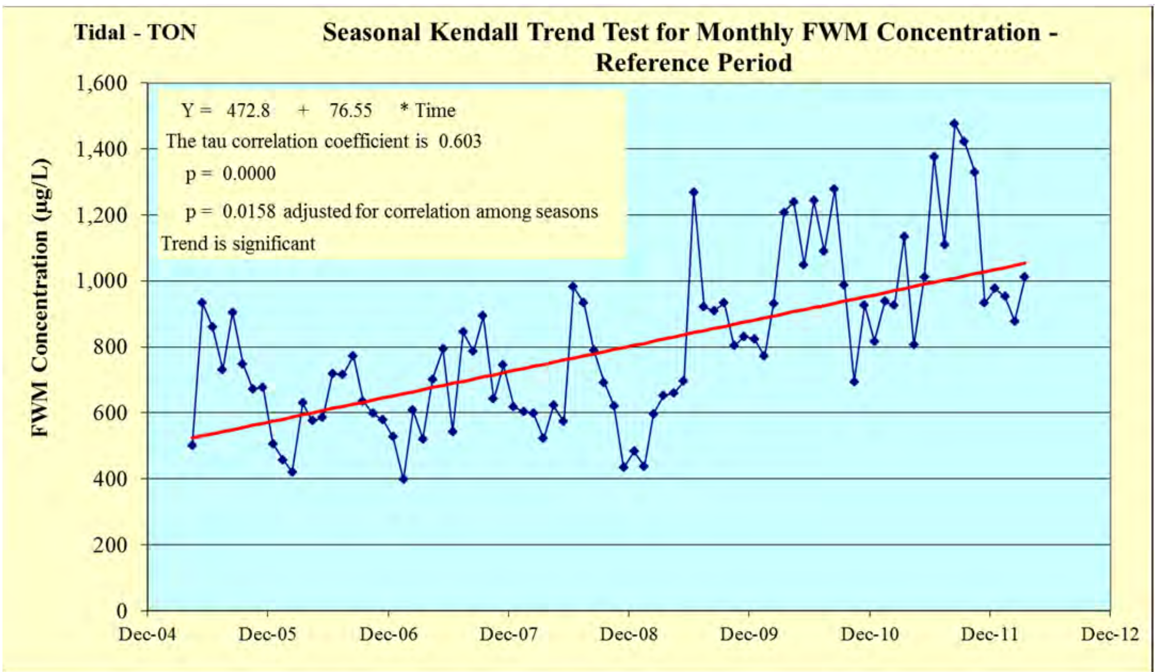







Tidal - TP
Seasonal Kendall Trend Test for Monthly FWM Concentration - Reference Period
Y = 83.00 + 0.000 * Time
The tau correlation coefficient is -0.004
p = 1.0000
p = 1.0000 adjusted for correlation among seasons
Trend is not significant
FWM Concentration (µg/L)
0
50
100
150
200
250
300
Dec-04
Dec-05
Dec-06
Dec-07
Dec-08
Dec-09
Dec-10
Dec-11
Dec-12


Tidal - TN
Seasonal Kendall Trend Test for Monthly FWM Concentration - Reference Period
Y = 635.0 + 68.02 * Time
The tau correlation coefficient is 0.540
p = 0.0000
p = 0.0275 adjusted for correlation among seasons
Trend is significant
FWM Concentration (µg/L)
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
Dec-04
Dec-05
Dec-06
Dec-07
Dec-08
Dec-09
Dec-10
Dec-11
Dec-12


Tidal - TON
Seasonal Kendall Trend Test for Monthly FWM Concentration - Reference Period
Y = 472.8 + 76.55 * Time
The tau correlation coefficient is 0.603
p = 0.0000
p = 0.0158 adjusted for correlation among seasons
Trend is significant
FWM Concentration (µg/L)
1,600
1,400
1,200
1,000
800
600
400
200
0
Dec-04
Dec-05
Dec-06
Dec-07
Dec-08
Dec-09
Dec-10
Dec-11
Dec-12

Composite Tidal Sub-watershed

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2006	12	67	65	66	12	830	867	811	12	670	675	648	0.81	0.83	0.81
2007	12	86	84	85	12	751	740	744	12	609	592	594	0.80	0.81	0.81
2008	12	112	95	108	12	825	818	814	12	691	672	681	0.84	0.83	0.84
2009	12	102	92	95	12	800	753	781	12	651	622	631	0.81	0.81	0.82
2010	12	106	97	96	12	1,037	1,026	1,020	12	896	871	880	0.86	0.87	0.87
2011	12	74	70	71	12	1,144	1,149	1,131	12	1,027	1,018	1,011	0.90	0.91	0.90
2012	12	100	69	84	12	1,219	1,114	1,194	12	1,106	1,012	1,085	0.91	0.90	0.91
2013	12	81	65	75	12	1,322	1,247	1,301	12	1,230	1,137	1,207	0.93	0.93	0.93
WY2006-2012 mean	12	92	81	86	12	944	923	928	12	806	780	790	0.85	0.85	0.85
WY2006-2012 monthly value	12	91	83	85	12	944	907	913	12	806	779	770	0.85	0.86	0.84

Bayshore Creek

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average Average	Median Geomean	Geometric µg/L	Using Average	Using Median	Using Geomean
2005	5	93	87	88	5	761	609	707	5	674	534	604	0.89	0.88	0.85
2006	10	169	115	144	10	1,105	1,115	1,059	10	1,001	964	956	0.91	0.86	0.90
2007	9	124	120	118	9	902	930	854	9	753	783	704	0.83	0.84	0.82
2008	10	144	110	130	10	959	930	932	10	861	850	831	0.90	0.91	0.89
2009	10	124	110	117	10	982	945	922	10	780	802	708	0.79	0.85	0.77
2010	11	119	110	109	11	1,300	1,440	1,260	11	1,184	1,266	1,149	0.91	0.88	0.91
2011	11	85	82	81	11	1,295	1,200	1,274	11	1,177	1,077	1,148	0.91	0.90	0.90
2012	11	113	96	101	11	1,448	1,426	1,427	11	1,323	1,286	1,300	0.91	0.90	0.91
2013	12	109	91	98	12	1,570	1,560	1,536	12	1,483	1,522	1,439	0.94	0.98	0.94
WY2006-2012 mean	10.3	125	106	114	10.3	1,142	1,141	1,104	10.3	1,011	1,004	971.0	0.89	0.88	0.88
WY2006-2012 monthly value	10.3	125	110	112	10.3	1,154	1,138	1,098	10.3	1,024	961	960	0.89	0.84	0.87

Billy Creek

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric µg/L	Using Average	Using Median	Using Geomean
2005	3	173	180	173	3	782	770	777	3	629	600	624	0.80	0.78	0.80
2006	12	230	185	214	12	1169	1120	1108	12	941	790	856	0.80	0.71	0.77
2007	9	242	250	238	9	910	900	897	9	682	651	665	0.75	0.72	0.74
2008	9	282	250	273	9	908	940	883	9	778	712	743	0.86	0.76	0.84
2009	9	243	250	240	9	811	800	803	9	603	547	591	0.74	0.68	0.74
2010	11	248	240	241	11	975	960	959	11	762	734	734	0.78	0.76	0.77
2011	2	275	275	271	2	1054	1054	1053	2	871	871	870	0.83	0.83	0.83
WY2006-2012 mean	8.7	253	242	246	8.7	971	962	951	8.7	773	718	743	0.80	0.80	0.75
WY2006-2012 monthly value	8.7	249	245	240	8.7	972	935	940	8.7	769	708	726	0.79	0.82	0.75

Chapel Branch

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average Average	Median Geomean	Geometric µg/L	Using Average	Using Median	Using Geomean
2005	2	105	105	102	2	769	769	742	2	672	672	652	0.87	0.87	0.88
2006	10	90	65	72	11	1255	1230	1208	11	936	900	888	0.75	0.73	0.74
2007	12	147	103	127	12	1213	1150	1151	12	1006	803	930	0.83	0.70	0.81
2008	12	112	93	98	12	998	1010	974	12	761	749	743	0.76	0.74	0.76
2009	12	145	125	127	12	983	935	952	12	685	672	639	0.70	0.72	0.67
2010	12	202	140	135	12	1502	1330	1321	12	1336	1126	1176	0.89	0.85	0.89
2011	12	84	70	73	12	1356	1475	1321	12	1127	1243	1098	0.83	0.84	0.83
2012	12	140	66	92	12	1357	1414	1322	12	1189	1227	1160	0.88	0.87	0.88
2013	11	78	63	74	11	1654	1704	1607	11	1440	1412	1382	0.87	0.83	0.86
WY2006-2012 mean	11.7	131.5	94.4	103.5	11.9	1237.8	1220.5	1178.4	11.9	1005.6	959.7	947.7	0.81	0.82	0.81
WY2006-2012 monthly value	11.7	132	90	101	11.9	1238	1220	1168	11.9	1006	900	927	0.81	0.82	0.77

Daughtrey Creek - Combined

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2005	4	117	89	89	4	679	613	528	4	606	504	454	0.89	0.82	0.86
2006	11	80	73	75	11	840	804	773	11	733	711	662	0.87	0.88	0.86
2007	12	132	118	123	12	772	867	695	12	668	761	595	0.87	0.88	0.86
2008	12	179	122	144	12	932	872	821	12	849	724	738	0.91	0.83	0.90
2009	12	155	92	126	12	791	824	690	12	641	685	513	0.81	0.83	0.74
2010	12	135	94	114	12	1040	984	945	12	892	792	790	0.86	0.81	0.84
2011	12	104	78	87	12	1197	1222	1137	12	1093	1074	1037	0.91	0.88	0.91
2012	12	198	106	124	12	1194	1210	1145	12	1116	1133	1061	0.93	0.94	0.93
2013	12	110	74	88	12	1357	1208	1256	12	1293	1125	1186	0.95	0.93	0.94
WY2006-2012 mean	11.9	140	98	113	11.9	966	989	886	11.9	856	840	771	0.89	0.88	0.95
WY2006-2012 monthly value	11.9	141	92	111	11.9	968	950	870	11.9	857	827	748	0.89	0.90	0.95

Deep Lagoon

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2005	6	71	69	65	6	951	944	930	6	814	826	792	0.86	0.88	0.85
2006	12	123	115	112	12	1105	1145	1079	12	940	916	911	0.85	0.80	0.84
2007	11	110	100	106	11	984	970	973	11	777	837	759	0.79	0.86	0.78
2008	12	116	115	112	12	1005	960	963	12	775	728	740	0.77	0.76	0.77
2009	12	98	110	90	12	858	870	823	12	653	692	605	0.76	0.79	0.74
2010	12	102	94	97	12	1014	1006	964	12	855	791	805	0.84	0.79	0.84
2011	12	102	99	90	12	1285	1480	1230	12	1094	1158	1046	0.85	0.78	0.85
2012	11	104	100	97	11	1147	1210	1105	11	1030	1028	989	0.90	0.85	0.90
2013	11	102	100	98	11	1401	1410	1359	11	1275	1327	1239	0.91	0.94	0.91
WY2006-2012 mean	11.7	108	105	100	11.7	1057	1092	1019	11.7	875	878	837	0.83	0.80	0.86
WY2006-2012 monthly value	11.7	108	110	100	11.7	1057	1005	1012	11.7	874	853	823	0.83	0.87	0.84

Hancock Creek

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2005	4	108	87	99	4	984	968	974	4	823	811	812	0.84	0.84	0.83
2006	12	165	170	161	12	1001	985	988	12	871	834	864	0.87	0.85	0.87
2007	12	166	150	158	12	833	810	810	12	747	768	721	0.90	0.95	0.89
2008	12	168	140	159	12	745	785	698	12	667	676	593	0.89	0.86	0.85
2009	12	173	145	160	12	834	820	809	12	742	701	719	0.89	0.85	0.89
2010	12	165	160	157	12	1012	1005	986	12	929	901	911	0.92	0.90	0.92
2011	12	121	110	114	12	1185	1111	1134	12	1141	1058	1085	0.96	0.95	0.96
2012	11	140	140	124	11	1247	1210	1210	11	1164	1184	1137	0.93	0.98	0.94
2013	11	125	130	123	11	1447	1410	1438	11	1370	1321	1361	0.95	0.94	0.95
WY2006-2012 mean	11.9	157	145	148	11.9	979	961	948	11.9	894	874	862	0.91	0.93	0.92
WY2006-2012 monthly value	11.9	157	150	147	11.9	976	920	929	11.9	891	835	838	0.91	0.97	0.90

Lower Orange River

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2004	10	50	39	38	10	621	573	569	10	499	460	442	0.80	0.80	0.78
2005	8	29	25	27	8	623	635	604	8	533	521	517	0.86	0.82	0.86
2006	11	35	30	33	11	759	826	721	11	576	639	526	0.76	0.77	0.73
2007	12	42	37	38	12	623	575	607	12	506	519	491	0.81	0.90	0.81
2008	12	28	27	26	12	600	590	595	12	542	536	536	0.90	0.91	0.90
2009	12	44	36	39	12	652	595	615	12	533	505	483	0.82	0.85	0.79
2010	12	37	31	32	12	928	915	905	12	792	811	777	0.85	0.89	0.86
2011	12	42	27	30	12	934	934	901	12	817	829	773	0.87	0.89	0.86
2012	12	30	18	22	12	927	871	902	12	800	825	780	0.86	0.95	0.86
2013	12	37	26	25	12	991	1025	938	12	912	955	851	0.92	0.93	0.91
WY2006-2012 mean	11.8	38	31	33	11.8	749	739	724	11.8	627	640	598	0.84	0.85	0.88
WY2006-2012 monthly value	11.8	37	32	31	11.8	775	780	737	11.8	653	636	611	0.84	0.84	0.86

Marsh Point

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2005	6	125	131	109	6	999	1022	801	6	754	760	604	0.79	0.74	0.75
2006	11	169	140	157	10	813	825	751	10	633	581	563	0.78	0.70	0.75
2007	9	203	160	186	9	861	830	840	9	683	606	651	0.79	0.73	0.77
2008	11	268	190	239	11	735	710	714	10	514	559	493	0.70	0.79	0.69
2009	12	290	185	249	12	721	700	664	12	536	443	475	0.74	0.63	0.72
2010	12	311	240	258	12	933	920	900	12	762	704	716	0.82	0.76	0.80
2011	12	137	120	130	12	972	958	956	12	837	827	824	0.86	0.86	0.86
2012	12	231	155	184	12	1081	1034	1070	12	995	948	985	0.92	0.92	0.92
2013	11	178	110	137	11	1298	1310	1274	11	1210	1175	1186	0.93	0.90	0.93
WY2006-2012 mean	11.3	230	170	200	11.1	874	854	842	11.0	709	667	673	0.81	0.83	0.79
WY2006-2012 monthly value	11.3	231	170	195	11.1	877	880	835	11.0	717	698	659	0.82	0.81	0.84

Otter Creek

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2005	2	61	61	57	2	755	755	754	2	714	714	713	0.95	0.95	0.95
2006	9	219	160	170	9	858	880	772	9	775	848	697	0.90	0.96	0.90
2007	9	204	170	179	9	969	830	903	9	880	803	812	0.91	0.97	0.90
2008	11	199	180	187	11	983	920	919	11	845	825	775	0.86	0.90	0.84
2009	10	261	175	200	10	966	894	878	10	852	718	773	0.88	0.80	0.88
2010	11	163	110	123	11	1248	1070	1187	11	1195	986	1132	0.96	0.92	0.95
2011	12	203	165	160	12	1361	1310	1263	12	1282	1236	1182	0.94	0.94	0.94
2012	12	185	150	149	12	1430	1340	1391	12	1342	1252	1310	0.94	0.93	0.94
2013	12	159	150	140	12	1772	1779	1750	12	1661	1638	1635	0.94	0.92	0.93
WY2006-2012 mean	10.6	205	159	167	10.6	1116	1035	1045	10.6	1024	953	954	0.92	0.99	0.91
WY2006-2012 monthly value	10.6	203	160	164	10.6	1137	1075	1044	10.6	1045	986	949	0.92	0.97	0.94

