SOUTH FLORIDA WATER MANAGEMENT DISTRICT

PERFORMANCE MEASURE METHODOLOGIES FOR COLLECTIVE SOURCE CONTROLS IN THE ST. LUCIE RIVER WATERSHED

DRAFT – TECHNICAL SUPPORT DOCUMENT: ST. LUCIE RIVER WATERSHED PERFORMANCE METRIC METHODOLOGIES

South Florida Water Management District

In Association With

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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.

(24) "Adjusted Rainfall" means the calculated rainfall that reflects the cumulative effect of the multiple variables that comprise the Annual Load Target equation. The annual performance determination will be suspended if the adjusted rainfall for the Evaluation Year is outside the range observed during the Base Period and the basin's Runoff Load exceeds the Annual Load Target.

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 for the Lake Okeechobee Watershed under the authority of the Surface Water and Improvement Management (SWIM) Act. This act declares that many natural surface water systems in Florida, including the Indian River Lagoon (IRL), have been or are becoming degraded. 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 Caloosahatchee River and the St. Lucie 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 for the Caloosahatchee River and St. Lucie River Watersheds, (Chapter 62.302 and 62.303 F.A.C). 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 C-44 Sub-watershed in the St. Lucie River Watershed, these metrics are not in alignment with the current water quality goals for the Lake Okeechobee and the St. Lucie 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 5-year moving average target load of 16.84 mt/yr for the Eastern Region, which includes inflows into Lake Okeechobee from the C-44 Sub-watershed at S-308. Additionally, TMDLs have been established for the St. Lucie Basin requiring a reduction of TP and TN from the discharges from the St. Lucie River Watershed (FDEP 2008). The NEEPP mandates that the district or the 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 St. Lucie River Watershed (**Figure 1-1**) recommended for consideration in amendments to Chapter 40E-61, F.A.C. Similar *Draft Technical Support Documents* were prepared for the Lake Okeechobee Watershed[1] and the Caloosahatchee River Watershed (Gary Goforth, Inc.

[1] Differences between the Lake Okeechobee Watershed technical support document and this document are identified in a companion memorandum (SFWMD 2013b).

2013a and 2013b). 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 of the data on which they are based.

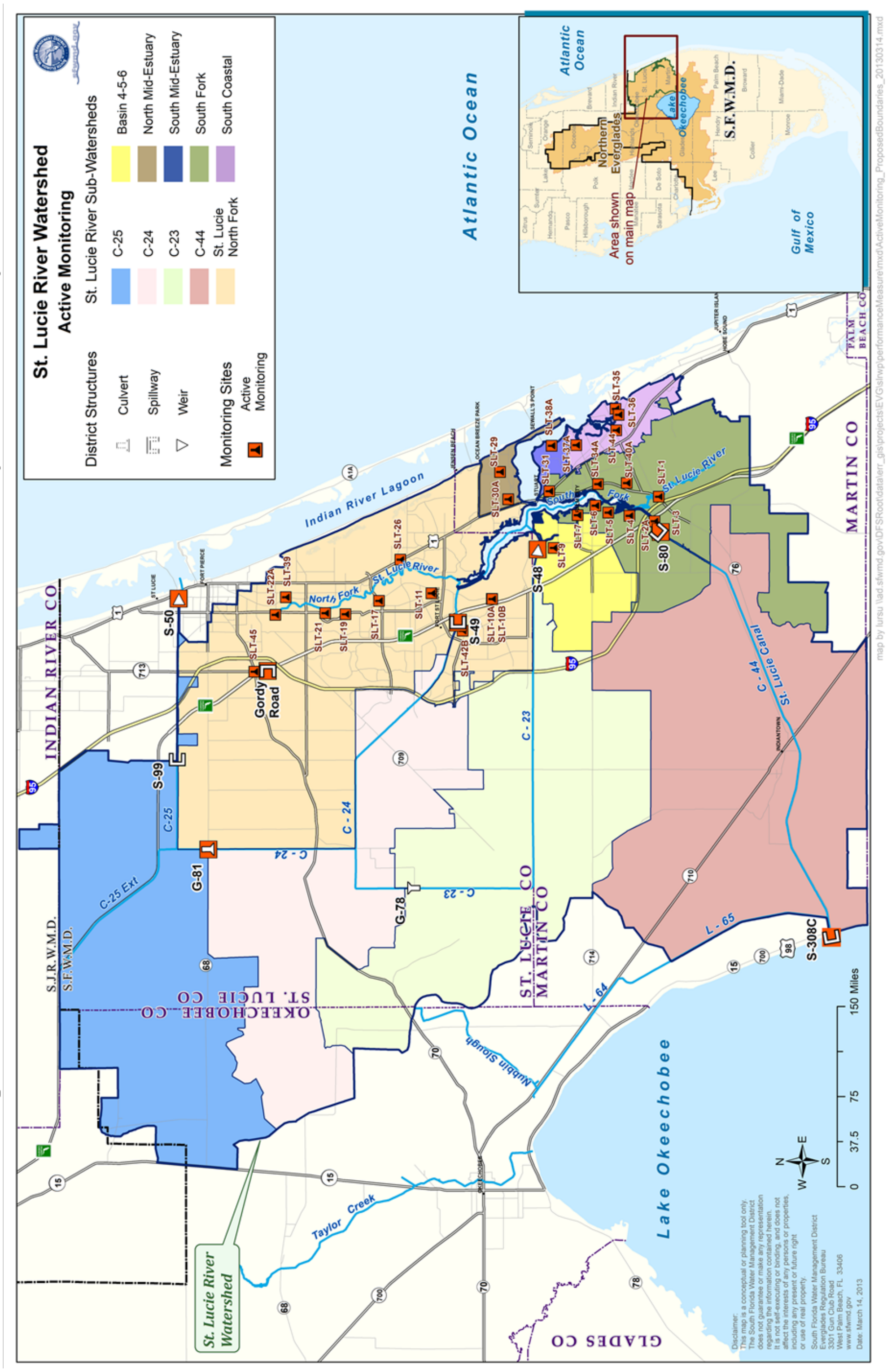


Figure 1-1. Sub-watersheds within the St. Lucie River Watershed (from SFWMD 2013)

Performance measures are typically nutrient loads incorporating hydrologic variability based on a representative base period dataset. Performance measures are proposed for 73 percent of the SLR Watershed: the C-23, C-24, C-25 and C-44 Sub-watersheds, and for the Ten Mile Creek basin within the North Fork Sub-watershed (**Table 1-1**). Performance indicators are recommended when all the criteria for establishing a performance measure are not met but a numeric nutrient level can be derived from historic data measured during a representative range of conditions. For a composite area made up of 17 tributaries representing the remaining six sub-watersheds, performance indicators are proposed. These 17 tributaries make up 36 percent of the six sub-watersheds that the composite metric represents. An additional 43 percent will be gained at 12 recently established sampling locations, and it is anticipated that performance metrics will be derived for these sites after a sufficient period of data collection[2]. 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 current 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.

[2] The remaining five percent of the St. Lucie River Watershed is unmonitored.

Table 1-1. Summary of Basins within the St. Lucie River Watershed.

Sub-watershed / Basin		Area (acres)	Performance Metric (PM) or Performance Indicator (PI)
C-23		110,872	PM
C-24		83,359	PM
C-25		99,726	PM
C-44		132,705	PM
North Fork	Ten Mile Creek	39,726	PM
	Five Mile Creek	9,022	PI
	Platts Creek	4,685	PI
	C-105	3,730	PI
	C-107	2,544	PI
	PSL Ditch 6	1,414	PI
	Hog Pen Slough	13,983	PI
	Elkcam Waterway	5,415	PI
	Canal 40	9,506	Future metric
	E-8 Canal	16,432	Future metric
	Blakely's Creek North		Future metric
	Blakely's Creek South		Future metric
South Fork	Fern Creek	599	PI
	Frazier Creek	377	PI
	Coral Gardens Ditch	2,093	PI
	South Fork	27,027	Future metric
	Hog Creek	3,765	Future metric
	Roebuck Creek	3,128	Future metric
	Mapps Creek	7,583	Future metric
	Piper's Ditch		Future metric
	All American Ditch	735	Future metric
Basins 4-5-6	Danforth Creek	3,931	PI
	Bessey Creek	9,237	PI
North Mid-Estuary	Warner Creek	1,111	PI
	Hainey Creek	1,301	Future metric
South Mid-Estuary	North Airport Ditch	1,178	PI
South Coastal	Salerno Creek	960	PI
	Manatee Creek	812	PI
	Willoughby Creek	487	PI
	East Fork	4,887	Future metric
Unmonitored Areas		35,181	To be determined
Total Area (acres)		***637,512***	

Pink shaded basins make-up the Composite Area
Blue shaded basins make-up Other Monitored Areas

Note: Basin acreage for other monitored areas are preliminary estimates and may be refined upon further investigation.

1.2 Performance Metric Methodologies Development

A load-based performance metric methodology is proposed for the C-23, C-24, C-25, C-44 Sub-watersheds and the Ten Mile Creek basin within the North Fork Sub-watershed. 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) load for each basin were calculated based on available historical data through Water Year 2013 (WY2013) 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, Caloosahatchee River and St. Lucie 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-weighed 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 Composite Area, and hence concentration-based performance metric methodologies are proposed for this area. The following general activities were conducted to develop the performance metric methodologies for this area.

1. Monthly nutrient concentration data for each of the seventeen basins within the Composite Area were compiled through WY2013 for representative water quality monitoring stations. A single water quality monitoring station was selected within each basin (encompassing the most acreage) to measure the collective source control performance while optimizing the monitoring costs that would be required to track performance in the long-term.

2. A WY2003-2012 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. 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 the Composite Area using monthly basin data.

3. Nutrient reduction goals were calculated based on work completed in the development of the watershed protection plans for Lake Okeechobee, Caloosahatchee River and St. Lucie 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 C-23, C-24, C-25, C-44 Sub-watersheds and the Ten Mile Creek basin. 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/basins are defined in **Sections 3.1, 3.2** and **3.3**.

A concentration-based performance metric methodology is proposed for the seventeen basins which make up the composite area. 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 basins are defined in **Sections 3.4** and **3.5**. Twelve additional basins are being monitored for TP and TN concentration and will be compared to the composite Annual Concentration Target and an Annual Concentration Limit to evaluate whether development of an individual metric would be warranted. The conceptual proposal is that if a basin exceeds the composite metric and increasing trends are observed development of an individual metric would be warranted.

The performance metric indicates how the sub-watershed/basin 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 five percent of the SLRW). 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 1.2 through **1.11** present the performance metrics for the C-23, C-24, C-25, C-44 Sub-watersheds and the Ten Mile Creek basin. 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 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

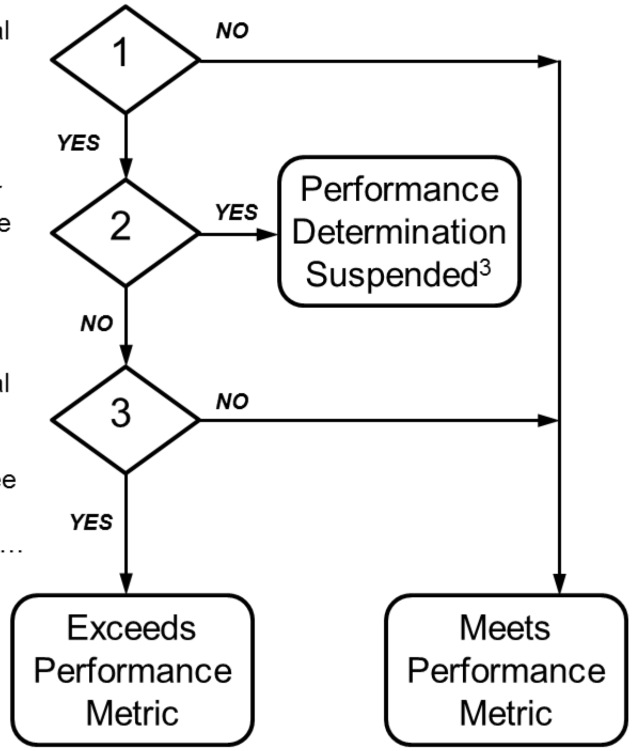
S_m = the average value of the rainfall skewness in the base period

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

Figures 1-4 through **1-13** present predicted annual nutrient loads derived from the Base Period data using a zero percent load reduction. The solid red lines show the five-year trend of load differences (observed vs. predicted), the solid blue line shows the preliminary source control reduction goal, while the diamond (♦) symbols represent the annual difference.

Figure 1-2. Flowchart - annual nutrient performance determination for C-23, C-24, C-25, C-44 Sub-watersheds and the Ten Mile Creek Basin.

1. Does the calculated annual runoff load[1] exceed the Annual Load Target[2]?
2. Is the water year rainfall or adjusted rainfall outside the range observed during the Base Period?
3. Does the calculated annual runoff load …
   a) exceed the Annual Load Target for three consecutive years (excluding suspension), or …
   b) exceed the Annual Load Limit[4]?

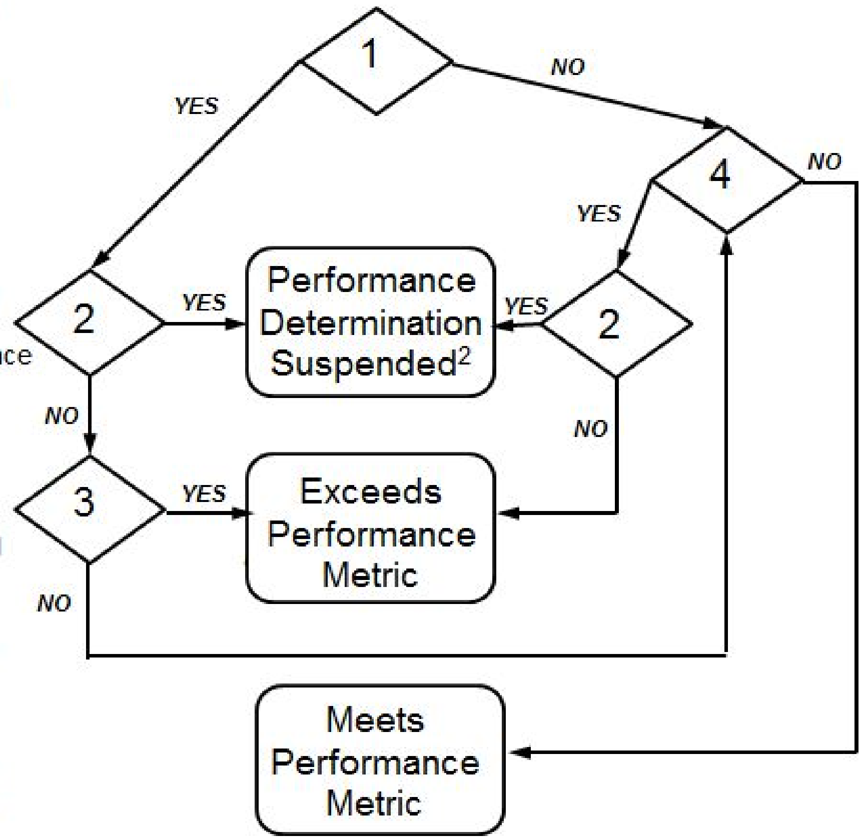


Notes:

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 Load 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 Composite Area and Tributaries with Concentration Targets and Limits.

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?



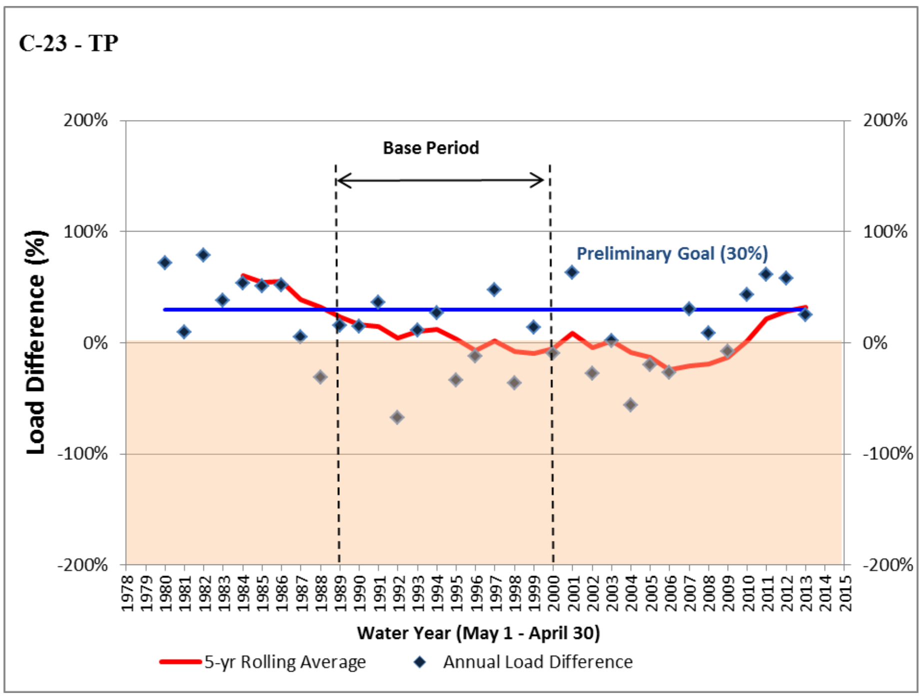
Notes:

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.
3. This assessment will be done for the composite area, and if the performance metric is not met, the individual tributaries would be assessed against their individual target and limits, if available.

Table 1-2. C-23 Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
51.112	86%	36.99	80.43
Target = -106.48094 + 2.1002 X + 63.27232 C			
Limit = Target + 1.38303 SE			
SE = 13.67884 [1 + 1/12 + 0.00073 $(X\text{-}X_m)^2$ + 2.19257 $(C\text{–}C_m)^2$ + -0.01966 $(X\text{-}X_m)$ $(C\text{–}C_m)$]$^{0.5}$			
Adjusted Rainfall = X + 30.12681 (C – 0.6870)			

[1] Based on adjusted rainfall values



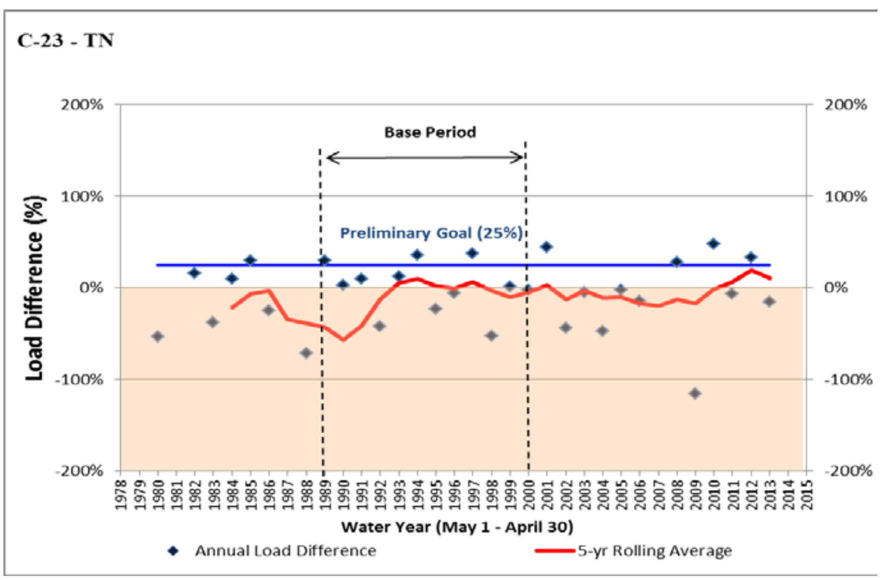
Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-4. C-23 Sub-watershed TP load trend.

Table 1-3. C-23 Sub-watershed TN Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
227.4	TN-based: 82% TON-based: 82%	38.42 / 38.46	78.46 / 78.10
Target = maximum of the following: TN-based Prediction = -1773.53909 + 451.15444 X + 390.33189 C + -132.06292 S TON-based Prediction = -1756.08502 + 447.85423 X + 383.5997 C - 133.76593 S			
Limit = Target + 1.39682 SE			
$SE_{TN} = 57.78788 [1 + 1/12 + 2.03637 (X-X_m)^2 + 8.69123 (S–S_m)^2 + 1.5039 (C-C_m)^2 + 0.44458 (X-X_m) (S–S_m) - 0.63412 (X-X_m) (C-C_m) + -6.26942 (S-S_m) (C-C_m)]^{0.5}$ $SE_{TON} = 57.65722 [1 + 1/12 + 2.03637 (X-X_m)^2 + 8.69123 (S–S_m)^2 + 1.5039 (C-C_m)^2 + 0.44458 (X-X_m) (S–S_m) - 0.63412 (X-X_m) (C-C_m) - 6.26942 (S-S_m) (C-C_m)]^{0.5}$			
TN-based Adjusted Rain = exp [X + 0.86518 (S-S_m) + -0.29272 (C – C_m)] TON-based Adjusted Rain = exp [X + 0.85653 (S-S_m) - 0.29868 (C – C_m)]			

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

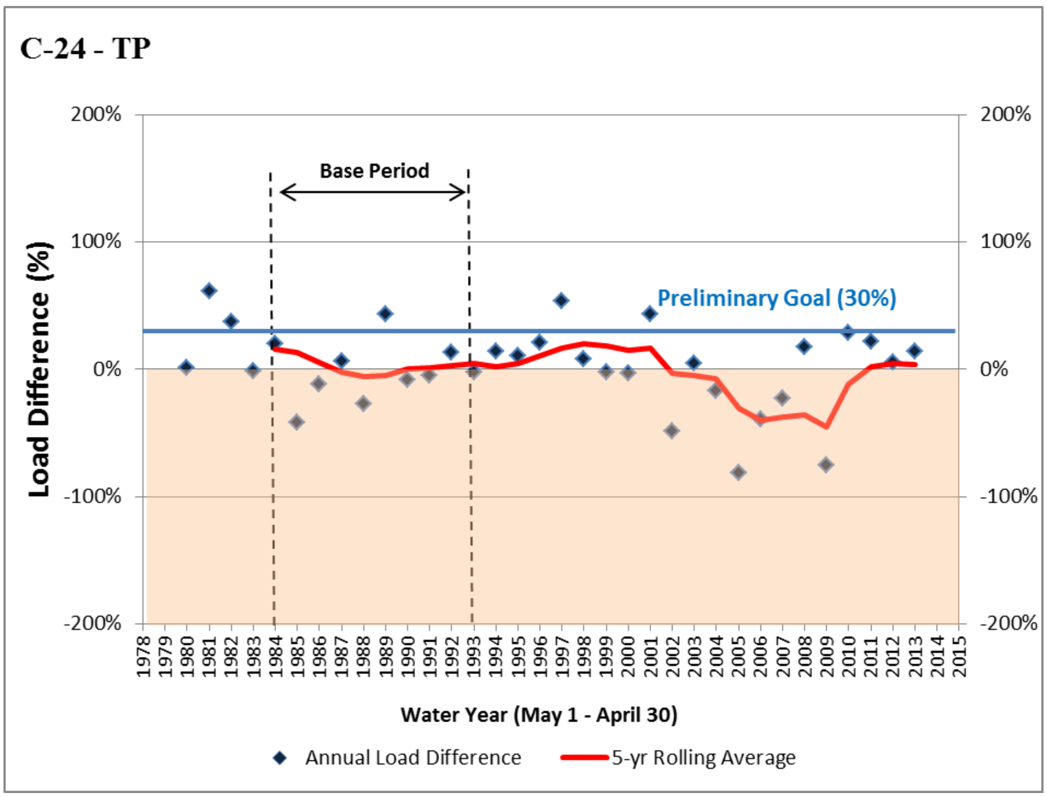


Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-5. C-23 Sub-watershed TN load trend.

Table 1-4. C-24 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
46.6	90%	33.81	68.51
Target = -35.78181 + 1.59471 X			
Limit = Target + 1.39682 SE			
$SE = 6.68247 [1 + 1/10 + (X-X_m)^2 / 1258.31109]^{0.5}$			

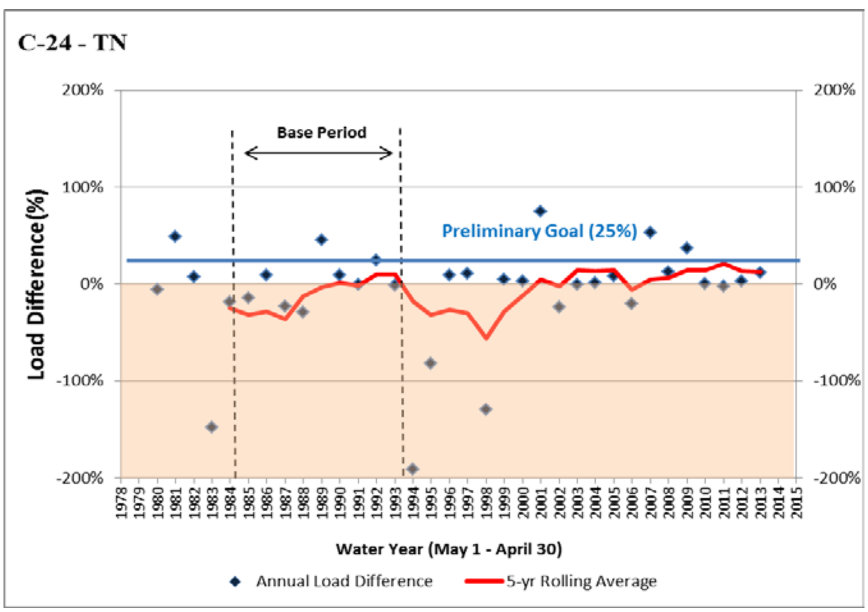


Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-6. C-24 Sub-watershed TP load trend.

Table 1-5. C-24 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
242.7	TN-based: 84% TON-based: 79%	31.24 / 33.81	75.82 / 68.51
Target = maximum of the following: TN-based Prediction = -308.32361 + 5.42005 X + 338.54912 C TON-based Prediction = -106.01203 + 6.11018 X			
TN-based UCL = TN-based Prediction + 1.41492 SE TON-based UCL = TON-based Prediction + 1.39682 SE			
$SE_{TN} = 37.63828\ [\ 1 + 1/10 + 0.00085\ (X\text{-}X_m)^2 + 17.37836\ (C\text{–}C_m)^2 - 0.0607\ (X\text{-}X_m)\ (C\text{–}C_m)\ ]^{0.5}$ $SE_{TON} = 39.84675\ [\ 1 + 1/10 + (X\text{-}X_m)^2 / 1258.31109]^{0.5}$			
TN-based Adjusted Rain = Observed Rain + 62.46190 (C – 0.7219)			



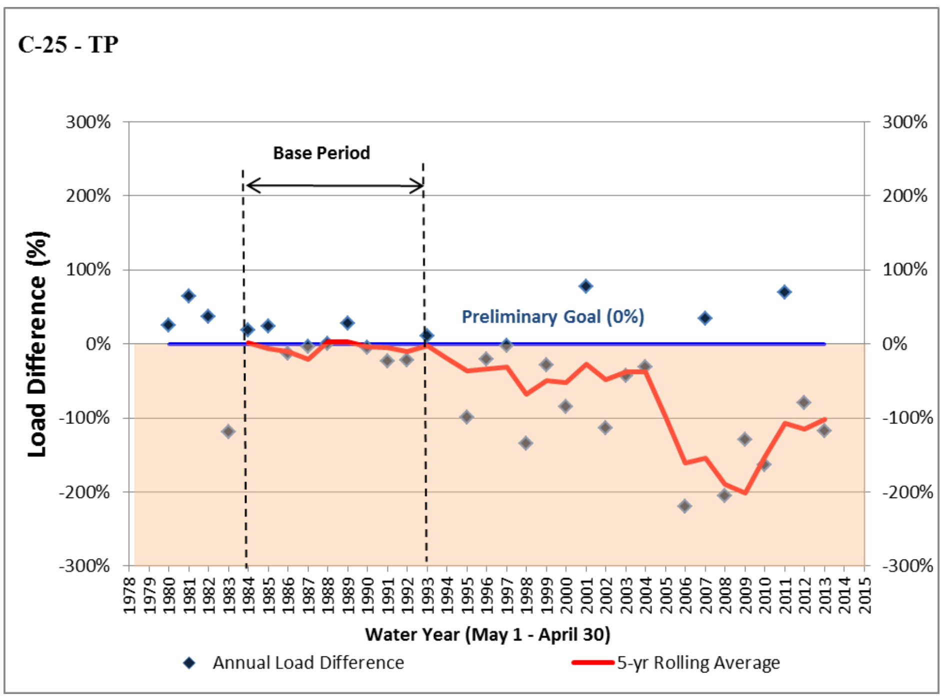
Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-7. C-24 Sub-watershed TN load trend.

Table 1-6. C-25 Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
18.6	88%	34.61	79.45
Target = -57.1881 + 0.74377 X + 58.79717 C			
Limit = Target + 1.41492 SE			
SE = 4.39487 [1 + 1/10 + 0.00154 $(X-X_m)^2$ + 7.87856 $(C–C_m)^2$ - 0.04036 $(X-X_m)$ $(C–C_m)$ $]^{0.5}$			
Adjusted Rainfall = X + 79.05289 (S – 0.7146)			

[1] Based on adjusted rainfall values



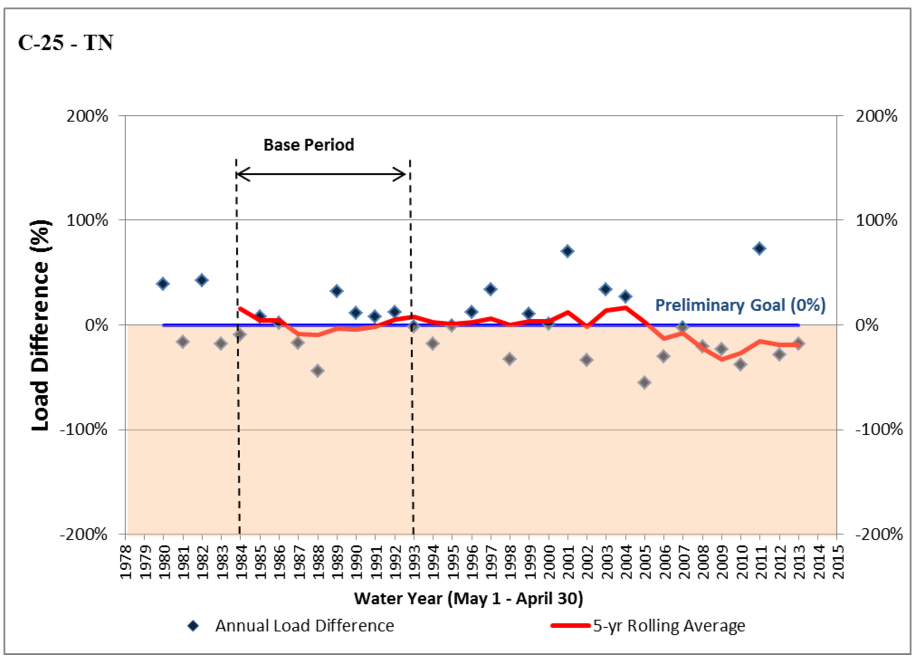
Notes: A positive load difference denotes a reduction in load in comparison to the base period.
An upward trend in the solid line denotes a reduction in loads.

Figure 1-8. C-25 Sub-watershed TP load trend.

Table 1-7. C-25 Sub-watershed TN Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
207.6	TN-based: 91% TON-based: 89%	39.75 / 39.81	72.44 / 71.96
Target = maximum of the following: TN-based Prediction = -453.2327 + 9.59569 X + 261.04618 C TON-based Prediction = -369.24022 + 7.2623 X + 221.87635 C			
Limit = Target + 1.41492 SE			
$SE_{TN} = 33.03366\ [1 + 1/10 + 0.00154\ (X\text{-}X_m)^2 + 7.87855\ (C\text{–}C_m)^2 - 0.04036\ (X\text{-}X_m)\ (C\text{–}C_m)]^{0.5}$ $SE_{TON} = 29.48874\ [1 + 1/10 + 0.00154\ (X\text{-}X_m)^2 + 7.87855\ (C\text{–}C_m)^2 - 0.04036\ (X\text{-}X_m)\ (C\text{–}C_m)]^{0.5}$			
TN-based Adjusted Rainfall = X + 27.20452 (C – 0.7146) TON-based Adjusted Rainfall = X + 30.5518 (C – 0.7146)			

[1] Based on adjusted rainfall values



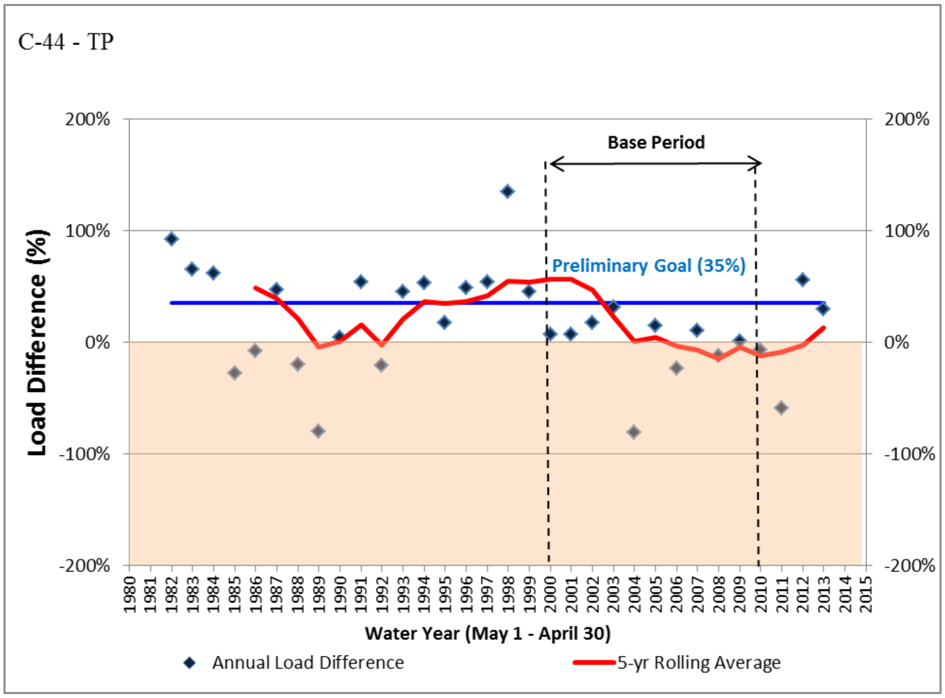
Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-9. C-25 Sub-watershed TN load trend.

Table 1-8. C-44 Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall[1] Minimum inches	Maximum inches
52.861	84%	29.81	61.38
Target = exp [-6.32749 + 2.47799 X + 0.32325 S]			
Limit = Target * exp [1.39682 SE]			
$SE = 0.28246 [1 + 1/11 + 2.17751 (X\text{-}X_m)^2 + 0.37714 (S–S_m)^2 - 0.19126 (X\text{-}X_m) (S–S_m)]^{0.5}$			
Adjusted Rainfall = exp [X + 0.13045 (S - 0.88018)]			

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

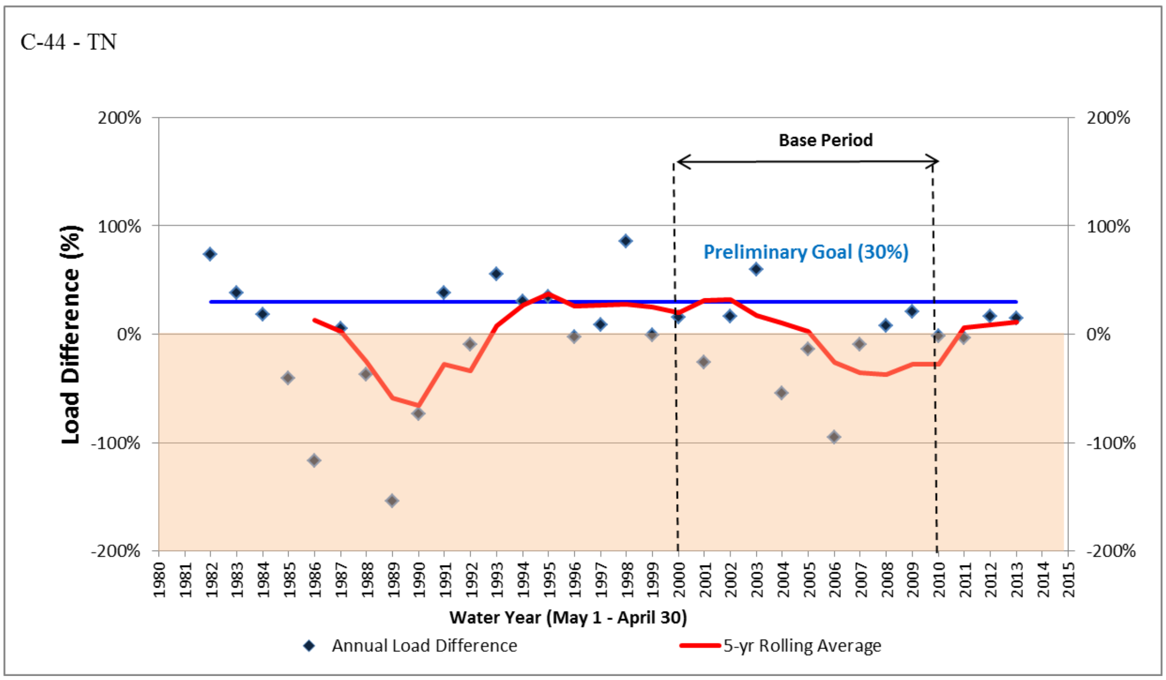


Notes: A positive load difference denotes a reduction in load in comparison to the base period. An upward trend in the solid line denotes a reduction in loads.

Figure 1-10. C-44 Sub-watershed TP load trend.

Table 1-9. C-44 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
283.54	TN-based: 63% TON-based: 63%	30.41	59.63
Target = maximum of the following: TN-based Prediction = exp (2.60861 + 0.05614 X) TON-based Prediction = exp (2.15967 + 0.06371 X)			
Limit = Target * exp (1.38303 SE)			
SE_{TN} = 0.42839 * sqrt [1 + 1/11 + $(X-X_m)^2$ / 883.57225] SE_{TON} = 0.48584 *sqrt [1 + 1/11 + $(X-X_m)^2$ / 883.57225]			



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 1-11. C-44 Sub-watershed TN load trend.

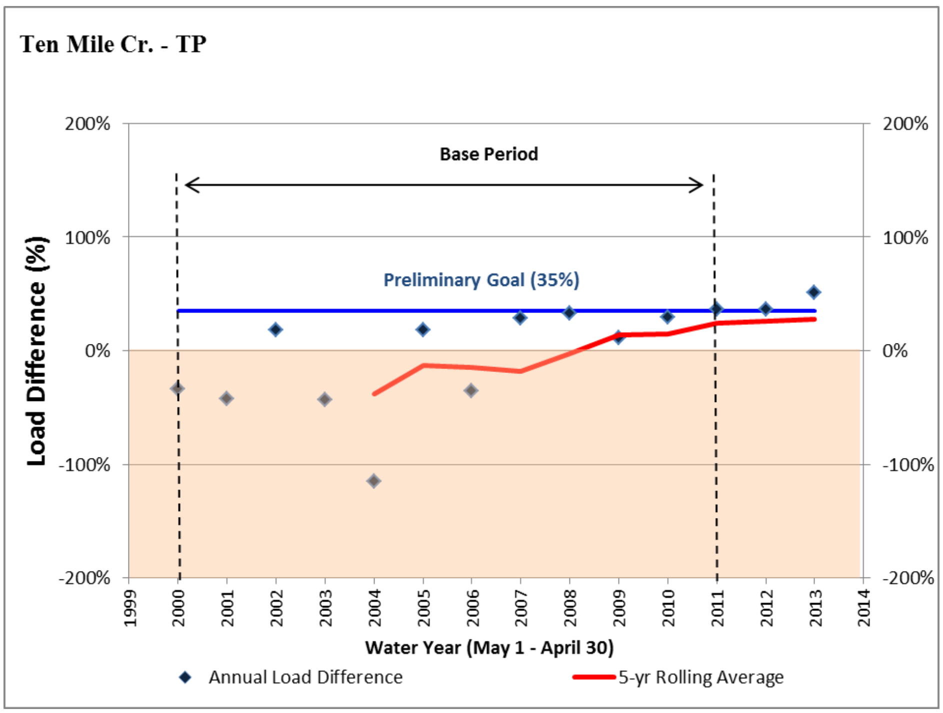
Table 1-10. Ten Mile Creek Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance (R^2)	Base Period Rainfall[1] Minimum inches	Maximum inches
60.8	79%	19.23	108.11
Target = exp (-3.69291 + 1.50647 X + 1.29272 S - 2.3533 C)			
Limit = Target * exp (1.39682 SE)			
$SE = 0.46271 [1 + 1/12 + 1.09047 (X-X_m)^2 + 0.6778 (S–S_m)^2 + 7.01426 (C-C_m)^2 - 0.32174 (X-X_m) (S–S_m) + 0.90494 (X-X_m) (C-C_m) - 3.72828 (S-S_m) (C-C_m)]^{0.5}$			
Adjusted Rain = exp [X + 0.85811 (S – 0.78725) - 1.56213 (C + 0.18227)]			

[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 CV 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 1-12. Ten Mile Creek Sub-Basin TP load trend.

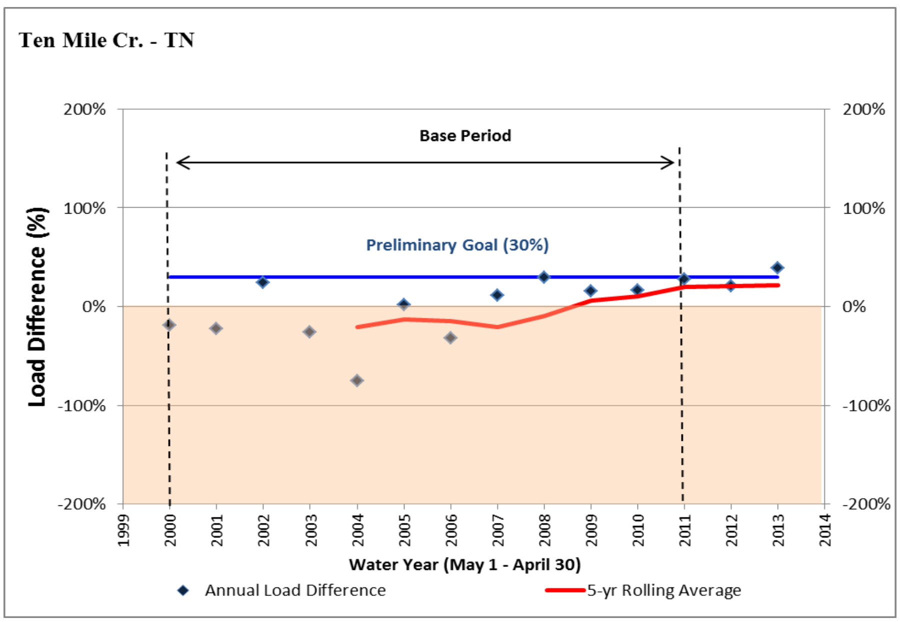
Table 1-11. Ten Mile Creek Basin TN Load Performance Measure.

<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[1]</th></tr>
<tr><th>Minimum
inches</th><th>Maximum
inches</th></tr>
<tr><td>203.9</td><td>TN-based: 82%
TON-based: 83%</td><td>21.03 / 21.02</td><td>95.28 / 96.44</td></tr>
<tr><td colspan="4">Target = maximum of the following:
TN-based Prediction = exp (-1.37646 + 1.30696 X + 1.03374 S - 2.18739 C)
TON-based Prediction = exp (-1.23302 + 1.28806 X + 1.02466 S - 2.13252 C)</td></tr>
<tr><td colspan="4">Limit = Target * exp (1.39682 SE)</td></tr>
<tr><td colspan="4">$SE_{TN} = 0.33503 [1 + 1/12 + 1.09051 (X-X_m)^2 + 0.67782 (S–S_m)^2 + 7.01447 (C-C_m)^2 – 0.32176 (X-X_m) (S–S_m) + 0.90496 (X-X_m) (C-C_m) - 3.72838 (S-S_m) (C-C_m)]^{0.5}$
$SE_{TON} = 0.3257 [1 + 1/12 + 1.09051 (X-X_m)^2 + 0.67783 (S–S_m)^2 + 7.0145 (C-C_m)^2 – 0.32176 (X-X_m) (S–S_m) + 0.90498 (X-X_m) (C-C_m) - 3.7284 (S-S_m) (C-C_m)]^{0.5}$</td></tr>
<tr><td colspan="4">TN-based Adjusted Rainfall = exp [X + 0.79094 (S - 0.78725) - 1.67364 (C + 0.18227)]
TON-based Adjusted Rainfall = exp [X + 0.79551 (S - 0.78725) - 1.65561 (C + 0.18227)]</td></tr>
</table>

[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 CV 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 1-13. Ten Mile Creek Basin TN load trend.

Table 1-12 summarizes the performance metrics for the sub-watersheds/basins of the St. Lucie River Watershed. The metrics for the Composite Area 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.

Table 1-12. Performance Metrics for the St. Lucie River Watershed.

Sub-watershed / Basin		Area (acres)	Nutrient	Performance Metric	Base Period	Recommended Source Control	
C-23		110,872	TP	Performance Measure	WY1989-2000	30%	
			TN	Performance Measure		25%	
C-24		83,359	TP	Performance Measure	WY1984-1993	30%	
			TN	Performance Measure		25%	
C-25		99,726	TP	Performance Measure	WY1984-1993	0%	
			TN	Performance Measure		0%	
C-44		132,705	TP	Performance Measure	WY2000-2010	35%	
			TN	Performance Measure		30%	
North Fork	**Ten Mile Creek**	39,726	TP	Performance Measure	WY2000-2011	35%	
			TN	Performance Measure		30%	
					Reference Period	**Target**	**Limit**
Composite Area		61,579	TP	Performance Indicator	WY2003-2012	10%	17%
			TN	Performance Indicator		10%	11%

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. This act declares that many natural surface water systems in Florida, including the Indian River Lagoon (IRL), have been or are becoming degraded. 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 Caloosahatchee River and the St. Lucie 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 for the Caloosahatchee River and St. Lucie 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 C-44 Sub-watershed in the St. Lucie

River Watershed, these metrics are not in alignment with the current water quality goals for the Lake Okeechobee and the St. Lucie 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 5-yr moving average target load of 16.89 mt/yr for the Eastern Region, which includes the C-44 Sub-watershed. Additionally, TMDLs have been established for TP, TN and dissolved oxygen for most of the basins within the St. Lucie River Watershed, with an associated Basin Management Action Plan (FDEP 2008, FDEP 2013). The NEEPP mandates that the district or the 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 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 C-23, C-24, C-25 and C-44 Sub-watersheds and the Ten Mile Creek basin of the North Fork Sub-watershed. Performance indicators are generally concentration-based and may be based on the central tendency of a multi-year dataset. For an area consisting of seventeen basins to the remaining six sub-watersheds (referred to as the "Composite Area"), 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 St. Lucie 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 nutrient Total Maximum Daily Loads (TMDLs) for the St. Lucie River and Estuary, a comparison between the performance metrics proposed herein and the reduction goals of the St. Lucie 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 St. Lucie River Watershed. **Section 3.1** presents the TP and TN performance metrics for the C-23 Sub-watershed. **Section 3.2** presents the TP and TN performance metrics for the C-24 Sub-watershed. **Section 3.3** presents the TP and TN performance metrics for the C-25 Sub-watershed. **Section 3.4** presents the TP and TN performance metrics for the C-44 Sub-watershed. **Section 3.5** presents the TP and TN performance metrics for the Ten Mile Creek basin. **Section 3.6** presents the TP and TN performance metrics for the Composite Area. **Appendix A** presents supplemental technical details of the derivation of the St. Lucie 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. **Appendix E** provides an algorithm to deal with small sample sizes. 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.