Owl Creek

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2005	5	65	60	53	5	834	600	763	5	728	577	644	0.87	0.96	0.84
2006	12	79	75	66	12	773	700	631	12	705	632	545	0.91	0.90	0.86
2007	11	94	90	77	11	725	710	650	11	632	560	546	0.87	0.79	0.84
2008	11	113	95	102	11	1019	790	844	11	817	687	693	0.80	0.87	0.82
2009	11	86	81	78	11	937	910	853	11	772	839	707	0.82	0.92	0.83
2010	12	67	73	65	12	939	919	921	12	873	871	849	0.93	0.95	0.92
2011	12	70	67	67	12	1389	1360	1306	12	1332	1311	1243	0.96	0.96	0.95
2012	12	60	52	51	12	1520	1660	1457	12	1449	1576	1393	0.95	0.95	0.96
2013	12	72	63	67	12	1521	1310	1456	12	1411	1175	1329	0.93	0.90	0.91
WY2006-2012 mean	11.6	81	76	72	11.6	1043	1007	952	11.6	940	925	854	0.90	0.93	0.97
WY2006-2012 monthly value	11.6	81	74	70	11.6	1049	930	916	11.6	948	857	809	0.90	0.92	0.92

Palm Creek

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2005	4	55	58	54	4	862	674	778	4	719	562	632	0.83	0.83	0.81
2006	11	111	80	91	11	1100	1110	1078	11	923	907	897	0.84	0.82	0.83
2007	12	117	79	98	12	888	815	796	12	755	638	665	0.85	0.78	0.84
2008	11	114	95	102	11	988	940	874	11	753	752	654	0.76	0.80	0.75
2009	12	101	87	93	12	961	990	915	12	733	770	676	0.76	0.78	0.74
2010	12	138	135	125	12	1252	1380	1211	12	1049	1115	1005	0.84	0.81	0.83
2011	12	92	87	85	12	1395	1425	1371	12	1221	1218	1194	0.88	0.85	0.87
2012	12	150	100	115	12	1596	1526	1547	12	1449	1372	1391	0.91	0.90	0.90
2013	12	83	70	77	12	1550	1377	1488	12	1431	1269	1357	0.92	0.92	0.91
WY2006-2012 mean	11.7	118	95	101	11.7	1168	1169	1113	11.7	983	967	926	0.84	0.84	0.87
WY2006-2012 monthly value	11.7	118	94	101	11.7	1172	1165	1087	11.7	987	932	892	0.84	0.80	0.80

Popash Creek

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2005	5	111	102	89	5	939	880	864	5	756	678	692	0.81	0.77	0.80
2006	11	140	130	125	11	1020	1070	1005	11	873	911	860	0.86	0.85	0.86
2007	11	151	150	143	11	855	940	824	11	730	645	696	0.85	0.69	0.84
2008	12	185	165	169	12	955	990	939	12	751	809	722	0.79	0.82	0.77
2009	12	219	195	190	12	921	905	876	12	714	649	660	0.78	0.72	0.75
2010	12	218	200	198	12	1229	1140	1199	12	1099	1026	1066	0.89	0.90	0.89
2011	12	160	165	152	12	1328	1415	1305	12	1180	1208	1159	0.89	0.85	0.89
2012	12	225	175	187	12	1525	1442	1515	12	1408	1373	1393	0.92	0.95	0.92
2013	12	233	195	172	12	1765	1730	1735	12	1660	1652	1621	0.94	0.95	0.93
WY2006-2012 mean	11.7	185.4	168.6	166.3	11.7	1119.0	1128.9	1094.7	11.7	964.9	945.7	936.7	0.86	0.85	0.86
WY2006-2012 monthly value	11.7	186	160	165	11.7	1123	1085	1075	11.7	989	919	907	0.86	0.85	0.85

Powell Creek

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2004	9	72	75	56	9	706	728	635	9	621	637	534	0.88	0.88	0.84
2005	7	77	71	73	7	760	666	737	7	684	605	661	0.90	0.91	0.90
2006	8	75	70	73	8	694	735	660	8	636	666	602	0.92	0.91	0.91
2007	7	146	90	124	7	690	770	650	7	608	666	557	0.88	0.86	0.86
2008	3	127	110	125	3	873	790	864	3	777	686	764	0.89	0.87	0.88
2009	4	145	110	125	4	1023	815	957	4	699	701	695	0.68	0.86	0.73
2010	9	278	130	174	9	1027	885	929	9	905	711	788	0.88	0.80	0.85
2011	6	113	98	108	6	1248	1290	1237	6	1154	1224	1140	0.92	0.95	0.92
2012	5	178	190	168	5	1053	980	1030	5	940	858	913	0.89	0.88	0.89
2013	11	160	170	126	11	1344	1410	1250	11	1270	1386	1165	0.94	0.98	0.93
WY2006-2012 mean	6.0	152	114	128	6.0	944	895	904	6.0	817	787	780	0.87	0.91	0.87
WY2006-2012 monthly value	6.0	158	105	123	6.0	931	852	863	6.0	815	727	747	0.88	0.85	0.85

SE Cape Coral – Combined

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2003	10	113	87	102	10	821	887	798	10	562	617	529	0.68	0.70	0.67
2004	12	142	90	103	12	805	797	775	12	481	467	464	0.60	0.59	0.60
2005	12	63	58	58	10	864	780	810	9	439	300	345	0.51	0.38	0.43
2006	12	46	50	44	12	754	835	717	12	358	334	313	0.48	0.40	0.44
2007	12	43	35	39	8	607	524	577	8	301	267	258	0.50	0.51	0.45
2008	12	41	33	37	12	543	543	528	12	367	384	345	0.68	0.71	0.65
2009	11	77	55	65	9	762	748	661	9	548	566	582	0.72	0.76	0.88
2010	12	90	83	77	12	787	786	731	12	563	617	506	0.71	0.78	0.69
2011	12	79	64	73	11	766	527	649	11	601	367	423	0.79	0.70	0.65
2012	12	75	77	70	12	966	946	940	12	783	750	752	0.81	0.79	0.80
2013	12	75	65	65	11	947	952	927	11	785	734	762	0.83	0.77	0.82
WY2006-2012 mean	11.9	64	57	58	10.9	741	701	686	10.9	503	469	454	0.68	0.72	0.68
WY2006-2012 monthly value	11.9	64	53	55	10.9	747	718	682	10.9	511	467	431	0.68	0.65	0.65

Stroud Creek

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2005	5	168	52	62	5	1002	487	701	5	862	338	550	0.86	0.69	0.78
2006	11	78	70	66	11	941	960	893	11	832	868	776	0.88	0.90	0.87
2007	12	99	90	87	12	903	940	872	12	799	816	768	0.88	0.87	0.88
2008	11	268	230	190	11	1125	1120	1101	11	921	927	892	0.82	0.83	0.81
2009	12	99	63	73	12	788	730	706	12	620	562	487	0.79	0.77	0.69
2010	12	144	81	104	12	1120	1005	1064	12	987	852	934	0.88	0.85	0.88
2011	12	60	50	54	12	1161	1105	1130	12	1034	952	997	0.89	0.86	0.88
2012	12	181	65	88	12	1483	1452	1443	12	1380	1368	1328	0.93	0.94	0.92
2013	12	103	78	74	12	1580	1516	1528	12	1478	1398	1410	0.94	0.92	0.92
WY2006-2012 mean	11.7	133	93	95	11.7	1074	1045	1030	11.7	939	906	883	0.87	0.90	0.88
WY2006-2012 monthly value	11.7	132	71	87	11.7	1075	1040	1007	11.7	941	883	850	0.87	0.85	0.85

Telegraph Creek

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2005	5	35	30	33	5	771	660	708	5	720	635	654	0.93	0.96	0.92
2006	12	42	35	39	12	805	890	712	12	745	844	647	0.93	0.95	0.91
2007	11	87	70	82	11	874	920	862	11	733	792	707	0.84	0.86	0.82
2008	11	163	120	142	11	1114	950	1069	11	958	854	908	0.86	0.90	0.85
2009	11	97	91	85	11	961	950	872	11	843	763	752	0.88	0.80	0.86
2010	12	111	76	79	12	1311	1216	1243	12	1212	1086	1144	0.92	0.89	0.92
2011	12	64	50	58	12	1484	1525	1463	12	1404	1421	1381	0.95	0.93	0.94
2012	11	85	54	67	11	1636	1510	1555	11	1556	1398	1476	0.95	0.93	0.95
2013	12	72	40	53	12	1695	1538	1643	12	1617	1469	1565	0.95	0.96	0.95
WY2006-2012 mean	11.4	93	71	79	11.4	1169	1137	1111	11.4	1064	1022	1002	0.91	0.94	0.92
WY2006-2012 monthly value	11.4	92	69	73	11.4	1171	1070	1072	11.4	1067	948	958	0.91	0.89	0.89

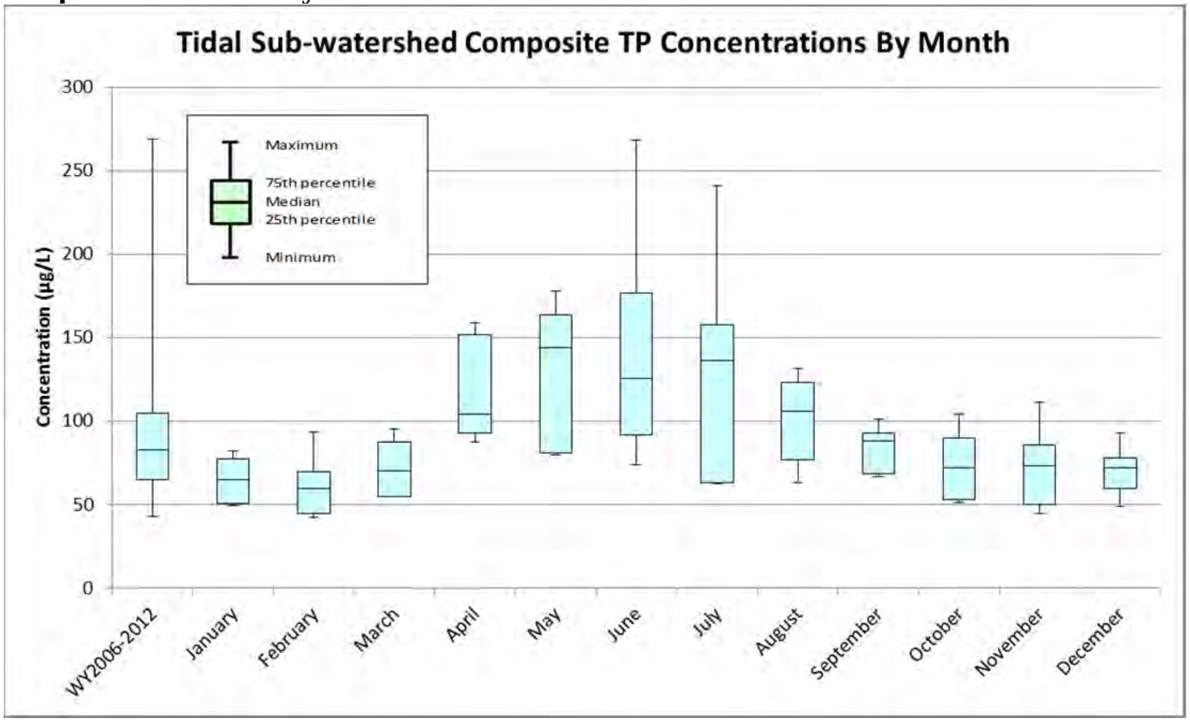
Trout Creek

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2005	5	36	40	34	5	745	618	661	5	455	286	371	0.61	0.46	0.56
2006	12	50	40	43	12	858	855	761	12	665	670	497	0.77	0.78	0.65
2007	11	63	60	60	11	738	730	690	11	480	369	385	0.65	0.51	0.56
2008	11	89	59	74	11	846	650	702	11	568	460	462	0.67	0.71	0.66
2009	11	63	50	57	11	848	720	733	11	651	489	445	0.77	0.65	0.61
2010	12	51	40	43	12	916	923	844	12	725	746	646	0.79	0.81	0.77
2011	12	57	50	47	12	1129	1010	1050	12	950	789	861	0.84	0.78	0.82
2012	12	90	63	65	12	1198	951	1087	12	1075	774	958	0.90	0.81	0.88
2013	12	60	55	56	12	1282	1054	1185	12	1173	917	1061	0.91	0.87	0.90
WY2006-2012 mean	11.6	66	52	56	11.6	933	834	838	11.6	731	611	608	0.78	0.88	0.73
WY2006-2012 monthly value	11.6	66	52	54	11.6	938	870	830	11.6	737	696	582	0.79	0.80	0.80

Whiskey Creek

Water Year	TP				TN				TON				Ratio of TON/TN		
	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	# of Samples	Average µg/L	Median µg/L	Geometric Mean, µg/L	Using Average	Using Median	Using Geomean
2005	5	29	26	27	5	483	480	445	5	412	361	379	0.85	0.75	0.85
2006	11	35	30	33	11	650	660	633	11	589	582	569	0.91	0.88	0.90
2007	12	44	37	40	12	593	555	563	12	522	488	486	0.88	0.88	0.86
2008	12	37	36	35	12	539	530	526	12	490	486	476	0.91	0.92	0.90
2009	12	61	46	53	12	563	505	529	12	459	434	399	0.82	0.86	0.75
2010	11	48	37	38	11	724	730	670	11	634	666	595	0.87	0.91	0.89
2011	10	41	42	36	10	738	765	701	10	653	741	604	0.89	0.97	0.86
2012	12	41	33	29	12	881	893	864	12	795	780	773	0.90	0.87	0.89
2013	9	28	26	25	9	831	850	815	9	768	793	747	0.92	0.93	0.92
WY2006-2012 mean	11.4	44	37	38	11.4	670	663	641	11.4	592	597	557	0.88	0.89	0.93
WY2006-2012 monthly value	11.4	44	40	37	11.4	668	625	630	11.4	590	566	544	0.88	0.90	0.90

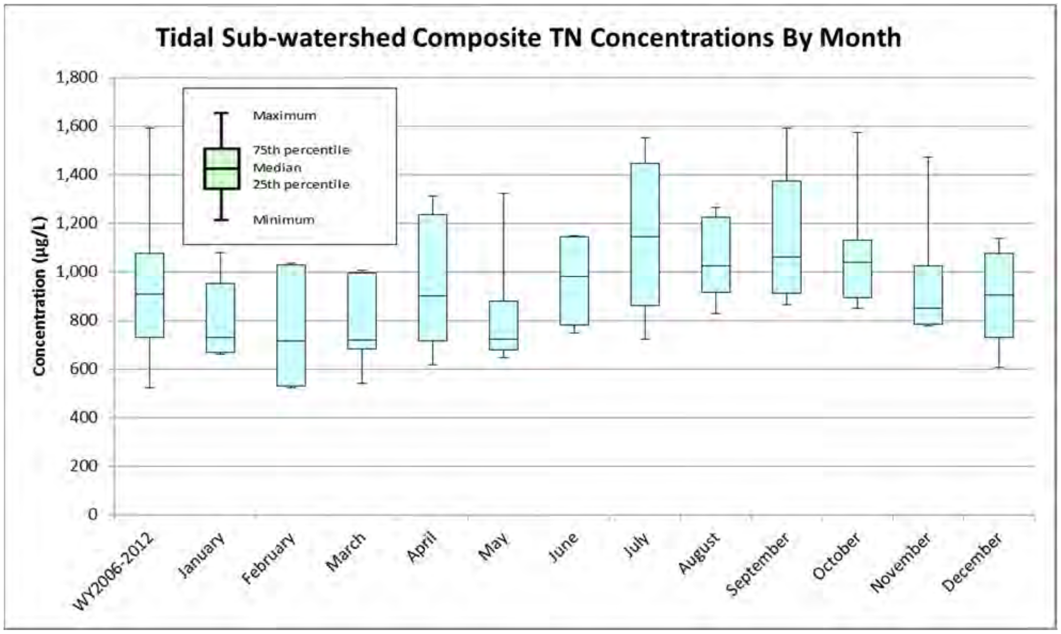
Comparison of monthly TP concentrations for the Tidal Caloosahatchee Sub-watershed.



Comparison of Tidal Caloosahatchee Sub-watershed monthly TP concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

Month	Monthly values significantly different from Reference Period values?
January	Yes
February	Yes
March	No
April	Yes
May	Yes
June	Yes
July	No
August	No
September	No
October	No
November	No
December	No

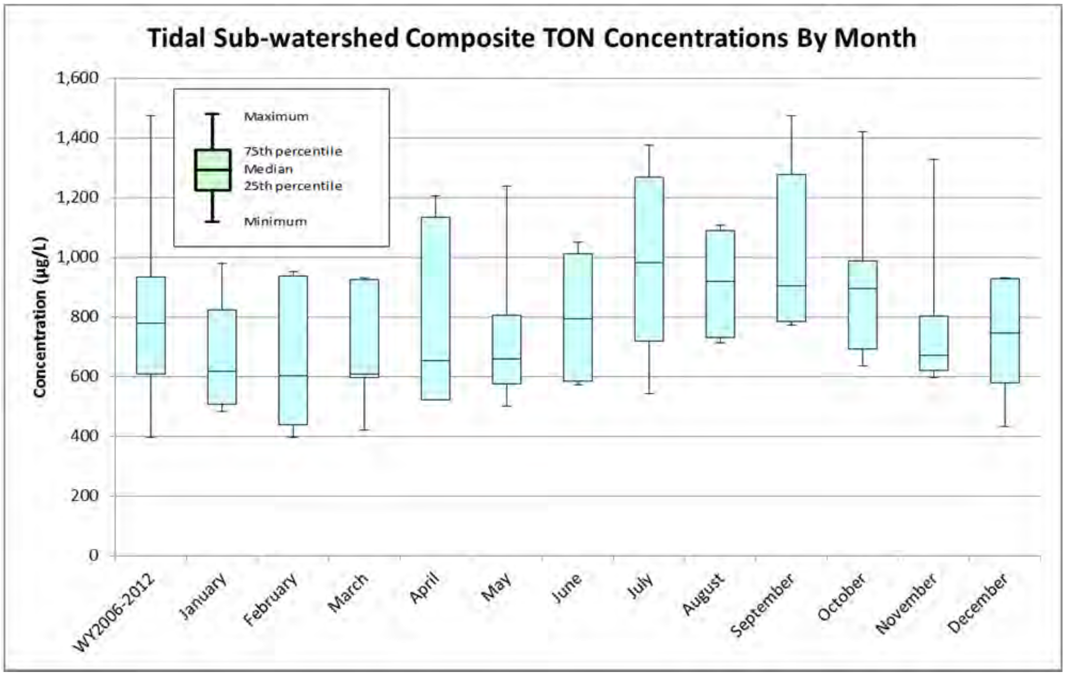
Comparison of monthly Tidal Caloosahatchee Sub-watershed TN concentrations.



Comparison of monthly Tidal Caloosahatchee Sub-watershed TN concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

Month	Monthly values significantly different from Reference Period values?
January	No
February	No
March	No
April	No
May	No
June	No
July	No
August	No
September	No
October	No
November	No
December	No

Comparison of monthly Tidal Caloosahatchee Sub-watershed TON concentrations.



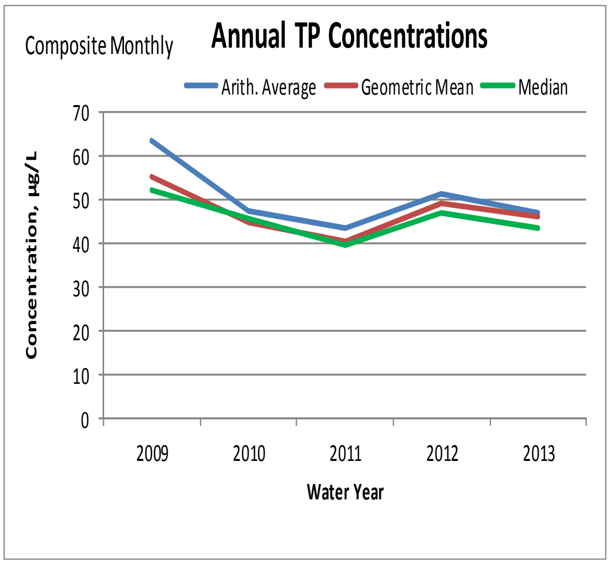
Comparison of monthly Tidal Caloosahatchee Sub-watershed TON concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

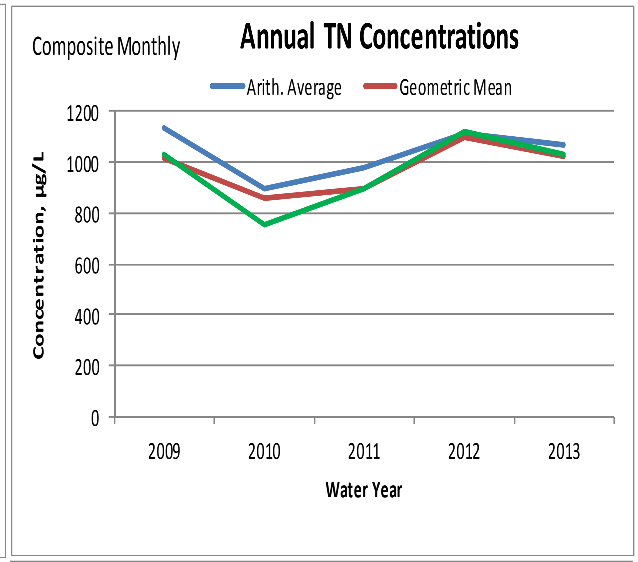
Month	Monthly values significantly different from Reference Period values?
January	No
February	No
March	No
April	No
May	No
June	No
July	Yes
August	Yes
September	Yes
October	Yes
November	No
December	No

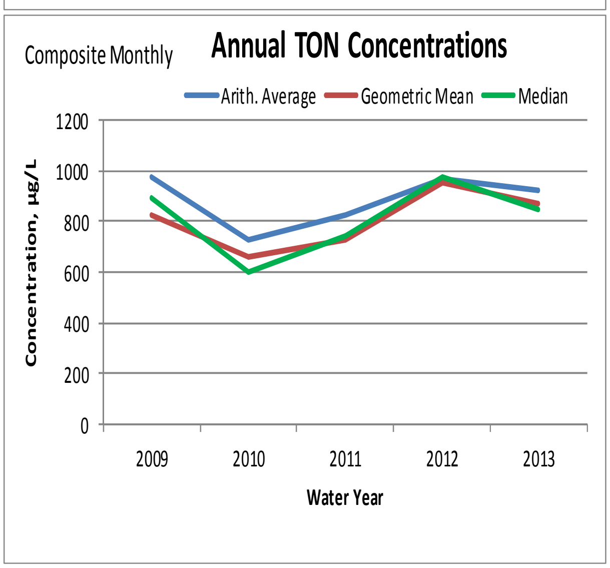
COASTAL CALOOSAHATCHEE SUB-WATERSHED

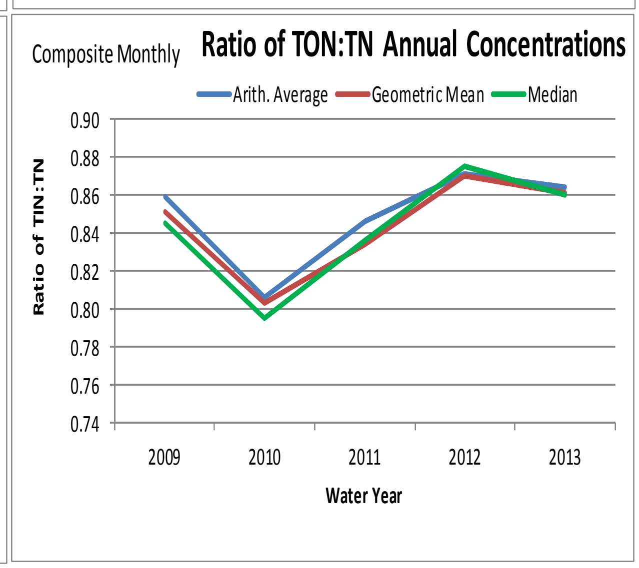
Annual Flow and Nutrient Levels

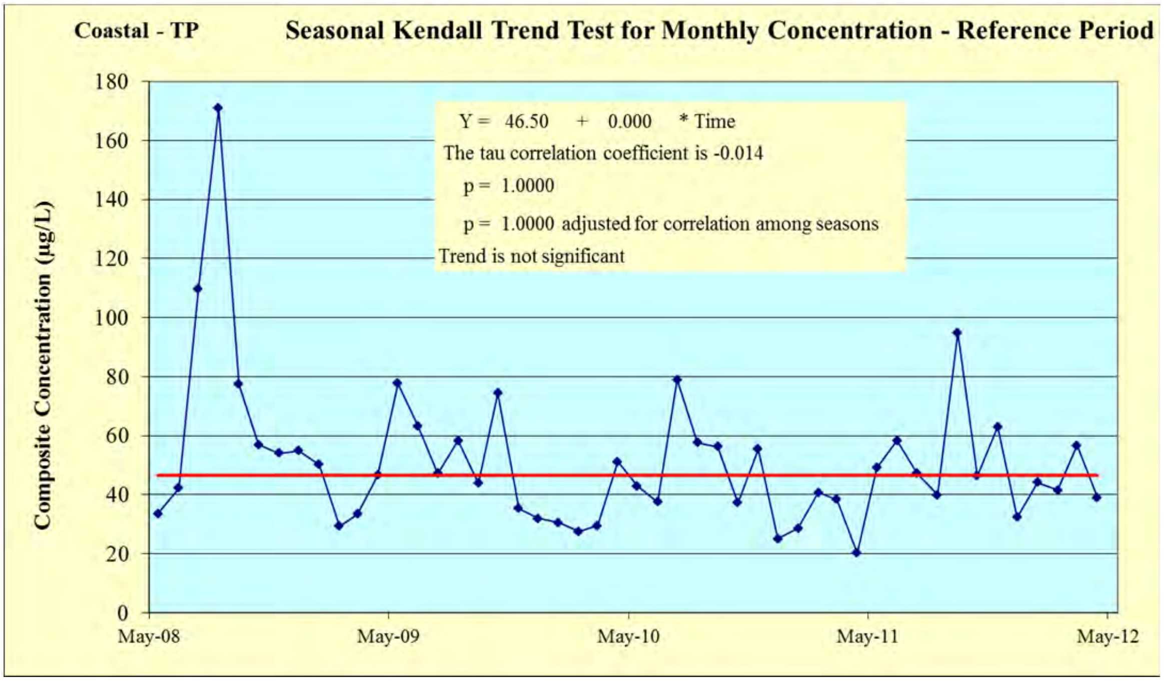
Annual summaries of Coastal Caloosahatchee Sub-watershed composite concentrations.

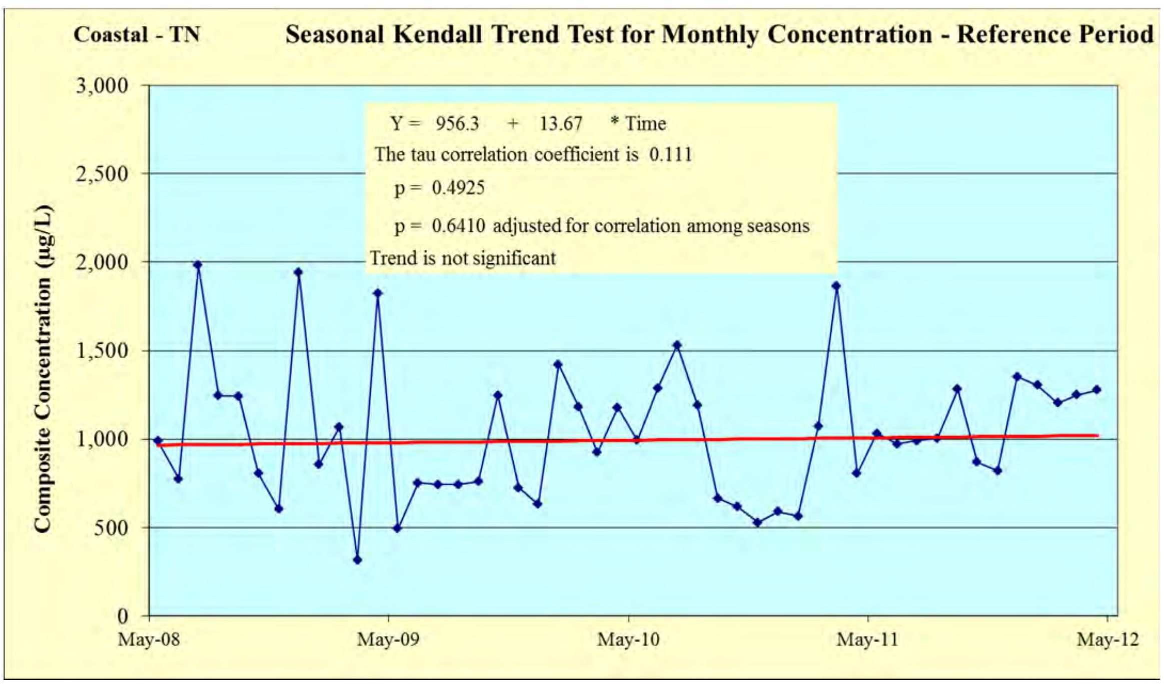


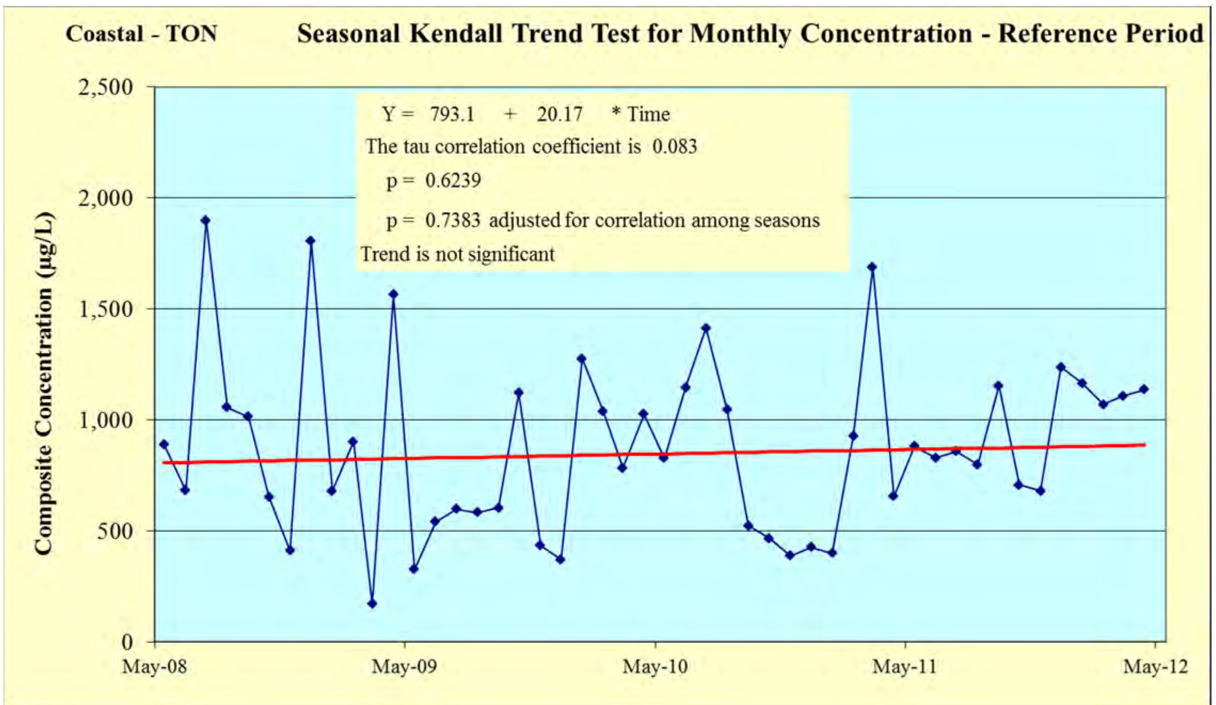







Coastal - TP
Seasonal Kendall Trend Test for Monthly Concentration - Reference Period
Y = 46.50 + 0.000 * Time
The tau correlation coefficient is -0.014
p = 1.0000
p = 1.0000 adjusted for correlation among seasons
Trend is not significant
Composite Concentration (µg/L)
0
20
40
60
80
100
120
140
160
180
May-08
May-09
May-10
May-11
May-12