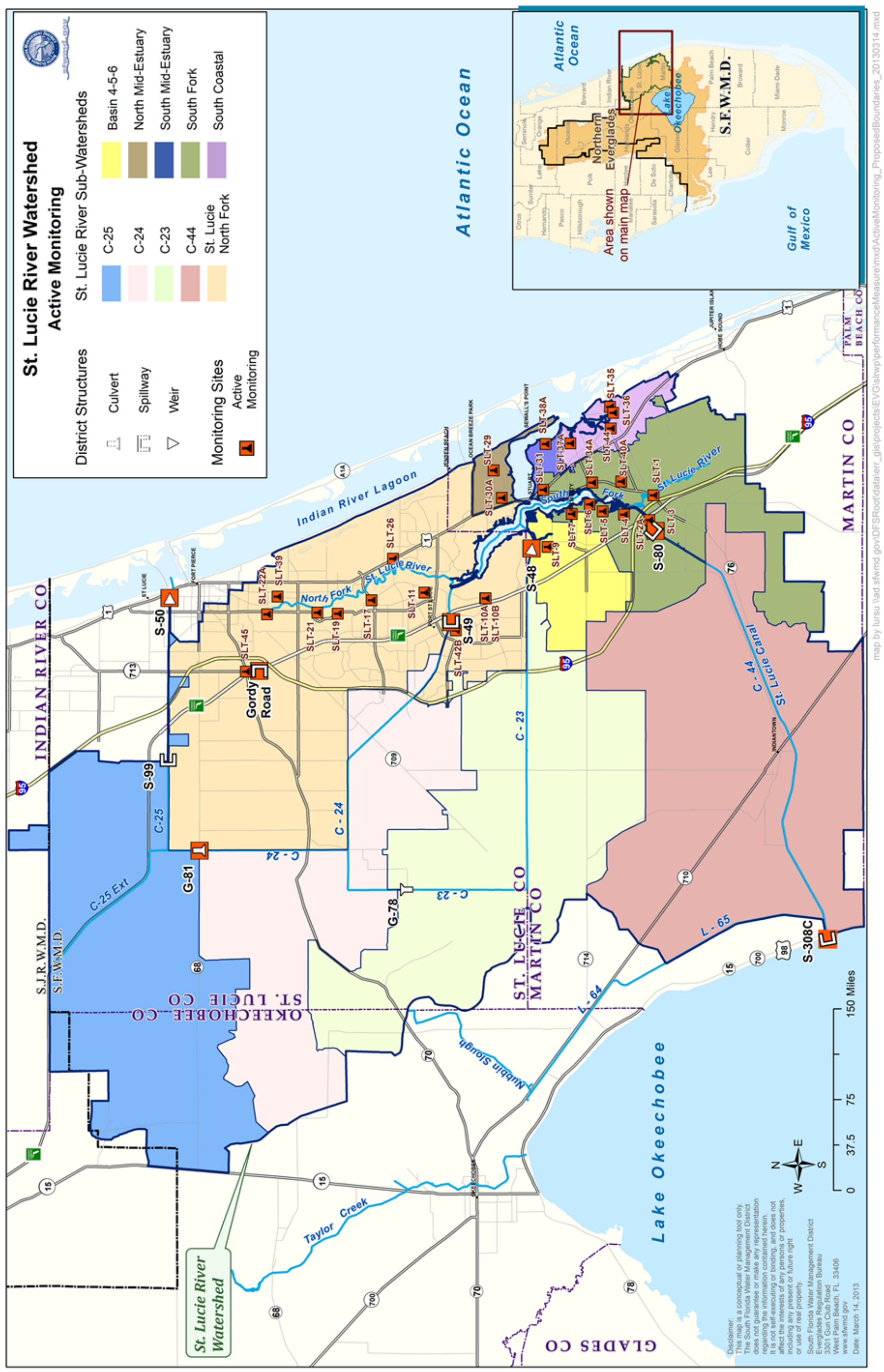
2.2 Authorization and Scope

This *Draft Technical Support Document* was developed under the provisions of Purchase Order PC 4500064757 - Professional Services in Support of St. Lucie River Source Control Program Regulatory Performance Measures between the District and Gary Goforth, Inc. (GGI) dated January 5, 2012, and amended in May 2012, September 2012, January 2013, September 2013 and October 8, 2013. 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). Historical data analyses and preliminary development of performance metrics for the St. Lucie River Watershed were prepared by HDR Engineering, Inc. (HDR 2011).

2.3 Background

The St. Lucie River Watershed includes much of Martin and St. Lucie counties, and a small portion of Okeechobee County at the northwest corner (**Figure 2-1**). It encompasses a drainage area of more than 635,000 acres and includes areas that drain naturally or are pumped, and the major canals that discharge into the either the North or South Forks of the St. Lucie River (C-23, C-24 and C-44). The single largest land use is agricultural citrus, which encompasses approximately 23 percent of the total watershed. Improved pasture is second, accounting for approximately 21 percent of the watershed, and wetland natural areas are third, accounting for approximately 12 percent. Urban areas are typical of the eastern reaches of the watershed and account for approximately 16 percent of the total area. Drainage basins within the St. Lucie River Watershed are generally defined by topography and empty into a specific tributary or canal that connects to the St. Lucie Estuary. Basin names typically coincide with the major drainage conveyance within the basin. For example, the C-44 Canal is the major drainage conveyance canal within the C-44 Basin. The St. Lucie River Watershed contains ten sub-watersheds that may consist of one or more basin:

Figure 2-1. Sub-watersheds within the St. Lucie River Watershed (from SFWMD 2013)



1. C-23 Sub-watershed,
2. C-24 Sub-watershed,
3. C-25 Sub-watershed,
4. C-44 Sub-watershed[3],
5. North Fork Sub-watershed,
6. South Fork Sub-watershed,
7. Basins 4-5-6 Sub-watershed,
8. North Mid-Estuary Sub-watershed,
9. South Mid-Estuary Sub-watershed, and
10. South Coastal Sub-watershed.

The North and South Forks of the St. Lucie River flow into the St. Lucie Estuary. The estuary extends downstream to Hell's Gate, where it enters the Indian River Lagoon. The St. Lucie River Watershed provides tremendous business and recreational opportunities for both year-round and seasonal residents (SFWMD et al. 2012). 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 river and 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 St. Lucie 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

[3] The C-44 Sub-watershed is also contained in the Lake Okeechobee Watershed since part of the runoff from this basin is directed to the lake during certain storm events.

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.

2.3.1 History of Source Controls in the St. Lucie 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 St. Lucie River Watershed (SLRW). A summary of the source control implementation time frame for the SLRW 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

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

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 enacted
1989	Chapter 40E-61, F.A.C., the Lake Okeechobee Works of the District Rule adopted by SFWMD which included the C-44 and S-153 Basins.
1989	SWIM Plan developed for Indian River Lagoon by St. John's River Water Management District and South Florida Water Management District
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
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)
2008	Nutrient and Dissolved Oxygen TMDLs are adopted for the St Lucie Basin
2011	FDACS amends BMP Rule 5M-3 to the entire Northern Everglades
2012	FDEP Numeric Nutrient Criteria approved by US EPA
2012	Elimination of land application of biosolids, unless a nutrient management plan is developed
2013	The Best Management Action Plan for the Implementation of TMDL for Nutrients and Dissolved Oxygen is adopted by FDEP

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 1986, 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 St. Lucie 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 Indian River Lagoon (IRL) SWIM Plan was developed in 1989 and updated in 1994 and 2002 directing the St. Johns River and South Florida Water Management Districts, with the cooperation of state agencies and local governments, to design and implement a plan for the improvement of surface waters and habitats in the IRL. The Lake Okeechobee SWIM Plan, which included the C-44 sub-watershed, was prepared in 1989 and the TP load target for Lake Okeechobee at that time was 360 metric tons. These SWIM Plans have led to the implementation of many initiatives that have been directed at improving the quality of water discharged to the St. Lucie River Watershed. Information about projects initiated as a part of the SWIM programs can be found in the 1989, 1994, and 2002 SWIM Plan Reports (SFWMD 1989, SFWMD 1994, 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 C-44 and S-153 Basins. Landowners in the C-44 and S-153 basins were issued no notice general permits. At the time the rule became effective, the assumption was that landowners were in compliance until their monitoring data indicated otherwise. Rule Chapter 40E-61 is scheduled to be amended to incorporate the requirements of the most recent legislation (NEEPP). At that time, the boundary of the rule will be expanded to include the St. Lucie River Watershed.

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 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 October 2008, FDEP adopted the St Lucie Basin TMDL for total nitrogen (TN) and total phosphorus (TP) for the estuary. In May 2013, FDEP completed the first phase of the Basin Management Action Plan (BMAP) by allocating approximately one third of the TP and TN load reductions required to achieve the estuary TMDL to existing and future projects in a subset of basins.

PROGRAMS THAT BEGAN IN THE 2000s

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

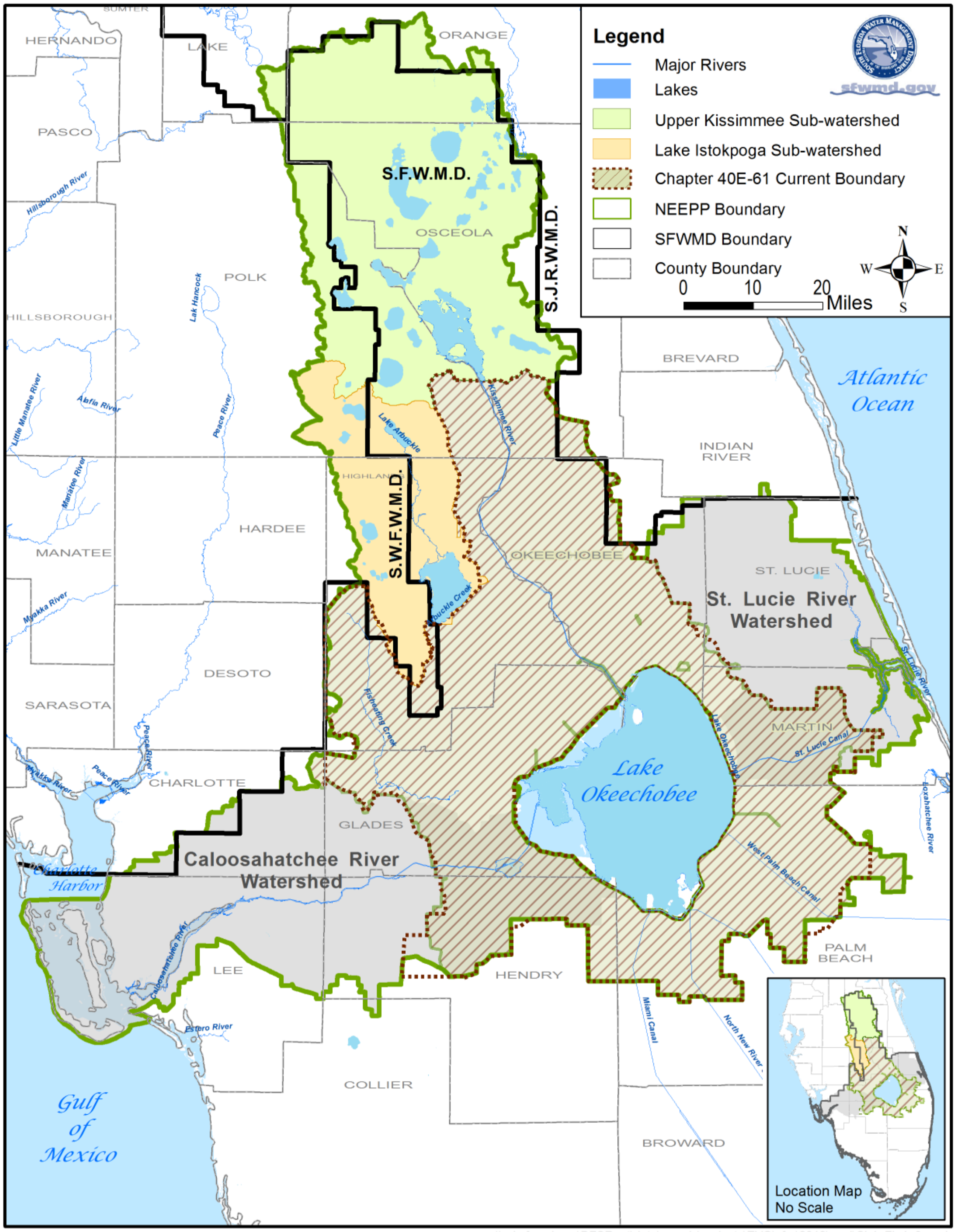
In 2000, the Florida legislature revised the Lake Okeechobee SWIM statute and it became the Lake Okeechobee Protection Act (LOPA) (Section 373.4595, F.S.) The LOPA required the

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.

In 2007, LOPA was subsumed by Northern Everglades and Estuaries Protection Program (NEEPP), which further refined the responsibilities of the coordinating agencies for the Lake Okeechobee, and also mandated the development and implementation of protection programs to reduce pollutant loadings, restoration of the natural hydrology, and compliance with applicable water quality standards (TMDL) for the St Lucie and Caloosahatchee watersheds. One of the programs being a Pollutant Control Program including (1) continued implementation of existing regulations and incentive-based BMPs, consistent with the Lake Okeechobee control program, (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, St. Lucie 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 St. Lucie 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).

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



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 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 2-2**.

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 St. Lucie River

Table 2-2. 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 St. Lucie River and St. Lucie River watersheds.

[3]Applicable to only the Lake Okeechobee Watershed.

[4]Partially funded by FDEP.

[5]No reductions considered.

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 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 2008). Florida's 303(d) list identifies impaired water segments and the basis for impairment.

In 2008, FDEP adopted a nutrient TMDL for the St. Lucie Basin (**Table 2-3**). The final TMDL for the St. Lucie Basin is 0.720 mg/L of TN and 0.081 mg/L of TP (Rule 62-302, Florida Administrative Code (FAC); FDEP 2008). The inland portion of the St. Lucie Estuary is composed of the South Fork and North Fork. The two forks converge at the Roosevelt Bridge to form a single waterbody that extends eastward, where it joins the Indian River Lagoon (IRL). Stormwater runoff, Lake Okeechobee deliveries and a limited number of point sources from six of the ten basins within the St. Lucie River Watershed (SLRW) contribute nutrient loads to the St. Lucie Estuary:

1. Basin 4-5-6 Sub-watershed,
2. C-23 Sub-watershed,
3. C-24 Sub-watershed,
4. C-44 and S-153 Sub-watershed,
5. North Fork Sub-watershed, and
6. South Fork Sub-watershed.

Table 2-3. Load Allocation (LA) as established in the FDEP TMDL (2008).

Waterbody	Parameter	Daily TMDL Loading	LA (% Reduction)	MOS
St. Lucie Estuary (3193)	TN	0.72 mg/L	21.4	Implicit
	TP	0.081 mg/L	41.3	Implicit
North Fork St. Lucie River (3194)	TN	384 lbs	25.0	Implicit
	TP	43 lbs	42.2	Implicit
	BOD	2.0 mg/L	74.0	Implicit
North Fork St. Lucie Estuary (3194B)	TN	284 lbs	28.8	Implicit
	TP	32 lbs	58.1	Implicit
C-24 Canal (3197)	TN	956 lbs	51.8	Implicit
	TP	108 lbs	72.2	Implicit
	BOD	2.0 mg/L	33.3	Implicit
C-23 Canal (3200)	TN	664 lbs	51.7	Implicit
	TP	75 lbs	78.6	Implicit
South Fork St. Lucie Estuary (3210)	TN	67 lbs	38.4	Implicit
	TP	8 lbs	57.2	Implicit
South Fork St. Lucie River (3210A)	TN	248 lbs	47.1	Implicit
	TP	28 lbs	61.8	Implicit
Bessey Creek (3211)	TN	82 lbs	23.9	Implicit
	TP	9 lbs	51.2	Implicit
C-44 Canal (3218)	TN	666 lbs	51.2	Implicit
	TP	75 lbs	55.0	Implicit
	BOD	2.0 mg/L	69.7	Implicit

Note: Margin of Safety (MOS) takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS can be Explicit meaning a portion of the loading capacity is "set aside" before the allocations are determined, or Implicit meaning conservative assumptions were used in developing the TMDL.

The C-25/C-25E, North Mid-Estuary, South Mid-Estuary, and South Coastal Sub-watersheds contribute nutrient loads to the IRL downstream of the Roosevelt Bridge, the St. Lucie Basin TMDL compliance point.

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 May 2013, FDEP completed a BMAP to address the first phase of TN and TP reductions required from the St. Lucie Basin towards achieving the St. Lucie Basin TMDL.

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 St. Lucie Basin TMDL (SFWMD 2012, FDEP 2013). The 2013 St. Lucie Basin BMAP (FDEP 2013) and the 2012 update to the St. Lucie River Watershed Protection Plan (SLRWPP) 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.

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 and TP 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 SLRW performance metric methodologies are described below.

1. Geographic Scope.

FDEP TMDL. The nutrient TMDLs do not apply to the entire St. Lucie River Watershed, as do the performance metrics described herein. The nutrient TMDLs apply only to nine basins of the watershed: St. Lucie River Lower Estuary, North Fork St. Lucie River, North St. Lucie Estuary, C-24, C-23, South Fork St. Lucie River, South St. Lucie Estuary, Bessey Creek, and the C-44 Canal[4]. The BMAP addresses TN and TP and loads reduced by 21.4 percent and 41.3 percent, respectively. The TMDL for the C-44 includes nutrient contributions from Lake Okeechobee releases.

SLRW Performance Metric Methodology. Performance metric methodologies are presented herein for all ten sub-watersheds of the St. Lucie River Watershed, each of which has the ability to discharge to the St. Lucie River and Estuary, including C-23, C-24, C-25 (via G-81 into the C-24 basin), C-44, North Fork, South Fork, Basins 4-5-6, North Mid-estuary, South Mid-estuary, and South Coastal. The performance metric for C-44 only addresses local runoff and separates nutrient contributions from Lake Okeechobee releases.

2. Annual Targets and Limits for TP and TN.

FDEP TMDL. Table 2-4 identifies the nutrient TMDLs for the St. Lucie Basin, and includes concentration targets of 81 µg/L for TP and 720 µg/L for TN for the lower estuary. For the first phase of the BMAP, projects that have been completed since 2000, or are expected to be complete within the first five-year iteration, were given project credits. The BMAP calls for projects and activities necessary to achieve reductions of 143.4 metric tons per year (mt/yr) of TN and 55 mt/yr of TP. Out of this total reductions,

[4] The remaining portions of the watershed were not considered in the 2008 TMDL because they already have TMDLs associated with them, are scheduled for TMDL development in the future, or have significant water improvement projects underway within their boundaries.

46.3 mt/yr of TN (32 percent) and 15.5 mt/yr of TP (28 percent) consist of projects indicated as complete (FDEP 2013)[5]. Project implementation during the first five year iteration count toward the total required reductions. The assessment for entities meeting their allocations is that the listed BMAP projects, or equivalent loading reduction projects, are completed in each iteration of the BMAP.

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

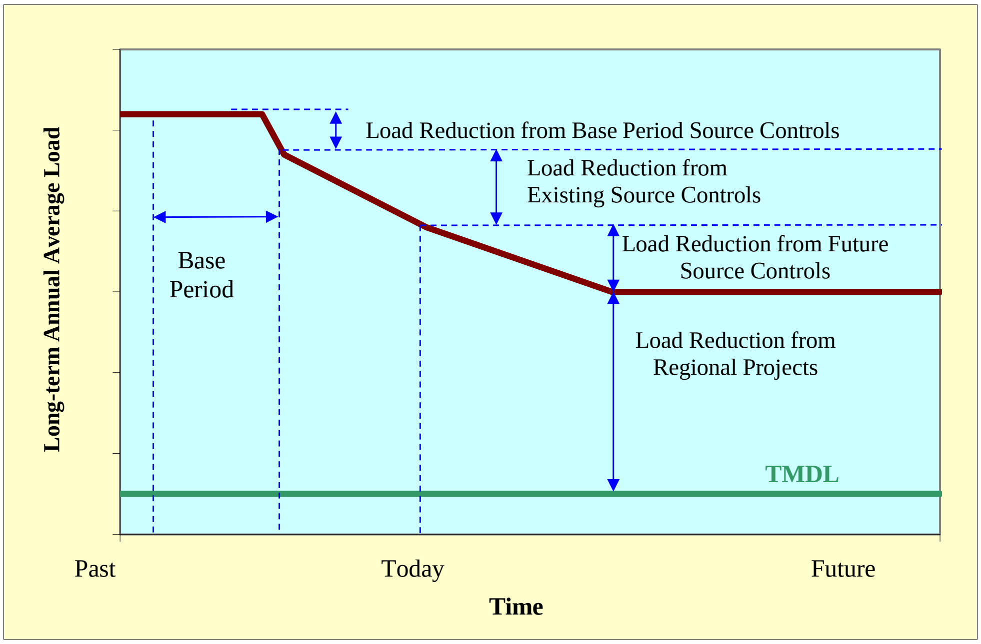
3. **Achievement of the St. Lucie Basin TMDL.**

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

SLRW 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 St. Lucie Estuary TMDL. Although an apples-to-apples comparison of the St. Lucie Estuary TMDL and the performance metrics is not feasible given the difference in methodologies, the relationship between the goals may be exemplified as follows.

[5] This estimate does not include agricultural credits based on existing enrolled NOIs. The agricultural required TP and TN load reductions exceed the total SLRW TP and TN load reductions required by the BMAP. During the first iteration of the BMAP, FDACS will work with FDEP to determine the agricultural load more accurately and recalculate the remaining reductions needed (FDEP 2013).

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



- The TMDL TN and TP load to the estuary from the C-23, C-24, and C-44/S-153 Sub-watersheds combined is approximately 344 mt/year and 38 mt/year, respectively (FDEP 2013), while the sum of the TN and TP performance metrics for these basins based on the Base Period median loads and reductions, as presented in **Table 2-4**, is approximately 551 mt/year and 103 mt/year, respectively. Because observed flows from all other sub-watersheds are not available, a comparison of loads from those areas is not presented.

Table 2-4. Comparison of TN and TP loads for the C-23, C-24, and C-44 sub-watersheds.

	Total Nitrogen (TN)				Total Phosphorus (TP)			
	TMDL/BMAP		This Technical Support Document		TMDL/BMAP		This Technical Support Document	
Sub-watershed	Baseline TN Load (mt/yr)	TMDL TN Load (mt/yr)	Base Period TN Load (mt/yr)	After Source Controls TN Load (mt/yr)	Baseline TP Load (mt/yr)	TMDL TP Load (mt/yr)	Base Period TP Load (mt/yr)	After Source Controls TP Load (mt/yr)
C-23	226	104	227	171	79	11	51	36
C-24	304	136	243	182	75	15	47	33
C-44 & S-153	242	105	284	198	43	13	53	34
Load to Estuary	**772**	**344**	**754**	**551**	**197**	**38**	**151**	**103**

- The TMDL TN and TP concentrations to the estuary from the North Fork, South Fork, and Basin 4-5-6 Sub-watersheds combined are approximately 628 ppm and 71 ppb respectively, while the TN and TP performance metrics for these basins based on the Reference Period median concentrations and reductions, as presented in **Table 2-5**, are approximately 757 ppm and 93 ppb, respectively.

4. The receiving water body, or bodies.

FDEP TMDL. The TMDL is based on achieving water quality standards for TP, TN for the St Lucie River and Estuary. Since it was estimated by FDEP that 42 percent of the freshwater discharges to the estuary are from Lake Okeechobee, achieving the St. Lucie and Estuary TMDLs is contingent on reducing nutrient loads from Lake Okeechobee. The St. Lucie River and Estuary TMDLs assume that the Lake Okeechobee TP TMDL has been met. In addition, the BMAP assumes that only 76.5 percent of the runoff from the C-44/S-153 basin runoff flows to the St. Lucie estuary, while the remaining 23.5

percent of the runoff flows to Lake Okeechobee, therefore only 76.5 percent of the runoff is applied to allocate nutrient loads in the BMAP.

Table 2-5. Comparison of TN and TP concentrations for the North Fork, South Fork, and Basin 4-5-6 sub-watersheds.

	Total Nitrogen Concentration (TN)				Total Phosphorus Concentration (TP)			
	TMDL/BMAP		This Technical Support Document		TMDL/BMAP		This Technical Support Document	
Sub-watershed	Baseline TN (ppm)	TMDL TN (ppm)	Base Period TN (ppm)	After Source Controls TN (ppm)	Baseline TP (ppb)	TMDL TP (ppb)	Base Period TP (ppb)	After Source Controls TP (ppb)
North Fork	1180	642	841	757	266	72	103	93
South Fork	1303	627	841	757	274	71	103	93
Basins 4-5-6	1113	529	841	757	251	60	103	93
Concentration to Estuary	**1209**	**628**	**841**	**757**	**267**	**71**	**103**	**93**

Note: The concentrations presented for the Technical Support Document for the Basin 4-5-6, North Fork, and South Fork sub-watersheds represent data from the seventeen tributaries that make up the composite area, therefore does not reflect each sub-watershed individually

SLRW Performance Metric Methodology. The performance metrics described herein establish technology-based annual nutrient targets and limits for TP and TN 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 total nutrient load at the source instead of to what receiving body it is directed to. Contributions from external sources are accounted for via calculation of pass-through load to individually measure performance and no assumptions regarding discharges to individual water bodies are made.

5. **Potentially different evaluation periods.**

FDEP TMDL. For the St. Lucie Basin BMAP, FDEP will organize the monitoring data, track project implementation, and present this information in an annual report. An assessment will be conducted every five years to determine whether there is reasonable progress in implementing the BMAP and achieving pollutant load reductions (FDEP 2013). Anticipated outcomes of BMAP implementation are the "modest improvement in water quality trends in the watershed tributaries and the St Lucie River and Estuary" and "Decreased loading of the target pollutants (TN, TP and BOD)". For reference, the BMAP discusses the Seasonal Kendall Tau Tests comparing concentration, nutrient load, salinity, and DO data between 1995 – 2005 and 2006 – 2010 (SFWMD 2012a).

SLRW 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 nutrient levels are below or above the long-term goal.

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

FDEP TMDL. For the St. Lucie Estuary TMDL, the TN and TP targets were estimated from the 2004 IRL-S Plan model, using flows and nutrient concentrations for the five-year period from 1999 through 2004. These targets were selected based on consistency with four other St. Lucie Estuary target development methods and best professional judgment of local scientists and stakeholders based on their knowledge of the estuary.

SLRW 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 ten to twelve years.

2.4.2 St. Lucie River Watershed Protection Plan

The 2012 update to the *St. Lucie River Watershed Protection Plan* (SLRWPP) 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. These are summarized in **Tables 2-6** through **Table 2-8**. The objectives of the projects and programs within the SLRWPP 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 SLRWPP, two general types of source controls are identified and simulated using spreadsheet tools for each of the sub-watersheds.

1. Projected reductions resulting from source control BMPs, and
2. Projected reductions resulting from ongoing dispersed, local and regional projects.

Table 2-6. Summary of estimated TN load reductions described in the SLRWPP.

Sub-watershed TN	Baseline TN Load (mt/yr)	TN Load Reductions (mt/yr)						TN Loads after all Reductions (mt/yr)
		Source Controls			*Dispersed/ Local/Regional Projects*			
		Current	Near-Term	Long-Term	Current	Near-Term	Long-Term	
Basins 4 5 6	31.4	0.9	1.5	4.1	0.1	0.0	0.0	24.9
C-23	286.9	34.3	6.4	7.3	0.0	0.6	107.1	131.2
C-24	348.0	45.3	9.9	12.8	0.0	0.1	53.4	226.5
C-44&S-153	270.8	13.1	4.2	7.6	5.0	0.0	114.2	126.7
North Fork	170.8	6.9	8.4	20.6	6.3	4.4	20.1	104.0
South Fork	83.4	1.9	3.3	9.2	0.4	0.0	1.4	67.0
C-25/C-25E	-	-	-	-	-	-	-	-
Ten Mile Creek	-	-	-	-	-	-	-	-
Total TN Load	**1191.3**	**102.3**	**33.8**	**61.6**	**11.8**	**5.2**	**296.2**	**680.3**

Table 2-7. Summary of estimated TP load reductions described in the SLRWPP.

Sub-watershed TP	Baseline TP Load (mt/yr)	TP Load Reductions (mt/yr)						TP Loads after all Reductions (mt/yr)
		Source Controls			*Dispersed/ Local/Regional Projects*			
		Current	Near-Term	Long-Term	Current	Near-Term	Long-Term	
Basins 4 5 6	6.4	0.2	0.2	0.4	0.0	0.0	0.0	5.6
C-23	87.0	11.7	2.0	1.5	0.0	0.2	29.3	42.4
C-24	75.9	10.9	2.0	1.5	0.0	0.0	13.1	48.3
C-44&S-153	38.0	2.1	0.6	0.8	0.7	0.0	19.6	14.3
North Fork	40.3	1.0	0.8	1.5	2.2	1.0	7.0	26.7
South Fork	19.2	0.3	0.5	1.4	0.1	0.0	3.0	13.8
C-25/C-25E	-	-	-	-	-	-	-	-
Ten Mile Creek	-	-	-	-	-	-	-	-
Total TP Load	**266.8**	**26.3**	**6.1**	**7.1**	**3.1**	**1.3**	**71.9**	**151.1**

Table 2-8. Comparison of nutrient load reductions described in the SLRWPP with those in this Technical Support Document.

Source Control % Reductions	SLRWPP		Technical Support	
Sub-watershed	TN Reductions	TP Reductions	TN Reductions	TP Reductions
Basins 4 5 6	21%	11%	-	-
C-23	17%	17%	25%	30%
C-24	20%	19%	25%	30%
C-44&S-153	9%	9%	30%	35%
North Fork	21%	8%	-	-
South Fork	17%	12%	-	-
C-25/C-25E	-	-	0%	0%
Ten Mile Creek	-	-	30%	35%

The SLRWPP and the TMDL were developed in parallel, and are subject to refinement and/or update in the future. 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 SLRWPP 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 SLRWPP is that the nutrient reduction estimates were based on specific land use estimates of reasonable source controls developed by Soil and Water Engineering Technology, Inc. (Bottcher 2006, SWET 2008). In the SLRWPP, these estimates are used for planning purposes and to calculate the load reductions expected from implementation of agricultural and non-agricultural BMPs.

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

1. **Nutrient Reduction Estimates.**

   SLRWPP. The 2012 SLRWPP presents planning-level nutrient load reduction estimates for all sub-watersheds within the St. Lucie River Watershed (**Tables 2-6** through **2-8** above). The load reduction estimates in the 2012 SLRWPP reflect nutrient reductions resulting from all initiatives described in the SLRWPP, including both source control and regional projects (SFWMD 2012). Ideally, source control measures and regional projects described in the SLRWPP will combine to meet the applicable TMDL and other water quality objectives.

SLRW Performance Metric Methodology. A comparison of the load reduction targets between the SLRWPP and this Technical Support Document was summarized in **Table 2-8** above. Load-based performance metrics were developed for the C-23, C-24, C-25, Ten Mile Creek, and C-44 Sub-watersheds that account for hydrologic variability. In addition, concentration-based performance metrics were developed for the Composite Area (Basin 4-5-6, North Fork and South Fork) and its seventeen tributaries. The goal for the collective nutrient source control programs in the St. Lucie 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 making 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.**

SLRWPP. For the 2012 SLRWPP, 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.

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

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

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

SLRW 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.**

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

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

Summary of comparison with SLRWPP.

The comparison below presents a general idea of how the SLRWPP estimates and the performance metrics compare using the medians of the base period as reference (see **Table 2-9**). Please note that the performance metrics are not single constant numbers, but rather a series of steps for performance determination to account for hydrologic variability and statistical uncertainty. For example, the performance metrics for the C-23, C-24, C-25, C-44 and Ten Mile

Creek basins 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 Composite Area, 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. 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 2-9. Comparison of nutrient levels between the SLRWPP and the performance metrics within this Technical Support Document

	SLRWPP				Technical Support Document			
Sub-watershed TN	**Baseline TN Load (mt/yr)**	**Baseline TN Concentration (ppb)**	**TN Loads 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)**
Basins 4 5 6	31.4	1,176	25.0	934		841		757
C-23	286.9	1,575	238.9	1,312	227.4	1,305	170.6	
C-24	348.0	1,642	280.0	1,321	242.7	1,643	182.0	
C-44&S-153	270.8	1,571	245.9	1,426	283.5	1,448	198.5	
North Fork	170.8	1,182	134.9	934		841		757
South Fork	83.4	1,233	68.9	1,019		841		757
C-25/C-25E	-	-	-	-	207.6	1,361	207.6	
Ten Mile Creek	-	-	-	-	203.9	1,264	142.7	
Total TN Load	**1191.3**	**1,479**	**993.6**	**1,234**	**1165.1**		**901.4**	

	SLRWPP				Technical Support Document			
Sub-watershed TP	**Baseline TP Load (mt/yr)**	**Baseline TP Concentration (ppb)**	**TP Loads 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)**
Basins 4 5 6	6.4	239	5.7	212		103		93
C-23	87.0	478	71.9	395	51.1	306	35.8	
C-24	75.9	358	61.4	290	46.6	342	32.6	
C-44&S-153	38.0	220	34.5	200	52.9	266	34.4	
North Fork	40.3	279	36.9	256		103		93
South Fork	19.2	283	16.9	250		103		93
C-25/C-25E	-	-	-	-	18.6	137	18.6	
Ten Mile Creek	-	-	-	-	60.8	374	39.5	
Total TP Load	**266.8**	**331**	**227.3**	**282**	**230.0**		**160.9**	

Note: The concentrations presented for the Technical Support Document for the Basin 4-5-6, North Fork, and South Fork sub-watersheds represent data from the seventeen tributaries that make up the composite area, therefore does not reflect each sub-watershed individually.

Comparison of nutrient reduction estimates with SLRWPP

- For the C-23 and the C-24 Sub-watersheds, the protection plan long-term nutrient loads after implementation of source controls are higher than the medians of the performance metrics. These differences are explained by the planning estimates using a more recent baseline that has higher nutrient loads than the earlier baselines used for the performance metrics, and because of the use of lower source reduction percentages on the basis of partial implementation of BMPs in 30 percent of the row crop acreage, 50 percent of ornamentals and nurseries, and 80 percent of the citrus acreage, as annotated in the spreadsheet used for development of the 2012 SLRWPP Update.
- For the C-44 Sub-watershed, the TN plan long-term planning estimate after implementation of source controls is higher than the medians of the performance metrics. The difference is primarily due to the assumptions of partial implementation, as for C-23 and C-24, since the baselines are only within five percent. For TP for the C-44 Sub-watershed the comparison between the performance metrics and the planning estimates must consider both discharges to the St Lucie Watershed and to Lake Okeechobee. Therefore, please refer to Section 2.4.3 which consolidates this comparison.
- For the C-25 Sub-watershed the protection plan does not include specific reductions. However, performance metrics were developed under this document on the basis of maintaining the nutrient loads observed during the WY1984 - 1993 period when discharges from the C-25 to the C-24 basin occur.
- For the Basin 4-5-6 Sub-watershed, the South Fork Sub-watershed and the North Fork Sub-watershed (except for the Ten Mile Creek Basin), which are basins where a composite concentration-based performance metric is proposed due to limited measured flow data, the long-term planning concentration estimates after implementation of source controls are higher than the composite metric. This is because the modeled baselines used for planning are higher than the actual measured data which are used for the performance metric baselines.

2.4.3 Lake Okeechobee Protection Plan

The C-44 Sub-watershed is also part of the Lake Okeechobee Watershed since a portion of its basin loads discharge to the lake. The TP performance metric methodology proposed herein for this sub-watershed was compared to the *Lake Okeechobee Protection Plan*. 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 2-10**, 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 Sub-watershed 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.

Table 2-10. 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)			
	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)	Owner and Cost share Implemented BMPs (1)		Watershed P Control Projects (2)		Regional Public Works Projects (3)		Other Regional and Sub-Regional Projects (4)							
					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	236	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	138	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 C-44 Sub-watershed are described below. The Lake Okeechobee Protection Plan does not contain TN targets or limits and so no comparisons are made for that nutrient.

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, i.e., S-308 for the C-44 Sub-watershed.

   SLRW Performance Metric Methodology. The performance measure described herein establishes an annual TP target for the basin, and includes TP loads from all structures through which the basin can discharge. For example, the methodology for the C-44 Sub-watershed includes TP loads at S-308 (which discharges into Lake Okeechobee) combined with TP loads at S-80 (which discharges into the St. Lucie River).

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.

   SLRW 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.

SLRW Performance Metric Methodology. The goal for the collective TP source control programs in the Lake Okeechobee Watershed (and the St. Lucie 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.

SLRW 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.

   SLRW 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 C-44 Sub-watershed.

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).

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

Summary of comparison of TP reduction estimates with LOPP.

- For the C-44 Sub-watershed, the LOPP and the SLRWP propose a reduction of approximately 10% from a combined baseline of 51 mt of TP. The combined baseline is within 5% of the performance metric baseline. Same as for C-23 and C-24, the LOPP's long-term load estimates after implementation of source controls are higher than the median nutrient load based on the performance metric, and the basis is due to the assumptions of partial implementation of BMPs.

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 St. Lucie River Watershed.

2.5.1 Consideration of Pass-through Flows and Loads

The performance metric methodologies for the C-24, C-25 and C-44 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

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

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 C-23, C-24, C-25 and C-44 Sub-watersheds and the Ten Mile Creek basin, the Base Periods selected met, as much as possible, the above criteria:

- C-23 Sub-watershed: Base Period of WY1989-2000 (May 1988 – April 2000)
- C-24 Sub-watershed: Base Period of WY1984-1993 (May 1983 – April 1993)
- C-25 Sub-watershed: Base Period of WY1984-1993 (May 1983 – April 1993)
- C-44 Sub-watershed: Base Period of WY2000-2010 (May 1999 – April 2010)
- Ten Mile Creek Basin: Base Period of WY2000-2011 (May 1999 – April 2011)

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 2-11**).

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.

Table 2-11. 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 Rain)^2
38	sqrt(Load)	S, CV, Rain	Annual Load Target = (a + b1 S + b2 CV + b3 Rain)^2
39	sqrt(Load)	CV, S, K, Rain	Annual Load Target = (a + b1 CV + b2 S + b3 K + b4 Rain)^2
40	sqrt(Load)	Rain, last year's Rain	Annual Load Target = (a + b1 Rain + b2 (last yr's Rain))^2
41	sqrt(Load)	S, CV, Rain, last year's Rain	Annual Load Target = (a + b1 S + b2 CV + b3 Rain + b4 (last yr's Rain))^2
42	sqrt(Load)	CV, Rain	Annual Load Target = (a + b1 CV + b2 Rain)^2
43	sqrt(Load)	Rain, S	Annual Load Target = (a + b1 Rain b2 S)^2
44	sqrt(Load)	ln(Rain)	Annual Load Target = (a + b ln(Rain))^2
45	sqrt(Load)	ln(Rain), ln(last year's Rain)	Annual Load Target = (a + b1 ln(Rain) + b2 ln(last year's Rain))^2
46	sqrt(Load)	ln(Rain), S	Annual Load Target = (a + b1 ln(Rain) + b2 S)^2
47	sqrt(Load)	Ln(Rain), CV, S	Annual Load Target = (a + b1 ln(Rain) + b2 CV + b3 S)^2
48	sqrt(Load)	ln(Rain), CV, S, K	Annual Load Target = (a + b1 ln(Rain) + b2 CV + b3 S + b4 K)^2
49	sqrt(Load)	ln(Rain), CV	Annual Load Target = (a + b1 ln(Rain) + b2 CV)^2
50	sqrt(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)^2
51	sqrt(Load)	ln(Rain), ln(last year's Rain), CV	Annual Load Target = (a + b1 ln(Rain) + b2 ln(last year's Rain) +b3 CV)^2
52	sqrt(Load)	ln(Rain), S, CV*S	Annual Load Target = (a + b1 ln(Rain) + b2 S + b3 CV*S)^2
53	sqrt(Load)	ln(CV), ln(Rain)	Annual Load Target = (a + b1 ln(CV) + b2 ln(Rain))^2
54	sqrt(Load)	ln(CV), ln(Rain), S	Annual Load Target = (a + b1 ln(CV) + b2 ln(Rain) + b3 S)^2

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. 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

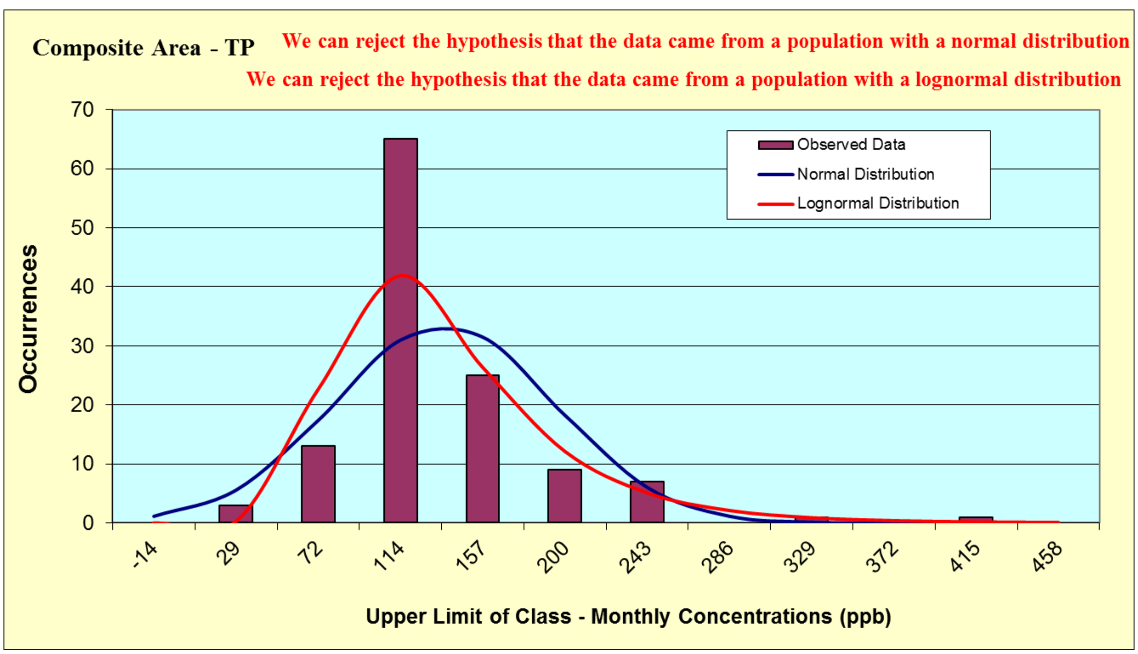
   Haan (1977) suggests a rule of thumb that the ratio should be above 2.86. As a reference, the regression equation used for the EAA Basin in Chapter 40E-63, F.A.C. had a ratio of 9 / 3 = 3.0.

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 Composite Area and its basins, the Reference Period selected that met, as much as possible, the above criteria was WY2003-2012 (May 2002 – April 2012)

The performance indicators for these basins 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 Composite Area for the Reference Period WY2003-2012.



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 (C-23, C-24, C-25, C-44 Sub-watersheds and the Ten Mile Creek basin) were ranked high or moderate for their overall technical strength and defensibility. All of the basins with concentration-based performance indicators (Composite Area and its basins) were ranked low for their overall technical strength and defensibility due to the uncertainty in the data sets, 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 St. Lucie 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 St. Lucie River Watershed are presented in **Table 2-12**; 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 2-13**. Note that reductions for basins to the Composite Area 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 2-13** will be refined. Please refer to **Appendix C** for additional clarification on the source control effectiveness methodologies.

Table 2-12. BMPs assumed to be implemented for estimates of nutrient reductions.

Land Use	Citrus	Improved Pastures	Residential and Urban	Other agriculture
Watershed Acreage Percentage	23 %	21 %	16 %	15 %
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 • 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 • 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:* • Cover crops • Sediment traps

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

Table 2-13. Proposed source control nutrient reductions for sub-watersheds and other basins of the St. Lucie River Watershed.