Coastal - TN
Seasonal Kendall Trend Test for Monthly Concentration - Reference Period
Y = 956.3 + 13.67 * Time
The tau correlation coefficient is 0.111
p = 0.4925
p = 0.6410 adjusted for correlation among seasons
Trend is not significant
Composite Concentration (µg/L)
0
500
1,000
1,500
2,000
2,500
3,000
May-08
May-09
May-10
May-11
May-12


Coastal - TON
Seasonal Kendall Trend Test for Monthly Concentration - Reference Period
Y = 793.1 + 20.17 * Time
The tau correlation coefficient is 0.083
p = 0.6239
p = 0.7383 adjusted for correlation among seasons
Trend is not significant
Composite Concentration (µg/L)
2,500
2,000
1,500
1,000
500
0
May-08
May-09
May-10
May-11
May-12

Composite Coastal Caloosahatchee Sub-watershed

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2009	12	63	52	55	12	1137	1028	1013	12	977	896	823	0.86	0.85	0.85
2010	12	48	46	45	12	899	756	859	12	725	600	662	0.81	0.80	0.80
2011	12	43	40	40	12	975	898	896	12	826	742	731	0.85	0.84	0.83
2012	12	51	47	49	12	1113	1117	1098	12	969	976	950	0.87	0.87	0.87
2013	12	47	43	46	12	1067	1028	1025	12	923	847	873	0.86	0.86	0.86
WY2009-2012 annual mean	12	51	46	47	12	1031	950	967	12	874	803	792	0.85	0.85	0.82
WY2009-2012 monthly values	48	51	47	47	48	1031	991	962	48	874	844	784	0.85	0.85	0.82

Durden Creek

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2007	5	13	10	12.1	5	786	680	757	5	736	648	707	0.94	0.95	0.93
2008	5	53	17	23.5	5	1116	450	740	5	1038	426	665	0.93	0.95	0.90
2009	9	18	17	17.5	9	799	820	765	9	713	709	681	0.89	0.86	0.89
2010	9	11	11	10.6	9	1107	1150	1059	9	1014	1086	978	0.92	0.94	0.92
2011	11	7	6	6.6	11	1150	1110	1118	11	1109	1076	1075	0.96	0.97	0.96
2012	12	8	9	8.1	12	1418	1461	1384	12	1369	1388	1335	0.97	0.95	0.96
2013	8	13	12	11.0	8	1347	1217	1306	8	1304	1174	1264	0.97	0.97	0.97
WY2009-2012 annual mean	10.3	11	11	11	10.3	1119	1135	1081	10.3	1051	1065	1017	0.94	0.93	0.98
WY2009-2012 monthly value	41	11	9	10	41	1142	1111	1082	41	1077	1083	1015	0.94	0.97	0.97

NW Cape Coral - Combined

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2009	7	39	50	37	5	510	550	418	5	360	400	110	0.71	0.73	0.26
2010	10	33	25	31	10	684	550	598	10	502	350	378	0.73	0.64	0.63
2011	10	31	28	27	9	667	450	589	9	517	300	417	0.78	0.67	0.71
2012	10	43	40	41	10	1007	950	982	10	845	775	814	0.84	0.82	0.83
2013	12	38	40	36	11	895	850	849	11	745	700	689	0.83	0.82	0.81
WY2009-2012 annual mean	9.3	37	36	34	8.5	717	625	647	8.5	556	456	430	0.78	0.89	0.71
WY2009-2012 monthly value	37	36	30	33	34	749	650	654	34	586	500	405	0.78	0.77	0.77

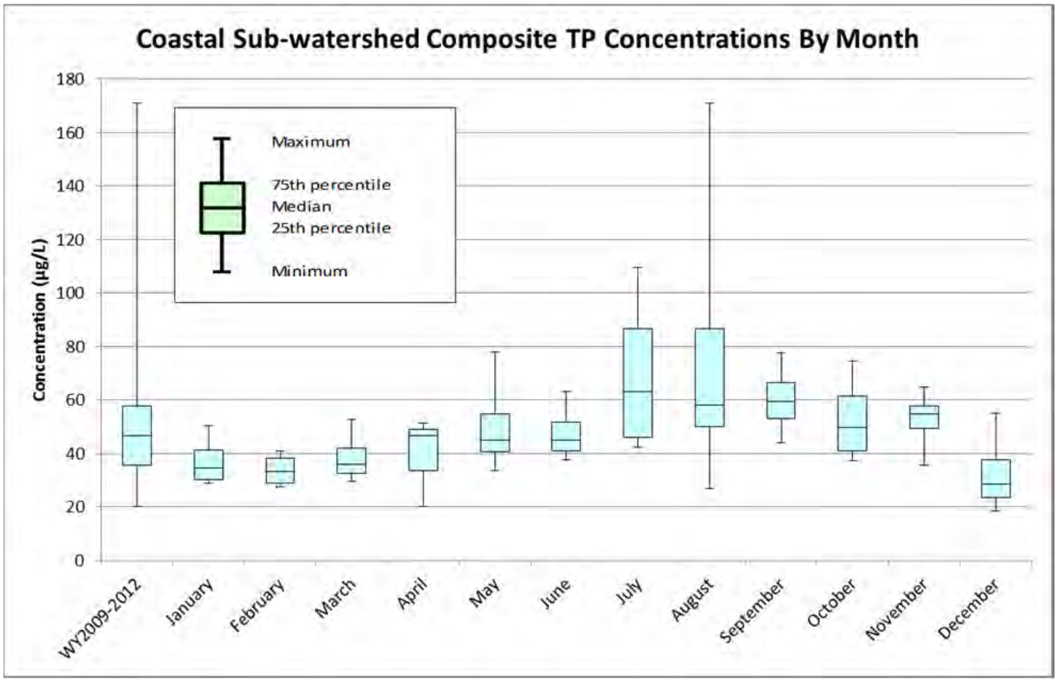
Sanibel Island – Combined

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2002	4	110	108	105	4	916	828	846	4	750	675	650	0.82	0.82	0.77
2003	12	109	98	103	12	1233	1208	1183	12	954	1000	890	0.77	0.83	0.75
2004	11	211	105	139	10	1269	1325	1222	10	1040	1100	983	0.82	0.83	0.80
2005	9	84	75	77	9	1325	1450	1203	9	1022	1050	843	0.77	0.72	0.70
2006	5	115	111	113	5	1627	1392	1546	5	1539	1281	1443	0.95	0.92	0.93
2007	12	95	86	90	12	1586	1559	1577	12	1331	1318	1309	0.84	0.85	0.83
2008	12	81	84	71	12	1336	1309	1309	12	1161	1171	1138	0.87	0.89	0.87
2009	12	96	88	88	12	1875	1909	1849	12	1708	1706	1689	0.91	0.89	0.91
2010	12	100	89	89	12	1794	1757	1784	12	1662	1586	1649	0.93	0.90	0.92
2011	12	77	74	75	12	1916	1880	1911	12	1763	1790	1755	0.92	0.95	0.92
2012	12	90	84	86	12	1778	1799	1769	12	1702	1723	1695	0.96	0.96	0.96
2013	11	104	87	95	11	1811	1819	1789	11	1736	1699	1710	0.96	0.93	0.96
WY2009-2012 annual mean	11.8	94	84	87	11.8	1835	1833	1820	11.8	1714	1701	1699	0.93	0.94	0.93
WY2009-2012 monthly value	48	91	84	84	48	1841	1843	1828	48	1709	1714	1696	0.93	0.93	0.93

SW Cape Coral - Combined

Water Year	TP # of Samples	TP Average µg/L	TP Median µg/L	TP Geometric Mean, µg/L	TN # of Samples	TN Average µg/L	TN Median µg/L	TN Geometric Mean, µg/L	TON # of Samples	TON Average µg/L	TON Median µg/L	TON Geometric Mean, µg/L	Ratio of TON/TN Using Average	Ratio of TON/TN Using Median	Ratio of TON/TN Using Geomean
2003	10	84	83	75	9	636	610	618	9	433	500	416	0.68	0.82	0.67
2004	11	94	65	72	11	719	705	689	11	495	500	472	0.69	0.71	0.69
2005	10	46	40	42	10	986	810	883	10	621	525	481	0.63	0.65	0.54
2006	12	40	38	39	12	688	638	654	12	363	313	307	0.53	0.49	0.47
2007	12	63	30	37	8	696	680	673	8	375	375	347	0.54	0.55	0.52
2008	12	25	25	25	12	574	550	552	12	400	375	376	0.70	0.68	0.68
2009	11	58	25	41	9	704	743	623	9	506	500	533	0.72	0.67	0.85
2010	12	52	53	49	12	749	714	715	12	538	525	462	0.72	0.74	0.65
2011	12	54	43	48	11	588	543	531	11	427	350	352	0.73	0.64	0.66
2012	12	47	43	43	12	815	800	807	12	654	650	642	0.80	0.81	0.80
2013	12	51	50	45	10	935	838	905	10	725	625	700	0.78	0.75	0.77
WY2009-2012 annual mean	10.0	53	45	47	9.2	757	731	722	9.2	575	542	548	0.76	0.79	0.75
WY2009-2012 monthly value	60	52	43	45	55	718	731	667	55	535	550	485	0.75	0.75	0.75

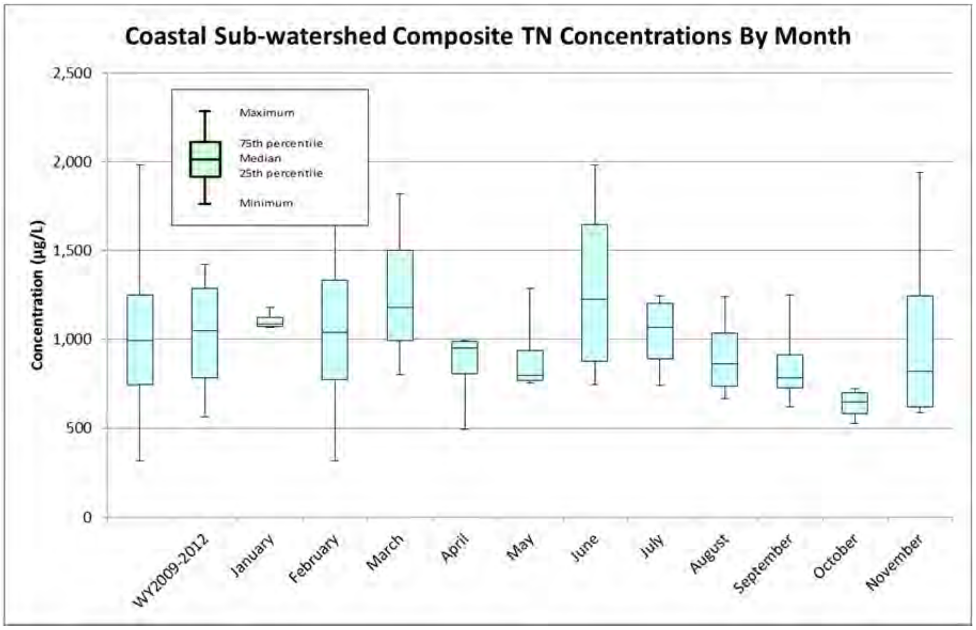
Comparison of monthly Coastal Caloosahatchee Sub-watershed TP concentrations.



Comparison of Coastal Caloosahatchee Sub-watershed monthly TP concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

Month	Monthly values significantly different from Reference Period values?
January	No
February	Yes
March	No
April	No
May	No
June	No
July	No
August	No
September	No
October	No
November	No
December	No

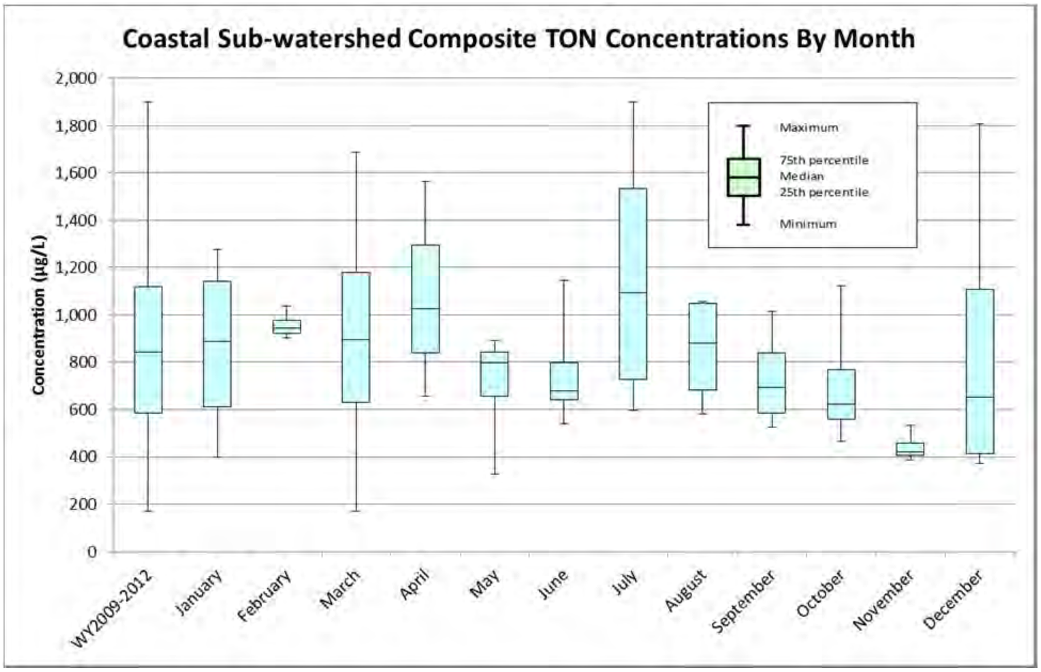
Comparison of monthly Coastal Caloosahatchee Sub-watershed TN concentrations.



Comparison of Coastal Caloosahatchee Sub-watershed monthly TN concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

Month	Monthly values significantly different from Reference Period values?
January	No
February	No
March	No
April	No
May	No
June	No
July	No
August	No
September	No
October	No
November	Yes
December	No

Comparison of monthly Coastal Caloosahatchee Sub-watershed TON concentrations.



Comparison of Coastal Caloosahatchee Sub-watershed monthly TON concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

Month	Monthly values significantly different from Reference Period values?
January	No
February	No
March	No
April	No
May	No
June	No
July	No
August	No
September	No
October	No
November	Yes
December	No

APPENDIX B – SUMMARY OF DATA SOURCES USED FOR THE DEVELOPMENT OF THE PERFORMANCE METRIC METHODOLOGIES

Data Collection Sources and Methods: Water Quantity – Flows

The District computes flow at all of the primary water control structures serving the basins within the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds. Water control structures include pumps, gated spillways, and gated culverts. The District's hydrologic database (DBHYDRO) stores one or more flow data sets at each structure. Each flow data set is created using a unique combination of sources of stage and control operations data. The District uses its data to perform water budget analyses and flow estimation techniques to obtain a "preferred" flow data set at each structure. **Table B-1** shows the basin discharge flow data sets used in the annual nutrient load calculation for those basins with a load-based performance measure; these are available in the District's hydrologic database. The list of outfall structures used in the annual nutrient load calculation will be adjusted by the District to account for any changes in outflow structures from the individual basins, including those changes caused by construction of regional projects.