Sub-watershed / Basin		Area (acres)	Nutrient	Performance Metric	Base Period	Recommended Source Control	
C-23		110,872	TP	Performance Measure	WY1989-2000	30%	
			TN	Performance Measure		25%	
C-24		83,359	TP	Performance Measure	WY1984-1993	30%	
			TN	Performance Measure		25%	
C-25		99,726	TP	Performance Measure	WY1984-1993	0%	
			TN	Performance Measure		0%	
C-44		132,705	TP	Performance Measure	WY2000-2010	35%	
			TN	Performance Measure		30%	
North Fork	Ten Mile Creek	39,726	TP	Performance Measure	WY2000-2011	35%	
			TN	Performance Measure		30%	
					Reference Period	**Target**	**Limit**
Composite Area		61,579	TP	Performance Indicator	WY2003-2012	10%	17%
			TN	Performance Indicator		10%	11%
North Fork	Five Mile Creek	9,022	TP	Performance Indicator	WY2003-2012	11%	18%
			TN	Performance Indicator		0%	12%
	Platts Creek	4,685	TP	Performance Indicator	WY2003-2012	10%	15%
			TN	Performance Indicator		11%	12%
	C-105	3,730	TP	Performance Indicator	WY2003-2012	0%	35%
			TN	Performance Indicator		13%	11%
	C-107	2,544	TP	Performance Indicator	WY2003-2012	0%	31%
			TN	Performance Indicator		7%	13%
	PSL Ditch 6	1,414	TP	Performance Indicator	WY2003-2012	8%	12%
			TN	Performance Indicator		6%	15%
	Hog Pen Slough	13,983	TP	Performance Indicator	WY2003-2012	0%	11%
			TN	Performance Indicator		10%	11%
	Elkcam Waterway	5,415	TP	Performance Indicator	WY2003-2012	0%	12%
			TN	Performance Indicator		12%	11%
South Fork	Fern Creek	599	TP	Performance Indicator	WY2003-2012	17%	26%
			TN	Performance Indicator		14%	11%
	Frazier Creek	377	TP	Performance Indicator	WY2003-2012	0%	11%
			TN	Performance Indicator		0%	14%
	Coral Gardens Ditch	2,093	TP	Performance Indicator	WY2003-2012	11%	16%
			TN	Performance Indicator		16%	11%
Basins 4-5-6	Danforth Creek	3,931	TN	Performance Indicator	WY2003-2012	18%	26%
			TP	Performance Indicator		13%	11%
	Bessey Creek	9,237	TN	Performance Indicator	WY2003-2012	15%	23%
			TP	Performance Indicator		11%	8%
North Mid-Estuary	Warner Creek	1,111	TP	Performance Indicator	WY2003-2012	0%	10%
			TN	Performance Indicator		11%	12%
South Mid-Estuary	North Airport Ditch	1,178	TP	Performance Indicator	WY2003-2012	0%	21%
			TN	Performance Indicator		17%	13%
South Coastal	Salerno Creek	960	TP	Performance Indicator	WY2003-2012	0%	12%
			TN	Performance Indicator		11%	14%
	Manatee Creek	812	TP	Performance Indicator	WY2003-2012	8%	12%
			TN	Performance Indicator		18%	14%
	Willoughby Creek	487	TP	Performance Indicator	WY2003-2012	0%	22%
			TN	Performance Indicator		14%	13%

2.5.10 Minimum Sample Size

There is no minimum number of samples for the annual performance determination for the C-23, C-24, C-25, C-44 Sub-watersheds and the Ten Mile Creek basin as water quality for these basins is based on continued collection of data using auto samplers. For the Composite Area and its basins, the Wilcoxon Rank Sum approach is used, and a minimum of at least one sample each quarter per basin, for at least 75 percent of the basins, 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.[6]

[6] 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. 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 St. Lucie River Watershed.

2.5.12.1 Load-Based Performance Determinations

The following section describes the annual performance determination for the C-23, C-24, C-25 and C-44 Sub-watersheds and the Ten Mile Creek basin.

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[7].

- **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. 3.3, 3.4 and 3.5. For TN, the Annual Load Target is set to the greater of two predicted loads, one based on TN and one based on TON, and the Annual Load Limit is set as the upper 90^{th} 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.

[7] 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.

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 2nd 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 Composite Area and its basins 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 basins, a monthly composite concentration will be calculated for the entire Composite Area using individual tributary data measured near each basin'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[8].

[8] 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.

- **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 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 listed in **Table 1-1**.

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 composite performance metric is not achieved, a performance determination of the tributary-specific performance metrics in **Table 2-13** above would be warranted, and could assist in prioritizing any necessary follow-up actions.

Unmonitored areas. Seventeen St. Lucie Tributary's (SLTs) located in the North Fork, South Fork, South Coastal, South Mid-Estuary, North Mid-Estuary, and Basin 4-5-6 sub-watersheds were selected and referred to as the composite area based on the unavailability to capture discharge at one representative location per sub-watershed. Unmonitored and monitored (composite area) land uses were compared for the North Fork, South Fork, South Coastal, South Mid-Estuary, North Mid-Estuary, and Basin 4-5-6 sub-watersheds. Twelve additional monitoring stations throughout these sub-watersheds were needed to proportionally represent all land uses and begun in WY14 (May 2013), (SFWMD, 2013c). Currently seventeen tributary basins make up the composite area which represents 36 percent of the total area. Once enough data at the twelve additional monitoring stations is collected, the composite metric may be refined if warranted and the metric would then represent 80 percent of the total area.

3. PERFORMANCE METRIC METHODOLOGIES FOR BASINS OF THE ST. LUCIE 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 basins within the St. Lucie River Watershed.

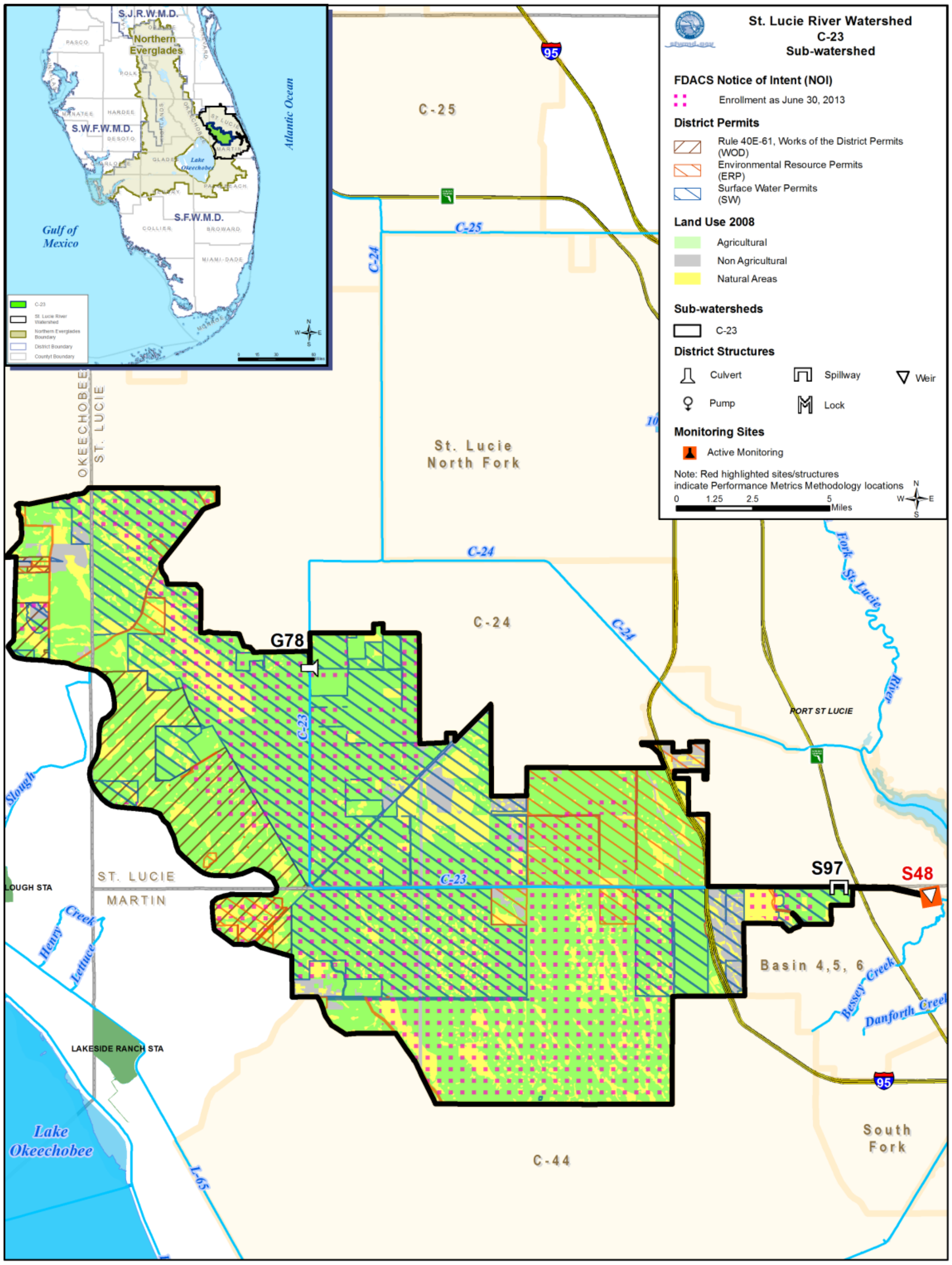
3.1 C-23 Sub-watershed

The following sections present a description of the C-23 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 C-23 Sub-watershed has a total drainage area of approximately 110,872 acres (**Figure 3-1**). The majority of the C-23 Sub-watershed is located in southwest St. Lucie County and northern Martin County, with a small section located in eastern Okeechobee County. Major land uses include pastures (approximately 47,000 acres), agricultural citrus (approximately 32,000 acres), and natural areas (approximately 20,000 acres). The C-23 Canal is the main drainage canal in the C-23 Sub-watershed. Water flows north to south from the C-24 down to the Martin-St. Lucie County line and heads east discharging into the North Fork of the St. Lucie River. There are three project control structures controlling flow in the C- 23 Sub-watershed: G-78 (a culvert located 3.6 miles southwest of where C-23 joins C-24), S-48 (a fixed crest weir located at the outlet of C-23 to the North Fork), and S-97 (a gated spillway located at the Florida Turnpike's crossing of C-23).

Figure 3-1. C-23 Sub-watershed schematic (from SFWMD 2013).



The main functions of the canal and control structures in the C-23 Sub-watershed include removing excess water from the basin, supplying water to the C-23, the C-24 and Basin 4-5-6 Sub-watersheds under low-flow conditions, and maintaining a groundwater table elevation west of S-48 adequate to prevent saltwater intrusion into local groundwater. Water in the north-south leg of the C-23 Canal may occasionally be diverted north into the C-24 Sub-watershed for water supply and flood protection purposes (SFWMD 1988a).

Flow and water quality data from S-48 were used to calculate the annual nutrient loads (TP, TN and TON) in runoff from the C-23 Sub-watershed, which were used in the development of the performance metric (flow and nutrient monitoring sites are identified in **Tables B-1** and **B-2**). Basin flows and loads were calculated using algorithms provided in **Appendix A**. The historical data analysis for the C-23 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 St. Lucie River Source Control Programs) with the District (HDR 2011a).

District staff identified the rainfall stations considered to be representative of the sub-watershed for the period WY1976-2013. 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 C-23 Sub-watershed for the WY1980-2013 period of record are summarized in **Tables 3-1** through **3-3**.

Table 3-1. Summary of historical TP data for the C-23 Sub-watershed.

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
1980	105,585	28.835	221	53.13	11.43	0.57	6.376	1.047	2.341
1981	42,612	6.939	132	32.38	4.61	0.14	-0.484	0.693	0.421
1982	77,950	15.521	161	49.06	8.44	0.31	0.505	0.855	1.046
1983	240,559	43.413	146	58.13	26.04	0.86	-0.349	0.530	0.275
1984	132,635	28.761	176	51.35	14.36	0.57	-1.043	0.670	0.485
1985	74,549	16.775	182	39.51	8.07	0.33	-0.643	0.754	0.309
1986	105,053	25.598	198	44.18	11.37	0.51	0.261	0.809	1.012
1987	197,712	55.734	229	46.32	21.40	1.11	1.969	0.794	1.217
1988	123,020	32.041	211	41.74	13.31	0.64	-0.243	0.567	0.229
1989	67,586	17.620	211	38.04	7.32	0.35	-1.279	0.652	0.153
1990	59,202	17.843	244	37.92	6.41	0.35	-1.405	0.656	0.391
1991	149,458	51.005	277	55.67	16.18	1.01	1.178	0.719	1.006
1992	142,934	51.219	291	41.68	15.47	1.02	-1.197	0.637	0.284
1993	282,712	134.879	387	75.31	30.60	2.68	0.993	0.857	1.070
1994	122,579	37.939	251	56.23	13.27	0.75	1.108	0.391	-0.202
1995	248,215	98.316	321	61.09	26.87	1.95	-1.415	0.469	-0.146
1996	283,019	148.909	427	64.45	30.63	2.96	-0.608	1.017	0.831
1997	76,827	19.507	206	47.30	8.32	0.39	-1.573	0.525	0.173
1998	157,214	69.703	359	53.96	17.02	1.39	-0.765	0.457	0.378
1999	75,676	45.291	485	41.94	8.19	0.90	0.331	0.870	1.076
2000	175,034	121.149	561	57.55	18.94	2.41	0.981	0.994	1.318
2001	38,332	17.072	361	35.03	4.15	0.34	0.144	1.032	0.887
2002	139,214	91.074	530	46.30	15.07	1.81	1.875	0.933	1.329
2003	125,217	60.424	391	51.02	13.55	1.20	-0.733	0.668	0.708
2004	139,692	80.358	466	42.08	15.12	1.60	-0.673	0.855	0.852
2005	232,808	186.704	650	66.35	25.20	3.71	5.689	1.205	2.150
2006	297,214	169.018	461	69.66	32.17	3.36	-0.375	0.842	0.619
2007	39,872	17.906	364	33.59	4.32	0.36	-0.103	0.851	1.025
2008	96,815	59.676	500	52.17	10.48	1.19	-1.420	0.677	0.531
2009	114,822	82.269	581	40.25	12.43	1.64	5.422	1.190	2.059
2010	112,375	44.611	322	59.53	12.16	0.89	-1.101	0.573	-0.138
2011	33,643	12.257	295	35.72	3.64	0.24	0.986	0.851	0.973
2012	60,600	27.511	368	46.18	6.56	0.55	0.555	0.874	1.129
2013	85,776	52.024	492	46.82	9.28	1.03	3.272	0.896	1.507
Minimum	***33,643***	***6.939***	***132***	***32.38***	***3.64***	***0.14***	***-1.573***	***0.391***	***-0.202***
Average	***131,074***	***57.879***	***358***	***49.17***	***14.19***	***1.15***	***0.478***	***0.777***	***0.803***
Maximum	***297,214***	***186.704***	***650***	***75.31***	***32.17***	***3.71***	***6.376***	***1.205***	***2.341***
Std. Dev.	***74,506***	***46.926***	***140***	***10.70***	***8.06***	***0.93***	***2.029***	***0.201***	***0.625***
Median	***118,701***	***44.951***	***322***	***47.06***	***12.85***	***0.89***	***-0.173***	***0.802***	***0.842***
Skewness	***0.854***	***1.331***	***0.445***	***0.528***	***0.85***	***1.33***	***1.694***	***0.161***	***0.633***

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 C-23 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
1980	105,585	242.457	1,862	53.13	11.43	4.82	6.376	1.047	2.341
1981	42,612	87.068	1,656	32.38	4.61	1.73	-0.484	0.693	0.421
1982	77,950	201.674	2,097	49.06	8.44	4.01	0.505	0.855	1.046
1983	240,559	422.169	1,423	58.13	26.04	8.39	-0.349	0.530	0.275
1984	132,635	242.007	1,479	51.35	14.36	4.81	-1.043	0.670	0.485
1985	74,549	129.798	1,412	39.51	8.07	2.58	-0.643	0.754	0.309
1986	105,053	196.190	1,514	44.18	11.37	3.90	0.261	0.809	1.012
1987	197,712	428.652	1,758	46.32	21.40	8.52	1.969	0.794	1.217
1988	123,020	231.369	1,525	41.74	13.31	4.60	-0.243	0.567	0.229
1989	67,586	96.010	1,152	38.04	7.32	1.91	-1.279	0.652	0.153
1990	59,202	91.846	1,258	37.92	6.41	1.83	-1.405	0.656	0.391
1991	149,458	226.920	1,231	55.67	16.18	4.51	1.178	0.719	1.006
1992	142,934	227.935	1,293	41.68	15.47	4.53	-1.197	0.637	0.284
1993	282,712	432.644	1,241	75.31	30.60	8.60	0.993	0.857	1.070
1994	122,579	192.316	1,272	56.23	13.27	3.82	1.108	0.391	-0.202
1995	248,215	467.390	1,527	61.09	26.87	9.29	-1.415	0.469	-0.146
1996	283,019	557.314	1,596	64.45	30.63	11.08	-0.608	1.017	0.831
1997	76,827	124.815	1,317	47.30	8.32	2.48	-1.573	0.525	0.173
1998	157,214	313.340	1,616	53.96	17.02	6.23	-0.765	0.457	0.378
1999	75,676	145.364	1,557	41.94	8.19	2.89	0.331	0.870	1.076
2000	175,034	367.741	1,703	57.55	18.94	7.31	0.981	0.994	1.318
2001	38,332	86.644	1,832	35.03	4.15	1.72	0.144	1.032	0.887
2002	139,214	279.585	1,628	46.30	15.07	5.56	1.875	0.933	1.329
2003	125,217	234.485	1,518	51.02	13.55	4.66	-0.733	0.668	0.708
2004	139,692	265.527	1,541	42.08	15.12	5.28	-0.673	0.855	0.852
2005	232,808	417.343	1,453	66.35	25.20	8.30	5.689	1.205	2.150
2006	297,214	592.779	1,617	69.66	32.17	11.79	-0.375	0.842	0.619
2007	39,872	95.478	1,941	33.59	4.32	1.90	-0.103	0.851	1.025
2008	96,815	197.982	1,658	52.17	10.48	3.94	-1.420	0.677	0.531
2009	114,822	247.722	1,749	40.25	12.43	4.93	5.422	1.190	2.059
2010	112,375	218.651	1,577	59.53	12.16	4.35	-1.101	0.573	-0.138
2011	33,643	61.842	1,490	35.72	3.64	1.23	0.986	0.851	0.973
2012	60,600	132.225	1,769	46.18	6.56	2.63	0.555	0.874	1.129
2013	85,776	173.812	1,643	46.82	9.28	3.46	3.272	0.896	1.507
Minimum	***33,643***	***61.842***	***1,152***	***32.38***	***3.64***	***1.23***	***-1.573***	***0.391***	***-0.202***
Average	***131,074***	***247.915***	***1,533***	***49.17***	***14.19***	***4.93***	***0.478***	***0.777***	***0.803***
Maximum	***297,214***	***592.779***	***2,097***	***75.31***	***32.17***	***11.79***	***6.376***	***1.205***	***2.341***
Std. Dev.	***74,506***	***138.927***	***215***	***10.70***	***8.06***	***2.76***	***2.029***	***0.201***	***0.625***
Skewness	***0.854***	***0.874***	***0.248***	***0.528***	***0.854***	***0.87***	***1.694***	***0.161***	***0.633***
Median	***118,701***	***227.428***	***1,549***	***47.06***	***12.85***	***4.52***	***-0.173***	***0.802***	***0.842***

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 C-23 Sub-watershed.

Water Year	Flow AF	TON Load mt	FWM TON Conc µg/L	Rainfall inches	Unit Area Runoff inches	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1980	105,585	211.843	1,627	53.13	11.43	4.21	6.376	1.047	2.341
1981	42,612	80.848	1,538	32.38	4.61	1.61	-0.484	0.693	0.421
1982	77,950	144.452	1,502	49.06	8.44	2.87	0.505	0.855	1.046
1983	240,559	340.269	1,147	58.13	26.04	6.77	-0.349	0.530	0.275
1984	132,635	204.454	1,250	51.35	14.36	4.07	-1.043	0.670	0.485
1985	74,549	87.960	957	39.51	8.07	1.75	-0.643	0.754	0.309
1986	105,053	150.024	1,158	44.18	11.37	2.98	0.261	0.809	1.012
1987	197,712	333.086	1,366	46.32	21.40	6.62	1.969	0.794	1.217
1988	123,020	184.090	1,213	41.74	13.31	3.66	-0.243	0.567	0.229
1989	67,586	75.398	904	38.04	7.32	1.50	-1.279	0.652	0.153
1990	59,202	74.604	1,022	37.92	6.41	1.48	-1.405	0.656	0.391
1991	149,458	193.488	1,050	55.67	16.18	3.85	1.178	0.719	1.006
1992	142,934	191.299	1,085	41.68	15.47	3.80	-1.197	0.637	0.284
1993	282,712	351.775	1,009	75.31	30.60	6.99	0.993	0.857	1.070
1994	122,579	162.944	1,078	56.23	13.27	3.24	1.108	0.391	-0.202
1995	248,215	392.948	1,283	61.09	26.87	7.81	-1.415	0.469	-0.146
1996	283,019	463.130	1,327	64.45	30.63	9.21	-0.608	1.017	0.831
1997	76,827	108.166	1,141	47.30	8.32	2.15	-1.573	0.525	0.173
1998	157,214	256.481	1,323	53.96	17.02	5.10	-0.765	0.457	0.378
1999	75,676	124.455	1,333	41.94	8.19	2.47	0.331	0.870	1.076
2000	175,034	294.020	1,362	57.55	18.94	5.85	0.981	0.994	1.318
2001	38,332	73.584	1,556	35.03	4.15	1.46	0.144	1.032	0.887
2002	139,214	227.797	1,327	46.30	15.07	4.53	1.875	0.933	1.329
2003	125,217	191.525	1,240	51.02	13.55	3.81	-0.733	0.668	0.708
2004	139,692	220.849	1,282	42.08	15.12	4.39	-0.673	0.855	0.852
2005	232,808	351.239	1,223	66.35	25.20	6.98	5.689	1.205	2.150
2006	297,214	494.866	1,350	69.66	32.17	9.84	-0.375	0.842	0.619
2007	39,872	79.289	1,612	33.59	4.32	1.58	-0.103	0.851	1.025
2008	96,815	161.059	1,349	52.17	10.48	3.20	-1.420	0.677	0.531
2009	114,822	213.122	1,505	40.25	12.43	4.24	5.422	1.190	2.059
2010	112,340	181.622	1,311	59.61	12.16	3.61	-1.059	0.574	-0.105
2011	33,643	55.548	1,339	35.72	3.64	1.10	0.986	0.851	0.973
2012	60,600	101.555	1,359	46.18	6.56	2.02	0.555	0.874	1.129
2013	85,776	140.122	1,324	46.82	9.28	2.79	3.272	0.896	1.507
Minimum	***33,643***	***55.548***	***904***	***32.38***	***3.64***	***1.10***	***-1.573***	***0.391***	***-0.202***
Average	***131,073***	***203.468***	***1,258***	***49.17***	***14.19***	***4.05***	***0.479***	***0.777***	***0.804***
Maximum	***297,214***	***494.866***	***1,627***	***75.31***	***32.17***	***9.84***	***6.376***	***1.205***	***2.341***
Std. Dev.	***74,506***	***114.939***	***182***	***10.71***	***8.06***	***2.29***	***2.028***	***0.201***	***0.624***
Skewness	***0.854***	***0.912***	***-0.056***	***0.528***	***0.854***	***0.91***	***1.696***	***0.161***	***0.644***
Median	***118,701***	***187.695***	***1,317***	***47.06***	***12.85***	***3.73***	***-0.173***	***0.802***	***0.842***

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 WY1989-2000 was recommended for the following reasons (HDR 2011a).

- Current nutrient loading levels are within approximately ±10 percent of the base period levels.
- Rainfall patterns during these periods are reasonably representative of long-term.
- Widespread implementation of source control measures began after 2001 – after the end of the proposed base period.
- No outliers were identified in the monthly or annual data.
- 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.

The Base Period is compared to the historical period of record and WY2004-2013 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 WY2004-2013 TP data for the C-23 Sub-watershed.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	33,643	6.939	132	32.38	0.14
Annual Average	131,074	57.879	358	49.17	1.15
Annual Median	118,701	44.951	322	47.06	0.89
Annual Maximum	297,214	186.704	650	75.31	3.71
Preliminary Base Period WY1989-2000					
Annual Minimum	59,202	17.620	206	37.92	0.35
Annual Average	153,371	67.782	358	52.60	1.35
Annual Median	146,196	51.112	306	54.82	1.02
Annual Maximum	283,019	148.909	561	75.31	2.96
Difference between Period of Record and Base Period					
Annual Minimum	-25,559	-10.681	-74	-5.54	-0.21
Annual Average	-22,297	-9.902	0	-3.43	-0.20
Annual Median	-27,496	-6.161	16	-7.76	-0.12
Annual Maximum	14,195	37.795	89	0.00	0.75
Annual Minimum	-43%	-61%	-36%	-15%	-61%
Annual Average	-15%	-15%	0%	-7%	-15%
Annual Median	-19%	-12%	5%	-14%	-12%
Annual Maximum	5%	25%	16%	0%	25%
WY2004-2013					
Annual Minimum	33,643	12.257	295	33.59	0.24
Annual Average	121,362	73.233	489	49.24	1.46
Annual Median	104,595	55.850	464	46.50	1.11
Annual Maximum	297,214	186.704	650	69.66	3.71
Difference between WY2004-2013 and Base Period					
Annual Minimum	-25,559	-5.363	89	-4.33	-0.11
Annual Average	-32,010	5.452	131	-3.36	0.11
Annual Median	-41,601	4.738	158	-8.32	0.09
Annual Maximum	14,195	37.795	89	-5.65	0.75
Annual Minimum	-43%	-30%	43%	-11%	-30%
Annual Average	-21%	8%	37%	-6%	8%
Annual Median	-28%	9%	51%	-15%	9%
Annual Maximum	5%	25%	16%	-8%	25%

Table 3-5. Comparison of Base Period with period of record and WY2004-2013 TN data for the C-23 Sub-watershed.

Metric	Flow AF	TN Load mt	TN Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	33,643	61.842	1,152	32.38	1.23
Annual Average	131,074	247.915	1,533	49.17	4.93
Annual Median	118,701	227.428	1,549	47.06	4.52
Annual Maximum	297,214	592.779	2,097	75.31	11.79
Preliminary Base Period WY1989-2000					
Annual Minimum	59,202	91.846	1,152	37.92	1.83
Annual Average	153,371	270.303	1,429	52.60	5.37
Annual Median	146,196	227.428	1,305	54.82	4.52
Annual Maximum	283,019	557.314	1,703	75.31	11.08
Difference between Period of Record and Base Period					
Annual Minimum	-25,559	-30.004	0	-5.54	-0.60
Annual Average	-22,297	-22.388	105	-3.43	-0.45
Annual Median	-27,496	0.000	244	-7.76	0.00
Annual Maximum	14,195	35.465	394	0.00	0.71
Annual Minimum	-43%	-33%	0%	-15%	-33%
Annual Average	-15%	-8%	7%	-7%	-8%
Annual Median	-19%	0%	19%	-14%	0%
Annual Maximum	5%	6%	23%	0%	6%
WY2004-2013					
Annual Minimum	33,643	61.842	1,453	33.59	1.23
Annual Average	121,362	240.336	1,605	49.24	4.78
Annual Median	104,595	208.317	1,630	46.50	4.14
Annual Maximum	297,214	592.779	1,941	69.66	11.79
Difference between WY2004-2013 and Base Period					
Annual Minimum	-25,559	-30.004	301	-4.33	-0.60
Annual Average	-32,010	-29.967	177	-3.36	-0.60
Annual Median	-41,601	-19.111	325	-8.32	-0.38
Annual Maximum	14,195	35.465	238	-5.65	0.71
Annual Minimum	-43%	-33%	26%	-11%	-33%
Annual Average	-21%	-11%	12%	-6%	-11%
Annual Median	-28%	-8%	25%	-15%	-8%
Annual Maximum	5%	6%	14%	-8%	6%

Table 3-6. Comparison of Base Period with period of record and WY2004-2013 TON data for the C-23 Sub-watershed.

Metric	Flow AF	TON Load mt	TON Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	33,643	55.548	904	32.38	1.10
Annual Average	131,073	203.468	1,258	49.17	4.05
Annual Median	118,701	187.695	1,317	47.06	3.73
Annual Maximum	297,214	494.866	1,627	75.31	9.84
Preliminary Base Period WY1989-2000					
Annual Minimum	59,202	74.604	904	37.92	1.48
Annual Average	153,371	224.059	1,184	52.60	4.46
Annual Median	146,196	192.394	1,113	54.82	3.83
Annual Maximum	283,019	463.130	1,362	75.31	9.21
Difference between Period of Record and Base Period					
Annual Minimum	-25,559	-19.056	0	-5.54	-0.38
Annual Average	-22,299	-20.591	74	-3.43	-0.41
Annual Median	-27,496	-4.699	204	-7.76	-0.09
Annual Maximum	14,195	31.736	265	0.00	0.63
Annual Minimum	-43%	-26%	0%	-15%	-26%
Annual Average	-15%	-9%	6%	-7%	-9%
Annual Median	-19%	-2%	18%	-14%	-2%
Annual Maximum	5%	7%	19%	0%	7%
WY2004-2013					
Annual Minimum	33,643	55.548	1,223	33.59	1.10
Annual Average	121,358	199.927	1,336	49.24	3.98
Annual Median	104,578	171.341	1,344	46.50	3.41
Annual Maximum	297,214	494.866	1,612	69.66	9.84
Difference between WY2004-2013 and Base Period					
Annual Minimum	-25,559	-19.056	319	-4.33	-0.38
Annual Average	-32,013	-24.132	151	-3.35	-0.48
Annual Median	-41,619	-21.053	231	-8.32	-0.42
Annual Maximum	14,195	31.736	250	-5.65	0.63
Annual Minimum	-43%	-26%	35%	-11%	-26%
Annual Average	-21%	-11%	13%	-6%	-11%
Annual Median	-28%	-11%	21%	-15%	-11%
Annual Maximum	5%	7%	18%	-8%	7%

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.

$$\text{TP Annual Load} = -152.11608 + 3.0003\,X + 90.3889\,C$$

Explained Variance = 85.8%, Standard Error of Regression = 19.541 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.

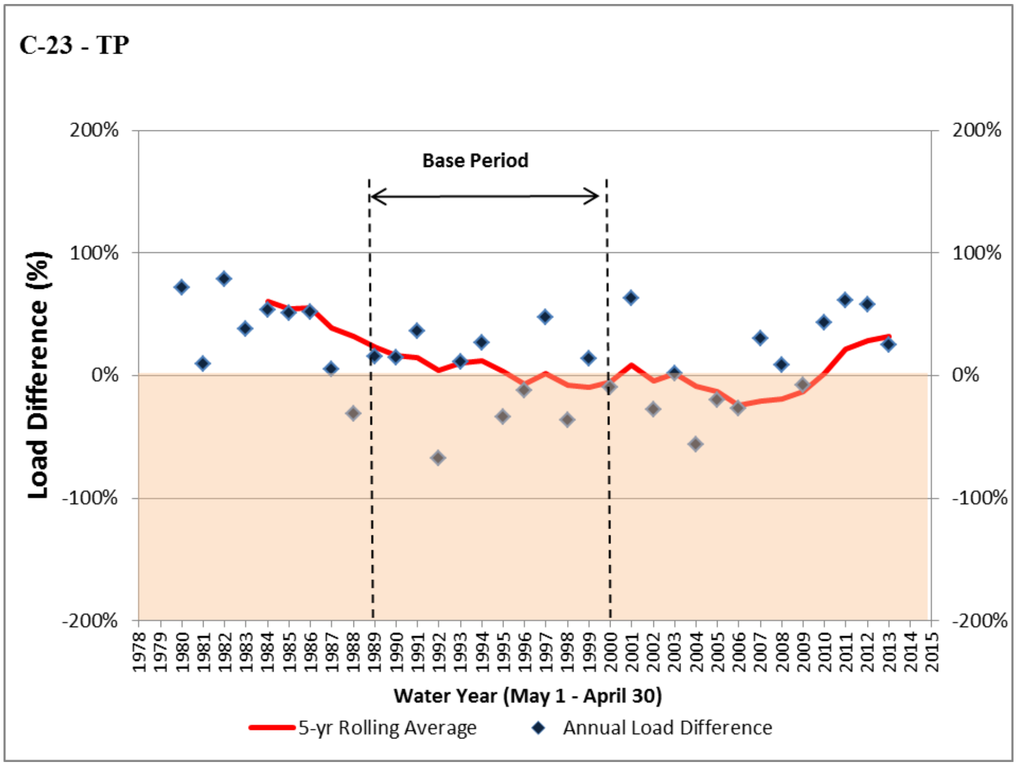
Table 3-7 presents the annual observed and predicted sub-watershed TP loads. The load trend is presented in **Figure 3-2**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-2** denotes a reduction in loads.

Table 3-7. WY1980 – WY2013 C-23 Sub-watershed TP measurements and calculations. (Base Period: WY1989-2000).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average
1980	53.13	28.835	101.927	72%	
1981	32.38	6.939	7.673	10%	
1982	49.06	15.521	72.361	79%	
1983	58.13	43.413	70.197	38%	
1984	51.35	28.761	62.510	54%	61%
1985	39.51	16.775	34.579	51%	55%
1986	44.18	25.598	53.562	52%	56%
1987	46.32	55.734	58.626	5%	39%
1988	41.74	32.041	24.367	-31%	32%
1989	38.04	17.620	20.949	16%	23%
1990	37.92	17.843	20.950	15%	17%
1991	55.67	51.005	79.900	36%	15%
1992	41.68	51.219	30.514	-68%	4%
1993	75.31	134.879	151.300	11%	10%
1994	56.23	37.939	51.933	27%	12%
1995	61.09	98.316	73.564	-34%	4%
1996	64.45	148.909	133.179	-12%	-7%
1997	47.30	19.507	37.252	48%	2%
1998	53.96	69.703	51.088	-36%	-8%
1999	41.94	45.291	52.355	13%	-10%
2000	57.55	121.149	110.398	-10%	-5%
2001	35.03	17.072	46.266	63%	8%
2002	46.30	91.074	71.130	-28%	-4%
2003	51.02	60.424	61.339	1%	2%
2004	42.08	80.358	51.419	-56%	-9%
2005	66.35	186.704	155.872	-20%	-13%
2006	69.66	169.018	132.992	-27%	-24%
2007	33.59	17.906	25.585	30%	-20%
2008	52.17	59.676	65.603	9%	-19%
2009	40.25	82.269	76.209	-8%	-13%
2010	59.53	44.611	78.284	43%	1%
2011	35.72	12.257	31.975	62%	22%
2012	46.18	27.511	65.437	58%	29%
2013	46.82	52.024	69.346	25%	32%

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

Figure 3-2. C-23 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.

$$\text{TN Annual Load} = -2364.71764 + 601.53918\,X + 520.44036\,C - 176.08307\,S$$

Explained Variance = 82.3%, Standard Error of Regression = 77.050 mt

Predictors (X, C and S) are calculated from the first three moment (m_1, m2, m3) 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

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

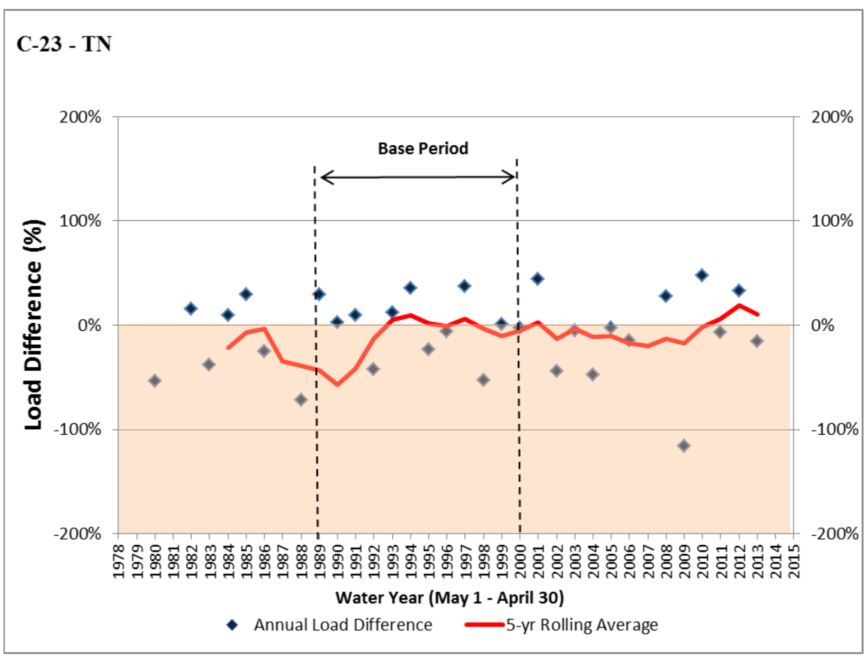
X = the natural logarithm of the 12-month total rainfall (inches) = 12 m_1

C = coefficient of variation from 12 monthly rainfall totals = $[(12/11)\ m_2]^{0.5}/m_1$

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

Table 3-8 presents the annual observed and predicted sub-watershed TN 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.

Figure 3-3. C-23 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.

Table 3-8. WY1980 – WY2013 C-23 Sub-watershed TN measurements and calculations. (Base Period: WY1989-2000).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1980	53.13	242.457	157.733	-54%	
1981	32.38	87.068	13.694	-536%	
1982	49.06	201.674	237.894	15%	
1983	58.13	422.169	306.555	-38%	
1984	51.35	242.007	267.838	10%	-22%
1985	39.51	129.798	184.876	30%	-7%
1986	44.18	196.190	156.917	-25%	-3%
1987	46.32	428.652	141.467	-203%	-34%
1988	41.74	231.369	134.668	-72%	-39%
1989	38.04	96.010	136.452	30%	-43%
1990	37.92	91.846	94.726	3%	-57%
1991	55.67	226.920	250.191	9%	-42%
1992	41.68	227.935	160.549	-42%	-13%
1993	75.31	432.644	492.510	12%	5%
1994	56.23	192.316	298.216	36%	10%
1995	61.09	467.390	378.816	-23%	2%
1996	64.45	557.314	524.191	-6%	-1%
1997	47.30	124.815	197.893	37%	6%
1998	53.96	313.340	205.649	-52%	-3%
1999	41.94	145.364	146.095	1%	-11%
2000	57.55	367.741	358.353	-3%	-5%
2001	35.03	86.644	155.388	44%	2%
2002	46.30	279.585	193.827	-44%	-13%
2003	51.02	234.485	223.653	-5%	-3%
2004	42.08	265.527	179.735	-48%	-11%
2005	66.35	417.343	407.257	-2%	-11%
2006	69.66	592.779	517.205	-15%	-18%
2007	33.59	95.478	11.638	-720%	-20%
2008	52.17	197.982	272.912	27%	-13%
2009	40.25	247.722	114.805	-116%	-17%
2010	59.53	218.651	415.972	47%	-2%
2011	35.72	61.842	57.778	-7%	6%
2012	46.18	132.225	196.776	33%	19%
2013	46.82	173.812	149.946	-16%	11%

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

3.1.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the C-23 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 = -106.48094 + 2.1002 X + 63.27232 C

Explained Variance = 85.8%, Standard Error of Regression = 13.68 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 + 1.38303 SE

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

$$SE = 13.67884 [1 + 1/12 + 0.00073 (X-X_m)^2 + 2.19257 (C–C_m)^2 + -0.01966 (X-X_m) (C–C_m)]^{0.5}$$

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 = 52.595 inches

C_m = average value of the predictor in base period = 0.6870

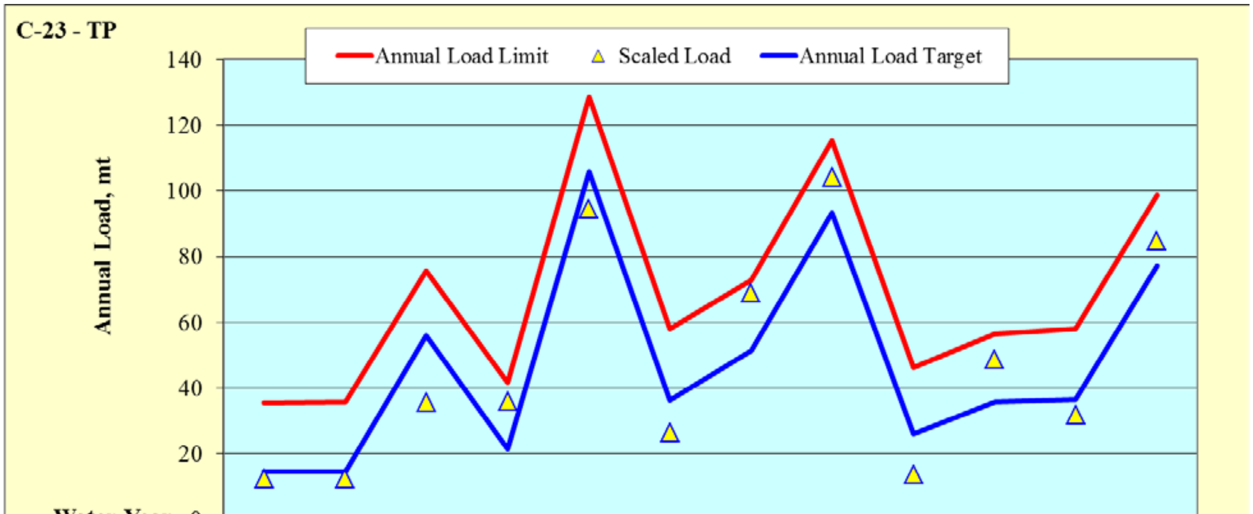
The first predictor (X) indicates that load increases with the total annual rainfall. The second predictor (C) indicates that the load resulting from a given annual rainfall is higher when the distribution of monthly rainfall has higher variability. For a given annual rainfall, the lowest load would 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 3-4.** 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 (36.99 – 80.43 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.

Adjusted Rain = X + 30.12681 (C – 0.6870)

Figure 3-4. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the C-23 Sub-watershed.



Water Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Annual Load Limit	35.644	35.671	75.686	41.776	128.655	57.974	72.868	115.184	46.314	56.544	58.031	98.664
Scaled Load	12.334	12.490	35.704	35.853	94.415	26.557	68.821	104.236	13.655	48.792	31.704	84.804
Annual Load Target	14.664	14.665	55.930	21.360	105.909	36.353	51.495	93.225	26.076	35.761	36.648	77.278

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1980-2013 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**.

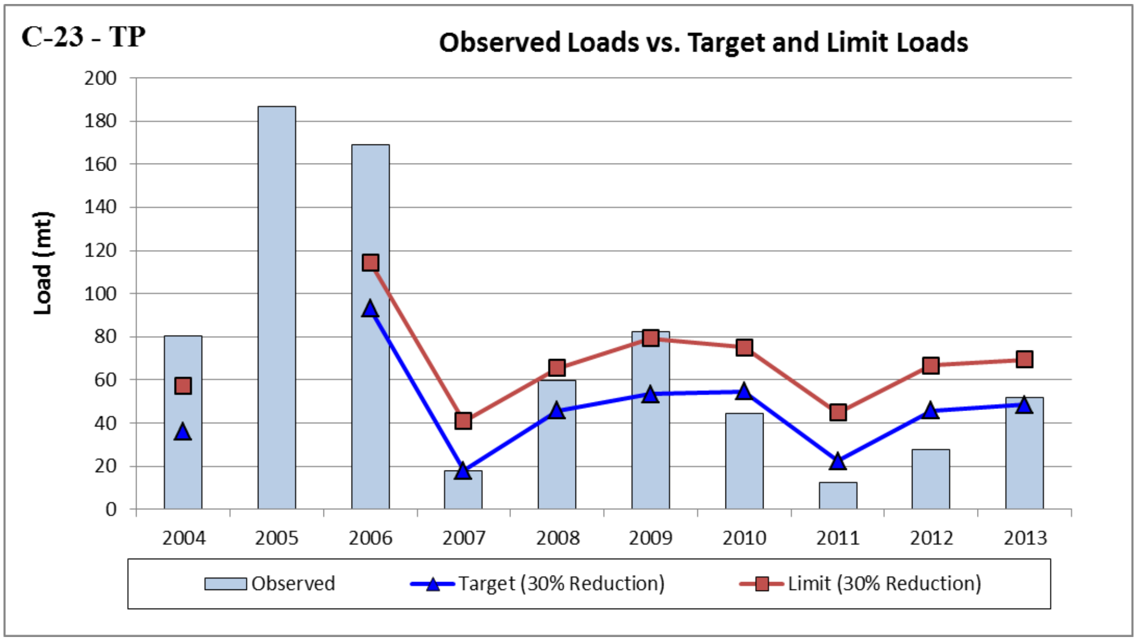
3.1.2.1.2 Comparison to WY2004-2013. A comparison of the WY2004-2013 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-5**.

Table 3-9. TP Annual Load Targets and Limits for the historical period of record for the C-23 Sub-watershed (Base Period: WY1989-2000).

Water Year	Observed Load, mt	Rain in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1980	28.835	53.13	1.047	71.349	93.443	63.98
1981	6.939	32.38	0.693	5.371	27.616	32.56
1982	15.521	49.06	0.855	50.653	71.081	54.12
1983	43.413	58.13	0.530	49.138	69.660	53.40
1984	28.761	51.35	0.670	43.757	63.460	50.84
1985	16.775	39.51	0.754	24.205	45.227	41.53
1986	25.598	44.18	0.809	37.493	58.109	47.86
1987	55.734	46.32	0.794	41.038	61.328	49.54
1988	32.041	41.74	0.567	17.057	37.563	38.12
1989	17.620	38.04	0.652	14.664	35.644	36.99
1990	17.843	37.92	0.656	14.665	35.671	36.99
1991	51.005	55.67	0.719	55.930	75.686	56.63
1992	51.219	41.68	0.637	21.360	41.776	40.17
1993	134.879	75.31	0.857	105.909	128.655	80.43
1994	37.939	56.23	0.391	36.353	57.974	47.31
1995	98.316	61.09	0.469	51.495	72.868	54.52
1996	148.909	64.45	1.017	93.225	115.184	74.39
1997	19.507	47.30	0.525	26.076	46.314	42.42
1998	69.703	53.96	0.457	35.761	56.544	47.03
1999	45.291	41.94	0.870	36.648	58.031	47.45
2000	121.149	57.55	0.994	77.278	98.664	66.80
2001	17.072	35.03	1.032	32.386	56.962	45.42
2002	91.074	46.30	0.933	49.791	71.155	53.71
2003	60.424	51.02	0.668	42.937	62.646	50.45
2004	80.358	42.08	0.855	35.993	57.231	47.14
2005	186.704	66.35	1.205	109.110	133.551	81.96
2006	169.018	69.66	0.842	93.094	114.627	74.33
2007	17.906	33.59	0.851	17.909	40.814	38.53
2008	59.676	52.17	0.677	45.922	65.615	51.87
2009	82.269	40.25	1.190	53.346	79.222	55.40
2010	44.611	59.53	0.573	54.799	75.195	56.10
2011	12.257	35.72	0.851	22.383	44.796	40.66
2012	27.511	46.18	0.874	45.806	66.646	51.81
2013	52.024	46.82	0.896	48.542	69.498	53.12

Note: 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.

Figure 3-5. Comparison of WY2004-2013 TP loads with Annual Load Targets and Limits for the C-23 Sub-watershed.



Notes:

1. The Base Period extended from WY1989-2000.
2. The performance determination for WY2005 would have been suspended due to rainfall above the maximum value during the Base Period coupled with the observed load being greater than the Load Target.

3.1.2.1.3 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 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 C-23 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%	5.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.2%
Step 4. Load > Annual Load Limit?	<10%	4.5%
Cumulative Exceedance Frequency	**<17.5%**	**14.3%**

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 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.

3.1.2.2.1 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 25 percent reduction.

$$\text{TN-based Prediction} = -1773.53909 + 451.15444\,X + 390.33189\,C + -132.06292\,S$$

Explained Variance = 82.3%, Standard Error of Regression = 53.935 mt

Predictors (X, C and S) are calculated from the first three moment (m_1, m2, m3) 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

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

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

C = coefficient of variation calculated from 12 monthly rainfall totals [(12/11) m_2] $^{0.5}$/m_1

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

TN-based UCL = TN-based Prediction + 1.39682 SE

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

SE_{TN} = 57.78788 [1 + 1/12 + 2.03637 $(X\text{-}X_m)^2$ + 8.69123 $(S\text{–}S_m)^2$ + 1.5039 $(C\text{-}C_m)^2$ + 0.44458 $(X\text{-}X_m)$ $(S\text{–}S_m)$ - 0.63412 $(X\text{-}X_m)$ $(C\text{-}C_m)$ + -6.26942 $(S\text{-}S_m)$ $(C\text{-}C_m)$]$^{0.5}$

Where:

X_m = average value of the predictor in the base period = 3.94054

C_m = average value of the predictor in the base period = 0.6870

S_m = average value of the predictor in the base period = 0.52767

The first predictor (X) indicates that load increases with the total annual rainfall. The second and third predictors (C and S) 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 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.

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 = -1756.08502 + 447.85423 X + 383.5997 C - 133.76593 S

Explained Variance = 82.3%, Standard Error of Regression = 57.657 mt

Predictors (X, C and S) are calculated from the first three moment (m_1, m2, m3) 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

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

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

C = coefficient of variation calculated from 12 monthly rainfall totals $[(12/11)\, m_2]^{0.5}/m_1$

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

TON-based UCL = TON-based Prediction + 1.39682 SE

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

$$SE_{TON} = 57.65722 [1 + 1/12 + 2.03637 (X-X_m)^2 + 8.69123 (S-S_m)^2 + 1.5039 (C-C_m)^2 + 0.44458 (X-X_m) (S-S_m) - 0.63412 (X-X_m) (C-C_m) - 6.26942 (S-S_m) (C-C_m)]^{0.5}$$

Where:

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

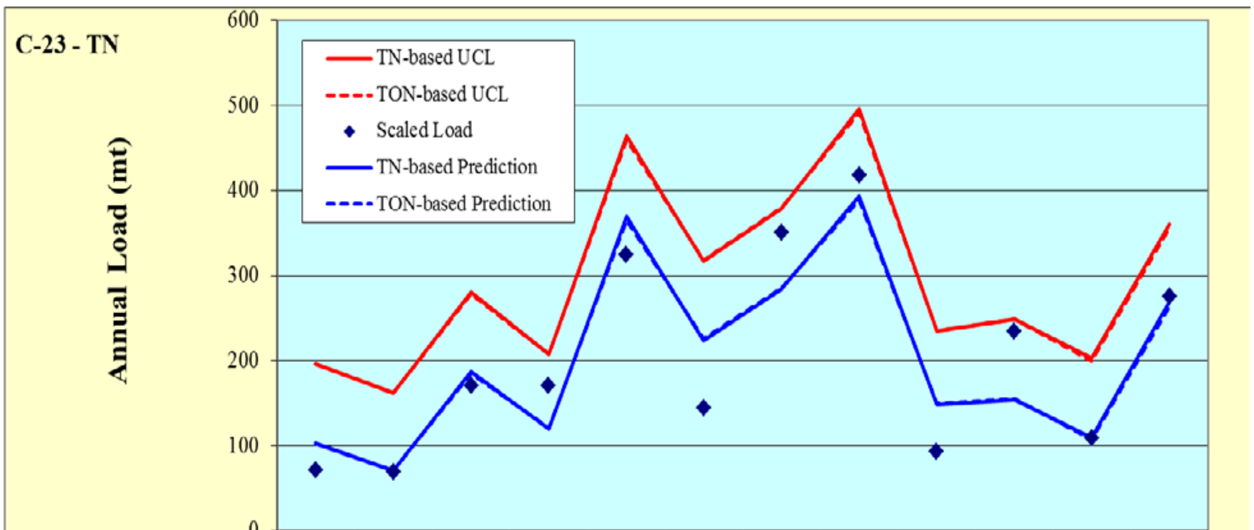
X_m = average value of the predictor in base period = 3.94054

C_m = average value of the predictor in the base period = 0.6870

S_m = average value of the predictor in the base period = 0.52767

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 3-6.**

Figure 3-6. Comparison of scaled annual TN loads with the Annual Load Targets and Limits for the C-23 Sub-watershed.



	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
TN-based UCL	195.830	161.669	280.741	208.110	464.628	316.996	378.764	496.318	234.677	248.552	202.902	360.990
TON-based UCL	196.414	161.838	278.166	208.283	460.012	318.652	379.524	491.528	235.380	248.910	200.125	355.924
Scaled Load	72.008	68.885	170.190	170.951	324.483	144.237	350.543	417.986	93.611	235.005	109.023	275.806
TN-based Prediction	102.339	71.044	187.643	120.412	369.383	223.662	284.112	393.144	148.420	154.236	109.571	268.765
TON-based Prediction	103.135	71.418	185.278	120.784	364.983	225.530	285.086	388.588	149.318	154.808	107.005	263.908

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 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.

3.1.2.2.4. 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 adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (38.42 – 78.46 inches for the TN-based equations and 38.46 – 78.10 inches for the TON-based equations).

TN-based Adjusted Rain = exp [X + 0.86518 (S-Sm) + -0.29272 (C – Cm)]

TON-based Adjusted Rain = exp [X + 0.85653 (S-Sm) - 0.29868 (C – Cm)]

The rainfall values, Annual Load Targets and Annual Load Limits for the WY1980-2013 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.

An example is the performance determinations for WY2005, which would have been suspended for TP but not for TN. 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.

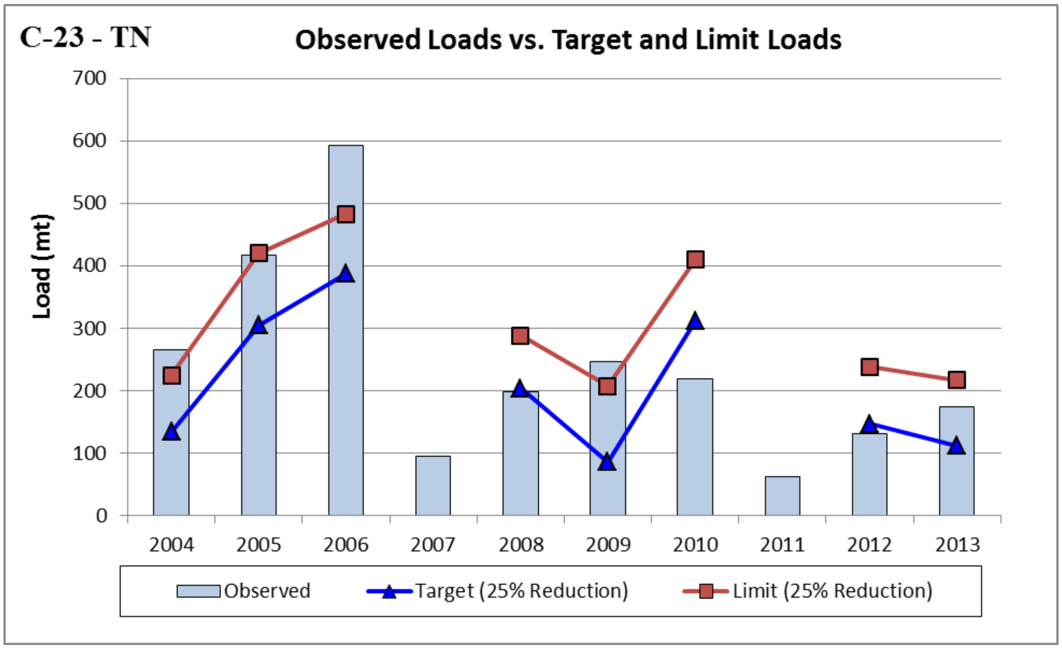
3.1.2.2.5. Comparison to WY2004-2013. A comparison of the WY2004-2013 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-7**. The annual performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

Table 3-11. TN Annual Load Targets and Limits for the historical period of record for the C-23 Sub-watershed (Base Period: WY1989-2013).

Water Year	Observed Rain, inches	TN-based Adjusted Rain, inches	TON-based Adjusted Rain, inches	Observed Load, mt	TN-based Prediction, mt	TN-based UCL mt	TON-based Prediction, mt	TON-based UCL mt
1980	53.13	42.67	42.08	242.457	118.299	258.861	111.607	251.851
1981	32.38	33.58	33.60	87.068	10.270	109.419	10.866	109.790
1982	49.06	48.75	48.53	201.674	178.421	266.970	175.490	263.838
1983	58.13	54.64	54.80	422.169	229.916	317.834	229.926	317.645
1984	51.35	51.24	51.26	242.007	200.879	284.920	199.998	283.849
1985	39.51	44.64	44.67	129.798	138.657	233.603	138.376	233.107
1986	44.18	42.61	42.44	196.190	117.688	209.038	115.470	206.613
1987	46.32	41.53	41.32	428.652	106.100	204.907	103.478	202.061
1988	41.74	41.06	41.18	231.369	101.001	188.630	101.934	189.364
1989	38.04	41.18	41.29	96.010	102.339	195.830	103.135	196.414
1990	37.92	38.42	38.46	91.846	71.044	161.669	71.418	161.838
1991	55.67	49.75	49.60	226.920	187.643	280.741	185.278	278.166
1992	41.68	42.87	42.95	227.935	120.412	208.110	120.784	208.283
1993	75.31	74.44	74.09	432.644	369.383	464.628	364.983	460.012
1994	56.23	53.89	54.26	192.316	223.662	316.996	225.530	318.652
1995	61.09	61.62	61.98	467.390	284.112	378.764	285.086	379.524
1996	64.45	78.46	78.10	557.314	393.144	496.318	388.588	491.528
1997	47.30	45.61	45.77	124.815	148.420	234.677	149.318	235.380
1998	53.96	46.20	46.34	313.340	154.236	248.552	154.808	248.910
1999	41.94	41.85	41.65	145.364	109.571	202.902	107.005	200.125
2000	57.55	59.56	59.12	367.741	268.765	360.990	263.908	355.924
2001	35.03	42.50	42.28	86.644	116.541	226.752	113.801	223.762
2002	46.30	45.30	44.99	279.585	145.370	241.007	141.623	237.044
2003	51.02	47.61	47.56	234.485	167.740	254.603	166.514	253.180
2004	42.08	44.26	44.11	265.527	134.802	225.186	132.708	222.887
2005	66.35	64.60	63.69	417.343	305.443	420.553	297.279	412.129
2006	69.66	77.56	77.41	592.779	387.904	483.628	384.631	480.138
2007	33.59	33.47	33.32	95.478	8.729	112.451	7.110	110.599
2008	52.17	51.67	51.67	197.982	204.684	288.753	203.625	287.505
2009	40.25	39.73	39.20	247.722	86.104	208.145	79.845	201.611
2010	59.53	65.54	65.37	218.651	311.980	410.328	308.896	405.671
2011	35.72	36.13	35.99	61.842	43.334	142.357	41.601	140.400
2012	46.18	45.53	45.29	132.225	147.582	238.978	144.582	235.771
2013	46.82	42.12	41.80	173.812	112.459	217.393	108.621	213.318

(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.

Figure 3-7. Comparison of WY2004-2013 TN loads with Annual Load Targets and Limits for the C-23 Sub-watershed.



Notes:

1. The Base Period extended from WY1989-2000.
2. The performance determination for WY2007 and WY2011 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 C-23 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%	10.6%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	8.8%
Step 4. Load > Annual Load Limit?	<10%	2.5%
Cumulative Exceedance Frequency	**<17.5%**	**10.7%**

Table 3-13. Exceedance frequencies for the TON-based prediction and UCL for the C-23 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%	2.5%
Cumulative Exceedance Frequency	**<17.5%**	**10.7%**

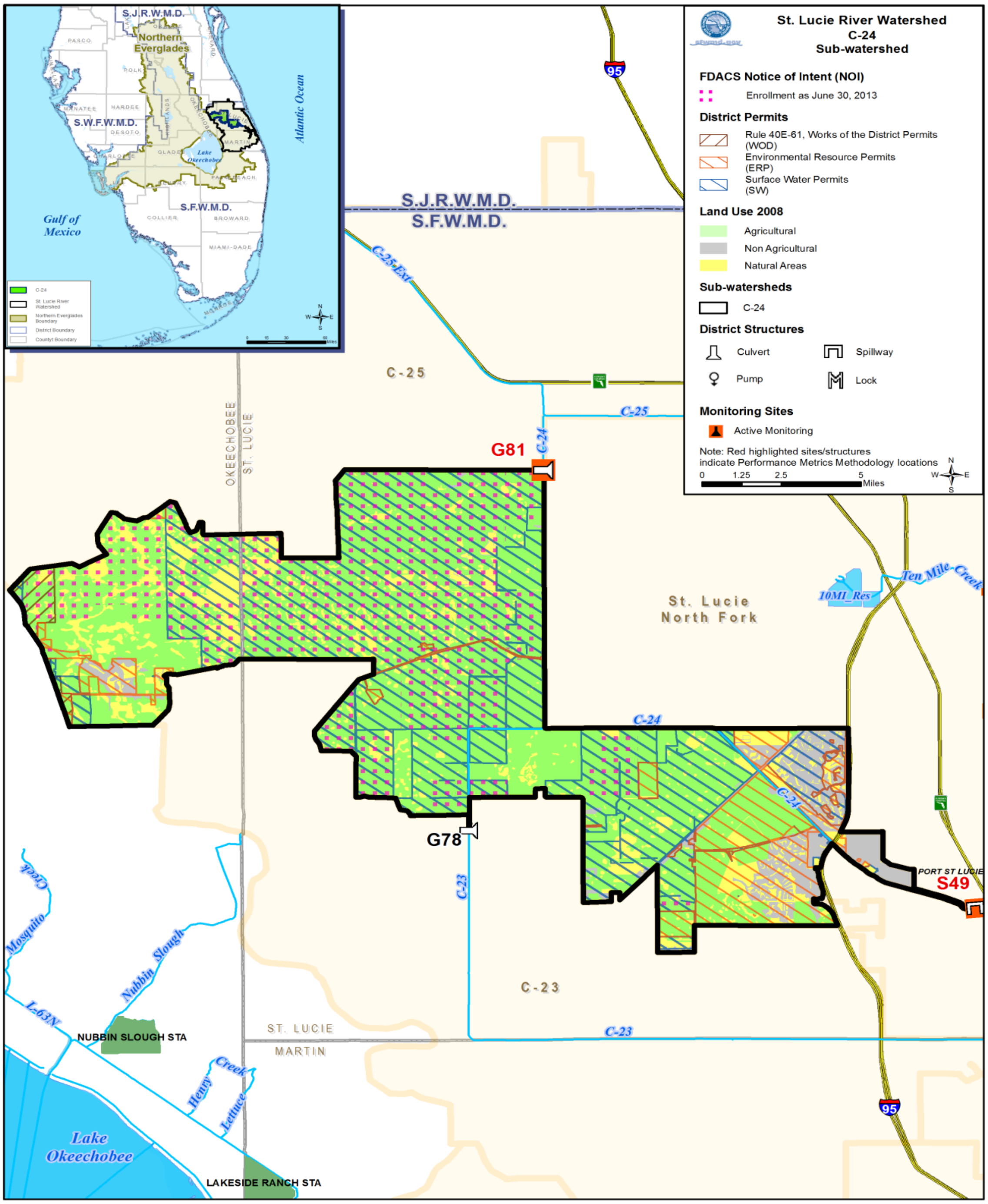
3.2 C-24 Sub-watershed

The following sections present a description of the C-24 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 C-24 Sub-watershed has a total drainage area of approximately 83,359 acres (**Figure 3-8**). The majority of the C-24 Sub-watershed is located in southwest St. Lucie County, with a small section located in eastern Okeechobee County. Major land uses include pastures (approximately 47,000 acres), citrus farms (approximately 17,500 acres), and natural areas (approximately 14,000 acres). The major drainage canals in the C-24 Sub-watershed include the C-24 Canal and a portion of the C-23 Canal. There are four control structures that regulate flow in the C-24 Basin: S-49 (a gated spillway that controls water surface elevations in C-24 and controls discharges from C-24 to tidewater), G-78 (a gated culvert southwest of the confluence of C-23 and C-24), G-79 (a culvert in the alignment of C-23 at the intersection of C-23 and C-24 that controls flows east and west), and G-81 (a steel sheet-pile dam with a gated weir that functions as a divide between the C-24 and C-25 basins). The main functions of the canals and control structures in the C-24 Sub-watershed include removing excess water, supplying water, and maintaining a groundwater table elevation west of S-49 to prevent saltwater intrusion into local groundwater. Water in the C-24 Canal can flow north to G-81, where it converges with the C-25 and flows east, or it can flow south to G-79 where it can either continue east and discharge into the North Fork of the St. Lucie River, or flow west and then south to the C-23 Canal (SFWMD 1988b; USACE and SFWMD 2004). Data from S-49 and G-81 were used in the development of the performance metric (flow and nutrient monitoring sites are identified in **Tables B-1** and **B-2**). Missing water quality data at G-81 was assumed to be adequately represented by measured and estimated water quality data at S-99, (HDR, 2011).

Figure 3-8. C-24 Sub-watershed schematic (from SFWMD 2013).



The historical data analysis for the C-24 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 St. Lucie River Source Control Programs) with the District (HDR 2011a).

The performance measure methodology is based on flows and nutrient loads (TP and TN) resulting from rainfall and runoff from the C-24 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 WY1979-2013. 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 C-24 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 WY1984-1993 was selected for the following reasons (HDR 2011a).

- This period precedes large scale implementation of source control measures,
- Current nutrient loading levels are within approximately ±25 percent of the base period levels.
- It contained a reasonably wide range of hydrologic conditions.
- Rainfall patterns during this period are reasonably representative of long-term conditions.
- 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 WY2004-2013 in **Tables 3-17** through **3-19** for TP, TN and TON, respectively**.**

Table 3-14. Summary of historical TP data for the C-24 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
1980	166,566	75.483	367	55.88	23.98	2.00	5.891	1.059	2.207
1981	15,174	5.870	314	29.16	2.18	0.16	-1.181	0.693	0.188
1982	91,554	39.801	352	50.25	13.18	1.05	-0.338	0.797	0.746
1983	276,762	71.499	209	53.31	39.84	1.89	-1.246	0.576	0.087
1984	122,743	43.018	284	46.09	17.67	1.14	-0.671	0.675	0.411
1985	92,557	40.208	352	34.85	13.32	1.06	-0.790	0.774	0.329
1986	121,641	60.437	403	46.15	17.51	1.60	-0.037	0.862	0.957
1987	113,170	48.994	351	45.42	16.29	1.30	0.373	0.746	0.882
1988	87,443	44.254	410	37.67	12.59	1.17	0.019	0.619	0.475
1989	46,905	19.225	332	37.40	6.75	0.51	0.766	0.650	0.869
1990	70,471	28.051	323	33.81	10.14	0.74	-1.596	0.709	0.209
1991	184,224	98.875	435	63.82	26.52	2.61	3.513	0.643	1.299
1992	149,207	55.248	300	50.37	21.48	1.46	-0.991	0.702	0.488
1993	273,314	107.789	320	68.51	39.35	2.85	1.135	0.839	1.080
1994	140,029	59.549	345	52.81	20.16	1.57	-1.082	0.444	-0.203
1995	264,484	79.089	242	61.11	38.07	2.09	-0.795	0.478	0.323
1996	243,056	74.456	248	63.96	34.99	1.97	-0.953	0.929	0.696
1997	97,162	27.323	228	48.37	13.99	0.72	-1.084	0.606	0.397
1998	209,866	71.577	276	56.50	30.21	1.89	-1.083	0.475	0.316
1999	115,937	46.285	324	42.37	16.69	1.22	-0.116	0.838	0.883
2000	204,812	88.020	348	59.85	29.48	2.33	-0.029	0.955	1.092
2001	50,233	19.377	313	37.47	7.23	0.51	1.637	1.187	1.269
2002	206,302	85.381	336	47.60	29.70	2.26	-0.420	0.888	0.860
2003	156,591	66.013	342	52.89	22.54	1.75	-0.201	0.727	0.702
2004	156,646	60.344	312	45.13	22.55	1.60	-1.202	0.819	0.682
2005	239,510	168.717	571	63.30	34.48	4.46	4.530	1.145	1.943
2006	259,534	119.545	373	59.99	37.36	3.16	-0.753	0.809	0.438
2007	41,879	23.669	458	30.90	6.03	0.63	0.153	0.870	1.052
2008	119,587	50.173	340	49.22	17.22	1.33	-1.323	0.681	0.391
2009	135,197	78.694	472	42.15	19.46	2.08	4.928	1.192	2.016
2010	160,124	62.525	317	60.83	23.05	1.65	-1.429	0.608	-0.277
2011	101,347	26.830	215	37.51	14.59	0.71	-1.360	0.706	0.003
2012	141,516	54.704	313	47.77	20.37	1.45	0.029	0.883	0.953
2013	153,652	56.213	297	51.04	22.12	1.49	1.696	0.858	1.099
Minimum	***15,174***	***5.870***	***209***	***29.16***	***2.18***	***0.16***	***-1.596***	***0.444***	***-0.277***
Average	***147,329***	***60.507***	***333***	***48.93***	***21.21***	***1.60***	***0.176***	***0.778***	***0.731***
Maximum	***276,762***	***168.717***	***571***	***68.51***	***39.84***	***4.46***	***5.891***	***1.192***	***2.207***
Std. Dev.	***70,099***	***32.385***	***74***	***10.35***	***10.09***	***0.86***	***1.899***	***0.188***	***0.578***
Skewness	***0.260***	***1.135***	***0.936***	***-0.063***	***0.260***	***1.14***	***1.805***	***0.503***	***0.748***
Median	***140,773***	***57.881***	***328***	***48.80***	***20.26***	***1.53***	***-0.379***	***0.760***	***0.699***

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

Table 3-15. Summary of historical TN data for the C-24 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
1980	166,566	497.986	2,424	55.88	23.98	13.17	5.891	1.059	2.207
1981	15,174	57.301	3,061	29.16	2.18	1.52	-1.181	0.693	0.188
1982	91,554	290.547	2,573	50.25	13.18	7.68	-0.338	0.797	0.746
1983	276,762	579.731	1,698	53.31	39.84	15.33	-1.246	0.576	0.087
1984	122,743	268.414	1,773	46.09	17.67	7.10	-0.671	0.675	0.411
1985	92,557	216.916	1,900	34.85	13.32	5.74	-0.790	0.774	0.329
1986	121,641	283.678	1,891	46.15	17.51	7.50	-0.037	0.862	0.957
1987	113,170	311.886	2,234	45.42	16.29	8.25	0.373	0.746	0.882
1988	87,443	181.601	1,684	37.67	12.59	4.80	0.019	0.619	0.475
1989	46,905	83.731	1,447	37.40	6.75	2.21	0.766	0.650	0.869
1990	70,471	139.225	1,602	33.81	10.14	3.68	-1.596	0.709	0.209
1991	184,224	341.465	1,503	63.82	26.52	9.03	3.513	0.643	1.299
1992	149,207	203.907	1,108	50.37	21.48	5.39	-0.991	0.702	0.488
1993	273,314	470.697	1,396	68.51	39.35	12.45	1.135	0.839	1.080
1994	140,029	498.410	2,886	52.81	20.16	13.18	-1.082	0.444	-0.203
1995	264,484	447.932	1,373	61.11	38.07	11.85	-0.795	0.478	0.323
1996	243,056	429.437	1,432	63.96	34.99	11.36	-0.953	0.929	0.696
1997	97,162	190.098	1,586	48.37	13.99	5.03	-1.084	0.606	0.397
1998	209,866	486.661	1,880	56.50	30.21	12.87	-1.083	0.475	0.316
1999	115,937	261.721	1,830	42.37	16.69	6.92	-0.116	0.838	0.883
2000	204,812	438.242	1,735	59.85	29.48	11.59	-0.029	0.955	1.092
2001	50,233	99.712	1,609	37.47	7.23	2.64	1.637	1.187	1.269
2002	206,302	413.516	1,625	47.60	29.70	10.94	-0.420	0.888	0.860
2003	156,591	300.363	1,555	52.89	22.54	7.94	-0.201	0.727	0.702
2004	156,646	281.160	1,455	45.13	22.55	7.44	-1.202	0.819	0.682
2005	239,510	515.924	1,746	63.30	34.48	13.64	4.530	1.145	1.943
2006	259,534	466.696	1,458	59.99	37.36	12.34	-0.753	0.809	0.438
2007	41,879	96.228	1,863	30.90	6.03	2.54	0.153	0.870	1.052
2008	119,587	220.633	1,496	49.22	17.22	5.84	-1.323	0.681	0.391
2009	135,197	272.647	1,635	42.15	19.46	7.21	4.928	1.192	2.016
2010	160,124	303.198	1,535	60.83	23.05	8.02	-1.429	0.608	-0.277
2011	101,347	183.601	1,469	37.51	14.59	4.86	-1.360	0.706	0.003
2012	141,516	323.327	1,852	47.77	20.37	8.55	0.029	0.883	0.953
2013	153,652	306.497	1,617	51.04	22.12	8.11	1.696	0.858	1.099
Minimum	***15,174***	***57.301***	***1,108***	***29.16***	***2.18***	***1.52***	***-1.596***	***0.444***	***-0.277***
Average	***147,329***	***307.738***	***1,693***	***48.93***	***21.21***	***8.14***	***0.176***	***0.778***	***0.731***
Maximum	***276,762***	***579.731***	***3,061***	***68.51***	***39.84***	***15.33***	***5.891***	***1.192***	***2.207***
Std. Dev.	***70,099***	***139.851***	***423***	***10.35***	***10.09***	***3.70***	***1.899***	***0.188***	***0.578***
Skewness	***0.260***	***0.077***	***1.664***	***-0.063***	***0.260***	***0.08***	***1.805***	***0.503***	***0.748***
Median	***140,773***	***295.455***	***1,630***	***48.80***	***20.26***	***7.81***	***-0.379***	***0.760***	***0.699***

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

Table 3-16. Summary of historical TON data for the C-24 Sub-watershed.

Water Year	Flow AF	TON Load mt	FWM TON Conc µg/L	Rainfall inches	Unit Area Runoff inches	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1980	166,566	430.869	2,097	55.88	23.98	11.40	5.891	1.059	2.207
1981	15,174	47.786	2,553	29.16	2.18	1.26	-1.181	0.693	0.188
1982	91,554	249.671	2,211	50.25	13.18	6.60	-0.338	0.797	0.746
1983	276,762	480.679	1,408	53.31	39.84	12.71	-1.246	0.576	0.087
1984	122,743	218.433	1,443	46.09	17.67	5.78	-0.671	0.675	0.411
1985	92,557	135.974	1,191	34.85	13.32	3.60	-0.790	0.774	0.329
1986	121,641	213.089	1,420	46.15	17.51	5.64	-0.037	0.862	0.957
1987	113,170	247.990	1,776	45.42	16.29	6.56	0.373	0.746	0.882
1988	87,443	152.370	1,413	37.67	12.59	4.03	0.019	0.619	0.475
1989	46,905	74.151	1,282	37.40	6.75	1.96	0.766	0.650	0.869
1990	70,471	115.084	1,324	33.81	10.14	3.04	-1.596	0.709	0.209
1991	184,224	284.155	1,250	63.82	26.52	7.52	3.513	0.643	1.299
1992	149,207	152.255	827	50.37	21.48	4.03	-0.991	0.702	0.488
1993	273,314	379.334	1,125	68.51	39.35	10.03	1.135	0.839	1.080
1994	140,029	455.925	2,640	52.81	20.16	12.06	-1.082	0.444	-0.203
1995	264,484	376.766	1,155	61.11	38.07	9.96	-0.795	0.478	0.323
1996	243,056	377.286	1,258	63.96	34.99	9.98	-0.953	0.929	0.696
1997	97,162	178.997	1,494	48.37	13.99	4.73	-1.084	0.606	0.397
1998	209,866	438.972	1,696	56.50	30.21	11.61	-1.083	0.475	0.316
1999	115,937	238.620	1,669	42.37	16.69	6.31	-0.116	0.838	0.883
2000	204,812	372.959	1,476	59.85	29.48	9.86	-0.029	0.955	1.092
2001	50,233	94.015	1,517	37.47	7.23	2.49	1.637	1.187	1.269
2002	206,302	343.427	1,350	47.60	29.70	9.08	-0.420	0.888	0.860
2003	156,591	263.542	1,364	52.89	22.54	6.97	-0.201	0.727	0.702
2004	156,646	246.107	1,274	45.13	22.55	6.51	-1.202	0.819	0.682
2005	239,510	462.465	1,565	63.30	34.48	12.23	4.530	1.145	1.943
2006	259,534	371.043	1,159	59.99	37.36	9.81	-0.753	0.809	0.438
2007	41,879	78.649	1,523	30.90	6.03	2.08	0.153	0.870	1.052
2008	119,587	192.438	1,305	49.22	17.22	5.09	-1.323	0.681	0.391
2009	135,197	242.761	1,456	42.15	19.46	6.42	4.928	1.192	2.016
2010	160,124	265.486	1,344	60.83	23.05	7.02	-1.429	0.608	-0.277
2011	33,643	177.423	4,275	35.72	4.84	4.69	0.986	0.851	0.973
2012	60,600	262.871	3,517	46.18	8.72	6.95	0.555	0.874	1.129
2013	85,776	274.499	2,594	46.82	12.35	7.26	3.272	0.896	1.507
Minimum	***15,174***	***47.786***	***827***	***29.16***	***2.18***	***1.26***	***-1.596***	***0.444***	***-0.277***
Average	***140,962***	***261.650***	***1,505***	***48.70***	***20.29***	***6.92***	***0.307***	***0.783***	***0.777***
Maximum	***276,762***	***480.679***	***4,275***	***68.51***	***39.84***	***12.71***	***5.891***	***1.192***	***2.207***
Std. Dev.	***74,433***	***121.406***	***710***	***10.42***	***10.72***	***3.21***	***1.939***	***0.188***	***0.579***
Skewness	***0.315***	***0.137***	***2.217***	***-0.018***	***0.315***	***0.14***	***1.614***	***0.421***	***0.637***
Median	***128,970***	***248.831***	***1,432***	***47.99***	***18.57***	***6.58***	***-0.270***	***0.786***	***0.724***

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

Table 3-17. Comparison of Base Period with period of record and WY2004-2013 data for the C-24 Sub-watershed: TP.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	15,174	5.870	209	29.16	0.16
Annual Average	147,329	60.507	333	48.93	1.60
Annual Median	140,773	57.881	328	48.80	1.53
Annual Maximum	276,762	168.717	571	68.51	49.00
Preliminary Base Period WY1984-1993					
Annual Minimum	46,905	19.225	284	33.81	0.51
Annual Average	126,168	54.610	351	46.41	1.44
Annual Median	117,406	46.624	342	45.76	1.23
Annual Maximum	273,314	107.789	435	68.51	2.85
Difference between Period of Record and Base Period					
Annual Minimum	-31,731	-13.355	-75	-4.65	-0.35
Annual Average	21,162	5.897	-18	2.52	0.16
Annual Median	23,367	11.257	-14	3.04	0.30
Annual Maximum	3,448	60.928	136	0.00	46.15
Annual Minimum	-68%	-69%	-26%	-14%	-69%
Annual Average	17%	11%	-5%	5%	11%
Annual Median	20%	24%	-4%	7%	24%
Annual Maximum	1%	57%	31%	0%	1619%
WY2004-2013					
Annual Minimum	41,879	23.669	215	30.90	0.63
Annual Average	150,899	70.141	377	48.78	1.86
Annual Median	147,584	58.279	329	48.50	1.54
Annual Maximum	259,534	168.717	571	63.30	4.46
Difference between WY2004-2013 and Base Period					
Annual Minimum	-5,026	4.444	-69	-2.91	0.12
Annual Average	24,732	15.532	26	2.38	0.41
Annual Median	30,179	11.655	-13	2.74	0.31
Annual Maximum	-13,780	60.928	136	-5.21	1.61
Annual Minimum	-11%	23%	-24%	-9%	23%
Annual Average	20%	28%	7%	5%	28%
Annual Median	26%	25%	-4%	6%	25%
Annual Maximum	-5%	57%	31%	-8%	57%

Table 3-18. Comparison of Base Period with period of record and WY2004-2013 data for the C-24 Sub-watershed: TN.

Metric	Flow AF	TN Load mt	TN Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	15,174	57.301	1,108	29.16	1.52
Annual Average	147,329	307.738	1,693	48.93	8.14
Annual Median	140,773	295.455	1,630	48.80	7.81
Annual Maximum	276,762	579.731	3,061	68.51	49.00
Preliminary Base Period WY1984-1993					
Annual Minimum	46,905	83.731	1,108	33.81	2.21
Annual Average	126,168	250.152	1,607	46.41	6.62
Annual Median	117,406	242.665	1,643	45.76	6.42
Annual Maximum	273,314	470.697	2,234	68.51	12.45
Difference between Period of Record and Base Period					
Annual Minimum	-31,731	-26.430	0	-4.65	-0.70
Annual Average	21,162	57.586	86	2.52	1.52
Annual Median	23,367	52.790	-13	3.04	1.40
Annual Maximum	3,448	109.034	827	0.00	36.55
Annual Minimum	-68%	-32%	0%	-14%	-32%
Annual Average	17%	23%	5%	5%	23%
Annual Median	20%	22%	-1%	7%	22%
Annual Maximum	1%	23%	37%	0%	294%
WY2004-2013					
Annual Minimum	41,879	96.228	1,455	30.90	2.54
Annual Average	150,899	296.991	1,596	48.78	7.85
Annual Median	147,584	292.179	1,576	48.50	7.73
Annual Maximum	259,534	515.924	1,863	63.30	13.64
Difference between WY2004-2013 and Base Period					
Annual Minimum	-5,026	12.497	347	-2.91	0.33
Annual Average	24,732	46.839	-12	2.38	1.24
Annual Median	30,179	49.514	-67	2.74	1.31
Annual Maximum	-13,780	45.227	-371	-5.21	1.20
Annual Minimum	-11%	15%	31%	-9%	15%
Annual Average	20%	19%	-1%	5%	19%
Annual Median	26%	20%	-4%	6%	20%
Annual Maximum	-5%	10%	-17%	-8%	10%

Table 3-19. Comparison of Base Period with period of record and WY2004-2013 data for the C-24 Sub-watershed: TON.

Metric	Flow AF	TON Load mt	TON Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	15,174	47.786	827	29.16	1.26
Annual Average	140,962	261.650	1,505	48.70	6.92
Annual Median	128,970	248.831	1,432	47.99	6.58
Annual Maximum	276,762	480.679	4,275	68.51	49.00
Preliminary Base Period WY1984-1993					
Annual Minimum	46,905	74.151	827	33.81	1.96
Annual Average	126,168	197.284	1,268	46.41	5.22
Annual Median	117,406	182.730	1,303	45.76	4.83
Annual Maximum	273,314	379.334	1,776	68.51	10.03
Difference between Period of Record and Base Period					
Annual Minimum	-31,731	-26.365	0	-4.65	-0.70
Annual Average	14,794	64.366	237	2.29	1.70
Annual Median	11,565	66.101	129	2.23	1.75
Annual Maximum	3,448	101.345	2,499	0.00	38.97
Annual Minimum	-68%	-36%	0%	-14%	-36%
Annual Average	12%	33%	19%	5%	33%
Annual Median	10%	36%	10%	5%	36%
Annual Maximum	1%	27%	141%	0%	388%
WY2004-2013					
Annual Minimum	33,643	78.649	1,159	30.90	2.08
Annual Average	129,250	257.374	1,614	48.02	6.81
Annual Median	127,392	254.489	1,490	46.50	6.73
Annual Maximum	259,534	462.465	4,275	63.30	12.23
Difference between WY2004-2013 and Base Period					
Annual Minimum	-13,262	4.498	332	-2.91	0.12
Annual Average	3,082	60.091	347	1.62	1.59
Annual Median	9,987	71.760	187	0.74	1.90
Annual Maximum	-13,780	83.131	2,499	-5.21	2.20
Annual Minimum	-28%	6%	40%	-9%	6%
Annual Average	2%	30%	27%	3%	30%
Annual Median	9%	39%	14%	2%	39%
Annual Maximum	-5%	22%	141%	-8%	22%

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 = -51.11786 + 2.27817 X

Explained Variance = 90.0% , Standard Error of Regression = 9.547 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.

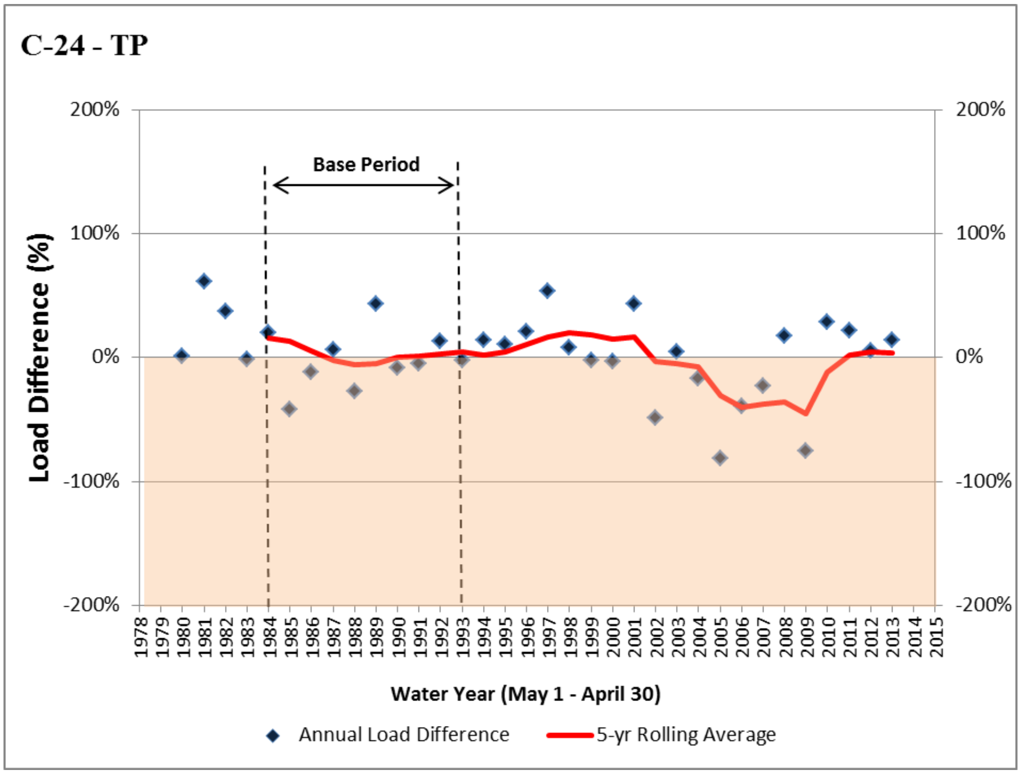
Table 3-20 presents the annual observed and predicted sub-watershed TP loads. The load trend is presented in **Figure 3-9**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-9** denotes a reduction in loads.

Table 3-20. WY1980 – WY2013 C-24 Sub-watershed TP measurements and calculations. (Base Period: WY1984-1993).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1980	55.88	75.483	76.186	1%	
1981	29.16	5.870	15.314	62%	
1982	50.25	39.801	63.360	37%	
1983	53.31	71.499	70.332	-2%	
1984	46.09	43.018	53.883	20%	16%
1985	34.85	40.208	28.276	-42%	13%
1986	46.15	60.437	54.020	-12%	6%
1987	45.42	48.994	52.357	6%	-2%
1988	37.67	44.254	34.701	-28%	-6%
1989	37.40	19.225	34.086	44%	-5%
1990	33.81	28.051	25.907	-8%	0%
1991	63.82	98.875	94.275	-5%	1%
1992	50.37	55.248	63.634	13%	3%
1993	68.51	107.789	104.960	-3%	4%
1994	52.81	59.549	69.192	14%	2%
1995	61.11	79.089	88.101	10%	5%
1996	63.96	74.456	94.594	21%	11%
1997	48.37	27.323	59.077	54%	16%
1998	56.50	71.577	77.599	8%	20%
1999	42.37	46.285	45.408	-2%	18%
2000	59.85	88.020	85.231	-3%	15%
2001	37.47	19.377	34.245	43%	16%
2002	47.60	85.381	57.323	-49%	-4%
2003	52.89	66.013	69.375	5%	-5%
2004	45.13	60.344	51.696	-17%	-7%
2005	63.30	168.717	93.091	-81%	-31%
2006	59.99	119.545	85.550	-40%	-40%
2007	30.90	23.669	19.278	-23%	-37%
2008	49.22	50.173	61.014	18%	-36%
2009	42.15	78.694	44.907	-75%	-45%
2010	60.83	62.525	87.463	29%	-12%
2011	37.51	26.830	34.336	22%	2%
2012	47.77	54.704	57.710	5%	4%
2013	51.04	56.213	65.160	14%	4%

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

Figure 3-9. C-24 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.

$$\text{TN Annual Load} = -411.09737 + 7.22673\ X + 451.39759\ C$$

Explained Variance = 84.0%, Standard Error of Regression = 50.184 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:

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

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

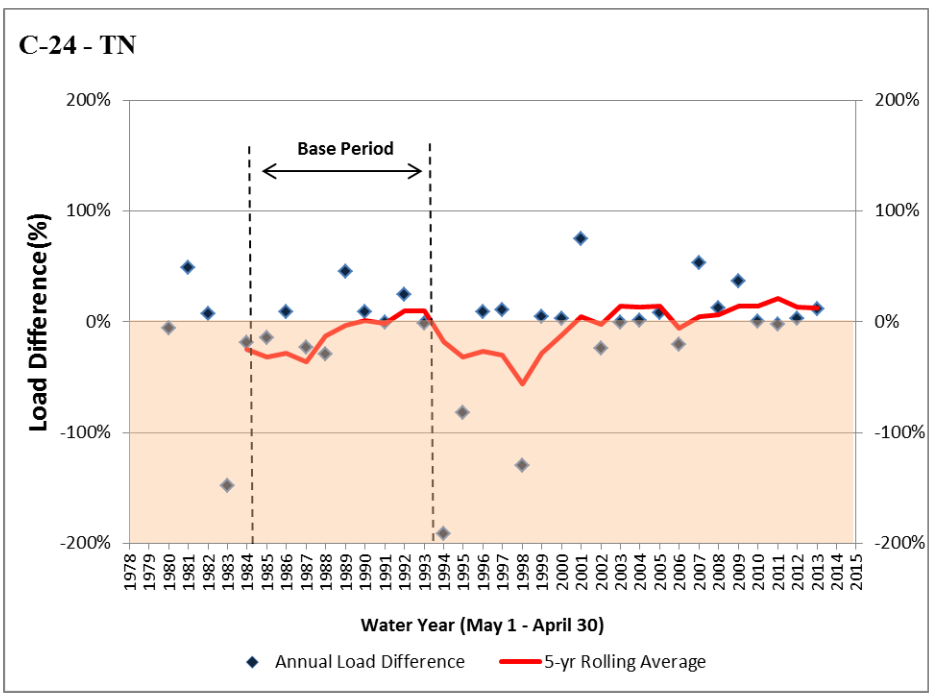
$X = 12\, m_1$

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

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 3-10.** 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 3-10** denotes a reduction in loads.

Figure 3-10. C-24 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.

Table 3-21. WY1980 – WY2013 C-24 Sub-watershed TN measurements and calculations. (Base Period: WY1984-1993).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1980	55.88	497.986	470.763	-6%	
1981	29.16	57.301	112.453	49%	
1982	50.25	290.547	311.810	7%	
1983	53.31	579.731	234.165	-148%	
1984	46.09	268.414	226.676	-18%	-25%
1985	34.85	216.916	190.136	-14%	-31%
1986	46.15	283.678	311.521	9%	-29%
1987	45.42	311.886	253.883	-23%	-37%
1988	37.67	181.601	140.549	-29%	-12%
1989	37.40	83.731	152.591	45%	-3%
1990	33.81	139.225	153.279	9%	1%
1991	63.82	341.465	340.361	0%	-2%
1992	50.37	203.907	269.794	24%	10%
1993	68.51	470.697	462.729	-2%	10%
1994	52.81	498.410	170.967	-192%	-18%
1995	61.11	447.932	246.296	-82%	-32%
1996	63.96	429.437	470.473	9%	-27%
1997	48.37	190.098	212.007	10%	-30%
1998	56.50	486.661	211.627	-130%	-57%
1999	42.37	261.721	273.370	4%	-28%
2000	59.85	438.242	452.507	3%	-11%
2001	37.47	99.712	395.497	75%	4%
2002	47.60	413.516	333.736	-24%	-2%
2003	52.89	300.363	299.291	0%	14%
2004	45.13	281.160	284.740	1%	13%
2005	63.30	515.924	563.205	8%	14%
2006	59.99	466.696	387.615	-20%	-6%
2007	30.90	96.228	204.925	53%	5%
2008	49.22	220.633	252.004	12%	7%
2009	42.15	272.647	431.575	37%	15%
2010	60.83	303.198	302.955	0%	14%
2011	37.50	183.601	179.043	-3%	21%
2012	47.75	323.326	333.015	3%	13%
2013	51.03	306.497	345.433	11%	13%

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

3.2.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the C-24 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 = -35.78181 + 1.59471 X

Explained Variance = 90.0%, Standard Error of Regression = 6.682 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 + 1.39682 SE

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

$$SE = 6.68247 [1 + 1/10 + (X-X_m)^2 / 1258.31109]^{0.5}$$

Where:

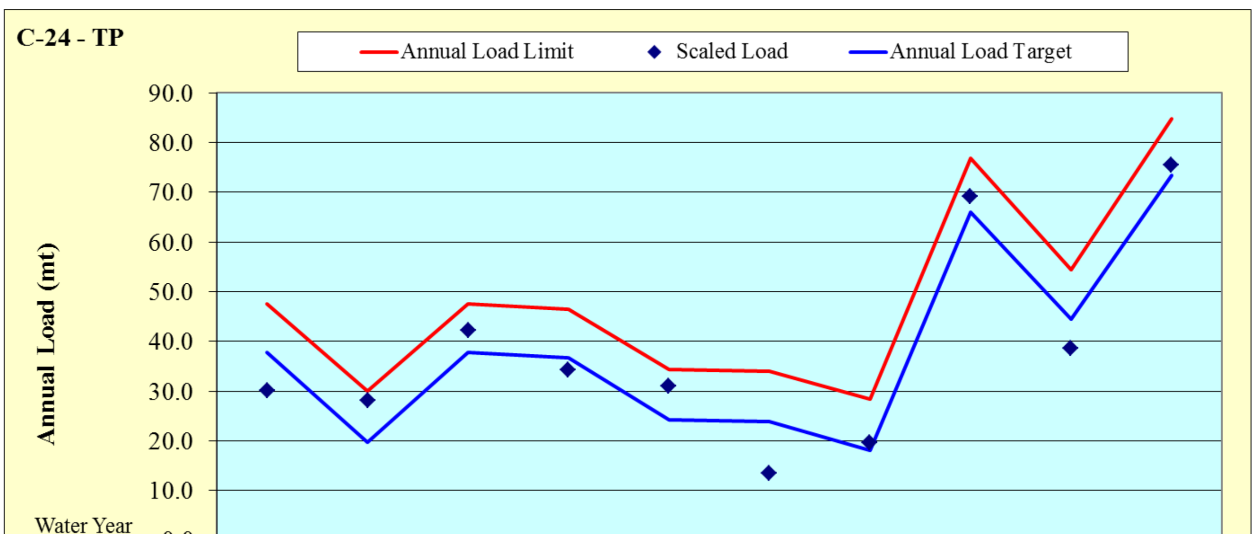
X = the 12-month total rainfall (inches)

X_m = average value of the predictor in base period = 46.409 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 3-11**. 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 3-11. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the C-24 Sub-watershed.