Water Quality

Raw water samples for the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds nutrient load calculations are collected by automatic samplers or grab samples. Current raw water sample collecting methods at structures utilized in the Caloosahatchee River Watershed basins nutrient load calculation are listed in **Table B-2**.

For basins within the Tidal Caloosahatchee and Coastal Sub-watersheds, nutrient data collected by multiple agencies were used, as identified in **Tables B-3** and **B-4**.

Table B-1. Database keys for structure flow data.

Sub-watershed	Structure	DBKEY	Type*	Period of Record	Frequency of Collection
S-4 / Industrial Canal	EPD-07	EAA EPD		WY1993-2010	Daily
S-4 / Industrial Canal	S-310	15628	PREF	WY1993-2010	Daily
S-4 / Industrial Canal	S-169	15590	NA	WY1993-2010	Daily
S-4 / Industrial Canal	S-4	15630	PREF	WY1993-2010	Daily
S-4 / Industrial Canal	S-235	15564	SP01	WY1993-2010	Daily
East Caloosahatchee	S-77	DJ235	COE	WY1982-2010	Daily
East Caloosahatchee	S-78	DJ236	COE	WY1982-2010	Daily
West Caloosahatchee	S-78	DJ236	COE	WY1982-2010	Daily
West Caloosahatchee	S-79	DJ237	COE	WY1982-2010	Daily

* Flow data type:

PREF	PREFERRED VALUE
CR10	CAMPBELL SCIENTIFIC INC. MEASUREMENT AND CONTROL MODULE
TELE	TELEMETRY (RADIO NETWORK)
NA	NOT APPLICABLE
SP01	SOLID STATE LOGGER
COE	U.S. ARMY CORPS OF ENGINEERS

Table B-2. Sampling methods for structure water quality data.

Sub-watershed	Structure or Station	TP Collection Site ID	Period of Record	Data Collection Frequency	Nutrient Collection Site	Instrument
S-4 / Industrial Canal	EPD-07	EPD-07	WY1993 - 2010	Monthly	Pump	Grab
S-4 / Industrial Canal	S-310	S310	WY1993 - 2010	Monthly	Gravity	Grab
S-4 / Industrial Canal	S-169	S169	WY1993 - 2010	Monthly	Gravity	Grab
S-4 / Industrial Canal	S-4	S4	WY1993 - 2010	Monthly	Pump	Grab
S-4 / Industrial Canal	S-235	S235	WY1993 - 2010	Monthly	Gravity	Grab
S-4 / Industrial Canal	S-236	S236	WY1993 - 2010	Monthly	Pump	Grab
East Caloosahatchee	S-77	S77	WY1982 - 2010	Monthly	Gravity	Grab
West Caloosahatchee	S-78	S78	WY1982 - 2010	Monthly	Gravity	Grab
West Caloosahatchee	S-79	S79	WY1982 - 2010	Monthly	Gravity	Grab

Table B-3. Water quality data sources in the Tidal Caloosahatchee Sub-watershed.

Basin	Monitoring Site	Agency Collecting Data	Period of Record
Bayshore Creek	22-7GR	Lee County	WY2006-2013
Billy Creek	CFMBILLY1	Lee County	WY2006-2010
Chapel Branch	21-7GR	Lee County	WY2006-2013
Daughtrey Creek	20-9GR & 20A11-GR	Lee County	WY2006-2013
Deep Lagoon	DEEPGR10	Lee County	WY2005-2013
Hancock Creek	16-3GR	Lee County	WY2006-2013
Lower Orange River	40-18GR	Lee County	WY2005-2013
Marsh Point	18-6GR	Lee County	WY2006-2013
Otter Creek	28-5GR	Lee County	WY2006-2013
Owl Creek	270-GR20	Lee County	WY2006-2013
Palm Creek	25-GR20	Lee County	WY2005-2013
Popash Creek	23-5GR	Lee County	WY2006-2013
Powell Creek	POWLGR20	Lee County	WY2004-2013
SE Cape Coral	400, 470, 540	Cape Coral	WY2003-2013
Stroud Creek	24-7GR	Lee County	WY2006-2013
Telegraph Creek	29-8GR	Lee County	WY2006-2013
Trout Creek	27-6GR	Lee County	WY2006-2013
Whiskey Creek	WHISGR10	Lee County	WY2005-2013

Table B-4. Water quality data sources in the Coastal Caloosahatchee Sub-watershed.

Basin	Monitoring Site	Agency Collecting Data	Period of Record
Durden Creek	BURNTS	Lee County	WY2008-2013
NW Cape Coral	271	Cape Coral	WY2009-2013
Sanibel Island	SANWQ5, SANWQ8	Sanibel Island	WY2002-2013
SW Cape Coral	590, 600	Cape Coral	WY2003-2013

APPENDIX C – ESTIMATION OF NUTRIENT REDUCTIONS RESULTING FROM IMPLEMENTATION OF COLLECTIVE SOURCE CONTROL PROGRAMS

In order to estimate nutrient load and concentration reductions resulting from the implementation of the collective source control programs, reductions were developed for each land use based on technical documentation and expert best professional judgment. Reductions were estimated assuming implementation of BMPs and source control programs in the entire watershed at typical levels of effectiveness. To estimate the collective reduction, the reduction for each land use was weighted based on the land use acreage and land use unit load. These are preliminary recommendations and can be adjusted with justification, e.g., if partial implementation during the base period is verified based on documentation of implementation and nutrient reductions in water quality data.

The following information is presented in this appendix:

1. Land use data for the historical and current period for which land use data are available.
2. Unit area load coefficients and BMP effectiveness that were used for this project and how they were developed through an iterative process beginning with their initial development in 2003 in support of the Lake Okeechobee Protection Plan through 2011 when they were modified for use in the St. Lucie River and Caloosahatchee Watershed River Protection Plans.
3. Descriptions of how the land use data, unit area loads, and source control reductions for each land use category were used in spreadsheet models that calculated the total nutrient load reductions for each basin.

C.1 Historic and Current Land Use Data

The initial step in this procedure was to determine the land use distribution for each basin for its base period, so that estimated land use specific unit nutrient loads could be applied. First, the availability and quality of the land use data had to be evaluated. A series of land use/ land cover (LCLU) maps have been produced by the South Florida Water Management District (SFWMD) since the early 1970s representing the following points in time:

- 1972
- 1988
- 1995
- 1999
- 2004
- 2008

After reviewing these land use datasets, the 1995 land use coverage was used for the S-4/Industrial Canal; for the remaining sub-watersheds, the 2004 dataset was selected for the reduction calculations[15]. The 2004 land use coverage was used in the 2012 update of the Caloosahatchee River Protection Plan and was near the time range of the base periods for the Tidal and Coastal Sub-watersheds (**Table C-1**). For the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee Sub-watersheds, a comparison of land uses between 1995 and 2004 is was conducted indicating that increases in acreage on more intensive land uses generally balanced themselves with decreasing in other land uses. Please refer to **Table C-2**.

Once the land use coverage for the entire Caloosahatchee River Watershed was completed, it was overlaid with the GIS coverages of the Sub-watersheds in order to generate a detailed land use distribution table for each basin (see Excel spreadsheets in **Attachment 1**). Standard ArcMap tools were used to complete this task.

Table C-1. Sub-watersheds Performance Metrics Benchmark Time Periods

Sub-watershed	**Base Period**
S-4/Industrial Canal	WY 1993 – 2001
East Caloosahatchee	WY 1982 - 1990
West Caloosahatchee	WY 1988 - 1997
Sub-watershed	**Reference Period**
Tidal Caloosahatchee	WY2006-2012
Coastal Caloosahatchee	WY2009-2012

[15] For the *Technical Support Document* for the Lake Okeechobee Watershed, the 1995 land use was used for the East Caloosahatchee Sub-watershed, however, the resulting load reduction goal was the same (30 percent). This and other differences with the Lake Okeechobee Watershed *Technical Support Document* are document in a companion memorandum (SFWMD 2013).

Table C-2. Comparison of 1995 and 2004 land use data (from SFWMD).

Land Use Category	Acreage							TP Loads (kg)							TN Loads (kg)					
	S4/Industrial Canal		East CRW		West CRW		TP UAL	S4/Industrial Canal		East CRW		West CRW		TN UAL	S4/Industrial Canal		East CRW		West CRW	
	1995	2004	1995	2004	1995	2004	(lb/ac)	1995	2004	1995	2004	1995	2004	(lb/ac)	1995	2004	1995	2004	1995	2004
Residential Low Density	345	640	1,468	3,001	11,218	14,845	0.58	91	168	386	790	2,951	3,906	5.65	885	1,640	3,762	7,692	28,750	38,046
Residential Medium Density	1,724	1,724	1,214	383	1,757	1,759	1.65	1,290	1,290	909	286	1,315	1,316	8.21	6,420	6,420	4,521	1,425	6,543	6,549
Residential High Density	0	0	0	59	166	395	3.54	0	0	0	95	267	635	12.32	0	0	0	330	928	2,209
Commercial and Services	130	130	88	191	450	689	1.65	97	97	66	143	337	515	11.29	665	666	451	978	2,304	3,526
Industrial	328	328	88	236	112	445	2.83	421	421	113	303	144	572	10.27	1,528	1,528	410	1,101	522	2,074
Extractive	0	0	443	553	0	22	0.78	0	0	157	196	0	8	7.19	0	0	1,445	1,804	0	72
Institutional	174	174	74	122	129	245	2.83	224	223	95	157	166	315	7.19	569	567	241	398	421	800
Recreational	313	313	106	72	288	470	1.13	161	160	54	37	148	241	7.19	1,022	1,021	346	236	939	1,533
Open Land	157	157	2,061	2,436	17,693	25,033	0.33	24	24	309	365	2,648	3,747	4.11	294	293	3,842	4,541	32,985	46,669
Improved Pasture	1,859	1,859	48,301	36,798	57,548	55,544	1.65	1,391	1,391	36,150	27,541	43,071	41,571	11.40	9,612	9,613	249,767	190,281	297,581	287,218
Unimproved Pasture	0	0	8,526	5,752	16,400	12,722	0.85	0	0	3,287	2,218	6,323	4,905	5.65	0	0	21,851	14,742	42,030	32,605
Woodland Pasture	0	0	310	5,939	1,600	9,994	0.71	0	0	100	1,913	515	3,219	4.21	0	0	591	11,342	3,055	19,086
Row Crops	156	156	4,717	1,080	8,060	6,393	2.95	209	209	6,311	1,446	10,785	8,555	15.40	1,089	1,090	32,947	7,546	56,302	44,660
Field Crops	72	72	698	502	1,248	1,308	3.50	114	114	1,109	798	1,981	2,077	6.80	222	222	2,154	1,550	3,849	4,034
Sugarcane	31,929	31,929	40,962	57,895		2,058	0.47	6,807	6,807	8,733	12,343	0	439	8.21	118,903	118,905	152,544	215,604	0	7,664
Mixed Crops	0	0	0	0	0	17	4.13	0	0	0	0	0	33	11.29	0	0	0	0	0	90
Citrus	151	151	23,693	26,592	68,437	69,005	0.77	53	53	8,275	9,288	23,903	24,102	8.73	597	598	93,820	105,302	271,004	273,255
Fruit Orchards	0	0	0	0	0	0	2.72	0	0	0	0	0	0	9.24	0	0	0	0	0	0
Other Groves	20	20	7	0	42	53	2.72	25	25	8	0	52	66	9.24	84	84	28	0	176	224
Cattle Feeding Operations	0	0	8	0	0	0	10.58	0	0	40	0	0	0	55.50	0	0	210	0	0	0
Poultry Feeding Operations	0	0	0	0	0	0	1.77	0	0	0	0	0	0	10.27	0	0	0	0	0	0
Tree Nurseries	0	0	0	174	22	111	3.42	0	0	0	270	34	173	12.32	0	0	0	973	123	622
Sod Farms	179	179	9	289	204	3,345	2.39	194	194	10	314	221	3,626	9.24	750	750	38	1,212	855	14,019
Ornamentals	35	35	2	16	50	369	3.42	55	54	4	25	78	572	12.32	198	196	14	90	279	2,062
Specialty Farms	0	76	0	0	0	79	2.15	0	74	0	0	0	77	8.21	0	283	0	0	0	296
Horse Farms	0	0	56	140	292	38	2.15	0	0	54	136	285	37	16.43	0	0	415	1,042	2,176	286
Dairies	34	34	1,853	18	0	0	11.08	173	171	9,311	91	0	0	20.53	321	317	17,252	168	0	0
Aquaculture	0	0	0	27	10	91	0.83	0	0	0	10	4	34	10.27	0	0	0	124	47	424
Fallow Crop Land	42	42	1,440	133	2233	1,124	0.83	16	16	542	50	841	423	7.19	136	137	4,695	433	7,283	3,667
Rangeland	51	51	7,902	5,063	26306	21,481	0.21	5	5	753	482	2,506	2,046	4.21	97	97	15,090	9,668	50,235	41,021
Upland Forests (not including 4400)	521	520	17,383	20,716	46290	52,159	0.08	19	19	631	752	1,680	1,893	2.57	607	606	20,264	24,150	53,962	60,804
Tree Plantation	0	0	6,719	0	21748	22	0.18	0	0	549	0	1,776	2	3.18	0	0	9,692	0	31,370	31
Water	1,428	1,428	2,233	2,125	1759	3,654	0.06	39	39	61	58	48	99	0.92	596	596	932	887	734	1,525
Wetlands	951	952	29,822	30,608	60540	63,554	0.01	4	4	135	139	275	288	1.54	665	665	20,832	21,381	42,290	44,395
Barren Land	656	656	1,678	1,987	2675	2,248	0.89	265	265	677	802	1,080	907	7.19	2,140	2,139	5,473	6,480	8,724	7,331
Transportation/Communications/Utilties	519	520	2,048	1,184	1724	838	0.57	134	134	530	306	446	217	6.16	1,451	1,453	5,722	3,308	4,817	2,342
Total	42,146	42,146	204,093	204,093	350,114	350,114		11,810	11,958	79,357	61,351	103,877	106,616		150,846	151,890	671,344	636,792	952,280	951,142
							Difference	1%		-29%		3%			1%		-5%		0%	

C.2 Unit Area Load Coefficients and BMP Effectiveness – Current Project

The major parameters that this analysis depends on are nutrient unit area loads (UALs) for the various land uses. Percent reductions expected to result from source control measures on a particular land use are applied to the UALs for that land use. UALs represent the annual average nutrient loads per unit area discharged in runoff. The UALs are typically presented in lbs/ac/yr and are calculated by multiplying daily concentration by daily flow, summing over the water year, and dividing by the land area of the respective land use. It is recognized that UALs will be different for each time period and for different areas with similar land uses due to many factors including variability in rainfall, runoff, nutrient soil concentrations, and management practices. However, the weighting effect of the UALs provides for an approximate ratio of contribution among the land uses. The combined effect of these variables is reflected in the observed UALs, Unit Area Flows (UAFs), and concentrations recorded at the monitoring locations for each basin.

The UALs and source control reductions used in this analysis are based on those that were initially developed in 2003 (Bottcher and Harper, 2003) and then incrementally refined in subsequent reports (Bottcher, 2006 and SWET, 2008). The UALs have been based on the results of prior studies to the extent possible, but it was also necessary to apply expert best professional judgment. The iterative process of developing the UALs used for this analysis is described below.

a. Letter Report Entitled: Estimation of Best Management Practices and Technologies Phosphorus Reduction Performance and Implementation Costs in the Northern Lake Okeechobee Watershed, October 2003 (Bottcher and Harper, 2003)

This letter report contained estimates of UALs for agricultural and urban land uses and estimates of TP load reductions that could be expected to result from implementation of best management practices (a.k.a. source control programs). The information presented in the report was based on prior studies to the extent possible. However, due the limitations of available documentation, it was also necessary to apply the expert best professional judgment of the authors, Dr. Del Bottcher and Dr. Harvey Harper. The UALs and TP load reductions were developed based on conditions that existed for the 2003 timeframe and are presented in **Table C-2** (see the column labeled, “Existing Unit Load (lbs-P/ac/yr”).