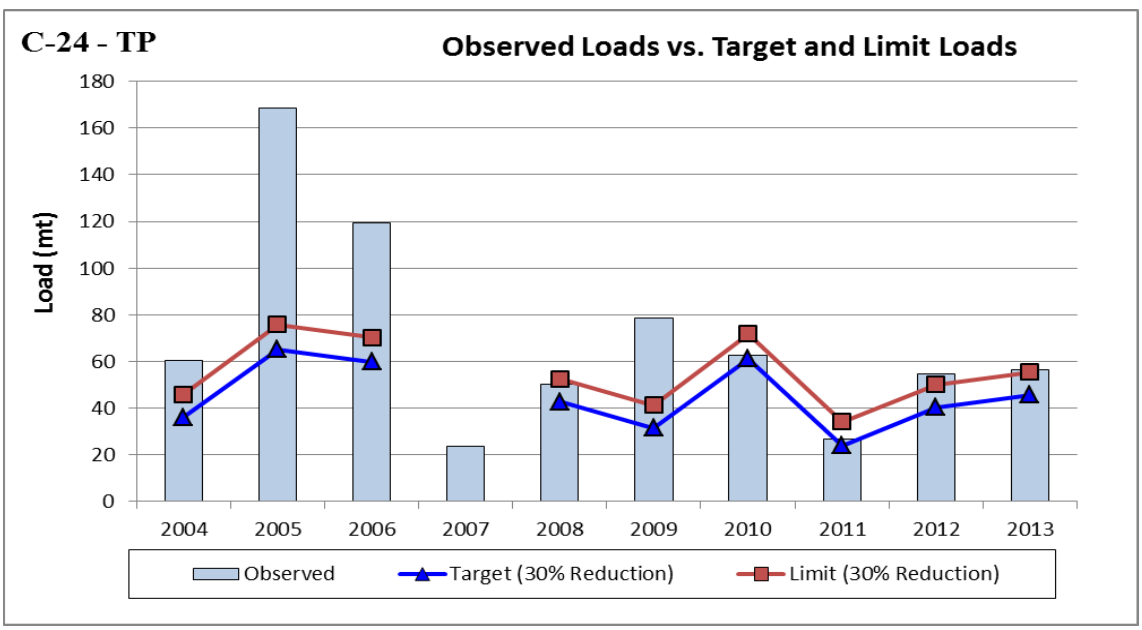


	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Annual Load Limit	47.509	30.045	47.604	46.443	34.347	33.933	28.471	76.802	54.389	84.859
Scaled Load	30.113	28.146	42.306	34.296	30.978	13.458	19.636	69.213	38.674	75.452
Annual Load Target	37.718	19.794	37.814	36.650	24.291	23.860	18.135	65.993	44.544	73.472

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 (33.81 – 68.51 inches). The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the WY1980-2013 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 WY2004-2013. A comparison of the WY2004-2013 observed TP loads to the Annual Load Targets and Limits is presented in **Figure 3-12**.

Figure 3-12. Comparison of WY2004-2013 TP loads with Annual Load Targets and Limits for the C-24 Sub-watershed.



Note: 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.

Table 3-22. TP Annual Load Targets and Limits for the historical period of record for the C-24 Sub-watershed (Base Period: WY1984-1993).

Water Year	Observed Load, mt	Rain inches	Target Load, mt	Limit Load, mt
1980	75.483	55.88	53.331	63.433
1981	5.870	29.16	10.720	21.511
1982	39.801	50.25	44.352	54.194
1983	71.499	53.31	49.232	59.189
1984	43.018	46.09	37.718	47.509
1985	40.208	34.85	19.794	30.045
1986	60.437	46.15	37.814	47.604
1987	48.994	45.42	36.650	46.443
1988	44.254	37.67	24.291	34.347
1989	19.225	37.40	23.860	33.933
1990	28.051	33.81	18.135	28.471
1991	98.875	63.82	65.993	76.802
1992	55.248	50.37	44.544	54.389
1993	107.789	68.51	73.472	84.859
1994	59.549	52.81	48.435	58.369
1995	79.089	61.11	61.671	72.197
1996	74.456	63.96	66.216	77.040
1997	27.323	48.37	41.354	51.158
1998	71.577	56.50	54.319	64.463
1999	46.285	42.37	31.786	41.633
2000	88.020	59.85	59.662	70.071
2001	19.377	37.47	23.972	34.040
2002	85.381	47.60	40.127	49.921
2003	66.013	52.89	48.563	58.500
2004	60.344	45.13	36.188	45.983
2005	168.717	63.30	65.163	75.915
2006	119.545	59.99	59.885	70.307
2007	23.669	30.90	13.495	24.101
2008	50.173	49.22	42.710	52.528
2009	78.694	42.15	31.435	41.289
2010	62.525	60.83	61.225	71.724
2011	26.830	37.51	24.036	34.102
2012	54.704	47.77	40.398	50.194
2013	56.213	51.04	45.612	55.478

Note: Shaded water year (WY2007) indicates the performance determination would have been suspended due to anomalous rainfall coupled with the observed load being greater than the Load Target.

3.2.2.1.3 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 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 C-24 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%	8.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.2%
Step 4. Load > Annual Load Limit?	<10%	5.0%
Cumulative Exceedance Frequency	**<17.5%**	**13.9%**

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 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.

3.2.2.2.1 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 25 percent reduction.

TN-based Prediction = -308.32361 + 5.42005 X + 338.54912 C
Explained Variance = 84.0%, Standard Error of Regression = 35.129 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) $m_2]^{0.5}/m_1$

TN-based UCL = Target + 1.41492 SE

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

SE_{TN} = 37.63828 [1 + 1/10 + 0.00085 $(X-X_m)^2$ + 17.37836 $(C–C_m)^2$ - 0.0607 $(X-X_m)$ $(C–C_m)$ $]^{0.5}$

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 = 46.409 inches

C_m = average value of the predictor in base period = 0.72190

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.

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 = -106.01203 + 6.11018 X

Explained Variance = 78.7%, Standard Error of Regression = 39.847 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 = 12 m_1

TON-based UCL = TON-based Prediction + 1.39682 SE

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

$SE_{TON} = 39.84675 [1 + 1/10 + (X-X_m)^2 / 1258.31109]^{0.5}$

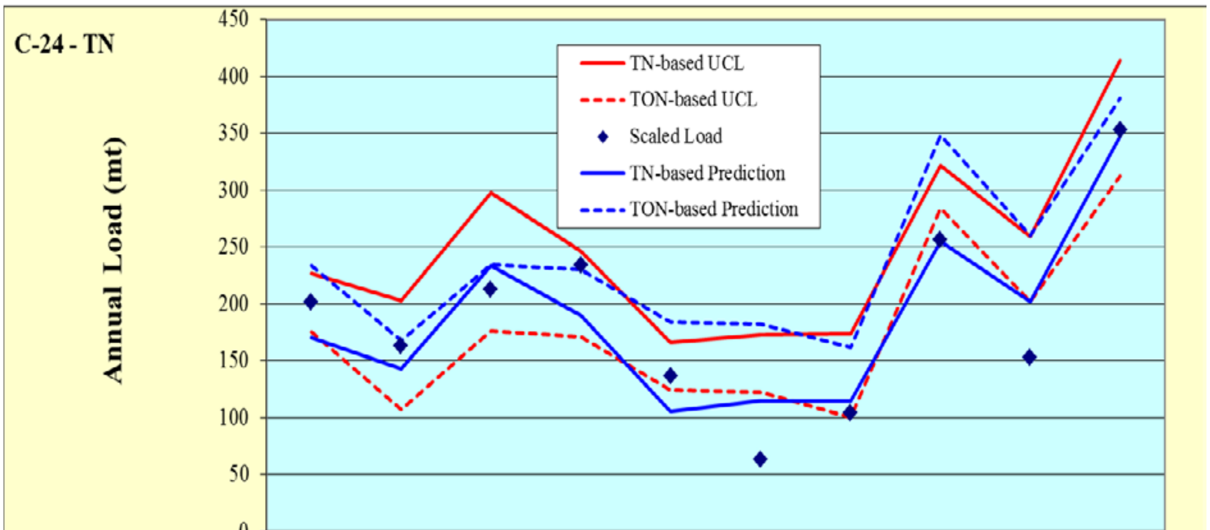
Where:

X = the 12-month total rainfall (inches)

X_m = average value of the predictor in base period = 46.409

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 3-13.**

Figure 3-13. Comparison of scaled annual TN loads with the Annual Load Targets and Limits for the C-24 Sub-watershed.



	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
TN-based UCL	226.803	203.252	297.622	246.580	165.995	173.249	173.965	321.542	258.831	414.310
TON-based UCL	175.606	106.928	175.973	171.512	124.159	122.509	100.573	283.940	201.758	312.597
Scaled Load	201.311	162.687	212.759	233.915	136.201	62.798	104.419	256.099	152.930	353.023
TN-based Prediction	170.007	142.602	233.641	190.413	105.412	114.443	114.960	255.271	202.346	347.047
TON-based Prediction	233.984	168.056	234.350	229.908	184.123	182.571	162.205	348.391	260.463	380.495

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 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.

3.2.2.2.4 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 adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (31.24 – 75.82 inches for the TN-based equations and 33.81 – 68.51 inches for the TON-based equations). Rainfall conditions will be assessed by calculating an adjusted rainfall amount which reflects the cumulative effect of the two variables that comprise the Load Target equation: Rain and C:

TN-based Adjusted Rainfall = equivalent rainfall for mean C variable (inches)

TN-based Adjusted Rain = Observed Rain + 62.46190 (C – 0.7219)

Since the TON-based equations have only one variable (Rain), there is no need for an adjustment.

The adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1980-2013 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**.

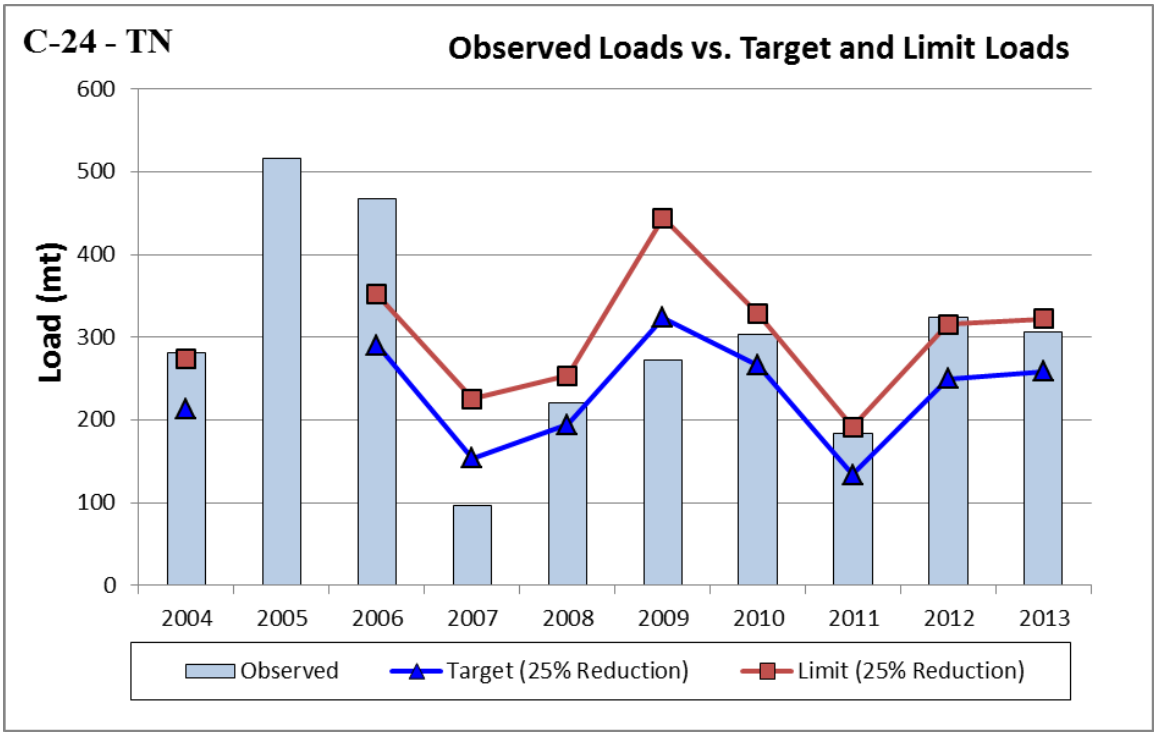
Table 3-24. TN Annual Load Targets and Limits for the historical period of record for the C-24 Sub-watershed (Base Period: WY1984-1993).

Water Year	Observed Rain, inches	Adjusted Rain inches	Observed Load, mt	TN-based Prediction, mt	TN-based UCL mt	TON-based Prediction, mt	TON-based UCL mt
1980	55.88	76.936	497.986	353.072	444.650	235.425	295.662
1981	29.16	27.355	57.301	84.340	145.906	72.161	136.505
1982	50.25	54.941	290.547	233.858	292.026	201.025	259.710
1983	53.31	44.197	579.731	175.624	242.383	219.722	279.093
1984	46.09	43.161	268.414	170.007	226.803	175.606	233.984
1985	34.85	38.104	216.916	142.602	203.252	106.928	168.056
1986	46.15	54.901	283.678	233.641	297.622	175.973	234.350
1987	45.42	46.925	311.886	190.413	246.581	171.512	229.908
1988	37.67	31.243	181.601	105.412	165.996	124.159	184.123
1989	37.40	32.909	83.731	114.443	173.249	122.509	182.571
1990	33.81	33.004	139.225	114.960	173.965	100.573	162.205
1991	63.82	58.892	341.465	255.271	321.542	283.940	348.391
1992	50.37	49.127	203.907	202.346	258.831	201.758	260.463
1993	68.51	75.824	470.697	347.047	414.311	312.597	380.495
1994	52.81	35.452	498.410	128.225	213.845	216.667	275.9
1995	61.11	45.875	447.932	184.722	269.507	267.381	330.149
1996	63.96	76.896	429.437	352.855	425.988	284.795	349.340
1997	48.37	41.131	190.098	159.005	220.893	189.537	247.994
1998	56.50	41.078	486.661	158.720	241.170	239.213	299.698
1999	42.37	49.622	261.721	205.028	267.51	152.876	211.595
2000	59.85	74.410	438.242	339.381	414.831	259.682	321.751
2001	37.47	66.521	99.712	296.624	417.823	122.936	182.973
2002	47.60	57.975	413.516	250.302	317.002	184.833	243.238
2003	52.89	53.209	300.363	224.468	281.18	217.155	276.410
2004	45.13	51.195	281.160	213.555	273.636	169.740	228.150
2005	63.30	89.728	515.924	422.404	529.167	280.762	344.872
2006	59.99	65.430	466.696	290.712	351.814	260.538	322.681
2007	30.90	40.151	96.228	153.694	225.628	82.793	146.037
2008	49.22	46.665	220.633	189.003	245.932	194.731	253.273
2009	42.15	71.514	272.647	323.682	443.683	151.532	210.289
2010	60.83	53.716	303.198	227.216	294.610	265.670	328.278
2011	37.51	36.517	183.601	133.998	191.428	112.244	172.981
2012	47.77	57.833	323.327	249.531	315.604	176.156	234.533
2013	51.04	59.541	306.497	258.791	321.844	180.067	238.446

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

3.2.2.2.5 Comparison to WY2004-2013. A comparison of the WY2004-2013 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-14**.

Figure 3-14. Comparison of WY2004-2013 TN loads with Annual Load Targets and Limits for the C-24 Sub-watershed.



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 C-24 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%	5.1%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.3%
Step 4. Load > Annual Load Limit?	<10%	3.4%
Cumulative Exceedance Frequency	**<17.5%**	**13.8%**

Table 3-26. Exceedance frequencies for the proposed TON-based prediction and UCL for the C-24 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%	8.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.2%
Step 4. Load > Annual Load Limit?	<10%	5.0%
Cumulative Exceedance Frequency	**<17.5%**	**13.9%**

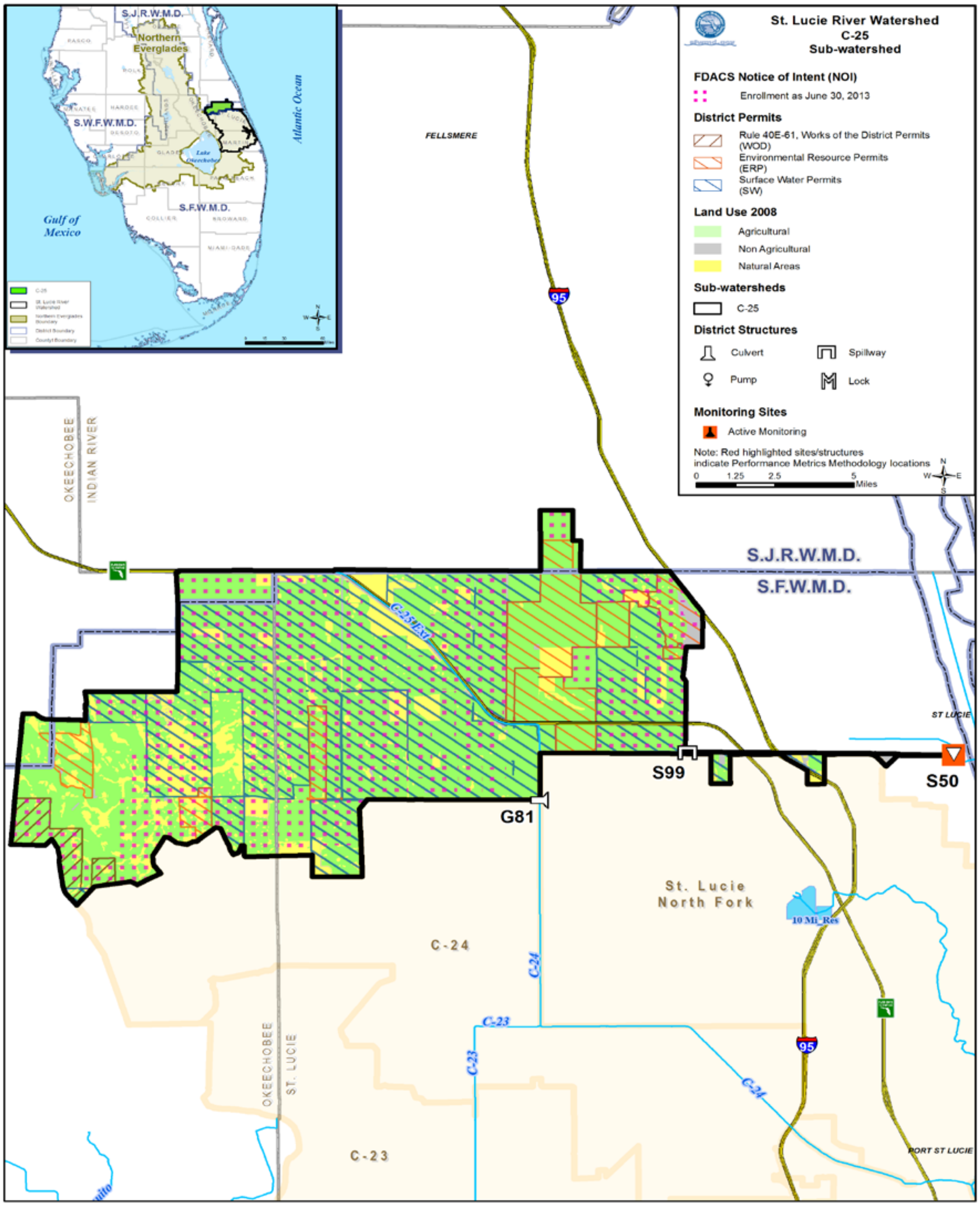
3.3 C-25 Sub-watershed

The following sections present a description of the C-25 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 C-25 Sub-watershed comprises the C-25 and C-25 East basins; these basins have a combined drainage area of approximately 99,726 acres (**Figure 3-15**). A majority of these basins are located in northern St. Lucie County, with a small section of the C-25 basin located in northeastern Okeechobee County. Major land uses in these basins include citrus farms (approximately 60,000 acres), pastures (approximately 29,000 acres), and natural areas including waterways (approximately 20,000 acres). In addition, urban areas along the Indian River Lagoon account for a significant portion of the C-25 East Basin (approximately 1,000 acres). The major drainage canals in the C-25 Sub-watershed include the C-25, C-25 South Leg, and the C-25 Extension. Two other canals that provide flood protection and drainage in the western portion of the C-25 Basin are the Turnpike Canal and the Orange Avenue Borrow Canal. Control structures include S50 (a weir controlling flood runoff, over drainage, and saltwater intrusion), G-81 (a steel sheet-pile dam with a gated weir that functions as a divide between the C-24 and C-25 sub-watersheds) and S-99 (a gated spillway that maintains optimum water level in Canal 25). The main functions of these canals and control structures are to remove excess water from the two basins, to supply water to the two basins and occasionally to the C-24 Basin, and to maintain groundwater table elevations adequate to prevent saltwater intrusion. Water flows southeast through the C-25 extension and then heads east where it discharges into the tidewater in the Indian River Lagoon west of the Fort Pierce inlet. Excess water may be discharged into the C-24 Sub-watershed if needed by way of G-81 (SFWMD, 1988b).

Figure 3-15. C-25 Sub-watershed schematic (from SFWMD 2013).



The C-25 and C-25 East basins typically drain into the Indian River Lagoon, but in some cases, excess water from the C-25 Sub-watershed can be discharged into the C-24 Sub-watershed by way of the G-81 control structure. When this occurs, the C-25 Sub-watershed is considered part of the St. Lucie River Watershed and water discharged into the C-24 from the C-25 Sub-watershed is captured in the discharge volumes from the C-24 Sub-watershed.

The performance metric methodologies are based on flows and nutrient (TP and TN) loads resulting from rainfall and runoff from the C-25 Sub-watershed. The historical data analysis for the C-25 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 St. Lucie River Source Control Programs) with the District, and was supplemented in collaboration with staff (HDR, 2011). Basin flows and loads, adjusted for pass-through flows and loads discharged from external sources, were calculated using algorithms provided in Appendix A. Data from S-50 and G-81 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**). Missing water quality data at G-81 was assumed to be adequately represented by measured and estimated water quality data at S-99, (HDR, 2011).

District staff identified the rainfall stations considered to be representative of the sub-watershed for the period WY1976-2013. Monthly rainfall data and weighting factors for the rainfall stations were developed and provided by the District (**Appendix B**). **Tables 3-27** through **3-29** present the period of record flow and nutrient load data for the C-25 Sub-watershed.

Table 3-27. Summary of historical TP data for the C-25 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
1980	135,312	39.755	238	63.44	16.28	0.88	5.596	1.065	2.243
1981	21,155	1.583	61	33.52	2.55	0.03	-1.182	0.624	-0.083
1982	80,489	18.700	188	56.99	9.69	0.41	0.799	0.758	1.023
1983	215,955	51.348	193	68.19	25.99	1.14	-1.204	0.510	0.024
1984	138,974	15.549	91	50.62	16.72	0.34	-1.334	0.656	0.321
1985	82,894	14.787	145	42.88	9.97	0.33	-1.282	0.760	0.289
1986	121,207	39.364	263	48.02	14.58	0.87	3.346	0.960	1.632
1987	122,123	21.708	144	49.20	14.70	0.48	-0.479	0.705	0.503
1988	79,576	11.443	117	43.44	9.58	0.25	-0.722	0.617	0.377
1989	67,055	7.608	92	43.51	8.07	0.17	0.062	0.602	0.877
1990	63,568	14.439	184	40.29	7.65	0.32	-1.742	0.697	0.075
1991	167,242	26.130	127	60.67	20.12	0.58	-0.208	0.566	0.153
1992	140,308	27.757	160	50.24	16.88	0.61	0.354	0.724	0.667
1993	245,739	39.080	129	68.03	29.57	0.86	1.965	0.859	1.252
1994	107,276	16.876	128	51.41	12.91	0.37	0.552	0.365	-0.925
1995	226,953	45.047	161	67.47	27.31	1.00	0.516	0.504	0.858
1996	196,046	47.925	198	63.15	23.59	1.06	-1.350	0.849	0.481
1997	96,596	20.818	175	55.93	11.62	0.46	-1.217	0.610	0.097
1998	207,884	44.809	175	65.62	25.01	0.99	-0.332	0.467	0.244
1999	97,364	36.945	308	46.11	11.72	0.82	-0.553	0.878	0.874
2000	188,154	74.821	322	64.15	22.64	1.65	-0.867	0.852	0.744
2001	40,703	8.422	168	41.25	4.90	0.19	-0.600	1.084	0.743
2002	182,402	67.504	300	56.90	21.95	1.49	-0.806	0.790	0.617
2003	157,427	51.823	267	63.98	18.94	1.15	1.563	0.779	1.143
2004	119,309	35.506	241	53.85	14.36	0.78	-1.572	0.754	0.549
2005	258,599	190.201	596	58.78	31.12	4.20	2.195	0.992	1.455
2006	227,680	108.952	388	58.47	27.40	2.41	0.650	0.812	0.839
2007	33,594	8.900	215	32.73	4.04	0.20	-1.200	0.790	0.692
2008	135,620	59.949	358	50.55	16.32	1.33	-0.507	0.667	0.522
2009	154,326	94.598	497	45.24	18.57	2.09	1.563	1.103	1.426
2010	184,768	54.010	237	54.47	22.23	1.19	-1.358	0.633	-0.226
2011	18,059	3.578	161	37.20	2.17	0.08	-1.300	0.705	0.122
2012	160,794	62.352	314	48.08	19.35	1.38	2.305	0.953	1.458
2013	172,462	59.765	281	52.70	20.75	1.32	0.456	0.774	0.885
Minimum	***18,059***	***1.583***	***61***	***32.73***	***2.17***	***0.03***	***-1.742***	***0.365***	***-0.925***
Average	***136,695***	***41.825***	***248***	***52.56***	***16.45***	***0.92***	***0.062***	***0.749***	***0.646***
Maximum	***258,599***	***190.201***	***596***	***68.19***	***31.12***	***4.20***	***5.596***	***1.103***	***2.243***
Std. Dev.	***65,182***	***36.762***	***115***	***9.93***	***7.84***	***0.81***	***1.619***	***0.177***	***0.611***
Skewness	***-0.057***	***2.216***	***1.416***	***-0.170***	***-0.057***	***2.22***	***1.562***	***0.146***	***0.153***
Median	***137,297***	***38.013***	***191***	***52.06***	***16.52***	***0.84***	***-0.493***	***0.756***	***0.642***

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

Table 3-28. Summary of historical TN data for the C-25 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
1980	135,312	265.051	1,588	63.44	16.28	5.86	5.596	1.065	2.243
1981	21,155	36.422	1,396	33.52	2.55	0.81	-1.182	0.624	-0.083
1982	80,489	169.052	1,703	56.99	9.69	3.74	0.799	0.758	1.023
1983	215,955	395.411	1,484	68.19	25.99	8.74	-1.204	0.510	0.024
1984	138,974	223.061	1,301	50.62	16.72	4.93	-1.334	0.656	0.321
1985	82,894	144.848	1,417	42.88	9.97	3.20	-1.282	0.760	0.289
1986	121,207	252.914	1,692	48.02	14.58	5.59	3.346	0.960	1.632
1987	122,123	237.665	1,578	49.20	14.70	5.25	-0.479	0.705	0.503
1988	79,576	179.533	1,829	43.44	9.58	3.97	-0.722	0.617	0.377
1989	67,055	82.106	993	43.51	8.07	1.82	0.062	0.602	0.877
1990	63,568	102.307	1,305	40.29	7.65	2.26	-1.742	0.697	0.075
1991	167,242	255.419	1,238	60.67	20.12	5.65	-0.208	0.566	0.153
1992	140,308	192.177	1,110	50.24	16.88	4.25	0.354	0.724	0.667
1993	245,739	431.178	1,422	68.03	29.57	9.53	1.965	0.859	1.252
1994	107,276	160.379	1,212	51.41	12.91	3.55	0.552	0.365	-0.925
1995	226,953	329.435	1,177	67.47	27.31	7.28	0.516	0.504	0.858
1996	196,046	327.637	1,355	63.15	23.59	7.24	-1.350	0.849	0.481
1997	96,596	161.545	1,356	55.93	11.62	3.57	-1.217	0.610	0.097
1998	207,884	397.565	1,550	65.62	25.01	8.79	-0.332	0.467	0.244
1999	97,364	195.261	1,626	46.11	11.72	4.32	-0.553	0.878	0.874
2000	188,154	382.538	1,648	64.15	22.64	8.46	-0.867	0.852	0.744
2001	40,703	68.216	1,359	41.25	4.90	1.51	-0.600	1.084	0.743
2002	182,402	400.879	1,782	56.90	21.95	8.86	-0.806	0.790	0.617
2003	157,427	240.719	1,240	63.98	18.94	5.32	1.563	0.779	1.143
2004	119,309	191.089	1,298	53.85	14.36	4.22	-1.572	0.754	0.549
2005	258,599	575.504	1,804	58.78	31.12	12.72	2.195	0.992	1.455
2006	227,680	415.833	1,481	58.47	27.40	9.19	0.650	0.812	0.839
2007	33,594	68.838	1,661	32.73	4.04	1.52	-1.200	0.790	0.692
2008	135,620	249.276	1,490	50.55	16.32	5.51	-0.507	0.667	0.522
2009	154,326	330.530	1,736	45.24	18.57	7.31	1.563	1.103	1.426
2010	184,768	323.807	1,421	54.47	22.23	7.16	-1.358	0.633	-0.226
2011	18,059	24.094	1,082	37.20	2.17	0.53	-1.300	0.705	0.122
2012	160,794	329.509	1,661	48.08	19.35	7.28	2.305	0.953	1.458
2013	172,462	300.669	1,413	52.70	20.75	6.65	0.456	0.774	0.885
Minimum	***18,059***	***24.094***	***993***	***32.73***	***2.17***	***0.53***	***-1.742***	***0.365***	***-0.925***
Average	***136,695***	***248.249***	***1,472***	***52.56***	***16.45***	***5.49***	***0.062***	***0.749***	***0.646***
Maximum	***258,599***	***575.504***	***1,829***	***68.19***	***31.12***	***12.72***	***5.596***	***1.103***	***2.243***
Std. Dev.	***65,182***	***128.461***	***218***	***9.93***	***7.84***	***2.84***	***1.619***	***0.177***	***0.611***
Skewness	***-0.057***	***0.262***	***-0.117***	***-0.170***	***-0.057***	***0.26***	***1.562***	***0.146***	***0.153***
Median	***137,297***	***244.998***	***1,422***	***52.06***	***16.52***	***5.42***	***-0.493***	***0.756***	***0.642***

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

Table 3-29. Summary of historical TON data for the C-25 Sub-watershed.

Water Year	Flow AF	TON Load mt	FWM TON Conc µg/L	Rainfall inches	Unit Area Runoff inches	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1980	135,312	206.443	1,237	63.44	16.28	4.56	5.596	1.065	2.243
1981	21,155	34.618	1,327	33.52	2.55	0.77	-1.182	0.624	-0.083
1982	80,489	149.494	1,506	56.99	9.69	3.30	0.799	0.758	1.023
1983	215,955	329.822	1,238	68.19	25.99	7.29	-1.204	0.510	0.024
1984	138,974	182.523	1,065	50.62	16.72	4.03	-1.334	0.656	0.321
1985	82,894	112.978	1,105	42.88	9.97	2.50	-1.282	0.760	0.289
1986	121,207	202.369	1,354	48.02	14.58	4.47	3.346	0.960	1.632
1987	122,123	190.743	1,266	49.20	14.70	4.22	-0.479	0.705	0.503
1988	79,576	143.914	1,466	43.44	9.58	3.18	-0.722	0.617	0.377
1989	67,055	64.524	780	43.51	8.07	1.43	0.062	0.602	0.877
1990	63,568	75.769	966	40.29	7.65	1.67	-1.742	0.697	0.075
1991	167,242	187.577	909	60.67	20.12	4.15	-0.208	0.566	0.153
1992	140,308	139.543	806	50.24	16.88	3.08	0.354	0.724	0.667
1993	245,739	368.686	1,216	68.03	29.57	8.15	1.965	0.859	1.252
1994	107,276	132.564	1,002	51.41	12.91	2.93	0.552	0.365	-0.925
1995	226,953	283.843	1,014	67.47	27.31	6.27	0.516	0.504	0.858
1996	196,046	280.893	1,162	63.15	23.59	6.21	-1.350	0.849	0.481
1997	96,596	132.475	1,112	55.93	11.62	2.93	-1.217	0.610	0.097
1998	207,884	346.007	1,349	65.62	25.01	7.65	-0.332	0.467	0.244
1999	97,364	176.743	1,472	46.11	11.72	3.91	-0.553	0.878	0.874
2000	188,154	318.501	1,372	64.15	22.64	7.04	-0.867	0.852	0.744
2001	40,703	59.235	1,180	41.25	4.90	1.31	-0.600	1.084	0.743
2002	182,402	316.826	1,408	56.90	21.95	7.00	-0.806	0.790	0.617
2003	157,427	199.060	1,025	63.98	18.94	4.40	1.563	0.779	1.143
2004	119,309	165.775	1,126	53.85	14.36	3.66	-1.572	0.754	0.549
2005	258,599	516.681	1,620	58.78	31.12	11.42	2.195	0.992	1.455
2006	227,680	345.003	1,228	58.47	27.40	7.63	0.650	0.812	0.839
2007	33,594	59.427	1,434	32.73	4.04	1.31	-1.200	0.790	0.692
2008	135,620	220.602	1,319	50.55	16.32	4.88	-0.507	0.667	0.522
2009	154,326	293.575	1,542	45.24	18.57	6.49	1.563	1.103	1.426
2010	184,768	278.489	1,222	54.47	22.23	6.16	-1.358	0.633	-0.226
2011	18,059	21.617	970	37.20	2.17	0.48	-1.300	0.705	0.122
2012	160,794	273.830	1,381	48.08	19.35	6.05	2.305	0.953	1.458
2013	172,462	250.845	1,179	52.70	20.75	5.55	0.456	0.774	0.885
Minimum	***18,059***	***21.617***	***780***	***32.73***	***2.17***	***0.48***	***-1.742***	***0.365***	***-0.925***
Average	***136,695***	***207.676***	***1,232***	***52.56***	***16.45***	***4.59***	***0.062***	***0.749***	***0.646***
Maximum	***258,599***	***516.681***	***1,620***	***68.19***	***31.12***	***11.42***	***5.596***	***1.103***	***2.243***
Std. Dev.	***65,182***	***111.661***	***209***	***9.93***	***7.84***	***2.47***	***1.619***	***0.177***	***0.611***
Skewness	***-0.057***	***0.454***	***-0.192***	***-0.170***	***-0.057***	***0.45***	***1.562***	***0.146***	***0.153***
Median	***137,297***	***194.902***	***1,225***	***52.06***	***16.52***	***4.31***	***-0.493***	***0.756***	***0.642***

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

The Base Period of WY 1984-1993 was recommended for the following reasons (HDR 2011a):

- It contained a reasonably wide range of hydrologic conditions.
- Rainfall patterns during this period are reasonably representative of long-term conditions,
- Only one outlier was identified in the monthly or annual data.
- Although there is a substantial discrepancy between base period TP load and current levels, no changes to the sub-watershed deeming the base period data unrepresentative were identified.
- A strong correlation exists between annual nutrient loads and rainfall, allowing for a performance metric methodology that explicitly incorporates hydrologic variability.

Tables 3-30 through **3-32** compare hydrologic and nutrient data for the period of record and Base Period and for the WY2004-2013 period. Additional information is provided in Appendix A.

Table 3-30. Comparisons of Base Period with period of record and WY2004-2013 data for the C-25 Sub-watershed: TP.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	18,059	1.583	61	32.73	0.03
Annual Average	136,695	41.825	248	52.56	0.92
Annual Median	137,297	38.013	191	52.06	0.84
Annual Maximum	258,599	190.201	596	68.19	4.20
Preliminary Base Period WY1984-1993					
Annual Minimum	63,568	7.608	91	40.29	0.17
Annual Average	122,869	21.787	144	49.69	0.48
Annual Median	121,665	18.629	137	48.61	0.41
Annual Maximum	245,739	39.364	263	68.03	0.87
Difference between Period of Record and Base Period					
Annual Minimum	-45,509	-6.025	-30	-7.56	-0.13
Annual Average	13,826	20.039	104	2.87	0.44
Annual Median	15,632	19.384	54	3.45	0.43
Annual Maximum	12,860	150.837	333	0.16	3.33
Annual Minimum	-72%	-79%	-33%	-19%	-79%
Annual Average	11%	92%	73%	6%	92%
Annual Median	13%	104%	40%	7%	104%
Annual Maximum	5%	383%	127%	0%	383%
WY2004-2013					
Annual Minimum	18,059	3.578	161	32.73	0.08
Annual Average	146,521	67.781	375	49.21	1.50
Annual Median	157,560	59.857	298	51.63	1.32
Annual Maximum	258,599	190.201	596	58.78	4.20
Difference between WY2004-2013 and Base Period					
Annual Minimum	-45,509	-4.030	70	-7.56	-0.09
Annual Average	23,653	45.995	231	-0.48	1.02
Annual Median	35,895	41.229	161	3.02	0.91
Annual Maximum	12,860	150.837	333	-9.25	3.33
Annual Minimum	-72%	-53%	77%	-19%	-53%
Annual Average	19%	211%	161%	-1%	211%
Annual Median	30%	221%	118%	6%	221%
Annual Maximum	5%	383%	127%	-14%	383%

Table 3-31. Comparisons of Base Period with period of record and WY2004-2013 data for the C-25 Sub-watershed: TN.

Metric	Flow AF	TN Load mt	TN Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	18,059	24.093	993	32.73	0.53
Annual Average	136,695	248.249	1,472	52.56	5.49
Annual Median	137,297	244.998	1,422	52.06	5.42
Annual Maximum	258,599	575.504	1,829	68.19	12.72
Preliminary Base Period WY1984-1993					
Annual Minimum	63,568	82.106	993	40.29	1.82
Annual Average	122,869	210.121	1,386	49.69	4.65
Annual Median	121,665	207.619	1,361	48.61	4.59
Annual Maximum	245,739	431.178	1,829	68.03	9.53
Difference between Period of Record and Base Period					
Annual Minimum	-45,509	-58.013	0	-7.56	-1.28
Annual Average	13,826	38.128	86	2.87	0.84
Annual Median	15,632	37.379	61	3.45	0.83
Annual Maximum	12,860	144.326	0	0.16	3.19
Annual Minimum	-72%	-71%	0%	-19%	-71%
Annual Average	11%	18%	6%	6%	18%
Annual Median	13%	18%	4%	7%	18%
Annual Maximum	5%	33%	0%	0%	33%
WY2004-2013					
Annual Minimum	18,059	24.093	1,082	32.73	0.53
Annual Average	146,521	280.915	1,554	49.21	6.21
Annual Median	157,560	312.238	1,486	51.63	6.90
Annual Maximum	258,599	575.504	1,804	58.78	12.72
Difference between WY2004-2013 and Base Period					
Annual Minimum	-45,509	-58.013	89	-7.56	-1.28
Annual Average	23,653	70.794	168	-0.48	1.57
Annual Median	35,895	104.619	125	3.02	2.31
Annual Maximum	12,860	144.326	-25	-9.25	3.19
Annual Minimum	-72%	-71%	9%	-19%	-71%
Annual Average	19%	34%	12%	-1%	34%
Annual Median	30%	50%	9%	6%	50%
Annual Maximum	5%	33%	-1%	-14%	33%

Table 3-32. Comparisons of Base Period with period of record and WY2004-2013 data for the C-25 Sub-watershed: TON.

Metric	Flow AF	TON Load mt	TON Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1980-2013					
Annual Minimum	18,059	21.617	780	32.73	0.48
Annual Average	136,695	207.676	1,232	52.56	4.59
Annual Median	137,297	194.902	1,225	52.06	4.31
Annual Maximum	258,599	516.681	1,620	68.19	11.42
Preliminary Base Period WY1984-1993					
Annual Minimum	63,568	64.524	780	40.29	1.43
Annual Average	122,869	166.863	1,101	49.69	3.69
Annual Median	121,665	163.219	1,085	48.61	3.61
Annual Maximum	245,739	368.686	1,466	68.03	8.15
Difference between Period of Record and Base Period					
Annual Minimum	-45,509	-42.907	0	-7.56	-0.95
Annual Average	13,826	40.814	131	2.87	0.90
Annual Median	15,632	31.683	140	3.45	0.70
Annual Maximum	12,860	147.995	154	0.16	3.27
Annual Minimum	-72%	-66%	0%	-19%	-66%
Annual Average	11%	24%	12%	6%	24%
Annual Median	13%	19%	13%	7%	19%
Annual Maximum	5%	40%	11%	0%	40%
WY2004-2013					
Annual Minimum	18,059	21.617	970	32.73	0.48
Annual Average	146,521	242.584	1,342	49.21	5.36
Annual Median	157,560	262.338	1,274	51.63	5.80
Annual Maximum	258,599	516.681	1,620	58.78	11.42
Difference between WY2004-2013 and Base Period					
Annual Minimum	-45,509	-42.907	190	-7.56	-0.95
Annual Average	23,653	75.722	241	-0.48	1.67
Annual Median	35,895	99.119	189	3.02	2.19
Annual Maximum	12,860	147.995	154	-9.25	3.27
Annual Minimum	-72%	-66%	24%	-19%	-66%
Annual Average	19%	45%	22%	-1%	45%
Annual Median	30%	61%	17%	6%	61%
Annual Maximum	5%	40%	11%	-14%	40%

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.

$$\text{TP Annual Load} = -57.1881 + 0.74377\,X + 58.79717\,C$$

Explained Variance = 87.8%, Standard Error of Regression = 4.395 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:

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

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

$$X = 12\, m_1$$

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

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 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.

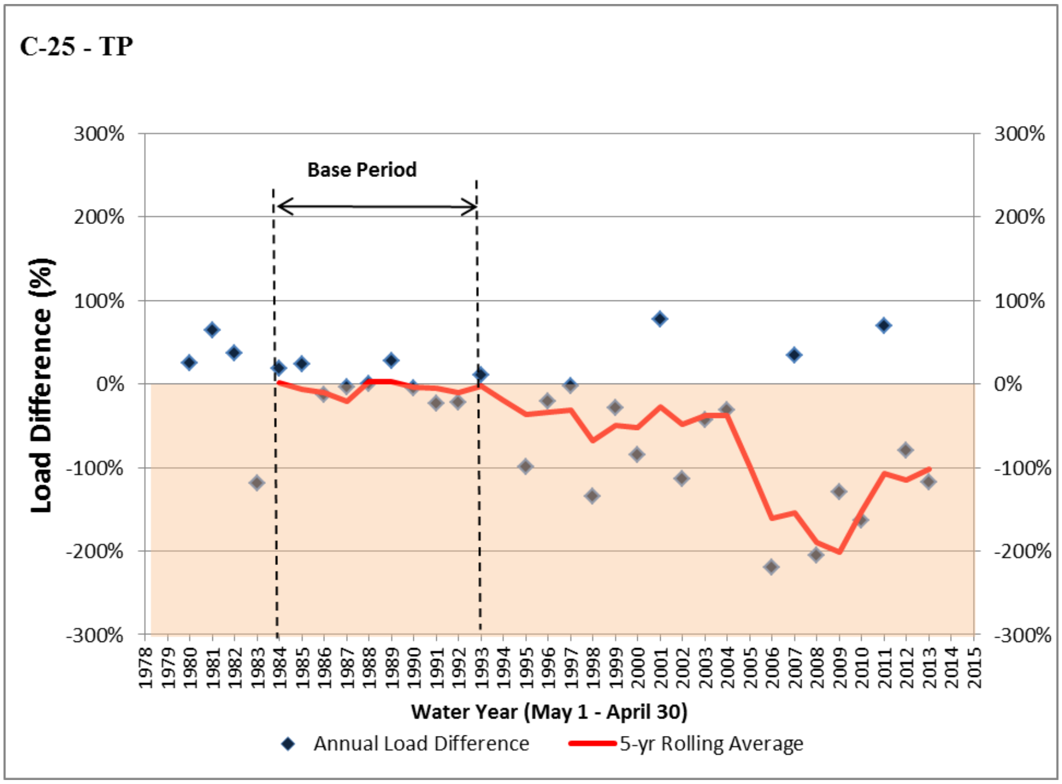
Table 3-33 presents the annual observed and predicted sub-watershed TP loads. The load trend is presented in **Figure 3-16**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-16** denotes a reduction in loads.

Table 3-33. WY1980 – WY2013 C-25 Sub-watershed TP measurements and calculations. (Base Period: WY1984-1993).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average
1980	63.44	39.755	52.616	24%	
1981	33.52	1.583	4.433	64%	
1982	56.99	18.700	29.768	37%	
1983	68.19	51.348	23.516	-118%	
1984	50.62	15.549	19.033	18%	2%
1985	42.88	14.787	19.391	24%	-6%
1986	48.02	39.364	34.973	-13%	-10%
1987	49.20	21.708	20.858	-4%	-21%
1988	43.44	11.443	11.399	0%	3%
1989	43.51	7.608	10.569	28%	2%
1990	40.29	14.439	13.760	-5%	-3%
1991	60.67	26.130	21.216	-23%	-5%
1992	50.24	27.757	22.748	-22%	-10%
1993	68.03	39.080	43.918	11%	-2%
1994	51.41	16.876	2.510	-572%	-19%
1995	67.47	45.047	22.628	-99%	-37%
1996	63.15	47.925	39.700	-21%	-34%
1997	55.93	20.818	20.277	-3%	-32%
1998	65.62	44.809	19.077	-135%	-68%
1999	46.11	36.945	28.731	-29%	-50%
2000	64.15	74.821	40.620	-84%	-52%
2001	41.25	8.422	37.229	77%	-27%
2002	56.90	67.504	31.582	-114%	-48%
2003	63.98	51.823	36.202	-43%	-37%
2004	53.85	35.506	27.197	-31%	-38%
2005	58.78	190.201	44.858	-324%	-100%
2006	58.47	108.952	34.044	-220%	-161%
2007	32.73	8.900	13.605	35%	-154%
2008	50.55	59.949	19.627	-205%	-190%
2009	45.24	94.598	41.314	-129%	-201%
2010	54.47	54.010	20.544	-163%	-153%
2011	37.20	3.578	11.932	70%	-107%
2012	48.07	62.352	34.599	-80%	-114%
2013	52.71	59.765	27.525	-117%	-102%

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

Figure 3-16. C-25 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 = -453.2327 + 9.59569 X + 261.04618 C

Explained Variance = 91.2%, Standard Error of Regression = 33.034 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) $m_2]^{0.5}/m_1$

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 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.

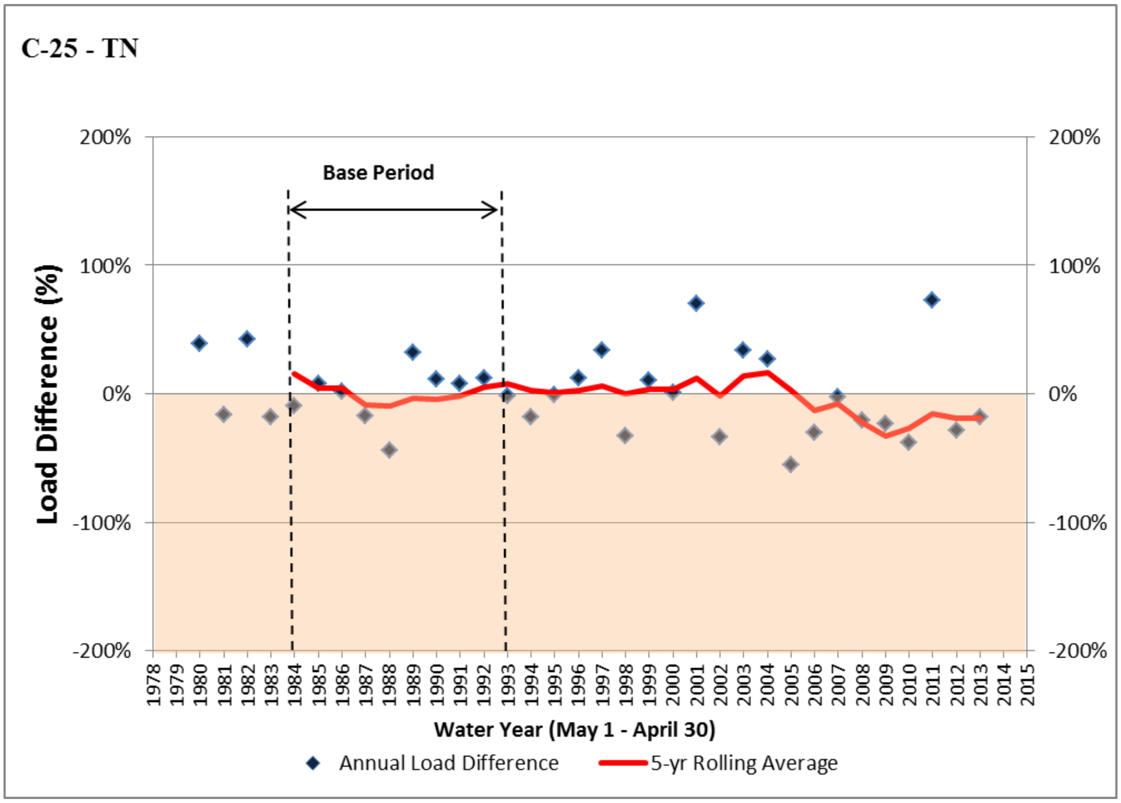
Table 3-34 presents the annual observed and predicted sub-watershed TN loads. The load trend is presented in **Figure 3-17**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-17** denotes a reduction in loads.

Table 3-34. WY1980 – WY2013 C-25 Sub-watershed TN measurements and calculations. (Base Period: WY1984-1993).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1980	63.44	265.051	433.532	39%	
1981	33.52	36.422	31.308	-16%	
1982	56.99	169.052	291.499	42%	
1983	68.19	395.411	334.231	-18%	
1984	50.62	223.061	203.747	-9%	16%
1985	42.88	144.848	156.626	8%	5%
1986	48.02	252.914	258.157	2%	5%
1987	49.20	237.665	202.913	-17%	-8%
1988	43.44	179.533	124.670	-44%	-10%
1989	43.51	82.106	121.426	32%	-4%
1990	40.29	102.307	115.327	11%	-4%
1991	60.67	255.419	276.690	8%	-2%
1992	50.24	192.177	217.852	12%	5%
1993	68.03	431.178	423.801	-2%	8%
1994	51.41	160.379	135.364	-18%	2%
1995	67.47	329.435	325.756	-1%	1%
1996	63.15	327.637	374.363	12%	2%
1997	55.93	161.545	242.692	33%	6%
1998	65.62	397.565	298.345	-33%	0%
1999	46.11	195.261	218.423	11%	3%
2000	64.15	382.538	384.742	1%	4%
2001	41.25	68.216	225.564	70%	12%
2002	56.90	400.879	298.989	-34%	-1%
2003	63.98	240.719	364.055	34%	14%
2004	53.85	191.089	260.324	27%	16%
2005	58.78	575.504	369.760	-56%	3%
2006	58.47	415.833	319.797	-30%	-13%
2007	32.73	68.838	67.061	-3%	-8%
2008	50.55	249.276	205.947	-21%	-23%
2009	45.24	330.530	268.810	-23%	-33%
2010	54.47	323.807	234.687	-38%	-27%
2011	37.20	24.093	87.765	73%	-15%
2012	48.07	329.509	256.809	-28%	-19%
2013	52.71	300.669	254.606	-18%	-19%

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

Figure 3-17. C-25 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 C-25 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 0 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 0 percent load reduction, and will be calculated according to the following equations and explanation.

TP Annual Load Target = -57.1881 + 0.74377 X + 58.79717 C

Explained Variance = 87.8%, Standard Error of Regression = 4.395 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 + 1.41492 SE

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

$SE = 4.39487 [1 + 1/10 + 0.00154 (X-X_m)^2 + 7.87856 (C–C_m)^2 - 0.04036 (X-X_m) (C–C_m)]^{0.5}$

Where:

X = the 12-month total rainfall (inches)

C = coefficient of variation calculated from 12 monthly rainfall totals

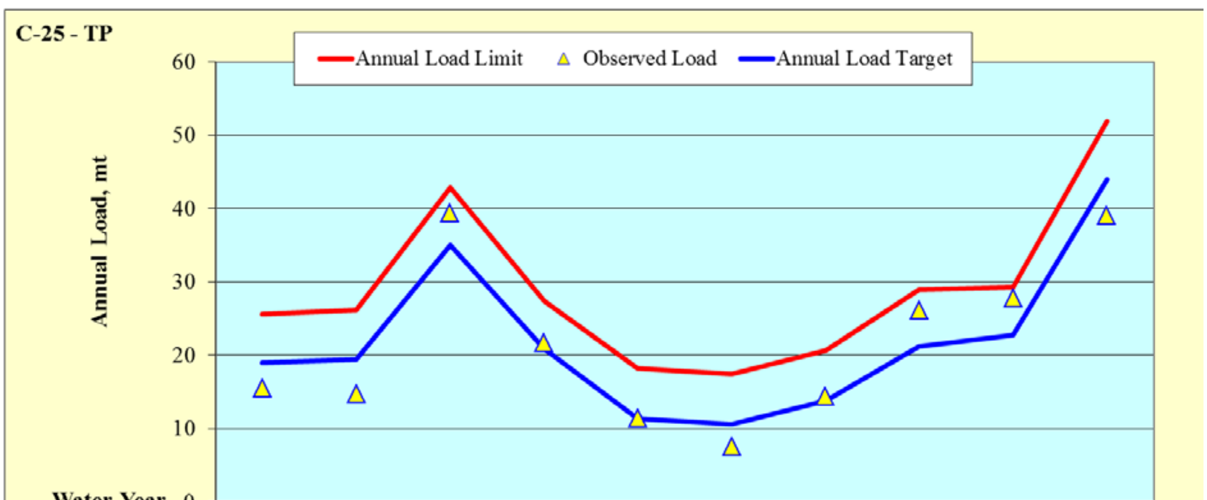
X_m = average value of the predictor in base period = 49.690 inches

C_m = average value of the predictor in base period = 0.7146

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 Base Period loads, scaled to reflect the 0 percent reduction goal, and the resulting Targets and Limits for are presented in **Figure 3-18.** 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 3-18. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the C-25 Sub-watershed.



Water Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Annual Load Limit	25.645	26.203	42.827	27.382	18.241	17.467	20.661	28.895	29.273	51.964
Observed Load	15.549	14.787	39.364	21.708	11.443	7.608	14.439	26.130	27.757	39.080
Annual Load Target	19.033	19.391	34.973	20.858	11.399	10.569	13.760	21.216	22.748	43.918

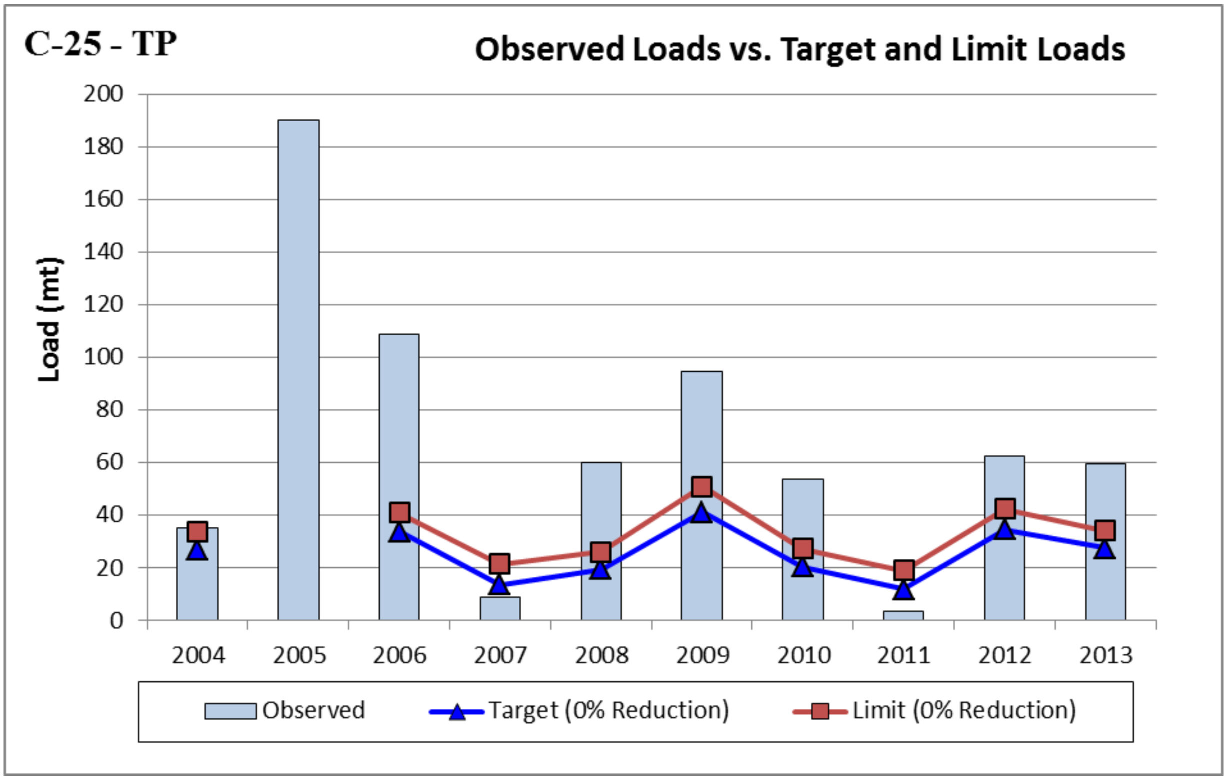
3.3.2.1.1 Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load, adjusted for regional projects (if present), from the basin exceeds the Annual Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (34.61 – 79.45 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.

$$\text{Adjusted Rain} = X + 79.05289\,(S - 0.7146)$$

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1982-2013 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 WY2004-2013. A comparison of the WY2004-2013 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-19**.

Figure 3-19. Comparison of WY2004-2013 TP loads with Annual Load Targets and Limits for the C-25 Sub-watershed.



Note: The performance determination for WY2005 would have been suspended due to rainfall above the maximum 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 C-25 Sub-watershed (Base Period: WY1984-1993).

Water Year	Observed Load, mt	Rain in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1980	39.755	63.44	1.065	52.616	61.762	91.14
1981	1.583	33.52	0.624	4.433	12.068	26.36
1982	18.700	56.99	0.758	29.768	36.534	60.42
1983	51.348	68.19	0.510	23.516	32.546	52.02
1984	15.549	50.62	0.656	19.033	25.645	45.99
1985	14.787	42.88	0.760	19.391	26.203	46.47
1986	39.364	48.02	0.960	34.973	42.827	67.42
1987	21.708	49.20	0.705	20.858	27.383	48.44
1988	11.443	43.44	0.617	11.399	18.241	35.72
1989	7.608	43.51	0.602	10.569	17.467	34.61
1990	14.439	40.29	0.697	13.760	20.661	38.90
1991	26.130	60.67	0.566	21.216	28.896	48.92
1992	27.757	50.24	0.724	22.748	29.273	50.98
1993	39.080	68.03	0.859	43.918	51.965	79.45
1994	16.876	51.41	0.365	2.510	11.504	23.77
1995	45.047	67.47	0.504	22.628	31.610	50.82
1996	47.925	63.15	0.849	39.700	47.182	73.77
1997	20.818	55.93	0.610	20.277	27.291	47.66
1998	44.809	65.62	0.467	19.077	28.157	46.05
1999	36.945	46.11	0.878	28.731	35.966	59.03
2000	74.821	64.15	0.852	40.620	48.210	75.01
2001	8.422	41.25	1.084	37.229	46.883	70.45
2002	67.504	56.90	0.790	31.582	38.402	62.86
2003	51.823	63.98	0.779	36.202	43.584	69.07
2004	35.506	53.85	0.754	27.197	33.814	56.96
2005	190.201	58.78	0.992	44.858	53.041	80.71
2006	108.952	58.47	0.812	34.044	41.021	66.17
2007	8.900	32.73	0.790	13.605	21.565	38.69
2008	59.949	50.55	0.667	19.627	26.210	46.79
2009	94.598	45.24	1.103	41.314	50.925	75.94
2010	54.010	54.47	0.633	20.544	27.365	48.02
2011	3.578	37.20	0.705	11.932	19.119	36.44
2012	62.352	48.07	0.953	34.599	42.384	66.92
2013	59.765	52.71	0.774	27.525	34.149	57.41

Note: Shaded water years indicate the performance determination would have been suspended due to adjusted rainfall outside the Base Period range coupled with the observed load being greater than the Load Target.

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 C-25 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%	10.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.0%
Step 4. Load > Annual Load Limit?	<10%	2.9%
Cumulative Exceedance Frequency	**<17.5%**	**11.3%**

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 0 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 0 percent reduction.

TN-based Prediction = -453.2327 + 9.59569 X + 261.04618 C

Explained Variance = 91.2%, Standard Error of Regression = 33.034 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:

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

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

$$X = 12 m_1$$

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

TN-based UCL = TN-based Prediction + 1.41492 SE_{TN}

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

$$SE_{TN} = 33.03366 [1 + 1/10 + 0.00154 (X-X_m)^2 + 7.87855 (C–C_m)^2 - 0.04036 (X-X_m) (C–C_m)]^{0.5}$$

Where:

X = the 12-month total rainfall (inches)

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

X_m = average value of the predictor in base period = 49.690 inches

C_m = average value of the predictor in base period = 0.7146

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.

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 = -369.24022 + 7.2623 X + 221.87635 C

Explained Variance = 88.6%, Standard Error of Regression = 29.489 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

TON-based UCL = T)N-based Prediction + 1.41492 SE_{TON}

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

$$SE_{TON} = 29.48874\ [\ 1 + 1/10 + 0.00154\ (X\text{-}X_m)^2 + 7.87855\ (C\text{–}C_m)^2\ -\ 0.04036\ (X\text{-}X_m)\ (C\text{–}C_m)\ ]^{0.5}$$

Where:

X = the 12-month total rainfall (inches)

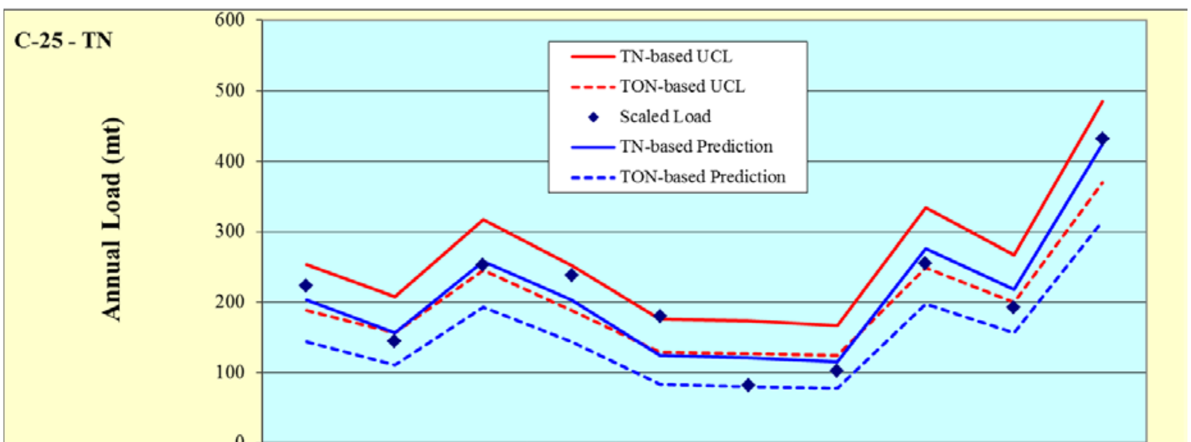
C = the coefficient of variation calculated from 12 monthly rainfall totals

X_m = average value of the predictor in base period = 49.690 inches

C_m = average value of the predictor in base period = 0.7146

A comparison of the Base Period TN loads with the TN-based Prediction (and associated UCL) and the TON-based Prediction (and associated UCL) is presented in **Figure 3-20.**

Figure 3-20. Comparison of scaled annual TN loads with the Annual Load Targets and Limits for the C-25 Sub-watershed.



	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
TN-based UCL	253.446	207.827	317.192	251.954	176.094	173.274	167.198	334.413	266.895	484.283
TON-based UCL	188.293	156.500	245.197	188.267	129.038	126.596	124.311	248.475	200.036	369.398
Scaled Load	223.061	144.848	252.914	237.665	179.533	82.106	102.307	255.419	192.177	431.178
TN-based Prediction	203.747	156.626	258.157	202.913	124.670	121.426	115.327	276.690	217.852	423.801
TON-based Prediction	143.928	110.793	192.497	144.488	83.132	80.312	78.006	196.946	156.256	315.406

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: 39.75 – 72.44 inches; and for the TON-based prediction: 39.81 – 71.96 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 = X + 27.20452 (C – 0.7146)

TON-based Adjusted Rainfall = X + 30.5518 (C – 0.7146)

The adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1982-2013 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**.

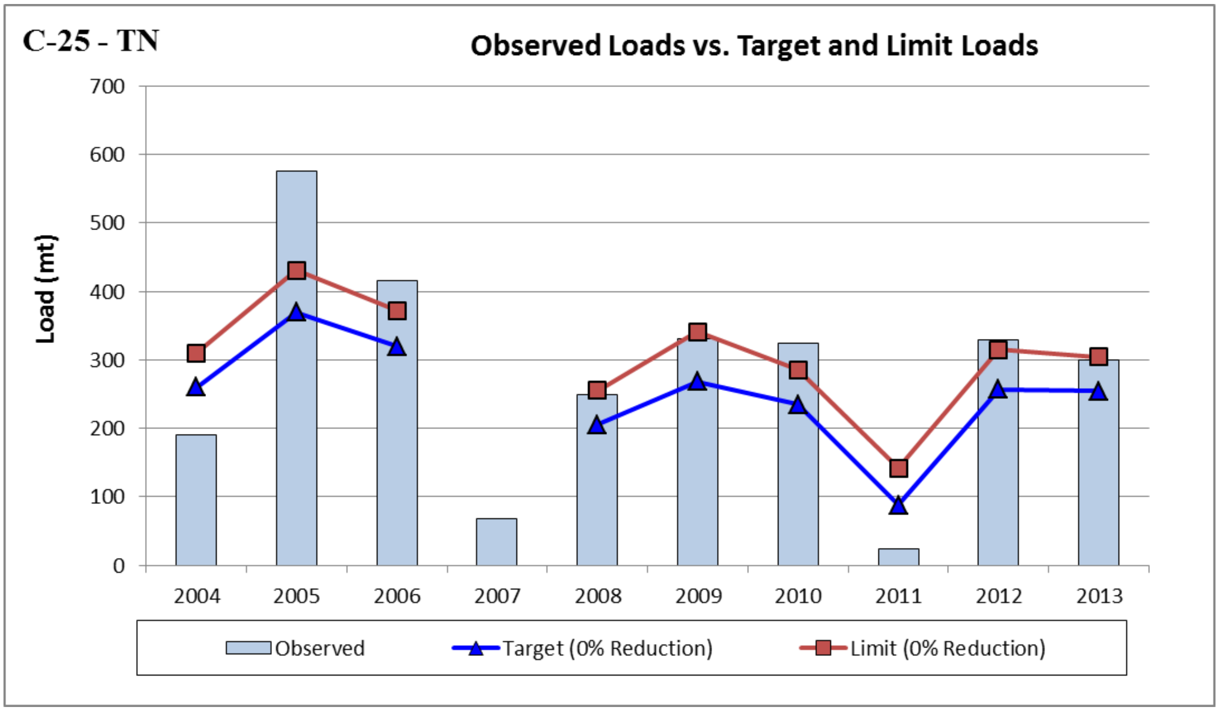
3.3.2.2.5 Comparison to WY2004-2013. A comparison of the WY2004-2013 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-21**.

Table 3-37. TN Annual Targets and Limits for the historical period of record for the C-25 Sub-watershed (Base Period: WY1984-1993).

Water Year	Observed Rain, inches	TN-based Adjusted Rain, inches	TON-based Adjusted Rain, inches	Observed Load, mt	TN-based Prediction, mt	TN-based UCL mt	TON-based Prediction, mt	TON-based UCL mt
1980	63.44	72.97	74.15	265.051	433.532	502.281	327.779	389.150
1981	33.52	31.06	30.75	36.422	31.308	88.696	12.643	63.872
1982	56.99	58.17	58.32	169.052	291.499	342.357	212.821	258.221
1983	68.19	62.62	61.94	395.411	334.231	402.105	239.133	299.723
1984	50.62	49.03	48.83	223.061	203.747	253.445	143.928	188.293
1985	42.88	44.12	44.27	144.848	156.626	207.827	110.793	156.500
1986	48.02	54.70	55.52	252.914	258.157	317.192	192.497	245.197
1987	49.20	48.94	48.91	237.665	202.913	251.954	144.488	188.267
1988	43.44	40.78	40.46	179.533	124.670	176.094	83.132	129.038
1989	43.51	40.45	40.07	82.106	121.426	173.274	80.312	126.596
1990	40.29	39.81	39.75	102.307	115.327	167.198	78.006	124.311
1991	60.67	56.63	56.13	255.419	276.690	334.413	196.946	248.475
1992	50.24	50.50	50.53	192.177	217.852	266.895	156.256	200.036
1993	68.03	71.96	72.44	431.178	423.801	484.283	315.406	369.398
1994	51.41	41.90	40.73	160.379	135.364	202.963	85.100	145.445
1995	67.47	61.74	61.04	329.435	325.756	393.272	232.573	292.844
1996	63.15	66.81	67.26	327.637	374.363	430.603	277.747	327.952
1997	55.93	53.08	52.73	161.545	242.692	295.415	172.285	219.35
1998	65.62	58.88	58.06	397.565	298.345	366.597	210.928	271.856
1999	46.11	50.56	51.10	195.261	218.423	272.804	160.432	208.977
2000	64.15	67.89	68.35	382.538	384.742	441.795	285.675	336.606
2001	41.25	51.30	52.54	68.216	225.564	298.131	170.844	235.623
2002	56.90	58.95	59.20	400.879	298.989	350.249	219.267	265.026
2003	63.98	65.73	65.95	240.719	364.055	419.545	268.244	317.779
2004	53.85	54.92	55.05	191.089	260.324	310.058	189.130	233.527
2005	58.78	66.33	67.26	575.504	369.760	431.264	277.739	332.642
2006	58.47	61.12	61.45	415.833	319.797	372.236	235.550	282.362
2007	32.73	34.78	35.03	68.838	67.061	126.892	43.737	97.148
2008	50.55	49.26	49.10	249.276	205.947	255.426	145.861	190.03
2009	45.24	55.81	57.11	330.530	268.810	341.049	204.036	268.523
2010	54.47	52.25	51.98	323.807	234.687	285.959	166.785	212.555
2011	37.20	36.94	36.91	24.094	87.765	141.784	57.340	105.562
2012	48.08	54.57	55.35	329.509	256.905	315.419	191.379	243.614
2013	52.70	54.32	54.52	300.669	254.510	304.294	185.215	229.657

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

Figure 3-21. Comparison of WY2004-2013 TN loads with Annual Load Targets and Limits for the C-25 Sub-watershed.



Note: 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.

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 C-25 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%	8.4%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.0%
Step 4. Load > Annual Load Limit?	<10%	2.9%
Cumulative Exceedance Frequency	**<17.5%**	**12.2%**

Table 3-39. Exceedance frequencies for the proposed TON-based prediction and UCL for the C-25 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%	8.6%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.9%
Step 4. Load > Annual Load Limit?	<10%	2.9%
Cumulative Exceedance Frequency	**<17.5%**	**12.1%**

3.4 C-44 Sub-watershed

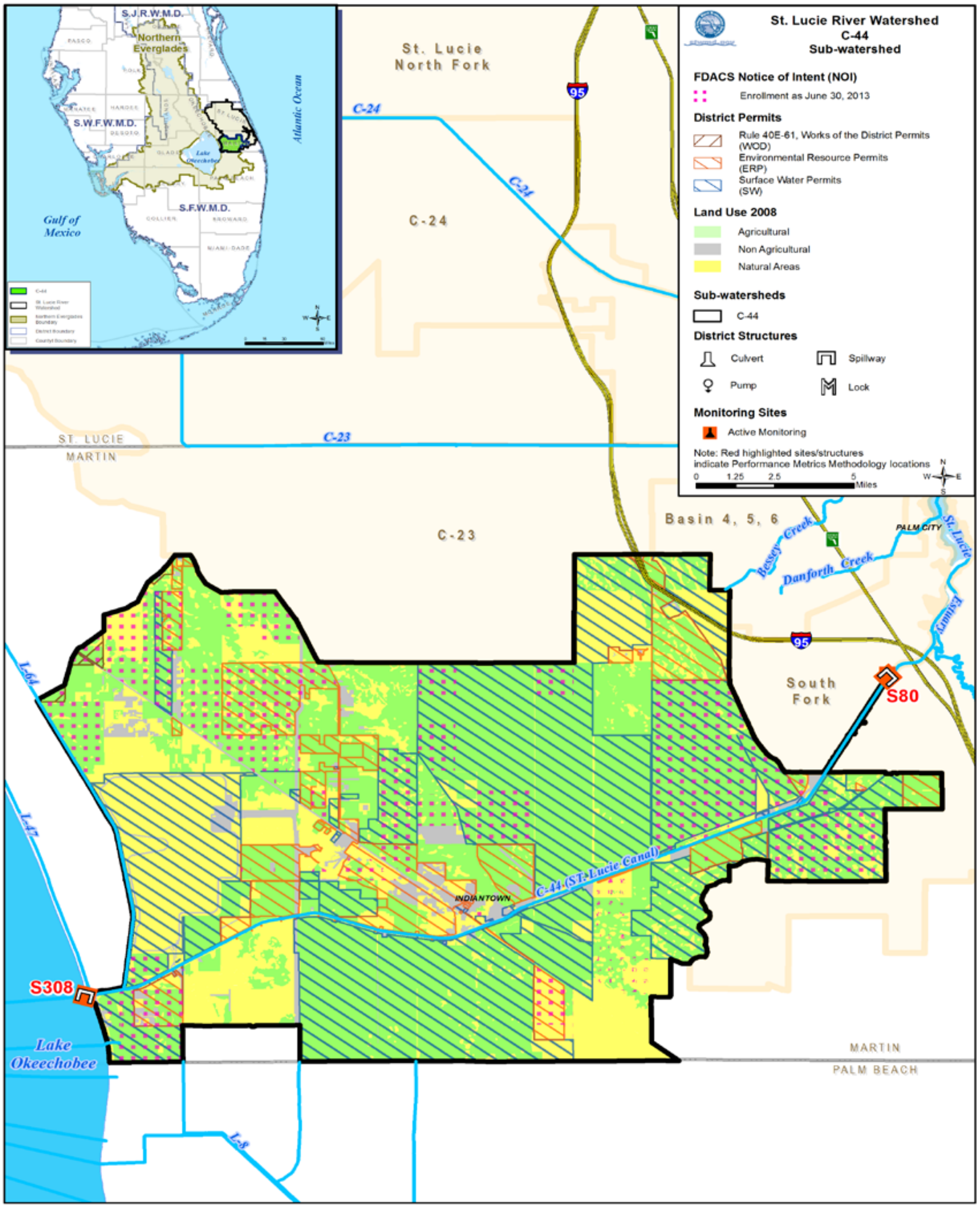
The following sections present a description of the C-44 Sub-watershed, a summary of historical flow and nutrient levels, nutrient reduction goals for the collective source control programs, and development of the performance metrics.

3.4.1 Background

The C-44 Sub-watershed is composed of 132,705 acres located in the south-central portion of Martin County (**Figure 3-22**). Land-use types in this sub-watershed are mostly characterized by citrus farms (approximately 43,000 acres), pastures (approximately 39,000 acres), and natural areas (approximately 28,000 acres). External surface inflows enter the basin from Lake Okeechobee via S-308. Outflows from the C-44 Sub-watershed are discharged in two directions: to Lake Okeechobee at S-308 and to the South Fork of the St Lucie River at S-80. Flow and nutrient monitoring sites are identified in **Tables B-1** and **B-2**.

The C-44 Sub-watershed comprises the C-44 and S-153 sub-basins. The C-44 sub-basin has a drainage area of approximately 120,112 acres. The primary conveyance that serves this basin is the C-44 Canal (also known as the St. Lucie Canal) that connects Lake Okeechobee to the South Fork of the St. Lucie River. There are two control structures located in the C-44 Canal: the S-80 gated spillway (also known as the St. Lucie Lock and Spillway) and the S-308 gated spillway (also known as the Port Mayaca Lock and Spillway). The operational goals of this system are to remove excess waters from the C-44 Basin, supply surface water to the C-44 Basin when needed, and maintain groundwater elevations sufficient to prevent saltwater intrusion. The C-44 is also an integral part of the Okeechobee Waterway Navigational Project and, along with the Caloosahatchee River, provides a primary outlet from Lake Okeechobee for flood control. Water surface elevations in the C-44 Basin are regulated by S-80, and regulatory releases from Lake Okeechobee are made by way of S-308 (SFWMD 1988a; USACE and SFWMD 2004).

Figure 3-22. C-44 Sub-watershed schematic (from SFWMD 2013).



The S-153 sub-basin has a drainage area of approximately 12,593 acres. The L-65 Borrow Canal within the S-153 sub-basin is part of a continuous borrow canal along the east side of L-64 and L-65 that parallels the Florida East Coast Railway from C-44 to the railway's crossing of State Road 710. The only control structure in the basin is the S-153 gated spillway aligned with the L-65 Borrow Canal at the canal's outlet to C-44, just north of the town of Port Mayaca. The canal and control structure provide flood protection and drainage for the S-153 sub-basin by discharging excess water into C-44 and regulating surface water elevations. Water supply to the S-153 sub-basin is from local rainfall (SFWMD 1988a).

The historical data analysis for the C-44 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 St. Lucie River Source Control Programs) with the District (HDR, 2011).

The TP and TN performance measures for the C-44 Sub-watershed were developed by HDR Engineering, Inc. (HDR 2011) and are summarized herein. They are based on flows and nutrient loads resulting from rainfall and runoff from the C-44 Sub-watershed (measured at S-80 and S-308) and account for pass-through flows and loads from Lake Okeechobee. The performance measures are based on the total discharges from the basin to Lake Okeechobee and to the St. Lucie Estuary. A few refinements were made to the performance measure methodology developed by HDR, including

1. The rainfall data were revised for the C-44 Sub-watershed.
2. Flow data entry errors on two days were corrected.
3. Minor refinements were made to the calculated area of the C-44 Sub-watershed, adding approximately 2,850 acres of contributing area from Basin 8.
4. A different protocol for significant digits was utilized in the Lake Okeechobee Watershed compared to the protocols used in the St. Lucie River Watershed, and this resulted in slight refinements to the regression equation coefficients.

5. As part of a general review of load reductions across the entire Lake Okeechobee Watershed, District staff rounded the TP load reduction for the C-44 Sub-watershed from 33 percent to 35 percent in recognition of inherent uncertainty (see Section 2.6).

As a result of these refinements, the performance measure was slightly revised from that found in the HDR final report[9] (HDR 2011). The performance metric methodologies are based on flows and nutrient (TP and TN) loads resulting from rainfall and runoff from the C-44 Sub-watershed. Basin flows and loads from the C-44 Sub-watershed, adjusted for pass-through flows and loads discharged from Lake Okeechobee, were calculated using algorithms provided in Appendix A. **Tables 3-40 through 3-42** provide a summary of the historical flow, load, and rainfall data for the C-44 Sub-watershed for the period of record WY1982-2013. The pass-through calculations for WY1998 yielded negative load and concentration for TP and TON, reflecting a decrease in concentrations as the pass-through flows transited the basin. District staff identified four rainfall stations considered to be representative of the C-44 Sub-watershed. Weighting factors, based on the Thiessen polygon areas for each rainfall station, were used to calculate daily basin rainfall values **(Appendix A)**. For the development of the performance measure methodology, a base period of WY2000-2010 was selected for the following reasons (HDR 2011a).

- Basin water management operations during the Base Period were similar to current operating conditions.
- Some level of source control implementation occurred, but no effects were observed in the basin's nutrient load levels.
- It contained a reasonably wide range of hydrologic conditions.
- Rainfall patterns during this period are reasonably representative of long-term conditions.
- No significant trends were identified for the monthly or annual data, and

[9] Differences between the Lake Okeechobee Watershed technical support document and this document are identified in a companion memorandum (SFWMD 2013b).

- A strong correlation exists between annual nutrient loads and rainfall, allowing for a performance metric methodology that explicitly incorporates hydrologic variability.

Table 3-40. Summary of historical TP data for the C-44 Sub-watershed.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff inches	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1982	33,046	5.929	145	51.15	2.99	1.913	0.917	1.413
1983	200,608	37.054	150	70.12	18.14	-0.839	0.491	0.138
1984	216,422	28.398	106	58.90	19.57	-0.732	0.630	0.360
1985	192,012	51.046	216	47.82	17.36	-0.771	0.704	-0.004
1986	231,132	54.573	191	46.55	20.90	0.826	0.797	0.933
1987	157,734	41.639	214	50.89	14.26	3.789	0.859	1.622
1988	283,533	51.435	147	48.34	25.64	-0.706	0.580	0.143
1989	280,208	52.859	153	40.56	25.34	-0.944	0.724	0.310
1990	245,569	43.126	142	45.17	22.21	-0.369	0.774	0.808
1991	148,997	27.331	149	54.32	13.47	-0.722	0.626	0.265
1992	209,541	38.721	150	41.83	18.95	-0.819	0.601	0.359
1993	359,991	72.274	163	68.22	32.55	0.742	0.792	0.962
1994	177,178	29.672	136	57.09	16.02	-0.100	0.470	0.086
1995	439,081	83.713	155	67.89	39.70	-1.129	0.472	0.209
1996	307,565	71.568	189	70.58	27.81	-0.165	0.993	0.891
1997	129,267	19.530	122	47.22	11.69	-1.053	0.497	0.311
1998	157,242	-20.783	-107	57.74	14.22	-0.642	0.463	-0.241
1999	148,620	27.924	152	45.45	13.44	0.431	0.844	1.129
2000	218,669	54.761	203	50.95	19.77	-0.418	0.795	0.727
2001	106,870	18.806	143	33.53	9.66	-1.050	0.913	0.619
2002	140,274	52.861	306	52.48	12.68	-0.608	0.795	0.738
2003	131,017	35.647	221	46.68	11.85	0.161	0.722	0.991
2004	200,494	69.695	282	40.07	18.13	0.910	0.865	1.247
2005	210,860	83.619	321	54.20	19.07	3.895	1.160	1.834
2006	370,607	121.527	266	59.63	33.51	1.091	0.921	1.096
2007	58,544	14.779	205	30.41	5.29	-0.764	0.825	0.728
2008	189,661	74.924	320	57.53	17.15	-1.420	0.535	0.176
2009	118,817	52.597	359	44.41	10.74	2.324	1.034	1.441
2010	136,615	37.479	222	44.84	12.35	-0.691	0.545	0.085
2011	54,755	21.660	321	27.92	4.95	-0.299	0.864	0.797
2012	50,349	10.551	170	34.29	4.55	0.194	0.797	0.973
2013	156,437	58.956	306	51.95	14.15	4.121	0.759	1.670
Minimum	***33,046***	***5.929***	***106***	***27.92***	***2.99***	***-1.420***	***0.470***	***-0.004***
Average	***190,467***	***46.602***	***198***	***49.71***	***17.22***	***0.219***	***0.752***	***0.744***
Maximum	***439,081***	***121.527***	***359***	***70.58***	***39.70***	***4.121***	***1.160***	***1.834***
Std. Dev.	***95,132***	***25.328***	***71***	***10.94***	***8.60***	***1.521***	***0.175***	***0.522***
Skewness	***0.669***	***0.795***	***0.762***	***0.128***	***0.669***	***1.508***	***0.095***	***0.383***
Median	***189,661***	***43.126***	***189***	***48.34***	***17.15***	***-0.369***	***0.792***	***0.738***

Notes:
1. The FWM TP concentration was calculated by dividing the annual TP load by the annual flow.
2. Summary statistics exclude WY1998 due to negative TP levels.
3. Slight differences in values presented in HDR (2011) are due to different protocol for significant digits, revised rainfall data, and a different estimate of basin area.

Table 3-41. Summary of historical TN data for the C-44 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
1982	33,046	89.365	2,192	51.15	2.99	1.48	1.913	0.917	1.413
1983	200,608	613.308	2,479	70.12	18.14	10.19	-0.839	0.491	0.138
1984	216,422	433.677	1,625	58.90	19.57	7.20	-0.732	0.630	0.360
1985	192,012	399.208	1,686	47.82	17.36	6.63	-0.771	0.704	-0.004
1986	231,132	574.096	2,014	46.55	20.90	9.54	0.826	0.797	0.933
1987	157,734	320.563	1,648	50.89	14.26	5.33	3.789	0.859	1.622
1988	283,533	402.422	1,151	48.34	25.64	6.69	-0.706	0.580	0.143
1989	280,208	479.831	1,388	40.56	25.34	7.97	-0.944	0.724	0.310
1990	245,569	424.944	1,403	45.17	22.21	7.06	-0.369	0.774	0.808
1991	148,997	254.608	1,385	54.32	13.47	4.23	-0.722	0.626	0.265
1992	209,541	222.965	863	41.83	18.95	3.70	-0.819	0.601	0.359
1993	359,991	399.256	899	68.22	32.55	6.63	0.742	0.792	0.962
1994	177,178	332.972	1,524	57.09	16.02	5.53	-0.100	0.470	0.086
1995	439,081	575.590	1,063	67.89	39.70	9.56	-1.129	0.472	0.209
1996	307,565	1,046.224	2,758	70.58	27.81	17.38	-0.165	0.993	0.891
1997	129,267	251.762	1,579	47.22	11.69	4.18	-1.053	0.497	0.311
1998	157,242	70.888	365	57.74	14.22	1.18	-0.642	0.463	-0.241
1999	148,620	251.887	1,374	45.45	13.44	4.18	0.431	0.844	1.129
2000	218,669	285.557	1,059	50.95	19.77	4.74	-0.418	0.795	0.727
2001	106,870	160.923	1,221	33.53	9.66	2.67	-1.050	0.913	0.619
2002	140,274	309.436	1,788	52.48	12.68	5.14	-0.608	0.795	0.738
2003	131,017	107.970	668	46.68	11.85	1.79	0.161	0.722	0.991
2004	200,494	283.541	1,147	40.07	18.13	4.71	0.910	0.865	1.247
2005	210,860	461.063	1,773	54.20	19.07	7.66	3.895	1.160	1.834
2006	370,607	1,076.850	2,356	59.63	33.51	17.89	1.091	0.921	1.096
2007	58,544	117.265	1,624	30.41	5.29	1.95	-0.764	0.825	0.728
2008	189,661	450.210	1,924	57.53	17.15	7.48	-1.420	0.535	0.176
2009	118,817	186.391	1,272	44.41	10.74	3.10	2.324	1.034	1.441
2010	136,615	244.023	1,448	44.84	12.35	4.05	-0.691	0.545	0.085
2011	54,755	95.784	1,418	27.92	4.95	1.59	-0.299	0.864	0.797
2012	50,349	111.184	1,790	34.29	4.55	1.85	0.194	0.797	0.973
2013	156,437	305.725	1,584	51.95	14.15	5.08	4.121	0.759	1.670
Minimum	***33,046***	***70.888***	***365***	***27.92***	***2.99***	***1.18***	***-1.420***	***0.463***	***-0.241***
Average	***189,429***	***354.359***	***1,517***	***49.96***	***17.13***	***5.89***	***0.192***	***0.743***	***0.713***
Maximum	***439,081***	***1,076.850***	***2,758***	***70.58***	***39.70***	***17.89***	***4.121***	***1.160***	***1.834***
Std. Dev.	***93,769***	***237.877***	***511***	***10.85***	***8.48***	***3.95***	***1.504***	***0.179***	***0.542***
Skewness	***0.709***	***1.614***	***0.262***	***0.066***	***0.709***	***1.61***	***1.557***	***0.102***	***0.306***
Median	***183,420***	***307.581***	***1,486***	***49.62***	***16.59***	***5.11***	***-0.394***	***0.783***	***0.733***

Notes:
1. The FWM TN concentration was calculated by dividing the annual TN load by the annual flow.
2. Slight differences in values presented in HDR (2011) are due to different protocol for significant digits, revised rainfall data, and a different estimate of basin area.

Table 3-42. Summary of historical TON data for the C-44 Sub-watershed.

Water Year	Flow AF	TON Load mt	FWM TON Conc µg/L	Rainfall inches	Unit Area Runoff inches	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1982	33,046	77.949	1,912	51.15	2.99	1.29	1.913	0.917	1.413
1983	200,608	573.681	2,318	70.12	18.14	9.53	-0.839	0.491	0.138
1984	216,422	362.017	1,356	58.90	19.57	6.01	-0.732	0.630	0.360
1985	192,012	317.491	1,340	47.82	17.36	5.27	-0.771	0.704	-0.004
1986	231,132	426.589	1,496	46.55	20.90	7.09	0.826	0.797	0.933
1987	157,734	253.201	1,301	50.89	14.26	4.21	3.789	0.859	1.622
1988	283,533	267.812	766	48.34	25.64	4.45	-0.706	0.580	0.143
1989	280,208	322.847	934	40.56	25.34	5.36	-0.944	0.724	0.310
1990	245,569	341.468	1,127	45.17	22.21	5.67	-0.369	0.774	0.808
1991	148,997	191.438	1,042	54.32	13.47	3.18	-0.722	0.626	0.265
1992	209,541	175.013	677	41.83	18.95	2.91	-0.819	0.601	0.359
1993	359,991	256.139	577	68.22	32.55	4.26	0.742	0.792	0.962
1994	177,178	279.318	1,278	57.09	16.02	4.64	-0.100	0.470	0.086
1995	439,081	435.159	803	67.89	39.70	7.23	-1.129	0.472	0.209
1996	307,565	889.490	2,345	70.58	27.81	14.78	-0.165	0.993	0.891
1997	129,267	199.822	1,253	47.22	11.69	3.32	-1.053	0.497	0.311
1998	157,242	-11.318	-58	57.74	14.22	-0.19	-0.642	0.463	-0.241
1999	148,620	208.325	1,136	45.45	13.44	3.46	0.431	0.844	1.129
2000	218,669	193.114	716	50.95	19.77	3.21	-0.418	0.795	0.727
2001	106,870	89.656	680	33.53	9.66	1.49	-1.050	0.913	0.619
2002	140,274	240.967	1,393	52.48	12.68	4.00	-0.608	0.795	0.738
2003	131,017	62.608	387	46.68	11.85	1.04	0.161	0.722	0.991
2004	200,494	152.877	618	40.07	18.13	2.54	0.910	0.865	1.247
2005	210,860	338.235	1,300	54.20	19.07	5.62	3.895	1.160	1.834
2006	370,607	934.960	2,045	59.63	33.51	15.53	1.091	0.921	1.096
2007	58,544	92.077	1,275	30.41	5.29	1.53	-0.764	0.825	0.728
2008	189,661	338.621	1,447	57.53	17.15	5.63	-1.420	0.535	0.176
2009	118,817	144.398	985	44.41	10.74	2.40	2.324	1.034	1.441
2010	136,615	203.030	1,205	44.84	12.35	3.37	-0.691	0.545	0.085
2011	54,755	70.975	1,051	27.92	4.95	1.18	-0.299	0.864	0.797
2012	50,349	90.025	1,450	34.29	4.55	1.50	0.194	0.797	0.973
2013	156,437	264.500	1,371	51.95	14.15	4.39	4.121	0.759	1.670
Minimum	***33,046***	***62.608***	***387***	***27.92***	***2.99***	***1.04***	***-1.420***	***0.470***	***-0.004***
Average	***190,467***	***283.671***	***1,207***	***49.71***	***17.22***	***4.71***	***0.219***	***0.752***	***0.744***
Maximum	***439,081***	***934.960***	***2,345***	***70.58***	***39.70***	***15.53***	***4.121***	***1.160***	***1.834***
Std. Dev.	***95,132***	***206.033***	***477***	***10.94***	***8.60***	***3.42***	***1.521***	***0.175***	***0.522***
Skewness	***0.669***	***1.916***	***0.702***	***0.128***	***0.669***	***1.92***	***1.508***	***0.095***	***0.383***
Median	***189,661***	***253.201***	***1,253***	***48.34***	***17.15***	***4.21***	***-0.369***	***0.792***	***0.738***

Notes:
1. The FWM TON concentration was calculated by dividing the annual TON load by the annual flow.
2. Summary statistics exclude WY1998 due to negative TON levels.
3. Slight differences in values presented in HDR (2011) are due to different protocol for significant digits, revised rainfall data, and a different estimate of basin area.