Table C-2. Table 1 From Bottcher and Harper, 2003: Estimates of TP UAL and load reductions expected from implementation of source control programs.

FLUCCS Description	Acres	% of Total Landuse Area	Existing Unit Load (lbs-P/ac/yr)	Total P Load (tons)	Estimated % Reduction	Total P after Reduction (tons)
Primary Agricultural Land Use						
Improved Pastures	431,391	36.24%	0.72	155	30	109
Unimproved Pastures	70,927	5.96%	0.27	10	20	8
Woodland Pastures	8,652	0.73%	0.27	1	20	1
Rangeland	110,579	9.29%	0.23	13	20	10
Urban	27,280	2.29%	0.66	9	30	6
Dairies	29,084	2.44%	3.38	49	32	33
Citrus	54,763	4.60%	1.62	44	40	27
Field Crops - Sugarcane	16,586	1.39%	0.63	5	25	4
Sod Farms	10,652	0.89%	2.52	13	40	8
Row Crops	7,024	0.59%	6.30	22	60	9
SUM OF "Primary Ag Land Uses"	**766,938**	**64.43%**	**Subtotal**	**322**	**33**	**215**
Other Land Uses						
Field Crops	3,000	0.25%	0.50	1	10	1
Fruit Orchards	6,665	0.56%	0.50	2	10	1
Other Groves	16	0.00%	0.50	0	10	0
Poultry Feeding Operations	49	0.00%	0.50	0	10	0
Tree Nurseries	411	0.03%	0.50	0	10	0
Ornamentals	7,320	0.61%	0.50	2	10	2
Floriculture	21	0.00%	0.50	0	10	0
Horse Farms	310	0.03%	0.50	0	10	0
Aquaculture	833	0.07%	0.50	0	10	0
Fallow Crop Land	2,477	0.21%	0.50	1	10	1
Upland Forests	115,989	9.74%	0.50	29	0	29
Pine Plantation	32,600	2.74%	0.18	3	11	3
Water	12,966	1.09%	0.50	3	0	3
Wetlands	224,117	18.83%	0.50	56	0	56
Barren Land	10,646	0.89%	0.50	3	0	3
Transportation, Communication, and Utilities	5,907	0.50%	0.50	1	0	1
Special Classifications	0	0.00%	0.50	0	0	0
SUM OF "Other Land Use"	**423,326**	**35.57%**	**Subtotal**	**101**	**1**	**100**
Grand Total	**1190264**	100.00%		**423**	**25**	**314**

b. Letter Report Entitled: Phosphorus Reduction Performance and Implementation Costs under BMPs and Technologies in the Lake Okeechobee Protection Plan Area, August 2006 (Bottcher, 2006)

In 2006, the work performed in the 2003 Letter Report (Bottcher and Harper) was re-evaluated and refined. A workshop was held with experts having specific knowledge of agricultural practices and water quality in the Lake Okeechobee Watershed. The following individuals participated:

- Dr. Joyce Zhang, SFWMD
- Drs. Don Graetz and Tom Obreza (Soil Science, University of Florida (UF))
- Drs. Roger Nordstedt, Ken Campbell, and Sanjay Shukla (ABE, UF)
- Dr. Ed Hanlon (Director, SWFREC, UC)
- Dr. Patrick Bohlen, Director of Research, MacArthur Agro-ecology Research Center
- Dr. Ike Ezenwa (Agronomy, UF) was not present at the workshop but provided input afterwards on sand-land sugarcane production practices.

The workshop participants agreed upon the following refinements to UALs and estimates of source control TP load reductions.

1. Table 1 from the 2003 letter report was reorganized to eliminate confusion for the listed primary land uses. Also, one of the land uses “ornamentals”, which was previously under “other land uses”, was considered significant enough to be analyzed separately during this assessment.
2. The stormwater retention and wetland restoration BMPs were separated with significantly less emphasis being placed on wetland restoration P reductions due to recent field data that showed these restoration projects are less effective than originally thought. Two important assumptions were: 1) stormwater retention systems will not impact in-field water tables, and 2) retention ponds are not constructed on fields with historical high P levels or if they are, the land is treated with alum prior to flooding.
3. New UALs and BMP reductions were developed for “unimproved pastures” to differentiate them from “range/woodland pastures”. The workshop group agreed that the typical definition of unimproved pasture has animal densities and grass and fertility practices somewhere in between the improved and range/woodland pastures categories. Table values were adjusted accordingly.
4. The land use category of “ornamentals” was added and assumed to be an intensive ornamental nursery operation, but it is recognized that ornamental field crops, such as caladiums, may also be mapped under this category. It was suggested that the “row crops” land use category include ornamental field crops.
5. An assessment table for the land use category of field crops was added and assumed to be a hay field that is fertilized with P. The workshop group helped develop estimates for existing BMPs, P reduction and cost estimates.
6. The workshop group found the previous P fertilizer rates for “citrus” to be high because P fertilization on citrus typically only occurs over the first few years after planting. This change significantly reduced the potential P reductions for the fertility BMP.
7. A “natural areas” category was broken out from “other land uses” and included, “upland forests”, “water”, “wetlands”, “barren land”, “open land”, “transportation, communication, and utilities”, and “special classifications” land use categories.
8. There were a few other minor changes made to TP reduction ranges and typical values and the estimated costs of implementation suggested by the workshop group. Most of these changes were associated with stormwater retention and the fertility BMP.
9. An assessment table was also developed for the urban land use category because of this land use’s importance in any watershed BMP implementation programs.

Table C-3 presents the UALs and TP load reductions expected to result from implementation of source control programs developed in the 2006 report. It addresses the northern Lake Okeechobee Watershed, except for the Upper Kissimmee Sub-watershed.

Table C-3. Table 1 From Bottcher, 2006, UALs and TP reductions.

Landuse Category	FLUCCS	FLUCCS Description	Unit Load (lbs/acre/ yr)	Owner Implemented BMPs (1)	Typical Cost Share BMPs	Alternative Practices
Urban	1009	Mobile Home Units	0.66	3%	0%	0%
	1100	Residential Low Density				
	1200	Residential Medium Density				
	1300	Residential High Density				
	1400	Commercial and Services				
	1500	Industrial				
	1600	Extractive				
	1700	Institutional				
	1800	Recreational				
Improved Pastures	2110	Improved Pastures	0.72	11%	19%	49%
Unimproved Pastures	2120	Unimproved Pastures	0.49	7%	13%	44%
Woodland Pastures/Rangeland	2130/3000	Woodland Pastures/Rangeland	0.27	4%	6%	35%
Row Crops	2140	Row Crops	6.30	30%	30%	50%
Sugarcane	2156	Field Crops - Sugarcane	0.63	10%	23%	52%
Citrus	2210	Citrus	1.62	12%	20%	42%
Sod / Turf	2420	Sod Farms	2.52	20%	27%	50%
Ornamentals	2430	Ornamentals	4.10	32%	35%	50%
Dairies	2520	Dairies	3.38	9%	28%	48%
Pine Plantations	4400	Tree Plantations/Pine	0.18	1%	10%	50%
Dairies in non-priority basins		Dairies in Istokpoga and Caloosahatchee	0.17	2%	30%	48%
Natural Areas	4000	Upland Forests (not including 4400's)	0.20	0%	0%	0%
	5000	Water				
	6000	Wetlands				
	7000	Barren Land				
	1900	Open Land				
	8000	Transportation, Communication, and Utilities				
	9000	Special Classifications				
Other Areas	2150	Field Crops	0.70	10%	0%	0%
	2230	Other Groves				
	2220	Fruit Orchards				
	2320	Poultry Feeding Operations				
	2410	Tree Nurseries				
	2450	Floriculture				
	2510	Horse Farms				
	2540	Aquaculture				
	2610	Fallow Crop Land				

c. Nutrient Loading Rates, Reduction Factors and Implementation Costs Associated with BMPs and Technologies, July 2008

This report was prepared in support of the St. Lucie River and Caloosahatchee River Watershed Protection Plans. Its purpose was to estimate TP and TN load reductions in both watersheds that could be expected to result from implementation of source control programs. Seven additional land use categories were added to replace the "urban" category; "low density residential", "medium density residential", "high density residential", "horse farms", "transportation", "utilities", and "other urban". This created a total of 20 land use categories. Land uses were further broken down within the 20 primary categories for refinement of UALs. However, the final results were reported by aggregating the results of the individual land uses into the 20 primary categories.

Initial UALs were based on those developed by Bottcher (2006) as described above, general Florida estimates by Harper and Baker (2003 and 2007), and data collected within the St Lucie River Watershed by Graves, et al (2004). Since UALs are a function of both concentration and flow, it was first necessary to establish reasonable unit area runoff (UAR) coefficients in inches/acre/year for each land use category (Harper and Baker, 2007). The resulting calculated average annual runoff for the period 1995 – 2005 was within 1 percent of the measured flow volume from the watershed to the St Lucie Estuary.

The final nutrient UALs were developed by iteratively adjusting the initial UALs using a spreadsheet to calculate the total loads from the watershed based on the UALs, and land use acreages. The UALs were iteratively adjusted until the calculated and measured values for flow, load, and concentration were reasonably close. Adjustments to the nutrient UALs were made for individual land uses, and then a global adjustment factor was used to obtain a reasonable agreement between the calculated and measured values. **Tables C-4 and C-5** present nutrient UALs used in the development of the St. Lucie River and Caloosahatchee River Watershed Protection Plans, respectively.

The primary sources of agricultural BMP information were research and extension reports completed by Institute of Food and Agriculture Sciences, University of Florida (IFAS, UF) in association with various state agencies and grower groups, while urban BMP information was primarily from summary reports by Environmental Research and Design, Inc. and University of Central Florida. For citrus, the studies by Brian Bowman and David Calvert at the Indian River Research and Education Center and Ashok Alva and S. Paramasivam at the Citrus Research and Education Center were primarily used, while the best source of cow-calf production studies came from the Cattle Research Station at Ona and the Buck Island Ranch studies. Vegetable production BMPs were reviewed from research studies across the state, but focused mostly on work out of IFAS' Gulf Coast (Immokalee) and the old Bradenton Research and Education Centers.

Though many of the research studies focused more on crop production responses to management practices as opposed to water quality responses, their results were very useful in bracketing the economic feasibility limits for BMPs. To further access the actual water quality responses, both field studies and hydrologic transport modeling were evaluated. The Watershed Assessment Model (WAM) model has been used extensively in the Okeechobee and Caloosahatchee basins to estimate water quality responses to BMPs which may not have been specifically addressed in the field studies.

A report developed by Dr. Harvey Harper (2003) for the northern Lake Okeechobee watershed was primarily used for the urban BMPs responses for TP. Load reductions were estimated on the assumption that specific source controls were being implemented, as described below for the land use categories with the largest acreage in the watershed (**Table C-6**). SWET (2008) indicates that these source control measures (BMPs) represent what would be expected to be implemented through a reasonably funded cost share program or a modest regulatory approach. The expected reductions from the ten most common land uses in the Lake Okeechobee Watershed and the expected nutrient reductions from those land use types are listed in **Table C-7**.

Table C-4. Table 3 from SWET, 2008, Unit Area Loads.

Table 3. Estimated Runoff, Unit N and P Loads and Concentration for 2004 Land Uses in the St. Lucie Watershed

Land Use Category	**Land Use Description**	**FLUCCS**	**Runoff** (in/yr)	**Unit N Load**)	**N Conc.** (mg/l)	**Unit P Load** (lbs/acre/yr)	**P Conc.** (mg/l)
Residential Low Density	Residential Low Density[1]	1100	17.57	4.95	1.25	0.49	0.12
Residential Medium Density	Residential Medium Density[1]	1200	20.76	7.20	1.53	1.40	0.30
Residential High Density	Residential High Density[1]	1300	23.96	10.80	1.99	3.00	0.55
Other Urban	Commercial and Services[2]	1400	25.55	9.90	1.71	1.40	0.24
	Industrial[2]	1500	27.15	9.00	1.47	2.40	0.39
	Extractive[2]	1600	23.96	6.30	1.16	0.66	0.12
	Institutional[2]	1700	23.96	6.30	1.16	2.40	0.44
	Recreational[2]	1800	17.57	6.30	1.59	0.96	0.24
Improved Pastures	Improved Pastures	2110	19.16	9.99	2.30	1.90	0.44
Unimproved Pastures	Unimproved Pastures	2120	15.97	4.95	1.37	0.92	0.25
Woodland Pastures/Rangeland	Woodland Pastures	2130	15.97	3.69	1.02	0.88	0.24
	Rangeland	3000	15.97	3.69	1.02	0.28	0.08
Row Crops	Row Crops	2140	22.36	13.50	2.67	4.50	0.89
Sugar Cane	Sugar Cane	2156	19.16	7.20	1.66	0.63	0.15
Citrus	Citrus	2210	19.16	7.65	1.76	1.80	0.42
Sod Farms	Sod Farms	2420	19.16	8.10	1.87	2.52	0.58
Ornamentals	Ornamentals	2430	19.16	10.80	2.49	2.90	0.67
Horse Farms	Horse Farms	2510	15.97	14.40	3.99	1.82	0.50
Dairies	Dairies	2520	15.97	18.00	4.98	9.38	2.60
Other Areas	Field Crops	2150	15.97	5.96	1.65	2.96	0.82
	Mixed Crops	2160	19.16	9.90	2.28	3.50	0.81
	Fruit Orchards	2220	19.16	8.10	1.87	2.30	0.53
	Other Groves	2230	19.16	8.10	1.87	2.30	0.53
	Cattle Feeding Operations	2310	19.16	48.65	11.22	8.96	2.07
	Poultry Feeding Operations	2320	19.16	9.00	2.08	1.50	0.35
	Tree Nurseries	2410	15.97	10.80	2.99	2.90	0.80
	Specialty Farms	2500	15.97	7.20	1.99	1.82	0.50
	Aquaculture	2540	7.99	9.00	4.98	0.70	0.39
	Fallow Crop Land	2610	19.16	6.30	1.45	0.70	0.16
Tree Plantations	Tree Plantations	4400	15.97	2.79	0.77	0.18	0.05
Water	Water	5000	3.19	0.81	1.12	0.05	0.07
Natural Areas	Upland Forests (not including 4400's)	4000	14.37	2.25	0.69	0.28	0.09
	Wetlands	6000	1.60	1.35	3.74	0.01	0.03
	Barren Land	7000	23.96	6.30	1.16	0.75	0.14
	Open Land	1900	15.97	3.60	1.00	0.28	0.08
Transportation	Transportation	8100	27.15	8.28	1.35	1.65	0.27
Communication/Utilities	Communications	8200	15.97	5.40	1.49	0.48	0.13
	Utilities	8300	15.97	5.40	1.49	0.48	0.13

1 Assumed on Septic
2 Assumed Discharge from WWT outside basin

Table C-5. Table 12 from SWET, 2008, Unit Area Loads.

Table 12. Estimated Runoff, Unit N and P Loads and Concentration for 2004 Land Uses in the Caloosahatchee Watershed

Land Use Category	Land Use Description	FLUCCS	Runoff (in/yr)	Unit N Load (lbs/acre/yr)	N Conc. (mg/l)	Unit P Load (lbs/acre/yr)	P Conc. (mg/l)
Residential Low Density	Residential Low Density[1]	1100	27.43	7.26	1.17	0.68	0.11
Residential Medium Density	Residential Medium Density[2]	1200	32.42	10.56	1.44	1.93	0.26
Residential High Density	Residential High Density[2]	1300	39.90	15.84	1.75	4.14	0.46
	Commercial and Services[2]	1400	39.90	14.52	1.61	1.93	0.21
	Industrial[2]	1500	42.39	13.20	1.38	3.31	0.35
	Extractive[2]	1600	37.41	9.24	1.09	0.91	0.11
	Institutional[2]	1700	37.41	9.24	1.09	3.31	0.39
Other Urban	Recreational[2]	1800	27.43	9.24	1.49	1.32	0.21
Improved Pastures	Improved Pastures	2110	29.93	14.65	2.16	1.93	0.29
Unimproved Pastures	Unimproved Pastures	2120	24.94	7.26	1.29	0.99	0.18
	Woodland Pastures	2130	24.94	5.41	0.96	0.83	0.15
Woodland Pastures/Rangeland	Rangeland	3000	19.95	5.41	1.20	0.25	0.06
Row Crops	Row Crops	2140	34.91	19.80	2.51	3.45	0.44
Sugar Cane	Sugar Cane	2156	29.93	10.56	1.56	0.55	0.08
Citrus	Citrus	2210	29.93	11.22	1.66	0.90	0.13
Sod Farms	Sod Farms	2420	29.93	11.88	1.75	2.79	0.41
Ornamentals	Ornamentals	2430	29.93	15.84	2.34	4.00	0.59
Horse Farms	Horse Farms	2510	24.94	21.12	3.74	2.51	0.45
Dairies	Dairies	2520	24.94	26.40	4.68	12.94	2.29
	Field Crops	2150	24.94	8.74	1.55	4.09	0.73
	Mixed Crops	2160	29.93	14.52	2.14	4.83	0.71
	Fruit Orchards	2220	29.93	11.88	1.75	3.17	0.47
	Other Groves	2230	29.93	11.88	1.75	3.17	0.47
	Cattle Feeding Operations	2310	29.93	71.35	10.54	12.37	1.83
	Poultry Feeding Operations	2320	29.93	13.20	1.95	2.07	0.31
	Tree Nurseries	2410	24.94	15.84	2.81	4.00	0.71
	Specialty Farms	2500	24.94	10.56	1.87	2.51	0.45
	Aquaculture	2540	12.47	13.20	4.68	0.97	0.34
Other Areas	Fallow Crop Land	2610	29.93	9.24	1.36	0.97	0.14
Tree Plantations	Tree Plantations	4400	14.96	4.09	1.21	0.21	0.06
Water	Water	5000	4.99	1.19	1.05	0.07	0.06
	Upland Forests (not including 4400's)	4000	14.96	3.30	0.97	0.10	0.03
	Wetlands	6000	7.48	1.98	1.17	0.01	0.01
	Barren Land	7000	37.41	9.24	1.09	1.04	0.12
Natural Areas	Open Land	1900	24.94	5.28	0.94	0.39	0.07
Transportation	Transportation	8100	49.88	12.14	1.08	2.28	0.20
	Communications	8200	27.43	7.92	1.28	0.66	0.11
Communication/Utilities	Utilities	8300	24.94	7.92	1.40	0.66	0.12

1 Assumed on Septic
2 Assumed about 70% of Discharge from WWT outside basin

Table C-6. BMPs assumed to be implemented for estimates of nutrient load reductions.

Land Use	Citrus	Improved Pastures	Residential and Urban	Dairies	Other agriculture
Watershed Acreage Percentage	9 %	11 %	14 %	0.01 %	23 %
Nutrient Management	*Typical:* • P: Soil testing • N: Use of standard recommendations, e.g., use slow release forms of N. • Split application, e.g., fertigation. • Controlled application (timing & placement, fertigation) • Spill prevention • Includes implementation of domestic wastewater residuals rule	*Typical:* • P: Soil testing • N: Use of standard recommendations, e.g., use slow release forms of N. • Split application, e.g., fertigation. • Spill prevention • Includes implementation of domestic wastewater residuals rule, the animal manure implementation rule, and the septage application rule • Grass management[1] and rotational grazing • Reduced cattle density • Alternate water sources, shade, restricted placement of feeders, supplements, and water, fencing	*Typical:* • Reduced fertilization in accordance with the Urban Turf Fertilizer Rule • Use slow release forms of N. • Split application, e.g., fertigation. • Controlled application (timing & placement) • Spill prevention	*Typical:* • P: Soil testing • Includes implementation of the CAFO rule, • Feed management • Grass management[1] and rotational grazing • Improved forage/sprayfield management - P balanced with high P uptake crop rotations	*Typical:* • P: Soil testing • N: Use of standard recommendations, e.g., use slow release forms of N. • Split application, e.g., fertigation. • Controlled application (timing & placement, fertigation) • Spill prevention • Includes implementation of domestic wastewater residuals rule
Water Management	*Typical:* • Improved Irrigation and Drainage Management • Storm water detention/ retention and water reuse for irrigation • ERP permitted systems	*Typical:* • Operation of existing control structures resulting in moderate wetland restoration • Retention of runoff from working pens by directing away from waterways	*Typical:* • Dry detention swales (0.25 inch) and wet detention (0.25 inch) • Rain gardens	*Typical:* • Improved Irrigation and Drainage Management • Wetland restoration	*Typical:* • Improved Irrigation and Drainage Management • Storm water detention/ retention and water reuse for irrigation • ERP permitted systems
Particulate Matter and Sediment Controls	*Typical:* • Grass management between trees • Sediment traps	Note: Grass management will also apply to particulate matter and sediment controls	*Typical:* • Street sweeping • Sediment traps / baffle boxes	*Typical:* • Buffer strips Note: Grass management and improved forage/sprayfield management will also apply to particulate matter and sediment controls	*Typical:* • Cover crops • Sediment traps

[1] Includes selecting the appropriate grass variety and mowing to ensure healthy and uniform grass coverage.

Table C-7. Reduction values from the top 10 land uses based on Bottcher 2006 and SWET 2008 reports

Land Use	Expected Typical TP Reduction	Expected Typical TN Reduction
Natural Areas	0	0
Improved Pasture	30	27
Urban	10	50
Citrus	32	30
Rangeland	10	10
Unimproved Pasture	20	19
Sugarcane	33	33
Tree Plantations	11	15
Dairies	37	60
Row Crops	60	60

C.3 Caloosahatchee River Watershed TP UALs and BMP Effectiveness

A spreadsheet model, consistent with the models developed for the Lake Okeechobee, Caloosahatchee River, and St. Lucie River Watershed Protection Plans, was used to calculate nutrient loads and reductions that could be reasonably expected from implementation of collective source control programs. The spreadsheet applies the unit area flow and unit area load for each land use to the respective land use areas and sums them to calculate basin flows and loads, as indicated below:

- The unit area flow coefficients (expressed in inches/year) developed for each land use in the SWET 2008 report were used as a starting point for this analysis. The unit area flow coefficients were adjusted based on expert best professional judgment for the Caloosahatchee River Watershed. The unit area flow coefficients were developed to represent the relative differences in flows that would be discharged from each land use. The unit area flow coefficient was multiplied times the number of acres of the corresponding land use to calculate the total flow from each land use. The simulated flows from all land uses were then added to calculate the flows from the sub-watershed.
- The UALs developed for each land use in the CRWPP from Bottcher 2008 report were used for this analysis. The UAL coefficients used in this analysis represent the relative differences in nutrient loads that would be discharged from each land use.
- The UALs and land use acreages were used to weight the BMP reduction estimates for each land use (see Table C-7) in order to obtain a "Low" (a conservative effectiveness scenario), a "High" (optimal effectiveness scenario), and a "Typical" (most likely condition scenario). For example, the BMP reduction for a land use with a unit area load

of 1 lb/acre/year would be half the BMP reduction from a land use with a UAL of 2 lb/acre/year.

Since load is a function of flow and concentration, the unit area loads for a given land use will vary temporally due to variations in rainfall and flow. The average annual flow and nutrient load measured during the base period were used to adjust the simulated loadings for each basin.

a. Adjustment Factors to Account for Differences in Source Control Implementation between Current and Base Period Conditions

The estimates of source control nutrient load reductions developed in Bottcher 2006 and SWET 2008 were based on reductions that could be achieved relative to current conditions, i.e., 1990s forward. The base periods for S-4/Industrial Canal (WY1993-2001), East Caloosahatchee (WY1982-1990) and West Caloosahatchee (WY1988-1997) were for similar periods, therefore the reductions in these reports were used without adjustment for these basins. For the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds, the base periods are also relatively current therefore adjustments were not considered necessary to account for the difference in base periods, however, other adjustment factors were considered as detailed in section .

b. Adjustment to Account for Background Nitrogen Levels

Since a large portion of nitrogen in the environment is from natural sources and a majority of it is likely to be present as total organic nitrogen (TON), the performance metric methodologies incorporate an additional consideration to ensure that estimates of TN reductions do not go beyond what could be reasonably expected from source controls on anthropogenic activities.

Based on review of literature and nitrogen levels at sites in south Florida, a preliminary threshold of 90 percent of the TON level was applied to the performance metrics (Bedregal 2012, Knight 2013). This approach assumes that a TN level equal to 90 percent of the reference period TON level is a reasonable approximation of the natural background TN level, and that the remaining ten percent is attributable to anthropogenic activities (e.g., use of organic fertilizers and cycling of inorganic nitrogen into TON) which could potentially be reduced through source controls.

The range of recommended reductions and the recommended reductions for each basin agreed upon by the consulting team and the District is shown in **Table C-8**; the spreadsheets associated with the recommended reductions are included in Attachment 1.

Table C-8. Range of nutrient load percent reductions relative to the base period anticipated for each basin.

Basin	Low Reduction, %	High Reduction, %	Typical Reduction, %	Recommended Target Reduction, %
Total Phosphorus				
S-4/Industrial Canal	8	50	28	30
East Caloosahatchee	9	49	29	30
West Caloosahatchee	8	46	29	30
Tidal Caloosahatchee	4	32	17	10
Coastal Caloosahatchee	2	26	12	0
Total Nitrogen				
S-4/Industrial Canal	9	66	33	35
East Caloosahatchee	9	52	27	30
West Caloosahatchee	7	42	24	25
Tidal Caloosahatchee	3	44	28	10
Coastal Caloosahatchee	2	32	18	15

c. Validation of Measured and Simulated Flows and Loads

The nutrient load discharged from an acre of any land use will not necessarily equal the load that reaches the receiving water. There are many potential reasons for this difference. For example, in-stream assimilation can significantly reduce the nutrient load after it flows from the source and before it reaches the receiving water, particularly if the flow distance is long and the stream is shallow with overbank wetlands. Another example is that surface water may be used for irrigation as it travels downstream from its source to the monitoring location at the sub-watershed outlet. The parcel to catchment adjustment factor may also account for variations in soil types and nutrient soil concentrations associated with the sub-watershed. The simulated concentrations, Unit flows and UALs are at the parcel level, while the measured data are collected downstream, at the basin level. To account for the differences between the simulated and measured values, a parcel to basin adjustment factor was estimated. While some attenuation is expected between the parcel and basin discharge levels (parcel loading based on unit flow, UAL and observed acreage, and basin loading based on measured data), the greater the difference, would suggest the higher uncertainty in the calculations.

For the Tidal Caloosahatchee and Coastal Caloosahatchee sub-watersheds, observed and simulated concentrations were compared to determine if there were differences that warranted adjustment, e.g., observed concentrations were substantially lower than simulated concentrations would suggest greater uncertainty in the estimates potentially due to assimilation, tidal influences, site-specific conditions or partial implementation. The nutrient concentrations after the reductions were also reviewed to determine whether these levels appeared reasonable. The BMP reductions were adjusted based on best professional judgment based on these various factors as detailed in the following section.

For the S-4/Industrial Canal, East Caloosahatchee and West Caloosahatchee basins, the nutrient load reduction percentage was rounded to the closest 5 percent increment recognizing the inherent uncertainty of the data. The nutrient loads after the reductions were applied were reviewed to determine whether these levels appeared reasonable based on reductions from other source control programs.

d. Procedure Used To Estimate Nutrient Reductions For the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-Watersheds and Their Tributaries

- Available water quality data collected by local governments were used. Data are collected at individual tributaries. Follow-up between the District and the agencies to ensure that the methods of collection are appropriate for their use in a regulatory program is required.

- Monitoring stations at the most downstream location of each tributary were selected, thus collectively capturing the activities conducted upstream while minimizing the number of stations needed. However, this did not prevent the lack of data for some areas: approximately 8 percent of the land area (i.e., excluding the acreage in the "Water" land use category) in the Tidal Caloosahatchee and approximately 15 percent of the land area in the Coastal Caloosahatchee sub-watershed are not captured by any stations. Based on comparison of the land uses of the unmonitored areas and those monitored, and the low percentage of unmonitored lands, it was considered that the monitored areas would be considered representative of those unmonitored, unless suggested otherwise by localized monitoring data or observed implementation.

Derivation of the Annual Concentration Target

1. As a first step, the nutrient reductions were calculated for the sub-watershed and tributaries based on the twenty land use categories established in the protection plan (SFWMD, 2009) using the 'Typical' reductions, observed land use acreage and simulated UAL. The reduction was applied to the monthly median concentration for each tributary resulting in a "preliminary Annual Concentration Target".

2. The preliminary Annual Concentration Targets were then compared against the TMDL-simulated (FDEP, 2009) median concentration at monitoring station CES06 for the Tidal Caloosahatchee Sub-watershed and for the San Carlos Station for the Coastal Caloosahatchee to ensure that these did not result in concentrations below those established as meeting water quality standards.
   a. Tidal TP: 22 µg/L
   b. Tidal TN: 458 µg/L
   c. Coastal TP: 36 µg/L
   d. Coastal TN: 426 µg/L

   None of the preliminary targets were below the simulated TMDL median concentrations.

3. Adjustments to the source control reduction goals were then made based on best professional judgment to account for uncertainties.

   - Although monitoring data are generally reported to be collected during discharge conditions, monitoring locations are likely subject to inflows from the river and tidal effects. Therefore, it was considered reasonable to conservatively adjust the reductions, or require maintaining historic levels only, if the observed nutrient concentrations were substantially lower than those simulated by the model based on existing land uses.

   - The BMP reductions from the protection plan (SFWMD, 2008) are based on nutrient load assumptions while the targets are concentration-based. The breakdown between the portion of the reduction that is due to concentration and the one that is due to flow may vary. It was considered that nutrient management and particulate matter BMPs would affect concentration levels, while the water management BMPs would affect concentration and flow. It seemed reasonable to adjust the reductions when the preliminary targets may not seem feasible to be achieved on a long-term basis.

   - In consideration of these uncertainties, it was decided that tributaries with a reference period TP median at or below specific thresholds, or if the source control reduction percentage applied to the median was at or below the threshold, then the source control goal would be to maintain existing conditions, i.e., reduction of 0 percent.

a. For TP, this threshold was established at 51 ppb for both sub-watersheds
    i. For the Tidal Caloosahatchee Sub-watershed, Whiskey Creek and Lower Orange River were below the threshold, so the reduction goal was set at 0 percent. Also, for Trout Creek and Southeast Cape Coral the source control reduction percentage applied to the median was at or below the threshold, and so this basin was assigned a zero percent reduction from the median.
    ii. For the Coastal Caloosahatchee Sub-watershed, the composite median was 47 ppb, and the sub-watershed and its four tributaries were assigned a reduction goal of 0 percent.

b. For TN, this threshold was established at 630 ppb for the Tidal Caloosahatchee Sub-watershed and 501 ppb for the Coastal Caloosahatchee Sub-watershed. The basis of using these values was that, given the potential tidal influences, the reductions from the upstream tributaries may not be measured below these levels once mixed with the river concentrations.
    i. For the Tidal Caloosahatchee Sub-watershed, Whiskey Creek was below the 630 ppb threshold, so the reduction goal was set at zero percent.
    ii. For the Coastal Caloosahatchee Sub-watershed, none of the four tributaries were at or below the 501 ppb threshold.

- One additional step was applied for TN, in that the preliminary targets were compared against a background TN threshold based on 90 percent of the historic TON median concentration ("surrogate TN background"). If the preliminary target was lower than the surrogate TN background, then the target would be set to the surrogate TN background. For both sub-watersheds, just under half of the preliminary targets were established as the surrogate TN background.