Tables 3-43 through **3-45** compare hydrologic and nutrient data for the period of record and Base Period and for the WY2004-2013 period. Additional information is provided in Appendix A.

Table 3-43. Comparisons of Base Period with period of record and WY2004-2013 data for the C-44 Sub-watershed: TP.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2013					
Annual Minimum	33,046	5.929	106	27.92	0.10
Annual Average	190,467	46.602	198	49.71	0.77
Annual Median	189,661	43.126	189	48.34	0.72
Annual Maximum	439,081	121.527	359	70.58	49.00
Preliminary Base Period WY2000-2010					
Annual Minimum	58,544	14.779	143	30.41	0.25
Annual Average	171,130	56.063	266	46.79	0.93
Annual Median	140,274	52.861	266	46.68	0.88
Annual Maximum	370,607	121.527	359	59.63	2.02
Difference between Period of Record and Base Period					
Annual Minimum	-25,498	-8.850	-37	-2.49	-0.15
Annual Average	19,337	-9.461	-67	2.92	-0.16
Annual Median	49,387	-9.735	-77	1.66	-0.16
Annual Maximum	68,474	0.000	0	10.95	46.98
Annual Minimum	-44%	-60%	-26%	-8%	-60%
Annual Average	11%	-17%	-25%	6%	-17%
Annual Median	35%	-18%	-29%	4%	-18%
Annual Maximum	18%	0%	0%	18%	2327%
WY2004-2013					
Annual Minimum	50,349	10.551	170	27.92	0.18
Annual Average	154,714	54.579	286	44.53	0.91
Annual Median	146,526	55.777	294	44.63	0.93
Annual Maximum	370,607	121.527	359	59.63	2.02
Difference between WY2004-2013 and Base Period					
Annual Minimum	-8,195	-4.228	27	-2.49	-0.07
Annual Average	-16,416	-1.484	20	-2.27	-0.02
Annual Median	6,252	2.916	28	-2.06	0.05
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	-14%	-29%	19%	-8%	-29%
Annual Average	-10%	-3%	8%	-5%	-3%
Annual Median	4%	6%	11%	-4%	6%
Annual Maximum	0%	0%	0%	0%	0%

Table 3-44. Comparisons of Base Period with period of record and WY2004-2013 data for the C-44 Sub-watershed: TN.

Metric	Flow AF	TN Load mt	TN Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2013					
Annual Minimum	33,046	70.888	365	27.92	1.18
Annual Average	189,429	354.359	1,517	49.96	5.89
Annual Median	183,420	307.581	1,486	49.62	5.11
Annual Maximum	439,081	1,076.850	2,758	70.58	49.00
Preliminary Base Period WY2000-2010					
Annual Minimum	58,544	107.970	668	30.41	1.79
Annual Average	171,130	334.839	1,586	46.79	5.56
Annual Median	140,274	283.541	1,448	46.68	4.71
Annual Maximum	370,607	1,076.850	2,356	59.63	17.89
Difference between Period of Record and Base Period					
Annual Minimum	-25,498	-37.082	-303	-2.49	-0.62
Annual Average	18,299	19.520	-70	3.17	0.32
Annual Median	43,146	24.040	38	2.94	0.40
Annual Maximum	68,474	0.000	402	10.95	31.11
Annual Minimum	-44%	-34%	-45%	-8%	-34%
Annual Average	11%	6%	-4%	7%	6%
Annual Median	31%	8%	3%	6%	8%
Annual Maximum	18%	0%	17%	18%	174%
WY2004-2013					
Annual Minimum	50,349	95.784	1,147	27.92	1.59
Annual Average	154,714	333.204	1,746	44.53	5.54
Annual Median	146,526	263.782	1,604	44.63	4.38
Annual Maximum	370,607	1,076.850	2,356	59.63	17.89
Difference between WY2004-2013 and Base Period					
Annual Minimum	-8,195	-12.186	479	-2.49	-0.20
Annual Average	-16,416	-1.635	160	-2.27	-0.03
Annual Median	6,252	-19.759	156	-2.06	-0.33
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	-14%	-11%	72%	-8%	-11%
Annual Average	-10%	0%	10%	-5%	0%
Annual Median	4%	-7%	11%	-4%	-7%
Annual Maximum	0%	0%	0%	0%	0%

Table 3-45. Comparisons of Base Period with period of record and WY2004-2013 data for the C-44 Sub-watershed: TON.

Metric	Flow AF	TON Load mt	TON Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2013					
Annual Minimum	33,046	62.608	387	27.92	1.04
Annual Average	190,467	283.671	1,207	49.71	4.71
Annual Median	189,661	253.201	1,253	48.34	4.21
Annual Maximum	439,081	934.960	2,345	70.58	49.00
Preliminary Base Period WY2000-2010					
Annual Minimum	58,544	62.608	387	30.41	1.04
Annual Average	171,130	253.686	1,202	46.79	4.21
Annual Median	140,274	193.114	1,205	46.68	3.21
Annual Maximum	370,607	934.960	2,045	59.63	15.53
Difference between Period of Record and Base Period					
Annual Minimum	-25,498	0.000	0	-2.49	0.00
Annual Average	19,337	29.985	6	2.92	0.50
Annual Median	49,387	60.087	48	1.66	1.00
Annual Maximum	68,474	0.000	300	10.95	33.47
Annual Minimum	-44%	0%	0%	-8%	0%
Annual Average	11%	12%	0%	6%	12%
Annual Median	35%	31%	4%	4%	31%
Annual Maximum	18%	0%	15%	18%	215%
WY2004-2013					
Annual Minimum	50,349	70.975	618	27.92	1.18
Annual Average	154,714	262.970	1,378	44.53	4.37
Annual Median	146,526	177.954	1,288	44.63	2.96
Annual Maximum	370,607	934.960	2,045	59.63	15.53
Difference between WY2004-2013 and Base Period					
Annual Minimum	-8,195	8.367	231	-2.49	0.14
Annual Average	-16,416	9.284	176	-2.27	0.15
Annual Median	6,252	-15.161	83	-2.06	-0.25
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	-14%	13%	60%	-8%	13%
Annual Average	-10%	4%	15%	-5%	4%
Annual Median	4%	-8%	7%	-4%	-8%
Annual Maximum	0%	0%	0%	0%	0%

3.4.1.1 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.

$$\text{TP Annual Load} = \exp\,[\,-5.89655 + 2.47795\,X + 0.32325\,S\,]^2$$

Explained Variance = 83.9%, Standard Error of Regression = 16.612 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) = $\ln [12m_1]$

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 logarithm 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.

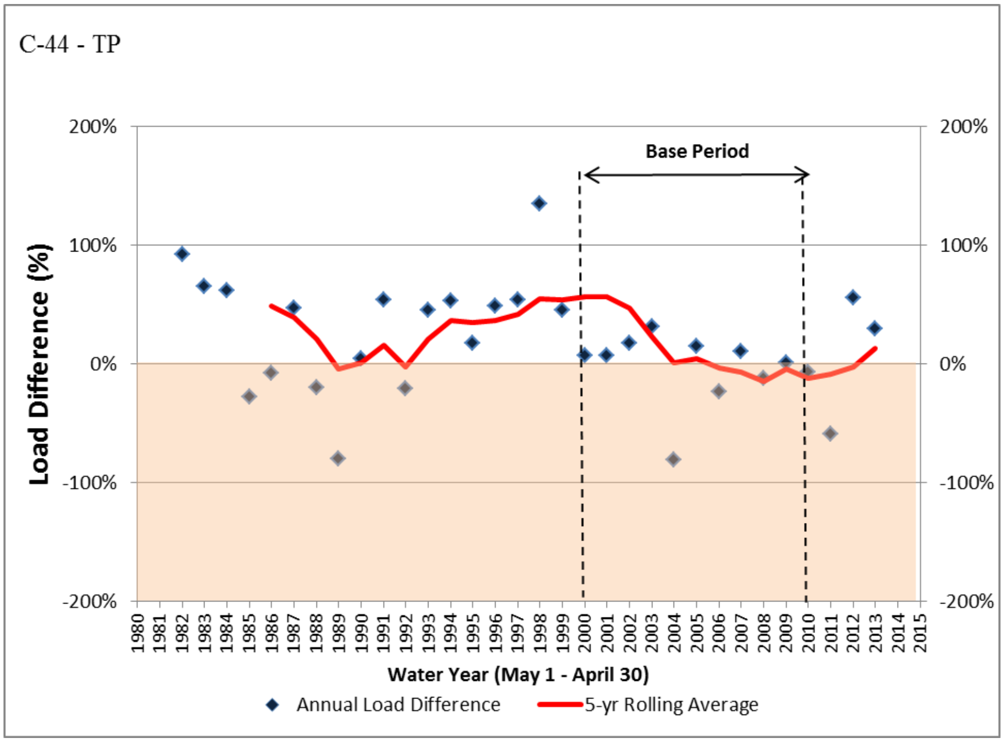
Table 3-46 presents the annual observed and predicted sub-watershed TP loads. The load trend is presented in **Figure 3-23**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-23** denotes a reduction in loads.

Table 3-46. WY1982 – WY2013 C-44 Sub-watershed TP measurements and calculations. (Base Period: WY2000-2010).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average
1982	51.15	5.929	74.466	92%	
1983	70.12	37.054	107.756	66%	
1984	58.90	28.398	75.155	62%	
1985	47.82	51.046	39.865	-28%	
1986	46.55	54.573	50.486	-8%	49%
1987	50.89	41.639	78.672	47%	40%
1988	48.34	51.435	42.941	-20%	21%
1989	40.56	52.859	29.340	-80%	-4%
1990	45.17	43.126	45.002	4%	1%
1991	54.32	27.331	59.636	54%	15%
1992	41.83	38.721	32.175	-20%	-2%
1993	68.22	72.274	131.389	45%	21%
1994	57.09	29.672	63.666	53%	36%
1995	67.89	83.713	101.772	18%	35%
1996	70.58	71.568	139.698	49%	37%
1997	47.22	19.530	42.779	54%	42%
1998	57.74	-20.783	58.909	135%	55%
1999	45.45	27.924	50.692	45%	54%
2000	50.95	54.761	59.079	7%	56%
2001	33.53	18.806	20.231	7%	57%
2002	52.48	52.861	63.801	17%	47%
2003	46.68	35.647	51.798	31%	23%
2004	40.07	69.695	38.542	-81%	1%
2005	54.20	83.619	98.490	15%	4%
2006	59.63	121.527	98.297	-24%	-4%
2007	30.41	14.779	16.451	10%	-7%
2008	57.53	74.924	66.805	-12%	-14%
2009	44.41	52.597	52.945	1%	-4%
2010	44.84	37.479	34.982	-7%	-12%
2011	27.92	21.660	13.613	-59%	-9%
2012	34.29	10.551	23.979	56%	-3%
2013	51.95	58.956	84.089	30%	14%

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

Figure 3-23. C-44 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.

3.4.1.2 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.

$$\text{TN Annual Load} = \exp\left[2.96528 + 0.05614\ X\right]$$

Explained Variance = 62.8%, Standard Error of Regression = 190.189 mt

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

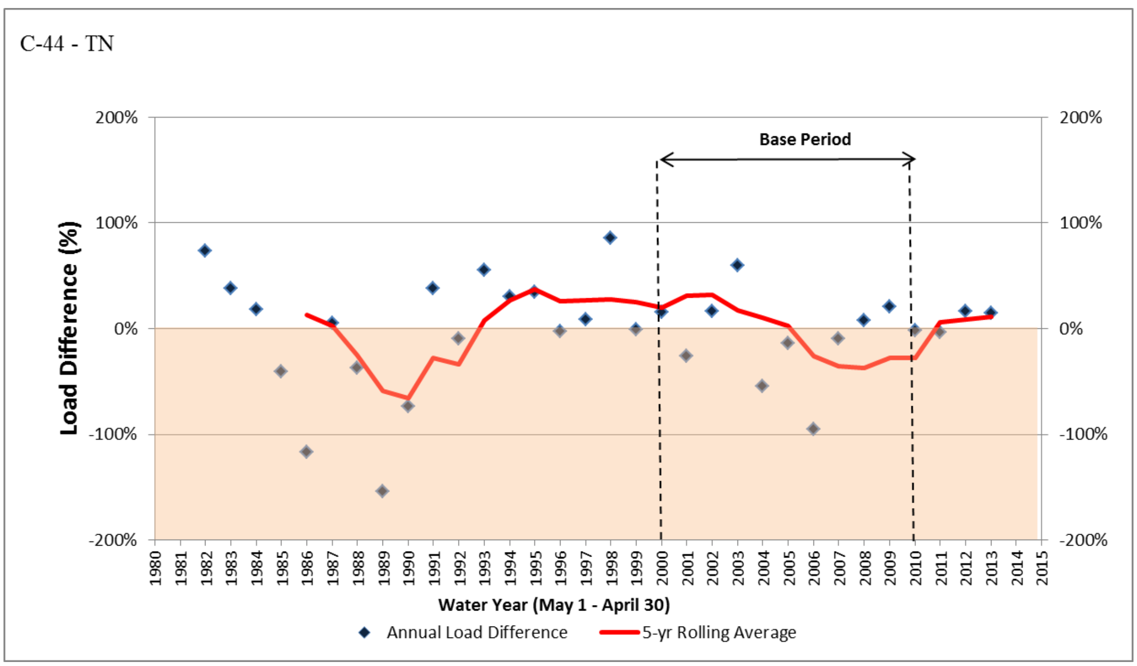
X = the 12-month total rainfall (inches) = $12m_1$

m_1 = Sum [r_i] / 12

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

Table 3-47 presents the annual observed and predicted sub-watershed TN loads. The load trend is presented in **Figure 3-24**. 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 3-24** denotes a reduction in loads.

Figure 3-24. C-44 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.

Table 3-47. WY1982 – WY2013 C-44 Sub-watershed TN measurements and calculations. (Base Period: WY2000-2010).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
1982	51.15	89.365	342.658	74%	
1983	70.12	613.308	993.932	38%	
1984	58.90	433.677	529.431	18%	
1985	47.82	399.208	284.233	-40%	
1986	46.55	574.096	264.674	-117%	13%
1987	50.89	320.563	337.693	5%	3%
1988	48.34	402.422	292.653	-38%	-25%
1989	40.56	479.831	189.092	-154%	-59%
1990	45.17	424.944	244.944	-73%	-66%
1991	54.32	254.608	409.399	38%	-28%
1992	41.83	222.965	203.065	-10%	-33%
1993	68.22	399.256	893.376	55%	8%
1994	57.09	332.972	478.278	30%	27%
1995	67.89	575.590	876.978	34%	38%
1996	70.58	1,046.224	1019.933	-3%	26%
1997	47.22	251.762	274.819	8%	26%
1998	57.74	70.888	496.053	86%	28%
1999	45.45	251.887	248.824	-1%	25%
2000	50.95	285.557	338.833	16%	20%
2001	33.53	160.923	127.432	-26%	31%
2002	52.48	309.436	369.222	16%	32%
2003	46.68	107.970	266.613	60%	17%
2004	40.07	283.541	183.961	-54%	11%
2005	54.20	461.063	406.650	-13%	2%
2006	59.63	1,076.850	551.578	-95%	-26%
2007	30.41	117.265	106.958	-10%	-35%
2008	57.53	450.210	490.239	8%	-37%
2009	44.41	186.391	234.713	21%	-28%
2010	44.84	244.023	240.448	-1%	-28%
2011	27.92	95.784	93.005	-3%	6%
2012	34.29	111.184	132.987	16%	9%
2013	51.95	305.725	358.398	15%	11%

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.

3.4.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the C-44 Sub-watershed.

3.4.2.1 Total Phosphorus Performance Metric Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.6, 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 35 percent was determined to be reasonable and appropriate. Details are provided in Appendix C and in the *Data Analysis and Performance Measure Development for the St. Lucie River Watershed Source Control Program* (HDR 2011).

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 35 percent load reduction. The Annual Load Target and Annual Load Limit for the C-44 Sub-watershed will be calculated according to the following equations and explanation.

Target = exp [-6.32749 + 2.47799 X + 0.32325 S]

Explained Variance = 83.9%, Standard Error of Regression = 10.798 mt

Predictors (X and S) are calculated from the first three moments (m_1, m_2, m_3) 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

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

X = ln (12 m_1)

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

Limit = Target * exp (1.39682 SE)

SE = standard error of the predicted ln(Load) for May-April interval

$SE = 0.28246\, [\, 1 + 1/11 + 2.17751\, (X - X_m)^2 + 0.37714\, (S - S_m)^2 - 0.19126\, (X - X_m)\, (S - S_m)\,]^{0.5}$

Where:

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

X_m = average value of the predictor in base period = 3.82565

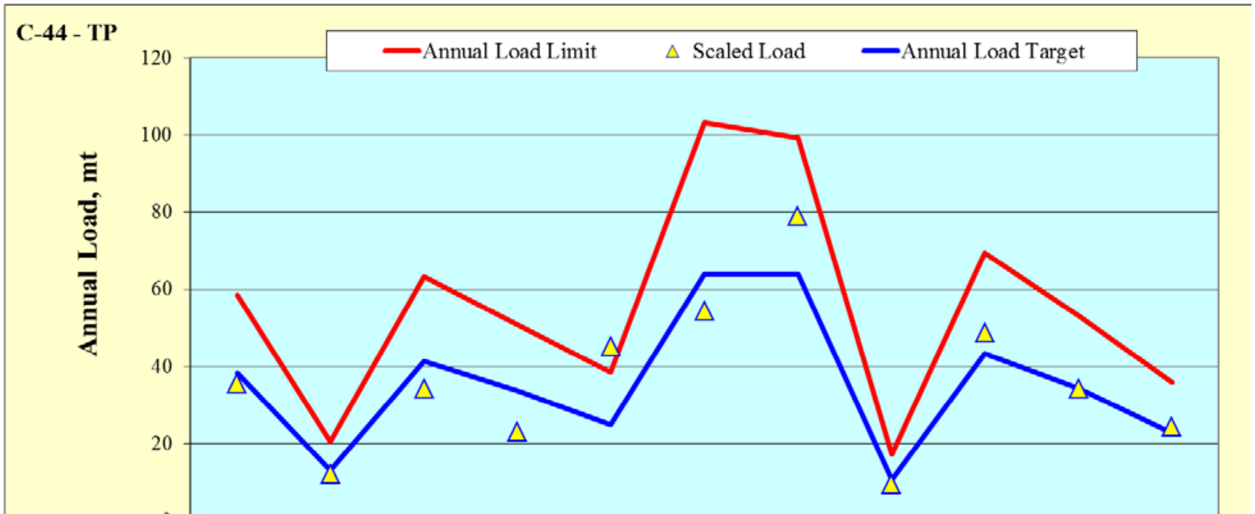
S = is the skewness of the annual rainfall calculated from 12 monthly rainfall totals

S_m = average value of the predictor in base period = 0.88018

The first predictor (X) indicates that load increases exponentially with 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 has higher skewness. For a given annual rainfall, the lowest load occurs when rainfall is evenly distributed across months and the highest load occurs when all of the rain falls in one month. Real cases fall in between.

A comparison of the Base Period loads, scaled to reflect the source control reduction goal, and the resulting Targets and Limits for are presented in **Figure 3-25.** The combined annual TP loads at S-308 and S-80, adjusted to account for pass-through loads and regional projects (if applicable), as described in Appendices A and D, respectively, will be evaluated against the performance measure described above.

Figure 3-25. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the C-44 Sub-watershed.



Water Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Annual Load Limit	58.378	20.672	63.217	50.886	38.533	103.194	99.279	17.211	69.492	53.166	35.822
Scaled Load	35.595	12.224	34.360	23.171	45.302	54.352	78.993	9.606	48.701	34.188	24.361
Annual Load Target	38.402	13.150	41.471	33.669	25.052	64.019	63.894	10.693	43.423	34.414	22.738

3.4.2.1.1 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 (29.81 to 61.38 inches), as derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall amount which reflects the cumulative effect of the two variables that comprise the Load Target equation: Rain and S:

Adjusted Rainfall = equivalent rainfall for mean S variable (inches)

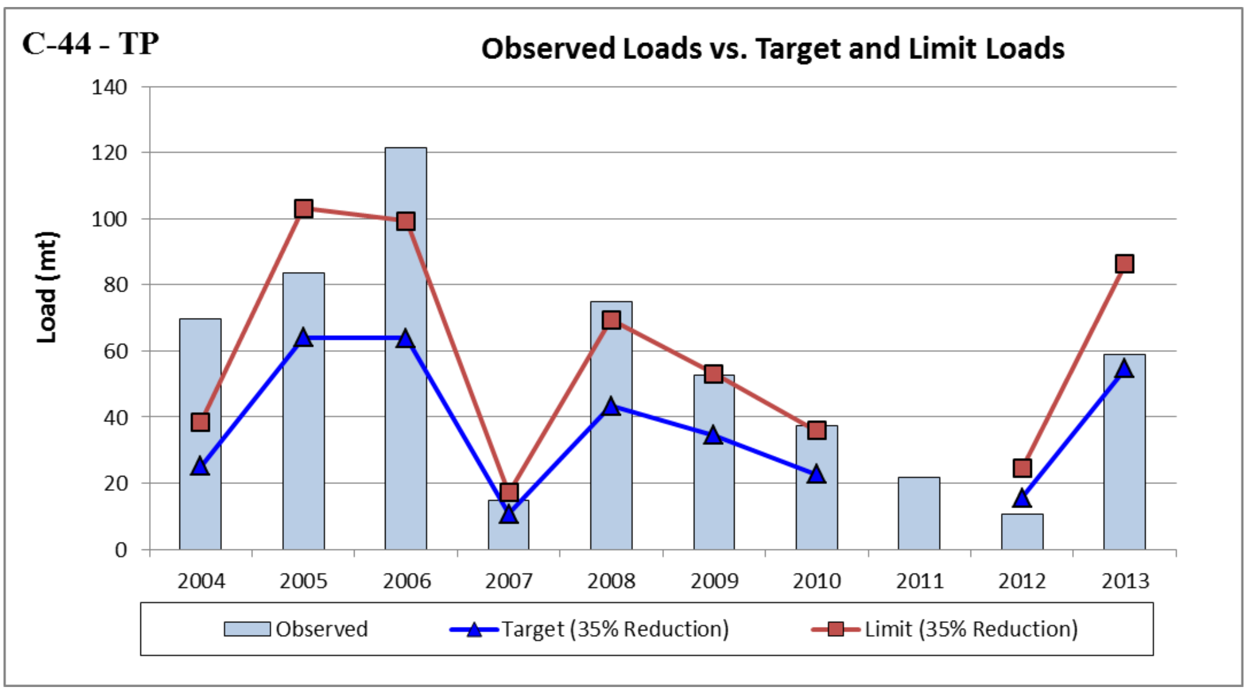
$$Rain_{adj} = \exp [\ln(Rain) + 0.13045 (S - 0.88018)]$$

Table 3-48 shows the calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the period of record.

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**.

Comparison to WY2004-2013. A comparison of the loads observed during WY2004-2013 to the Annual Load Targets and Limits is presented in **Figure 3-26**.

Figure 3-26. Comparison of WY2004-2013 TP loads with Annual Load Targets and Limits for the C-44 Sub-watershed.



Note: The Base Period extended from WY2000-2010.
The performance determination for WY2011 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 3-48. TP Annual Load Targets and Limits for the historical period of record for the C-44 Sub-watershed (Base Period: WY2000-2010).

Water Year	Observed Load, mt	Observed Rain, in	Skewness	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1982	5.929	51.15	1.413	48.403	74.744	54.83
1983	37.054	70.12	0.138	70.043	118.068	63.65
1984	28.398	58.90	0.360	48.851	77.317	55.04
1985	51.046	47.82	-0.004	25.912	41.305	42.61
1986	54.573	46.55	0.933	32.816	49.564	46.87
1987	41.639	50.89	1.622	51.137	80.288	56.06
1988	51.435	48.34	0.143	27.911	43.838	43.91
1989	52.859	40.56	0.310	19.071	29.556	37.65
1990	43.126	45.17	0.808	29.251	44.187	44.75
1991	27.331	54.32	0.265	38.764	60.952	50.13
1992	38.721	41.83	0.359	20.914	32.236	39.08
1993	72.274	68.22	0.962	85.404	136.907	68.95
1994	29.672	57.09	0.086	41.383	66.731	51.47
1995	83.713	67.89	0.209	66.153	109.748	62.20
1996	71.568	70.58	0.891	90.805	147.097	70.68
1997	19.530	47.22	0.311	27.806	42.979	43.84
1998	-20.783	57.74	-0.241	38.291	64.338	49.88
1999	27.924	45.45	1.129	32.950	49.978	46.95
2000	54.761	50.95	0.727	38.402	58.378	49.94
2001	18.806	33.53	0.619	13.150	20.672	32.41
2002	52.861	52.48	0.738	41.471	63.217	51.52
2003	35.647	46.68	0.991	33.669	50.886	47.36
2004	69.695	40.07	1.247	25.052	38.533	42.03
2005	83.619	54.20	1.834	64.019	103.194	61.38
2006	121.527	59.63	1.096	63.894	99.279	61.33
2007	14.779	30.41	0.728	10.693	17.211	29.81
2008	74.924	57.53	0.176	43.423	69.492	52.48
2009	52.597	44.41	1.441	34.414	53.166	47.78
2010	37.479	44.84	0.085	22.738	35.822	40.42
2011	21.660	27.92	0.797	8.848	14.625	27.62
2012	10.551	34.29	0.973	15.586	24.370	34.71
2013	58.956	51.95	1.670	54.658	86.316	57.59

Notes:

1. Shaded water years indicate the performance determination would have been suspended due to adjusted rainfall outside 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.

3.4.2.1.2 Exceedance Frequency Analysis. Using the approach described in Section 2.6, an approximation of the cumulative exceedance frequency for the determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP loads of the Base Period (**Table 3-49**). 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 were determined to be reasonable and defensible since the cumulative exceedance frequency is less than the theoretical value of approximately 17.5 percent.

Table 3-49. Exceedance frequencies for the proposed TP performance determination methodology for the C-44 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%	5.9%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.9%
Step 4. Load > Annual Load Limit?	<10%	4.1%
Cumulative Exceedance Frequency	**<17.5%**	**13.8%**

3.4.2.2 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.

3.4.2.2.1 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 30 percent reduction.

TN-based Prediction = exp (2.60861 + 0.05614 X)

Explained Variance = 62.8%, Standard Error of Regression = 133.132 mt

The predictor X is calculated from the first moments (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 = (12 m_1)

TN-based UCL = TN-based Prediction * exp (1.38303 SE_{TN})

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

SE_{TN} = 0.42839 * sqrt [1 + 1/11 + $(X-Xm)^2$ / 883.57225]

Where:

X = the 12-month total rainfall (inches)

X_m = average value of the predictor in calibration period = 46.794

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

3.4.2.2.2 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 = exp (2.15967 + 0.06371 X)

Explained Variance = 62.8%, Standard Error of Regression = 120.837 mt

The predictors 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 = (12 m_1)

TON-based UCL = TON-based Prediction + 1.38303 SE

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

$SE_{TON} = 0.48584 * \text{sqrt} [1 + 1/11 + (X-X_m)^2 / 883.57225]$

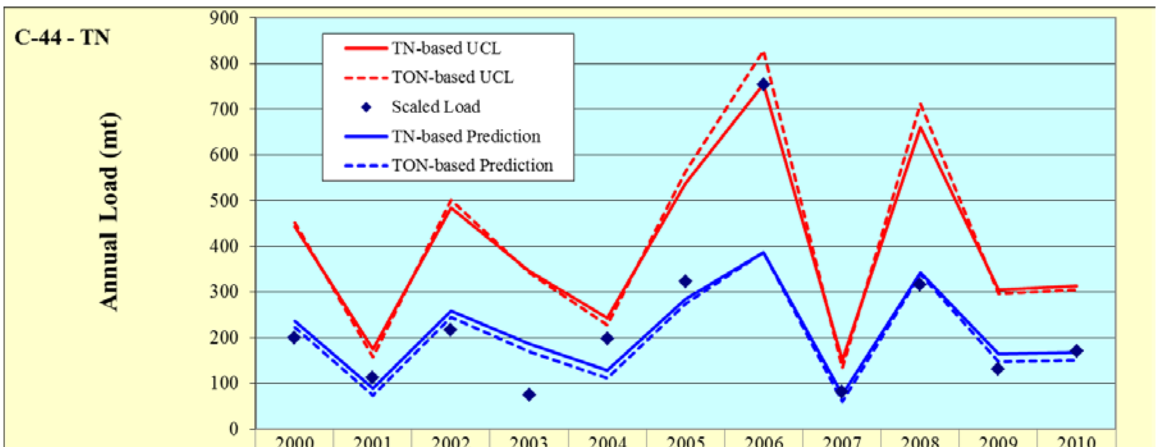
Where:

X = the 12-month total rainfall (inches)

X_m = average value of the predictor in calibration period = 46.794

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 3-27.**

Figure 3-27. Comparison of scaled annual TN loads with the Annual Load Targets and Limits for the C-44 Sub-watershed.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TN-based UCL	442.820	174.833	484.844	346.520	242.550	537.783	754.251	150.724	660.493	305.614	312.894
TON-based UCL	452.012	157.434	500.995	342.207	228.278	563.514	827.209	133.033	711.538	296.740	304.776
Scaled Load	199.8899	112.6461	216.6052	75.579	198.4787	322.7441	753.795	82.0855	315.147	130.4737	170.8161
TN-based Prediction	237.182	89.203	258.455	186.629	128.773	284.655	386.103	74.870	343.166	164.299	168.313
TON-based Prediction	222.657	73.393	245.453	169.626	111.328	273.878	387.076	60.163	338.605	146.786	150.863

3.4.2.2.3 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.

3.4.2.2.4 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 rainfall falls outside the range of rainfall values for the Base Period (30.41 - 59.63 inches).

The rainfall values, Annual Load Targets and Annual Load Limits for the WY1982-2013 period of record are summarized in **Table 3-50**.

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**.

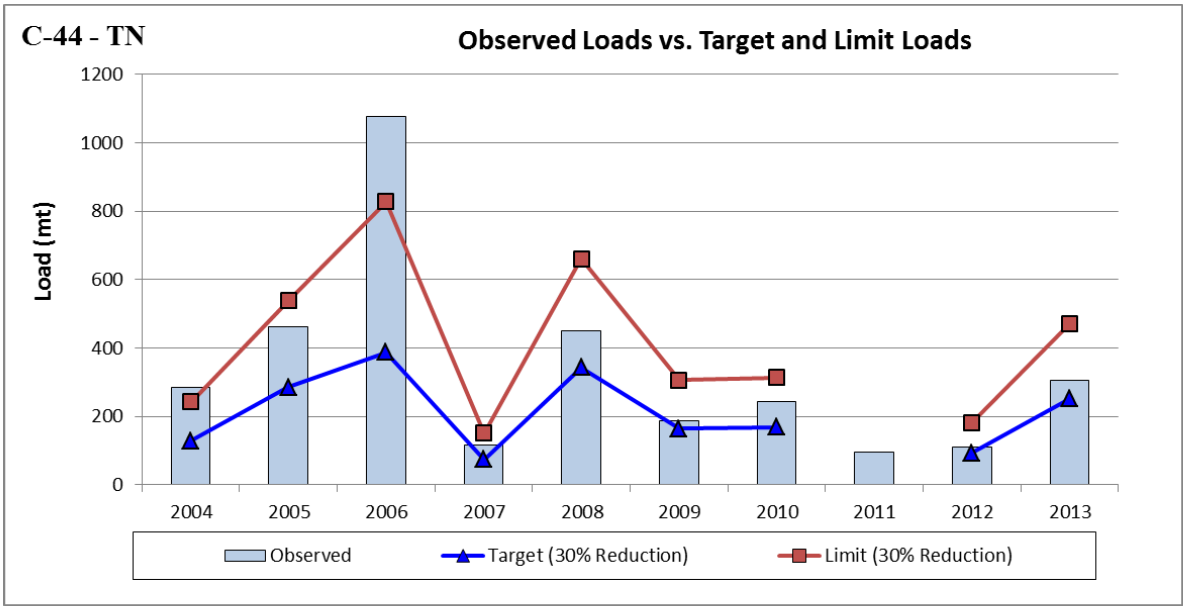
3.4.2.2.5 Comparison to WY2004-2013. A comparison of the WY2004-2013 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-28**.

Table 3-50. TN Annual Targets and Limits for the historical period of record for the C-44 Sub-watershed (Base Period: WY2000-2010).

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	51.15	89.365	239.861	448.064	225.512	458.089
1983	70.12	613.308	695.751	1508.702	755.157	1816.663
1984	58.90	433.677	370.601	720.052	369.487	784.778
1985	47.82	399.208	198.963	369.545	182.404	368.125
1986	46.55	574.096	185.272	344.006	168.227	339.391
1987	50.89	320.563	236.385	441.262	221.807	450.206
1988	48.34	402.422	204.857	380.655	188.548	380.710
1989	40.56	479.831	132.365	248.819	114.858	234.984
1990	45.17	424.944	171.461	318.625	154.068	311.117
1991	54.32	254.608	286.579	541.722	275.980	568.199
1992	41.83	222.965	142.146	266.008	124.538	253.494
1993	68.22	399.256	625.362	1326.376	669.064	1569.643
1994	57.09	332.972	334.795	642.570	329.245	689.665
1995	67.89	575.590	613.883	1297.199	655.144	1530.521
1996	70.58	1,046.224	713.952	1556.773	777.615	1882.485
1997	47.22	251.762	192.373	357.205	175.563	354.206
1998	57.74	70.888	347.237	669.250	343.165	722.250
1999	45.45	251.887	174.177	323.586	156.841	316.621
2000	50.95	285.557	237.183	442.822	222.657	452.012
2001	33.53	160.923	89.203	174.834	73.393	157.434
2002	52.48	309.436	258.455	484.845	245.453	500.995
2003	46.68	107.970	186.629	346.520	169.626	342.207
2004	40.07	283.541	128.773	242.551	111.328	228.278
2005	54.20	461.063	284.655	537.784	273.878	563.514
2006	59.63	1,076.850	386.104	754.252	387.076	827.209
2007	30.41	117.265	74.871	150.725	60.163	133.033
2008	57.53	450.210	343.167	660.494	338.605	711.538
2009	44.41	186.391	164.299	305.614	146.786	296.740
2010	44.84	244.023	168.314	312.896	150.863	304.776
2011	27.92	95.784	65.104	134.313	51.337	116.715
2012	34.29	111.184	93.091	181.398	77.034	164.160
2013	51.95	305.725	250.879	469.779	237.303	483.363

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

Figure 3-28. Comparison of WY2004-2013 TN loads with Annual Load Targets and Limits for the C-44 Sub-watershed.



Note: The Base Period extended from WY2000-2010.
The performance determination for WY2011 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.

3.4.2.2.6 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 3-51** and **3-52**). 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 3-51. Exceedance frequencies for the proposed TN-based prediction and UCL for the C-44 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%	6.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.8%
Step 4. Load > Annual Load Limit?	<10%	5.5%
Cumulative Exceedance Frequency	**<17.5%**	**14.7%**

Table 3-52. Exceedance frequencies for the proposed TON-based prediction and UCL for the C-44 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%	6.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.8%
Step 4. Load > Annual Load Limit?	<10%	5.5%
Cumulative Exceedance Frequency	**<17.5%**	**14.7%**

3.5 Ten Mile Creek Basin

The following sections present a description of the Ten Mile Creek Basin, 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 Ten Mile Creek basin is the largest tributary delivering water to the North Fork of the St. Lucie River Watershed (**Figure 3-29**). Water releases are regulated through the Gordy Road structure which is controlled by the North St. Lucie Water Control District. Flow and water quality data are available for the Gordy Road structure for the period from WY2000 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**). The historical data analysis for the Ten Mile Creek Basin 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 St. Lucie River Source Control Programs) with the District and was supplemented in collaboration with staff (HDR, 2011).

The performance metric methodologies are based on flows and nutrient (TP and TN) loads resulting from rainfall and runoff from the Ten Mile Creek Basin, as reported for the Gordy Road structure. 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 WY1979-2013. Monthly rainfall data and weighting factors for the rainfall stations were developed and provided by the District. **Tables 3-53** through **3-55** present the period of record flow and load data for the Ten Mile Creek Basin.

Figure 3-29. Ten Mile Creek basin schematic (from SFWMD 2013).

Table 3-53. Summary of historical TP data for the Ten Mile Creek Basin.

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
2000	117,927	74.542	512	40.23	35.62	4.14	0.587	0.894	1.123
2001	50,257	23.619	381	29.85	15.18	1.31	0.180	1.034	0.801
2002	111,733	59.386	431	53.51	33.75	3.30	-1.087	0.729	0.628
2003	269,473	121.844	367	46.03	81.40	6.76	0.070	0.678	0.792
2004	262,241	109.668	339	49.00	79.21	6.09	-1.273	0.699	0.377
2005	294,123	154.049	425	60.04	88.85	8.55	5.231	1.175	2.098
2006	144,043	62.215	350	64.68	43.51	3.45	-1.485	0.834	0.296
2007	59,253	16.973	232	25.14	17.90	0.94	0.111	0.784	0.773
2008	102,841	49.984	394	51.76	31.07	2.77	-0.135	0.803	0.862
2009	142,084	94.565	540	50.53	42.92	5.25	4.445	1.260	1.988
2010	119,790	39.466	267	63.16	36.18	2.19	-1.168	0.659	0.050
2011	49,364	8.956	147	37.37	14.91	0.50	-1.677	0.686	-0.341
2012	93,187	31.448	274	51.50	28.15	1.75	-0.567	0.853	0.659
2013	81,339	23.968	239	49.01	24.57	1.33	-0.069	0.906	0.814
Minimum	***49,364***	***8.956***	***147***	***25.14***	***14.91***	***0.50***	***-1.677***	***0.659***	***-0.341***
Average	***135,547***	***62.192***	***372***	***47.99***	***40.94***	***3.45***	***0.226***	***0.857***	***0.780***
Maximum	***294,123***	***154.049***	***540***	***64.68***	***88.85***	***8.55***	***5.231***	***1.260***	***2.098***
Std. Dev.	***81,665***	***43.762***	***110***	***11.59***	***24.67***	***2.43***	***2.082***	***0.186***	***0.653***
Skewness	***1.059***	***0.783***	***-0.009***	***-0.540***	***1.059***	***0.78***	***1.788***	***1.098***	***0.680***
Median	***114,830***	***54.685***	***359***	***49.77***	***34.69***	***3.03***	***-0.102***	***0.819***	***0.783***

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

Table 3-54. Summary of historical TN data for the Ten Mile Creek Basin.

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
2000	117,927	219.131	1,506	40.23	35.62	12.16	0.587	0.894	1.123
2001	50,257	79.378	1,280	29.85	15.18	4.41	0.180	1.034	0.801
2002	111,733	188.595	1,368	53.51	33.75	10.47	-1.087	0.729	0.628
2003	269,473	358.688	1,079	46.03	81.40	19.91	0.070	0.678	0.792
2004	262,241	330.767	1,023	49.00	79.21	18.36	-1.273	0.699	0.377
2005	294,123	461.195	1,271	60.04	88.85	25.59	5.231	1.175	2.098
2006	144,043	223.209	1,256	64.68	43.51	12.39	-1.485	0.834	0.296
2007	59,253	81.820	1,119	25.14	17.90	4.54	0.111	0.784	0.773
2008	102,841	174.303	1,374	51.76	31.07	9.67	-0.135	0.803	0.862
2009	142,084	242.165	1,382	50.53	42.92	13.44	4.445	1.260	1.988
2010	119,790	178.000	1,205	63.16	36.18	9.88	-1.168	0.659	0.050
2011	49,364	47.356	778	37.37	14.91	2.63	-1.677	0.686	-0.341
2012	93,187	138.685	1,207	51.50	28.15	7.70	-0.567	0.853	0.659
2013	81,339	102.587	1,022	49.01	24.57	5.69	-0.069	0.906	0.814
Minimum	***49,364***	***47.356***	***778***	***25.14***	***14.91***	***2.63***	***-1.677***	***0.659***	***-0.341***
Average	***135,547***	***201.849***	***1,207***	***47.99***	***40.94***	***11.20***	***0.226***	***0.857***	***0.780***
Maximum	***294,123***	***461.195***	***1,506***	***64.68***	***88.85***	***25.59***	***5.231***	***1.260***	***2.098***
Std. Dev.	***81,665***	***117.499***	***188***	***11.59***	***24.67***	***6.52***	***2.082***	***0.186***	***0.653***
Skewness	***1.059***	***0.830***	***-0.668***	***-0.540***	***1.059***	***0.83***	***1.788***	***1.098***	***0.680***
Median	***114,830***	***183.298***	***1,232***	***49.77***	***34.69***	***10.17***	***-0.102***	***0.819***	***0.783***

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

Table 3-55. Summary of historical TON data for the Ten Mile Creek Basin.

Water Year	Flow AF	TON Load mt	FWM TON Conc µg/L	Rainfall inches	Unit Area Runoff inches	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
2000	117,927	163.390	1,123	40.23	35.62	9.07	0.587	0.894	1.123
2001	50,257	64.226	1,036	29.85	15.18	3.56	0.180	1.034	0.801
2002	111,733	147.086	1,067	53.51	33.75	8.16	-1.087	0.729	0.628
2003	269,473	296.663	893	46.03	81.40	16.46	0.070	0.678	0.792
2004	262,241	271.513	839	49.00	79.21	15.07	-1.273	0.699	0.377
2005	294,123	390.832	1,077	60.04	88.85	21.69	5.231	1.175	2.098
2006	144,043	183.060	1,030	64.68	43.51	10.16	-1.485	0.834	0.296
2007	59,253	69.953	957	25.14	17.90	3.88	0.111	0.784	0.773
2008	102,841	145.461	1,147	51.76	31.07	8.07	-0.135	0.803	0.862
2009	142,084	206.936	1,181	50.53	42.92	11.48	4.445	1.260	1.988
2010	119,790	141.886	960	63.16	36.18	7.87	-1.168	0.659	0.050
2011	49,364	41.096	675	37.37	14.91	2.28	-1.677	0.686	-0.341
2012	93,187	112.139	976	51.50	28.15	6.22	-0.567	0.853	0.659
2013	81,339	84.260	840	49.01	24.57	4.68	-0.069	0.906	0.814
Minimum	***49,364***	***41.096***	***675***	***25.14***	***14.91***	***2.28***	***-1.677***	***0.659***	***-0.341***
Average	***135,547***	***165.607***	***990***	***47.99***	***40.94***	***9.19***	***0.226***	***0.857***	***0.780***
Maximum	***294,123***	***390.832***	***1,181***	***64.68***	***88.85***	***21.69***	***5.231***	***1.260***	***2.098***
Std. Dev.	***81,665***	***98.783***	***139***	***11.59***	***24.67***	***5.48***	***2.082***	***0.186***	***0.653***
Skewness	***1.059***	***0.966***	***-0.712***	***-0.540***	***1.059***	***0.97***	***1.788***	***1.098***	***0.680***
Median	***114,830***	***146.274***	***1,003***	***49.77***	***34.69***	***8.12***	***-0.102***	***0.819***	***0.783***

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

The Base Period of WY 2000-2011 is recommended because:

- This period incorporates the earliest available flow and nutrient data.
- 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.

Tables 3-56 through **3-58** compare hydrologic and nutrient data for the period of record, the Base Period and WY2004-2013. Additional information is provided in Appendix A.

Table 3-56. Comparisons of Base Period with period of record and WY2004-2013 data for the Ten Mile Creek Basin: TP.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY2000-2013					
Annual Minimum	49,364	8.956	147	25.14	0.50
Annual Average	135,547	62.192	372	47.99	3.45
Annual Median	114,830	54.685	359	49.77	3.03
Annual Maximum	294,123	154.049	540	64.68	49.00
Preliminary Base Period WY2000-2011					
Annual Minimum	49,364	8.956	147	25.14	0.50
Annual Average	143,594	67.939	384	47.61	3.77
Annual Median	118,859	60.801	374	49.77	3.37
Annual Maximum	294,123	154.049	540	64.68	8.55
Difference between Period of Record and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-8,047	-5.747	-12	0.38	-0.32
Annual Median	-4,029	-6.116	-16	0.00	-0.34
Annual Maximum	0	0.000	0	0.00	40.45
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-6%	-8%	-3%	1%	-8%
Annual Median	-3%	-10%	-4%	0%	-10%
Annual Maximum	0%	0%	0%	0%	473%
WY2004-2013					
Annual Minimum	49,364	8.956	147	25.14	0.50
Annual Average	134,827	59.129	356	50.22	3.28
Annual Median	111,316	44.725	307	51.02	2.48
Annual Maximum	294,123	154.049	540	64.68	8.55
Difference between WY2004-2013 and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-8,768	-8.810	-28	2.61	-0.49
Annual Median	-7,543	-16.076	-68	1.25	-0.89
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-6%	-13%	-7%	5%	-13%
Annual Median	-6%	-26%	-18%	3%	-26%
Annual Maximum	0%	0%	0%	0%	0%

Table 3-57. Comparisons of Base Period with period of record and WY2004-2013 data for the Ten Mile Creek Basin: TN.