- After review of the intermediate results, and in further consideration of the uncertainties, the Tidal Caloosahatchee Sub-watershed TP source control reduction goal was reduced from 17 percent ("Typical Reduction") to 10 percent, and the TN source control reduction goal was reduced from 23 percent ("Typical Reduction") to 10 percent.

    a. In consideration of the composite Tidal Caloosahatchee Sub-watershed reduction goal being reset to 10 percent, the individual tributaries' goals were also reduced. The tributary reduction goals were adjusted such that the ratio of the cumulative basins' flow-weighted mean concentration (using the theoretical annual basin flow volumes) to the composite area concentration was the same after source control reductions as it was for the Reference Period.

b. For example, for TP, the tributaries' cumulative flow-weighted mean concentration during the reference period was calculated as the sum of the tributaries' median concentration times the basin's annual runoff divided by the sum of the tributaries' annual runoff (76 ppb). The median of the composite area was 83 ppb, which yields a resulting ratio of 76/83=0.911. This ratio was preserved after the reduction goals with the application of an adjustment factor that adjusted the reduction percentages value until the reference period ratio was achieved.

c. For TN, the tributaries' cumulative flow-weighted mean concentration during the reference period was 904 ppb. The median of the composite area was 907 ppb, which yields a resulting ratio of 904/907=0.996. This ratio was preserved after the reduction goals with the application of an adjustment factor that adjusted the reduction percentages value until the reference period ratio was achieved. For example, the preliminary TN Target for Lower Orange River tributary was 630 ppb, however after the sub-watershed reduction goal was revised to 10 percent, the tributary reductions were proportionately revised and the resulting Target concentration for the Lower Orange River tributary was adjusted to 693 ppb.

The resulting Annual Concentration Targets and reduction goals are presented in **Table C-9**. While many of the Targets were close to the surrogate TN background, after adjustment of the sub-watershed reduction goal, the surrogate TN background was not a limiting factor for any tributary in either the Tidal Caloosahatchee or Coastal Caloosahatchee Sub-watersheds.

Table C-9. Estimates of the Annual Concentration Targets for the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds.

Basin	TP Source Control Target Reduction Goal	Reference Period Median Concentration, µg/L	Annual TP Concentration Target - Median Concentration, µg/L	TN Source Control Target Reduction Goal	Reference Period Median Concentration, µg/L	Annual TN Concentration Target - Median Concentration, µg/L
Tidal Sub-watershed	***10%***	***83***	***75***	***10%***	***907***	***816***
Bayshore Creek	24%	110	84	16%	1,138	952
Billy Creek	7%	245	227	25%	935	701
Chapel Branch	11%	90	80	18%	1,220	999
Daughtrey Creek	11%	92	82	5%	950	902
Deep Lagoon	5%	110	104	16%	1,005	845
Hancock Creek	6%	150	141	10%	920	827
Lower Orange River	0%	32	32	11%	780	693
Marsh Point	6%	170	160	21%	880	693
Otter Creek	20%	160	128	9%	1,075	976
Owl Creek	23%	74	57	9%	930	848
Palm Creek	20%	94	75	17%	1,165	966
Popash Creek	12%	160	141	5%	1,085	1,030
Powell Creek	9%	105	96	16%	852	719
Southeast Cape Coral	0%	53	53	3%	718	693
Stroud Creek	18%	71	58	16%	1,040	875
Telegraph Creek	19%	69	56	8%	1,070	986
Trout Creek	0%	52	52	17%	870	719
Whiskey Creek	0%	40	40	0%	625	625
Coastal Sub-watershed	***0%***	***47***	***47***	***15%***	***991***	***842***
Durden Creek	0%	9	9	6%	1,111	1,040
Northwest Cape Coral	0%	30	30	17%	650	540
Sanibel Island	0%	84	84	11%	1,843	1,640
Southwest Cape Coral	0%	43	43	17%	731	607

Notes:

1. The Reference Period for the Tidal Caloosahatchee Sub-watershed is WY2006-2012.
2. The Reference Period for the Coastal Caloosahatchee Sub-watershed is WY2009-2012.
3. The Annual Concentration Target is a distribution of monthly concentrations, represented here by the median concentration of the distribution, adjusted by the nutrient reduction goal.
4. Target concentrations are rounded to whole ppb and/or three significant digits, which may have slightly revised the percent reduction.

Derivation of the Annual Concentration Limit

The calculation of the Annual Concentration Limit used the maximum monthly concentration observed during the Reference Period as the benchmark concentration.

1. Preliminary estimates of Limit.
   a. The tributaries and composite sub-watershed maximum concentrations were above both the simulated TMDL median and TP threshold of 50 ppb.

b. The tributaries and composite sub-watershed maximum concentrations were above both the simulated TMDL median and the TN threshold (630 ppb for Tidal Caloosahatchee and 501 ppb for Coastal Caloosahatchee).

c. The "surrogate TN background" was established as 90 percent of the TON concentration observed at the time of the maximum TN concentration. This threshold was the limiting factor in the preliminary estimates of the Limit in more than half of the Tidal Caloosahatchee tributaries, and was the limiting factor in the Coastal Caloosahatchee Sub-watershed and one of its tributaries.

2. After review of the intermediate results, and in further consideration of the uncertainties, the "Typical" reduction goals were adjusted.

    a. Tidal Caloosahatchee Sub-watershed: the reduction goals were adjusted to 15 percent for both TP and TN to account for potential tidal influence and other uncertainties.

    b. Coastal Caloosahatchee Sub-watershed the reduction goals were adjusted to 0 percent for TP and 15 percent for TN.
        i. No reductions are proposed for the Coastal Caloosahatchee Sub-watershed TP target because the calculated reductions were relatively small (<10 percent), the monthly medians are low and TP may not be a nutrient of concern for the Coastal Caloosahatchee Sub-watershed.

    c. The tributary Limits were adjusted in proportion to the sub-watershed adjustment in the same manner as for the Target derivation.

The resulting Annual Concentration Limits and reduction goals are presented in **Table C-10**. Even after the downward adjustment in "Typical" source control reductions, more than half of the Annual TN Concentration Limits were established by the surrogate TN background in the Tidal Caloosahatchee or Coastal Caloosahatchee Sub-watersheds.

Table C-10. Estimates of the Annual Concentration Limits for the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds.

Basin	TP Source Control Limit Reduction Goal	Reference Period Maximum Concentration, µg/L	Annual TP Concentration Limit, µg/L	TN Source Control Limit Reduction Goal	Reference Period Maximum Concentration, µg/L	Annual TN Concentration Limit, µg/L
Tidal Sub-watershed	***15%***	***269***	***228***	***15%***	***1,591***	***1,350***
Bayshore Creek	24%	390	296	19%	1,910	1,550
Billy Creek	10%	490	442	11%	2,380	2,120
Chapel Branch	13%	910	788	15%	3,715	3,150
Daughtrey Creek	13%	665	578	12%	2,021	1,780
Deep Lagoon	9%	270	246	11%	1,910	1,700
Hancock Creek	9%	360	328	19%	1,915	1,550
Lower Orange River	13%	170	148	14%	1,510	1,300
Marsh Point	9%	880	803	14%	1,517	1,310
Otter Creek	21%	740	585	12%	2,525	2,220
Owl Creek	23%	240	184	22%	2,830	2,200
Palm Creek	20%	410	326	14%	2,440	2,100
Popash Creek	14%	540	467	11%	2,010	1,790
Powell Creek	11%	1,300	1,160	18%	2,210	1,810
Southeast Cape Coral	9%	180	164	24%	1,648	1,260
Stroud Creek	20%	940	755	12%	2,340	2,050
Telegraph Creek	20%	440	353	14%	2,654	2,270
Trout Creek	25%	250	188	13%	2,430	2,120
Whiskey Creek	12%	170	150	33%	1,210	806
Coastal Sub-watershed	***0%***	***171***	***171***	***14%***	***1,982***	***1,710***
Durden Creek	0%	22	22	12%	2,010	1,770
Northwest Cape Coral	0%	70	70	14%	1,450	1,250
Sanibel Island	0%	221	221	14%	2,292	1,980
Southwest Cape Coral	0%	243	243	14%	1,250	1,080

Notes:

1. The Reference Period for the Tidal Caloosahatchee Sub-watershed is WY2006-2012.
2. The Reference Period for the Coastal Caloosahatchee Sub-watershed is WY2009-2012.
3. The Annual Concentration Limit is the maximum observed monthly concentration during the reference period, adjusted by the nutrient reduction goal.
4. Source control reduction goals for TN also account for background TN concentrations, as represented by 90 percent of the historical TON concentration.
5. Target and Limit concentrations are rounded to whole ppb and/or three significant digits, which may have slightly revised the percent reduction.

References

Bottcher and Harper. 2003. Estimation of Best Management Practices and Technologies Phosphorus Reduction Performance and Implementation Costs in the Northern Watershed of Lake Okeechobee. Letter report to South Florida Water Management District, West Palm Beach, FL.

Bottcher, A.B. 2006. Phosphorus Reduction Performance and Implementation Costs under BMPs and technologies in the Lake Okeechobee Protection Plan Area. Letter Report to South Florida Water Management District, West Palm Beach, FL.

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Harper, H. H. 2003. Evaluation of Runoff Load Reductions from Urban Land Uses. Submitted to South Florida Water Management District as Attachment 2 to the Bottcher and Harper Letter Report (Bottcher and Harper, 2003).

Harper, H. H. and D.M. Baker. 2007. Evaluation of Current Stormwater Design Criteria within the State of Florida. Final Report prepared by Environmental Research and Design for the Florida Department of Environmental Protection, Tallahassee, FL.

HDR Engineering, Inc. 2011. Data Analysis And Performance Measure Development For The St. Lucie River Watershed Source Control Program; Deliverable 6.1 Collective Source Control Performance Measures for St. Lucie River Watershed Technical Report, prepared for the South Florida Water Management District, September 2011.

SFWMD (South Florida Water Management District). 2011. South Florida Environmental Report. West Palm Beach, FL.

SWET (Soil and Water Engineering Technology, Inc.). 2008. Final Report For Project Entitled Nutrient Loading Rates, Reduction Factors and Implementation Costs Associated with BMPs and Technologies, First Revision. Prepared for the South Florida Water Management District, West Palm Beach, FL.

APPENDIX D – ADJUSTMENTS TO ACCOUNT FOR REGIONAL PROJECTS

1. The Annual Load Target and Annual Load Limit may be adjusted for regional projects according to the following equations.

   a. Calculate the area adjustment factor (AAF)

AAF = (total basin area minus area of regional project) / (average area in Base Period)

   b. Adjust the Annual Load Target for the regional projects

adjusted Annual Load Target = AAF * Annual Load Target

   c. Calculate the adjusted Annual Load Limit using basin-specific equations in Section 3 using the adjusted Annual Load Target calculated above.

2. The annual Runoff Load will be adjusted for regional projects according to the following equations.

   a. Calculate the regional project load reduction as the annual load entering the regional project from the watershed less the annual load leaving the regional project and returning to the watershed

regional project load reduction = regional project inflow load – regional project outflow load

   a. Calculate the basin's Runoff Load as the load observed at the basin discharge monitoring location(s) minus the pass-through loads

Runoff Load = observed outflow load – pass-through load

   b. Adjust the basin's Runoff Load by the regional project load reduction

adjusted Runoff Load = Runoff Load + regional projects load reduction

Example

total basin area = 100,000 acres

area of regional project = 5,000 acres

average area in Base Period = 100,000 acres

AAF = (total basin area minus area of regional project) / (average area in Base Period)

AAF = (100,000 – 5,000) / (100,000) = 0.95

Annual Load Target = 20 mt (from prediction equation)

adjusted Annual Load Target = 0.95 * 20.0 mt = 19.0 mt

Annual Load Limit = adjusted Annual Load Target + 1.43976 SE (from prediction equation)

Annual Load Limit = 19.0 mt + 1.43976 (3.5) = 24.0 mt

regional project inflow load = 8.5 mt

regional project outflow load = 3.5 mt

regional project load reduction = regional project inflow load – regional project outflow load

regional project load reduction = 8.5 mt – 3.5 mt = 5 mt

adjusted Runoff Load = Runoff Load + regional projects load reduction

Runoff Load = observed outflow load – pass-through load

observed load at basin outlet structures = 16.0 mt

pass-through load = 2.5 mt

Therefore,

adjusted Runoff Load = 16.0 mt – 2.5 mt + 5 mt = 18.5 mt

ATTACHMENT 1 – ASSOCIATED EXCEL SPREADSHEETS

The following Excel spreadsheets containing the relevant data analyses are attached by reference to this Draft *Technical Support Document*.

S-4/Industrial Canal Sub-watershed spreadsheets:

DRAFT PM1 Stats S4IC TP – 9 30 2013

DRAFT PM2 Stats S4IC TP - 9 30 2013

MC 14 S4IC TP – 9 30 2013

(07-12-12) Revised SB-S-4_LU_95_UnitLoads XP

DRAFT PM1 Stats S4IC TN - 9 30 2013

DRAFT PM2 Stats S4IC TN - 9 30 2013

MC 16 S4IC TN – 9 30 2013

DRAFT PM1 Stats S4IC TON - 9 30 2013

DRAFT PM2 Stats S4IC TON - 9 30 2013

MC 16 S4IC TON – 9 30 2013

(11-02-12) S4 Industrial Canal

S-4/Industrial Canal Sub-watershed SKT files

East Caloosahatchee Sub-watershed spreadsheets:

DRAFT PM1 Stats EC TP – 9 30 2013

DRAFT PM2 Stats EC TP – 9 30 2013

MC 1 EC TP - 9 30 2013

(07-12-12) Revised SB-S-4_LU_95_UnitLoads XP

DRAFT PM1 Stats EC TN - 9 30 2013

DRAFT PM2 Stats EC TN – 9 30 2013

MC 16 EC TN - 9 30 2013

DRAFT PM1 Stats EC TON - 9 30 2013

DRAFT PM2 Stats EC TON – 9 30 2013

MC 16 EC TON - 9 30 2013

(11-02-12) East Caloosahatchee

East Caloosahatchee Sub-watershed SKT files

West Caloosahatchee Sub-watershed spreadsheets:

DRAFT PM1 Stats WC TP - 9 30 2013

DRAFT PM2 Stats WC TP – 9 30 2013

MC 19 sqrt(L) WC TP – 9 30 2013

DRAFT PM1 Stats WC TN - 9 20 2012

DRAFT PM2 Stats WC TN – 9 30 2013

MC 35 WC TN – 9 30 2013

DRAFT PM1 Stats WC TON - 9 30 2013

DRAFT PM2 Stats WC TON – 9 30 2013

MC 35 WC TON – 9 30 2013

(11-02-12) West Caloosahatchee

West Caloosahatchee Sub-watershed SKT files

Tidal Caloosahatchee Sub-watershed spreadsheets:

DRAFT PM1 Stats Tidal TP with rain – 9 30 2013

DRAFT PM1 Stats Tidal TN with rain – 9 30 2013

DRAFT PM1 Stats Tidal TON with rain – 9 30 2013

Draft – Tidal Tributary Concentrations – 9 26 2013

Tidal Sub-watershed SKT files

Coastal Caloosahatchee Sub-watershed spreadsheets:

DRAFT PM1 Stats Coastal TP – 9 30 2013

DRAFT PM1 Stats Coastal TN – 9 30 2013

DRAFT PM1 Stats Coastal TON – 9 30 2013

Draft – Coastal Tributary Concentrations – 9 26 2013

Coastal Sub-watershed SKT files

CRW Loads – 7 19 2013

CRW Rainfall – 7 15 13

Spreadsheets prepared by Ximena Pernett

(9-20-13) Landuse Comparison

(9-20-13) TMDL-BMAP-CRWPP Comparison

Spreadsheet in support of 2012 update to CRWPP

CRWPP11_WQ_2011_12_15