Metric	Flow AF	TN Load mt	TN Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY2000-2013					
Annual Minimum	49,364	47.356	778	25.14	2.63
Annual Average	135,547	201.849	1,207	47.99	11.20
Annual Median	114,830	183.298	1,232	49.77	10.17
Annual Maximum	294,123	461.195	1,506	64.68	49.00
Preliminary Base Period WY2000-2011					
Annual Minimum	49,364	47.356	778	25.14	2.63
Annual Average	143,594	215.384	1,216	47.61	11.95
Annual Median	118,859	203.863	1,264	49.77	11.31
Annual Maximum	294,123	461.195	1,506	64.68	25.59
Difference between Period of Record and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-8,047	-13.535	-9	0.38	-0.75
Annual Median	-4,029	-20.566	-32	0.00	-1.14
Annual Maximum	0	0.000	0	0.00	23.41
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-6%	-6%	-1%	1%	-6%
Annual Median	-3%	-10%	-3%	0%	-10%
Annual Maximum	0%	0%	0%	0%	91%
WY2004-2013					
Annual Minimum	49,364	47.356	778	25.14	2.63
Annual Average	134,827	198.009	1,191	50.22	10.99
Annual Median	111,316	176.152	1,206	51.02	9.78
Annual Maximum	294,123	461.195	1,382	64.68	25.59
Difference between WY2004-2013 and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-8,768	-17.375	-25	2.61	-0.96
Annual Median	-7,543	-27.712	-58	1.25	-1.54
Annual Maximum	0	0.000	-124	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-6%	-8%	-2%	5%	-8%
Annual Median	-6%	-14%	-5%	3%	-14%
Annual Maximum	0%	0%	-8%	0%	0%

Table 3-58. Comparisons of Base Period with period of record and WY2004-2013 data for the Ten Mile Creek Basin: TON.

Metric	Flow AF	TON Load mt	TON Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY2000-2013					
Annual Minimum	49,364	41.096	675	25.14	2.28
Annual Average	135,547	165.607	990	47.99	9.19
Annual Median	114,830	146.274	1,003	49.77	8.12
Annual Maximum	294,123	390.832	1,181	64.68	49.00
Preliminary Base Period WY2000-2011					
Annual Minimum	49,364	41.096	675	25.14	2.28
Annual Average	143,594	176.842	998	47.61	9.81
Annual Median	118,859	155.238	1,033	49.77	8.61
Annual Maximum	294,123	390.832	1,181	64.68	21.69
Difference between Period of Record and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-8,047	-11.235	-8	0.38	-0.62
Annual Median	-4,029	-8.964	-30	0.00	-0.50
Annual Maximum	0	0.000	0	0.00	27.31
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-6%	-6%	-1%	1%	-6%
Annual Median	-3%	-6%	-3%	0%	-6%
Annual Maximum	0%	0%	0%	0%	126%
WY2004-2013					
Annual Minimum	49,364	41.096	675	25.14	2.28
Annual Average	134,827	164.714	990	50.22	9.14
Annual Median	111,316	143.674	968	51.02	7.97
Annual Maximum	294,123	390.832	1,181	64.68	21.69
Difference between WY2004-2013 and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-8,768	-12.128	-8	2.61	-0.67
Annual Median	-7,543	-11.565	-65	1.25	-0.64
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-6%	-7%	-1%	5%	-7%
Annual Median	-6%	-7%	-6%	3%	-7%
Annual Maximum	0%	0%	0%	0%	0%

3.5.1.1 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.

$$\text{TP Annual Load} = \exp(-3.2619 + 1.50642\ X + 1.2927\ S - 2.35325\ C)$$

Explained Variance = 78.7%, Standard Error of Regression = 31.53 mt

Predictors (X, C 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) = $12m_1$

C = the natural logarithm of the coefficient of variation calculated from 12 monthly rainfall totals $[\ (12/11)\ m_2]^{0.5}/m_1$

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

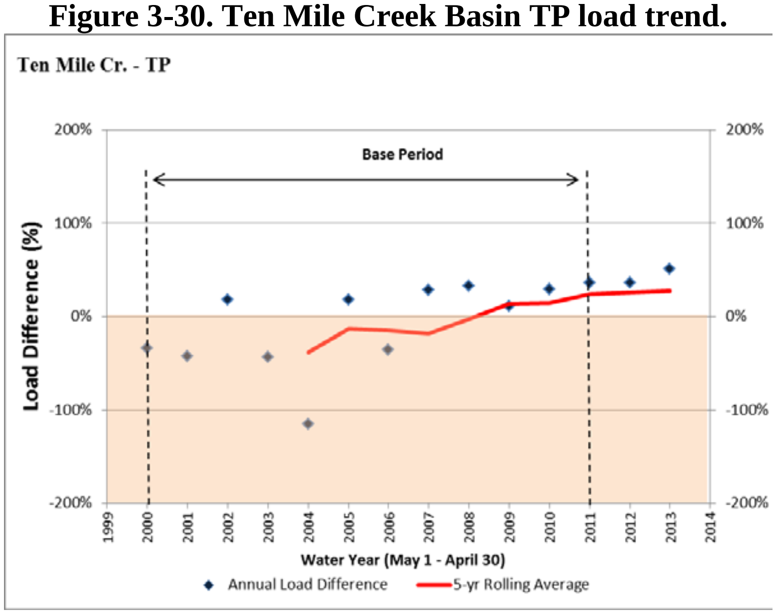
Table 3-59 presents the annual observed and predicted sub-watershed TP loads. The load trend is presented in **Figure 3-30**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-30** denotes a reduction in loads.

Table 3-59. WY2000 - WY2013 Ten Mile Creek Basin TP measurements and calculations. (Base Period: WY2000-2011).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
2000	40.23	74.542	55.653	-34%	
2001	29.85	23.619	16.626	-42%	
2002	53.51	59.386	72.901	19%	
2003	46.03	121.844	85.195	-43%	
2004	49.00	109.668	50.952	-115%	-38%
2005	60.04	154.049	188.574	18%	-13%
2006	64.68	62.215	46.010	-35%	-14%
2007	25.14	16.973	23.746	29%	-18%
2008	51.76	49.984	74.738	33%	-2%
2009	50.53	94.565	107.036	12%	14%
2010	63.16	39.466	56.219	30%	14%
2011	37.37	8.956	13.996	36%	24%
2012	51.50	31.448	49.493	36%	26%
2013	49.01	23.968	48.701	51%	28%

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

Figure 3-30. Ten Mile Creek Basin 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.

3.5.1.2 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.

$$\text{TN Annual Load} = \exp(-1.01979 + 1.30697\,X + 1.03373\,S - 2.18739\,C)$$

Explained Variance = 82.0%, Standard Error of Regression = 73.02 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 = $\ln\{[\,(12/11)\, m_2]^{0.5}/m_1\}$

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

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

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

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.

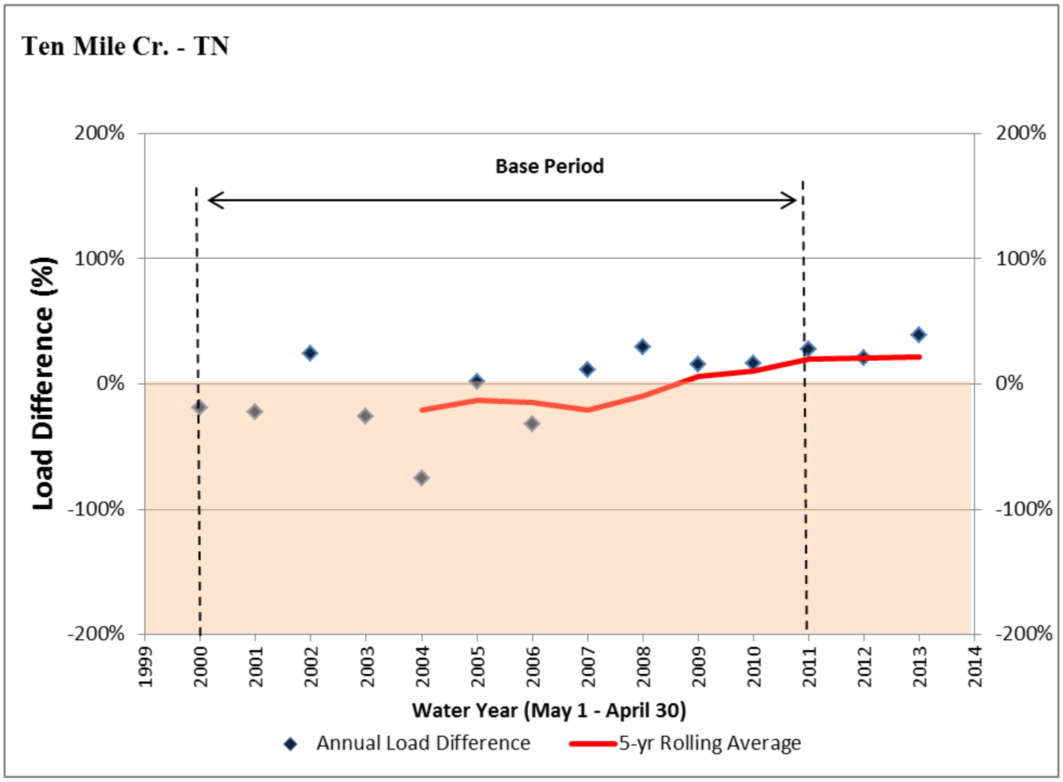
Table 3-60 presents the annual observed and predicted sub-watershed TN loads. The load trend is presented in **Figure 3-31**. The solid line shows the five-year trend of load differences (observed vs. predicted). The diamond (♦) symbol represents the annual difference. An upward trend in the solid line in **Figure 3-31** denotes a reduction in loads.

Table 3-60. WY2000 – WY2013 Ten Mile Creek Basin TN measurements and calculations. (Base Period: WY2000-2011).

Water Year	Annual Rainfall (inches)	Observed Load (mt)	Predicted Load (mt)	Annual Load Difference	5-yr Rolling Average Difference
2000	40.23	219.131	183.998	-19%	
2001	29.85	79.378	64.962	-22%	
2002	53.51	188.595	250.220	25%	
2003	46.03	358.688	285.351	-26%	
2004	49.00	330.767	188.617	-75%	-21%
2005	60.04	461.195	467.907	1%	-13%
2006	64.68	223.209	169.455	-32%	-15%
2007	25.14	81.820	92.374	11%	-21%
2008	51.76	174.303	246.978	29%	-9%
2009	50.53	242.165	286.119	15%	6%
2010	63.16	178.000	213.228	17%	11%
2011	37.37	47.356	65.657	28%	20%
2012	51.50	138.685	174.294	20%	21%
2013	49.01	102.587	168.064	39%	22%

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

Figure 3-31. Ten Mile Creek Basin 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.

3.5.2 Performance Metric Methodologies

The following sections describe the derivation of TP and TN performance metric methodologies for the Ten Mile Creek Basin.

3.5.2.1 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 35 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 35 percent load reduction, and will be calculated according to the following equations and explanation.

TP Annual Load Target = exp (-3.69291 + 1.50647 X + 1.29272 S - 2.3533 C)

Explained Variance = 78.7%, Standard Error of Regression = 20.50 mt

Predictors (X, C and S) are calculated from the first three moment (m_1, m2, m3) 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

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

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

C = the natural logarithm of the coefficient of variation calculated from 12 monthly rainfall totals [(12/11) $m_2]^{0.5}/m_1$

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

TP Annual Load Limit = Target * exp (1.39682 SE)

SE = standard error of the Target prediction

$$SE = 0.46271 [1 + 1/12 + 1.09047 (X-X_m)^2 + 0.6778 (S-S_m)^2 + 7.01426 (C-C_m)^2 - 0.32174 (X-X_m) (S-S_m) + 0.90494 (X-X_m) (C-C_m) - 3.72828 (S-S_m) (C-C_m)]^{0.5}$$

Where:

X_m = average value of the predictor in the base period = 3.82637

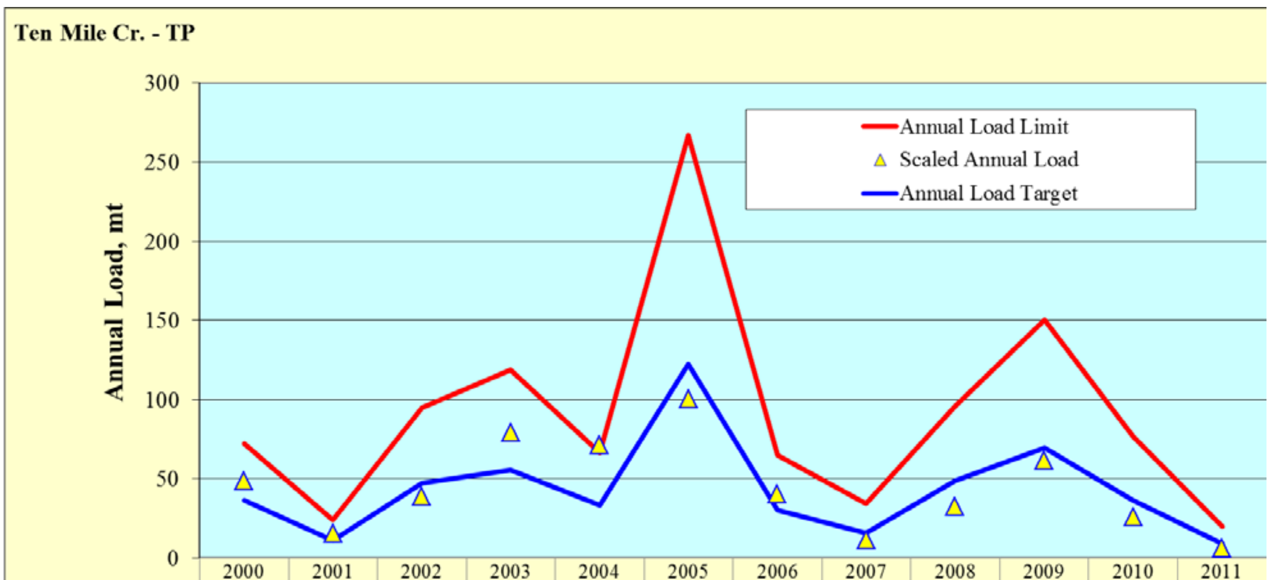
C_m = average value of the predictor in the base period = -0.18227

S_m = average value of the predictor in the base period = 0.78725

The first predictor (X) indicates that load increases with the total annual rainfall. The second and third predictors (C and S) 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 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 Base Period loads, scaled to reflect the 35 percent reduction goal, and the resulting Targets and Limits for are presented in **Figure 3-32.** 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 3-32. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the Ten Mile Creek Basin.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Annual Load Limit	71.934	23.965	95.099	118.489	66.198	266.628	64.796	34.349	96.156	150.190	76.616	19.548
Scaled Annual Load	48.452	15.352	38.601	79.199	71.284	100.132	40.440	11.032	32.490	61.467	25.653	5.821
Annual Load Target	36.174	10.806	47.385	55.377	33.118	122.575	29.906	15.434	48.580	69.574	36.542	9.097

3.5.2.1.1 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 (19.23 – 108.11 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.

$$\text{Adjusted Rain} = \exp\left[X + 0.85811\,(S - 0.78725) - 1.56213\,(C + 0.18227)\right]$$

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY2000-2012 period of record are summarized in **Table 3-61**. 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**.

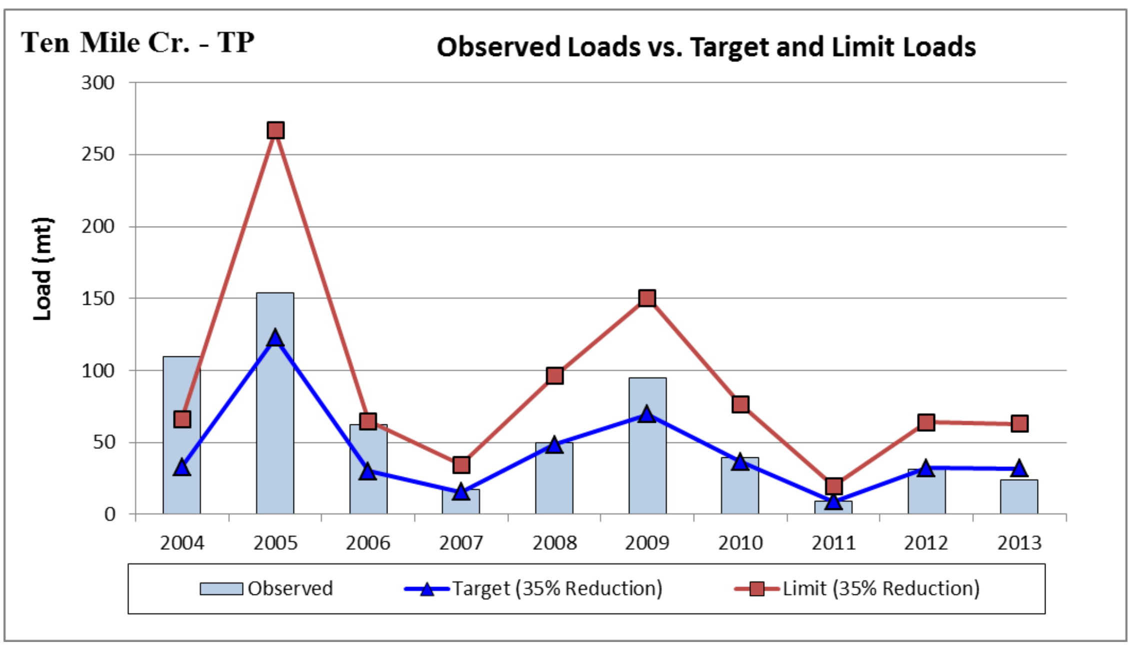
Table 3-61. TP Annual Load Targets and Limits for the historical period of record for the Ten Mile Creek Basin (Base Period: WY2000-2011).

Water Year	Observed Load, mt	Rain in	Ln(Rain)	S	ln(CV)	Target Load, mt	Limit Load, mt	Adjusted Rain, in
2000	74.542	40.23	3.69461	1.123	-0.11205	36.174	71.934	48.09
2001	23.619	29.85	3.39618	0.801	0.03343	10.806	23.965	21.56
2002	59.386	53.51	3.97987	0.628	-0.31608	47.386	95.099	57.53
2003	121.844	46.03	3.82929	0.792	-0.38861	55.377	118.489	63.80
2004	109.668	49.00	3.89182	0.377	-0.35810	33.119	66.199	45.35
2005	154.049	60.04	4.09501	2.098	0.16127	122.576	266.630	108.11
2006	62.215	64.68	4.16945	0.296	-0.18152	29.907	64.797	42.38
2007	16.973	25.14	3.22446	0.773	-0.24335	15.434	34.349	27.32
2008	49.984	51.76	3.94662	0.862	-0.21940	48.580	96.156	58.48
2009	94.565	50.53	3.92257	1.988	0.23111	69.573	150.189	74.23
2010	39.466	63.16	4.14567	0.050	-0.41703	36.542	76.617	48.41
2011	8.956	37.37	3.62087	-0.341	-0.37688	9.097	19.548	19.23
2012	31.448	51.50	3.94158	0.659	-0.15900	32.170	63.970	44.49
2013	23.968	49.01	3.89202	0.814	-0.09872	31.655	62.993	44.01

3.5.2.1.2 Comparison to WY2004-2013. A comparison of the WY2004-2013 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-33**.

3.5.2.1.3 Exceedance Frequency Analysis. Using the approach described in Section 2.5, 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 3-62**). 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**.**

Figure 3-33. Comparison of WY2004-2013 TP loads with Annual Load Targets and Limits for the Ten Mile Creek Basin.



Note: The Base Period is WY2000-2011.

Table 3-62. Exceedance frequencies for the proposed TP performance determination methodology for the Ten Mile Creek Basin.

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%	7.1%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.2%
Step 4. Load > Annual Load Limit?	<10%	0.0%
Cumulative Exceedance Frequency	**<17.5%**	**10.2%**

3.5.2.2 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.

3.5.2.2.1 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 = exp (-1.37646 + 1.30696 X + 1.03374 S - 2.18739 C)

Explained Variance = 82.0%, Standard Error of Regression = 51.12 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 = Sum [r_i] / 12

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

m_3 = 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 * exp (1.39682 SE)

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

SE_{TN} = 0.33503 [1 + 1/12 + 1.09051 $(X-X_m)^2$ + 0.67782 $(S–S_m)^2$ + 7.01447 $(C-C_m)^2$ – 0.32176 $(X-X_m)$ $(S–S_m)$ + 0.90496 $(X-X_m)$ $(C-C_m)$ - 3.72838 $(S-S_m)$ $(C-C_m)$ $]^{0.5}$

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 the base period = 3.82637

C_m = average value of the predictor in the base period = -0.18227

S_m = average value of the predictor in the base period = 0.78725

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.

3.5.2.2.2 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 = exp (-1.23302 + 1.28806 X + 1.02466 S - 2.13252 C)

Explained Variance = 82.6%, Standard Error of Regression = 53.99 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 = Sum [r_i] / 12

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

m_3 = 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 * exp (1.39682 SE)

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

$$SE_{TON} = 0.3257 [1 + 1/12 + 1.09051 (X-X_m)^2 + 0.67783 (S–S_m)^2 + 7.0145 (C-C_m)^2 – 0.32176 (X-X_m) (S–S_m) + 0.90498 (X-X_m) (C-C_m) - 3.7284 (S-S_m) (C-C_m)]^{0.5}$$

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

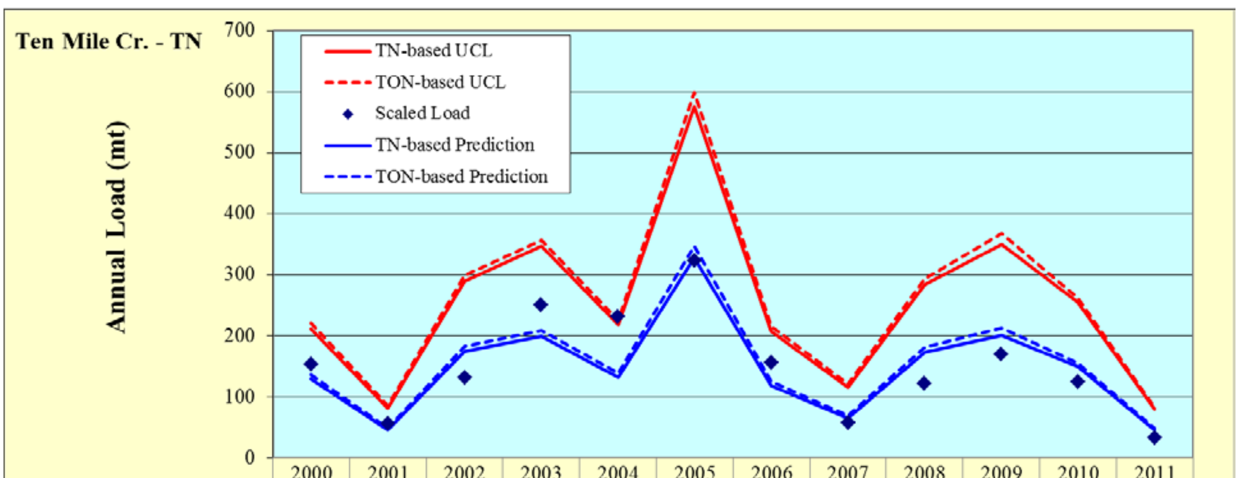
X_m = average value of the predictor in the base period = 3.82637

C_m = average value of the predictor in the base period = -0.18227

S_m = average value of the predictor in the base period = 0.78725

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 3-34.**

Figure 3-34. Comparison of scaled annual TN loads with the Annual Load Targets and Limits for the Ten Mile Creek Basin.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
TN-based UCL	211.873	80.948	290.050	346.477	218.001	574.955	207.627	115.401	283.440	349.646	255.122	79.970
TON-based UCL	221.268	85.759	299.214	356.028	225.278	598.518	215.319	120.829	293.592	366.983	262.051	83.397
Scaled Load	153.392	55.565	132.017	251.082	231.537	322.837	156.246	57.274	122.012	169.516	124.600	33.149
TN-based Prediction	128.798	45.473	175.154	199.746	132.031	327.534	118.618	64.662	172.885	200.285	149.258	45.960
TON-based Prediction	136.387	48.956	183.244	208.424	138.356	346.342	124.945	68.805	181.560	213.503	155.618	48.674

3.5.2.2.3 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.

3.5.2.2.4 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: 21.03 – 95.28 inches; and for the TON-based prediction: 21.02 – 96.44 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 + 0.79094 (S - 0.78725) - 1.67364 (C + 0.18227)]

TON-based Adjusted Rainfall = exp [X + 0.79551 (S - 0.78725) - 1.65561 (C + 0.18227)]

The adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY2000-2013 period of record are summarized in **Table 3-63**.

Table 3-63. TN Annual Targets and Limits for the historical period of record for the Ten Mile Creek Basin (Base Period: WY2000-2011).

Water Year	Observed Rain, inches	TN-based Adj. Rain, inches	TON-based Adj. Rain, inches	Observed Load, mt	TN-based Prediction, mt	TN-based UCL mt	TON-based Prediction, mt	TON-based UCL mt
2000	40.23	46.65	46.86	219.131	128.799	211.874	136.387	221.268
2001	29.85	21.03	21.13	79.378	45.473	80.948	48.956	85.759
2002	53.51	59.02	58.72	188.595	175.154	290.051	183.244	299.214
2003	46.03	65.26	65.04	358.688	199.746	346.477	208.424	356.028
2004	49.00	47.54	47.32	330.767	132.032	218.004	138.356	225.278
2005	60.04	95.28	96.27	461.195	327.536	574.959	346.342	598.518
2006	64.68	43.80	43.73	223.209	118.618	207.628	124.945	215.319
2007	25.14	27.53	27.52	81.820	64.662	115.400	68.805	120.829
2008	51.76	58.43	58.39	174.303	172.885	283.440	181.560	293.592
2009	50.53	65.40	66.19	242.165	200.284	349.643	213.503	366.983
2010	63.16	52.22	51.80	178.000	149.259	255.123	155.618	262.051
2011	37.37	21.20	21.04	47.356	45.960	79.970	48.674	83.397
2012	51.50	44.75	44.77	138.685	122.006	200.692	128.802	208.956
2013	49.01	43.53	43.60	102.587	117.645	193.625	124.552	202.167

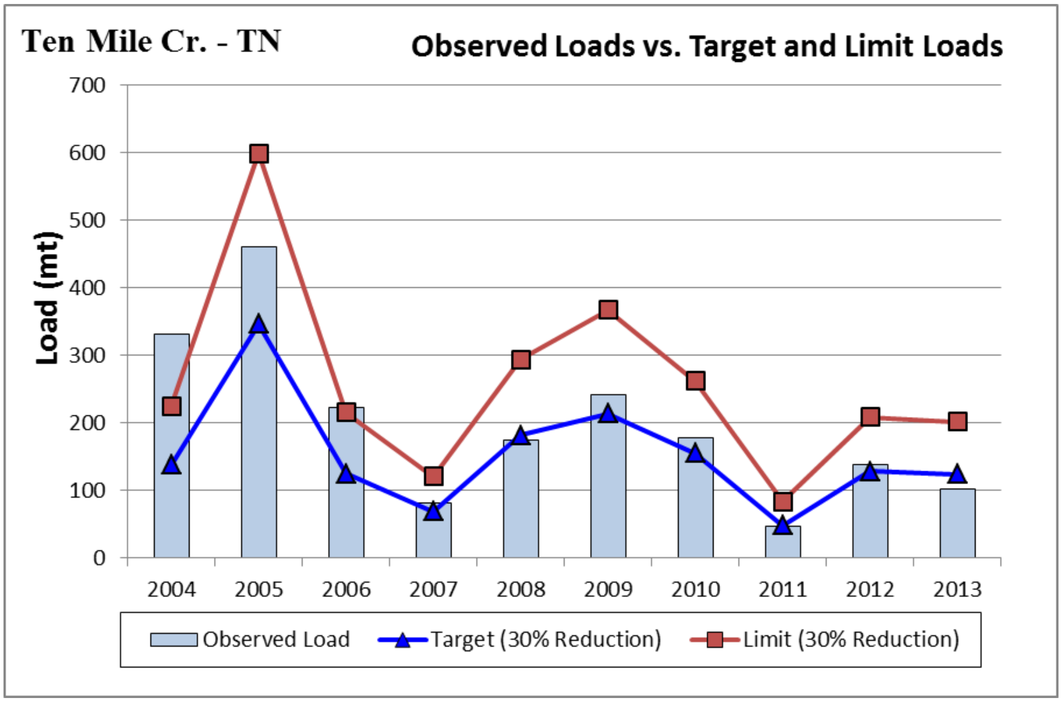
(pink)	Indicates the Annual TN Target
(blue)	Indicates the Annual TN Limit

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**.

3.5.2.2.5 Comparison to WY2004-2013. A comparison of the WY2004-2013 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-35**.

3.5.2.2.6 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 3-64** and **3-65**). 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.

Figure 3-35. Comparison of WY2004-2013 TN loads with Annual Load Targets and Limits for the Ten Mile Creek Basin.



Note: The Base Period is WY2000-2011.

Table 3-64. Exceedance frequencies for the proposed TN-based prediction and UCL for the Ten Mile Creek Basin.

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%	9.3%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.3%
Step 4. Load > Annual Load Limit?	<10%	0.0%
Cumulative Exceedance Frequency	**<17.5%**	**9.3%**

Table 3-65. Exceedance frequencies for the proposed TON-based prediction and UCL for the Ten Mile Creek Basin.

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%	9.1%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.4%
Step 4. Load > Annual Load Limit?	<10%	0.0%
Cumulative Exceedance Frequency	**<17.5%**	**9.4%**

3.6 Composite Area

The area referred to as the Composite Area consists of 61,579 acres located adjacent to the St. Lucie River and Estuary Watershed (**Table 3-66 and Figure 3-36**).

Table 3-66. Monitored Tributary Basins (from SFWMD).

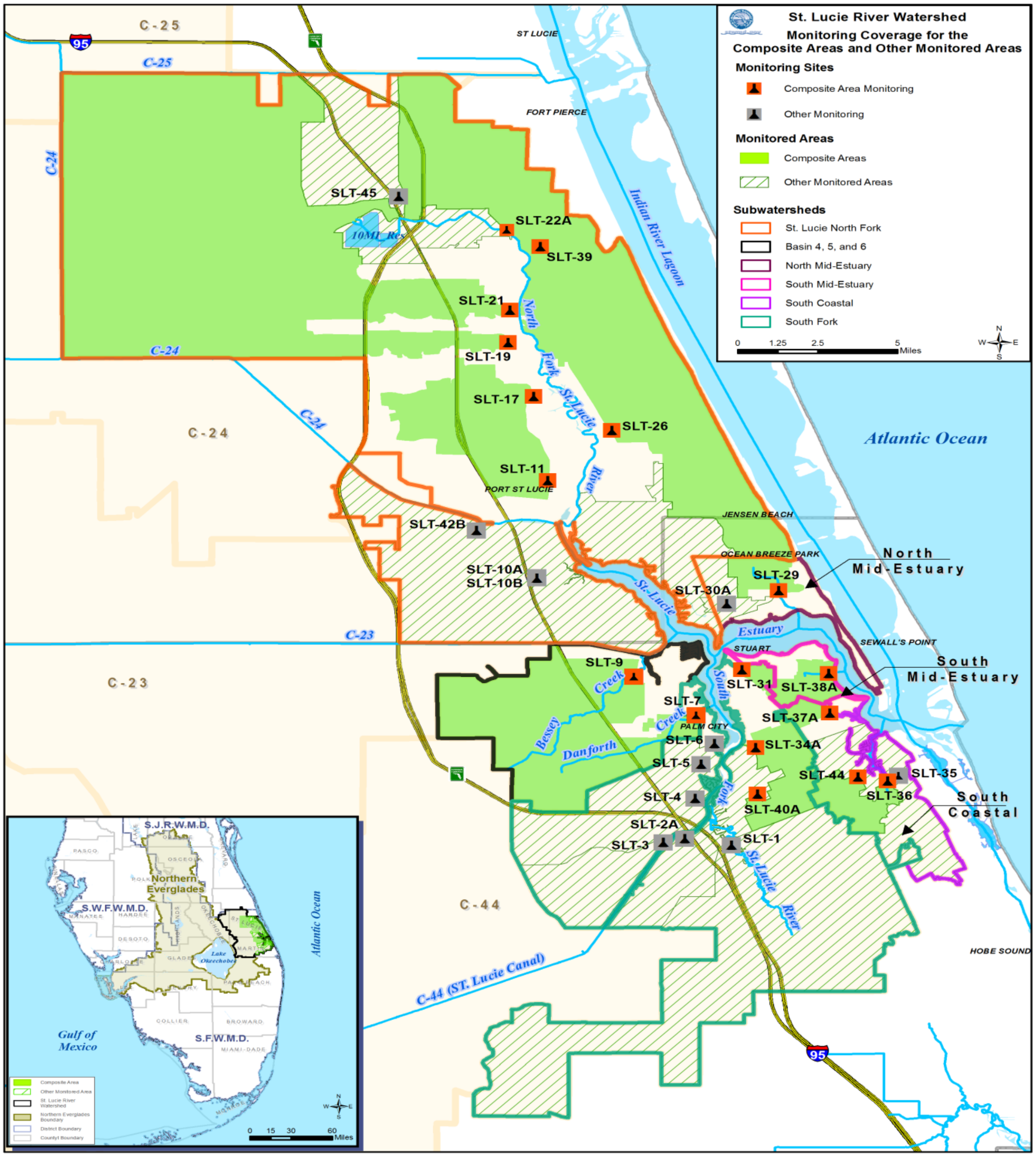
Sub-watershed	Station	Basin	Basin Area (acres)
North Fork St. Lucie River	SLT-22A	Five Mile Creek	9,022
	SLT-39	Platts Creek	4,685
	SLT-21	C-105	3,730
	SLT-19	C-107	2,544
	SLT-17	PSL Ditch 6	1,414
	SLT-26	Hog Pen Slough	13,983
	SLT-11	Elkcam Waterway	5,415
	SLT-45	Canal 40	9,506
	SLT-42B	E-8 Canal	16,432
	SLT-10A	Blakely's Creek North	
	SLT-10B	Blakely's Creek South	
South Fork	SLT-40	Fern Creek	599
	SLT-31	Frazier Creek	377
	SLT-34A	Coral Gardens Ditch	2,093
	SLT-1	South Fork	27,027
	SLT-3	Hog Creek	3,765
	SLT-2A	Roebuck Creek	3,128
	SLT-4	Mapps Creek	7,583
	SLT-5	Piper's Ditch	
	SLT-6	All American Ditch	735
Basins 4-5-6	SLT-7	Danforth Creek	3,931
	SLT-9	Bessey Creek	9,237
North Mid-Estuary	SLT-29	Warner Creek	1,111
	SLT-30A	Hainey Creek	1,301
South Mid-Estuary	SLT-38	North Airport Ditch	1,178
South Coastal	SLT-44	Salerno Creek	960
	SLT-36	Manatee Creek	812
	SLT-37A	Willoughby Creek	487
	SLT-35	East Fork	4,887
		Composite Area	***61,579***
		Other Monitored Areas	***74,364***
		Total Monitored Area	135,943
		Unmoniotred Areas	35,181

Note: Basin acreage for other monitored areas are preliminary estimates and may be refined upon further investigation.

The following sections summarize the historical water quality data analyses, nutrient reduction goals for the collective source control programs, and development of the TP and TN performance metrics for the Composite Area. The performance metrics consist of Annual Concentration Targets and Annual Concentration Limits based on 17 tributary basins for which water quality data are available. If the Composite Area performance metrics are not achieved, a performance determination of basin-specific performance metrics would be warranted, and could assist in prioritizing any necessary follow-up actions.

Twelve additional basins are being monitored for TP and TN concentration and will be compared to the composite Annual Concentration Target and an Annual Concentration Limit to evaluate whether development of an individual metric would be warranted. The conceptual proposal is that if a basin exceeds the composite metric and increasing trends are observed development of an individual metric would be warranted.

Figure 3-36. Monitored Tributary Basins.



3.6.1 Background

The Composite Area contains 17 basins located adjacent to the St. Lucie River and Estuary. 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 St. Lucie River Source Control Programs) (HDR 2011a). At that time the focus was on annual nutrient loads, and many of the basins were not fully analyzed due to lack of flow data. However, under the contract with GGI, 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 basins within the Composite Area (**Table 3-67**). Due to the proximity of the monitoring stations near the St. Lucie Estuary with the intent to capture runoff from the entire tributary basin, the samples are subject to twice daily tidal cycles. Samples containing specific conductivity readings of 2,500 µmhos/cm or higher were excluded from analyses to minimize the influence of tidal waters. Furthermore, flow monitoring is not available at the tributary monitoring stations, therefore only samples that report a discharge code of 1, indicating flow was observed at the time of collection, were used in the analyses.

Basic synoptic statistics were calculated for TP, TN and TON for each basin and the data were examined for outliers[10] (**Table 3-68**; additional details provided in **Appendix A** and in Goforth (2013c**))**. Based on the review of individual tributary periods of record, a common Reference Period of WY2003-WY2012 (May 2002 – April 2012) was selected for the Composite Area.

[10] The sample for Hog Pen Creek collected on March 17, 2011 was discarded as a result of this review, which identified the sample was likely contaminated by bottom sediments during collection.

Table 3-67. Water quality data sources in the Composite Area for the WY2003-2012 Reference Period.

Basin	Water Quality Station	Basin Area acres	Period of Record Begins[1] Water Year	Reference Period Ends[1] Water Year	Total Phosphorus Missing / Omitted Data[2]	Total Nitrogen Missing / Omitted Data[2]	Total Organic Nitrogen Missing / Omitted Data[2]
Five Mile Creek	SLT-22/22A	9,022	2003	2012	25%	26%	27%
Platts Creek	SLT-39	4,685	2004	2012	40%	43%	43%
C-105	SLT-21	3,730	2003	2012	13%	15%	16%
C-107	SLT-19	2,544	2003	2012	8%	9%	10%
PSL Ditch 6	SLT-17	1,414	2003	2012	29%	30%	30%
Hog Pen Slough	SLT-26	13,983	2003	2012	19%	20%	21%
Elkcam Waterway	SLT-11	5,415	2003	2012	8%	8%	8%
Fern Creek	SLT-40	599	2004	2012	60%	62%	62%
Frazier Creek	SLT-31	377	2003	2012	26%	27%	27%
Coral Gardens Ditch	SLT-34A	2,093	2008	2012	56%	56%	56%
Salerno Creek	SLT-44	960	2008	2012	58%	58%	59%
Manatee Creek	SLT-36	812	2003	2012	49%	51%	51%
Willoughby Creek	SLT-37/37A	487	2003	2012	15%	16%	16%
Danforth Creek	SLT-07	3,931	2003	2012	51%	51%	51%
Bessey Creek	SLT-09	9,237	2003	2012	69%	69%	69%
Warner Creek	SLT-29	1,111	2003	2012	33%	33%	34%
North Airport Ditch	SLT-38	1,178	2003	2012	72%	73%	73%
Composite Area		***61,579***	***2003***	***2012***	***7%***	***7%***	***7%***

Notes: 1. Water Year of the Reference Period, beginning May 1 of the previous calendar year and ending April 30 of the Water Year.
2. Missing/Omitted data is the percentage of months without data in the reference period. This may be due to sample collection not performed, omitted sample from the analysis due to a conductivity of greater than 2500 µmhos/cm, or a sample omitted due to collection when flow was not observed.
3. While other water quality stations are shown in Figure 2-1, they could not be included in this analysis due to limited periods of record.

Table 3-68. Summary of Reference Period monthly data for the Composite Area and its basins.

Basin	Reference Period (WY2003-WY2012) Summary - Monthly Data					
	TP Median, µg/L	TP Maximum, µg/L	TN Median, µg/L	TN Maximum, µg/L	TON Median, µg/L	TON @ Max TN, µg/L
Five Mile Creek	150	1,168	721	4,161	596	3,815
Platts Creek	195	1,140	810	5,022	512	4,739
C-105	37	125	831	1,681	805	1,668
C-107	36	179	771	1,601	726	1,359
PSL Ditch 6	95	387	768	1,835	683	1,536
Hog Pen Slough	57	782	809	7,267	682	7,168
Elkcam Waterway	56	316	816	2,416	746	2,392
Fern Creek	99	252	1,002	2,861	918	2,827
Frazier Creek	74	185	711	1,703	617	912
Coral Gardens Ditch	141	495	1,137	2,805	834	2,780
Salerno Creek	36	102	813	1,274	691	1,214
Manatee Creek	253	1,277	1,609	4,044	798	920
Willoughby Creek	21	194	835	2,165	516	707
Danforth Creek	171	477	1,030	1,683	885	1,502
Bessey Creek	206	302	1,096	1,473	895	1,335
Warner Creek	23	125	810	1,764	724	1,543
North Airport Ditch	80	350	863	1,424	757	757
Composite Area	***104***	***415***	***841***	***3,358***	***717***	***3,306***

3.6.1.1 Nutrient Concentration Analyses. Spatially composite sub-watershed nutrient concentrations were calculated from the individual basin concentrations for each month of the WY2003-2012 Reference Period using the following algorithm.

Composite monthly value = sum (basin conc * basin runoff) / sum (basin runoff)

Where basin runoff = basin unit area runoff * basin area

basin unit area runoff = sum (land use unit area runoff coefficient * land use area)

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. The land use unit area runoff coefficients and areas for each land use were obtained from the 2012 St. Lucie River Watershed Protection Plan (SFWMD 2012). Annual summaries of the sub-watershed composite nutrient data are presented in **Table 3-69**; additional details are provided in **Appendix A**.

Table 3-69. Annual summary of median composite concentrations for the Composite Area.

Water Year	TP		TN		TON		Ratio of TON/TN
	# of Samples	Median µg/L	# of Samples	Median µg/L	# of Samples	Median µg/L	Using Median
2003	12	120	12	823	12	754	0.92
2004	10	115	10	820	10	632	0.77
2005	12	120	12	956	12	747	0.78
2006	12	136	12	1030	12	873	0.85
2007	12	87	12	738	12	658	0.89
2008	12	90	12	867	12	738	0.85
2009	12	96	12	869	12	749	0.86
2010	12	106	12	815	12	671	0.82
2011	12	100	12	830	12	710	0.86
2012	6	97	6	864	6	767	0.89
2013	12	82	12	813	12	699	0.86
WY2003-2012 Monthly Median		103		841		717	0.85

Note: "# of Samples" is the number of months when at least one sample was available from the 17 basins.

3.6.1.2 Rainfall Analyses. The performance indicators for the Composite Area 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 all the basins, rainfall data were analyzed as a measure of the hydrologic variability. Daily rainfall data at six representative stations were compiled by the District using the Thiessen polygon weights shown in **Appendix B**. The cumulative frequency distribution for WY1991-2013 annual rainfall is shown in **Figure 3-37**. Annual rainfall during the WY2003-WY2012 Reference Period (28.02 to 67.26 inches) ranged from 3 percent to 80 percent of the range observed during the WY1991-2013 period (28.02 to 85.23 inches). Potential temporal trends in the data were analyzed using the Seasonal Kendall Tau algorithm, and no trend was observed in the Reference Period monthly rainfall although a statistically significant ($p<0.05$) decreasing trend was observed over the period of record monthly values (**Figure 3-38**).

Figure 3-37. Frequency distribution for annual Composite Area rainfall.

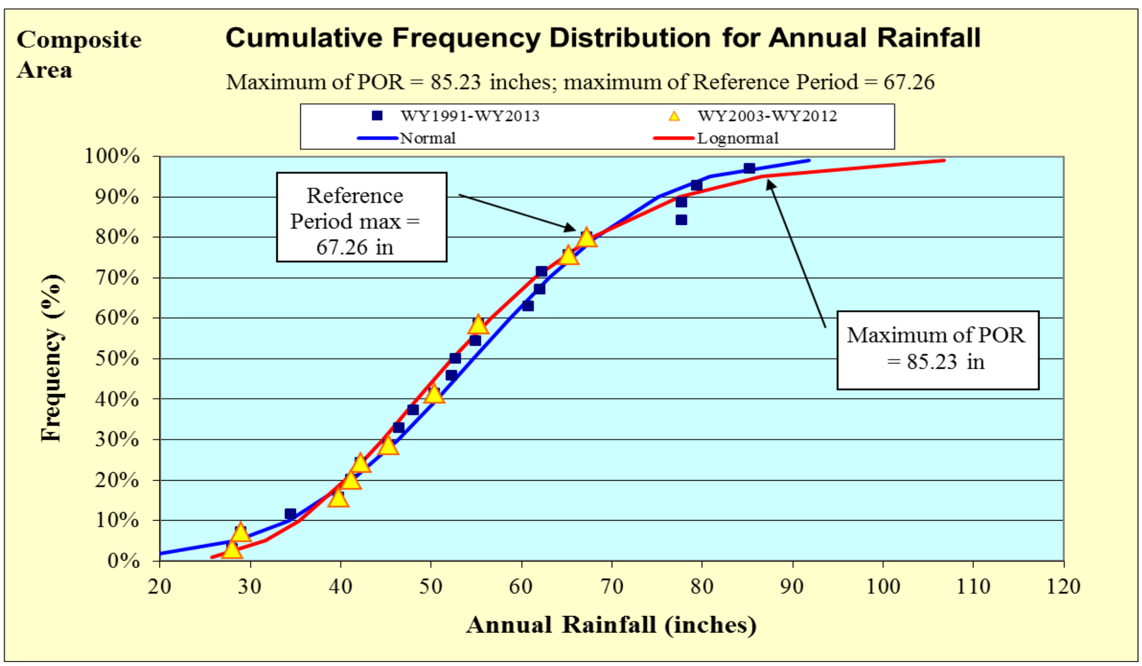
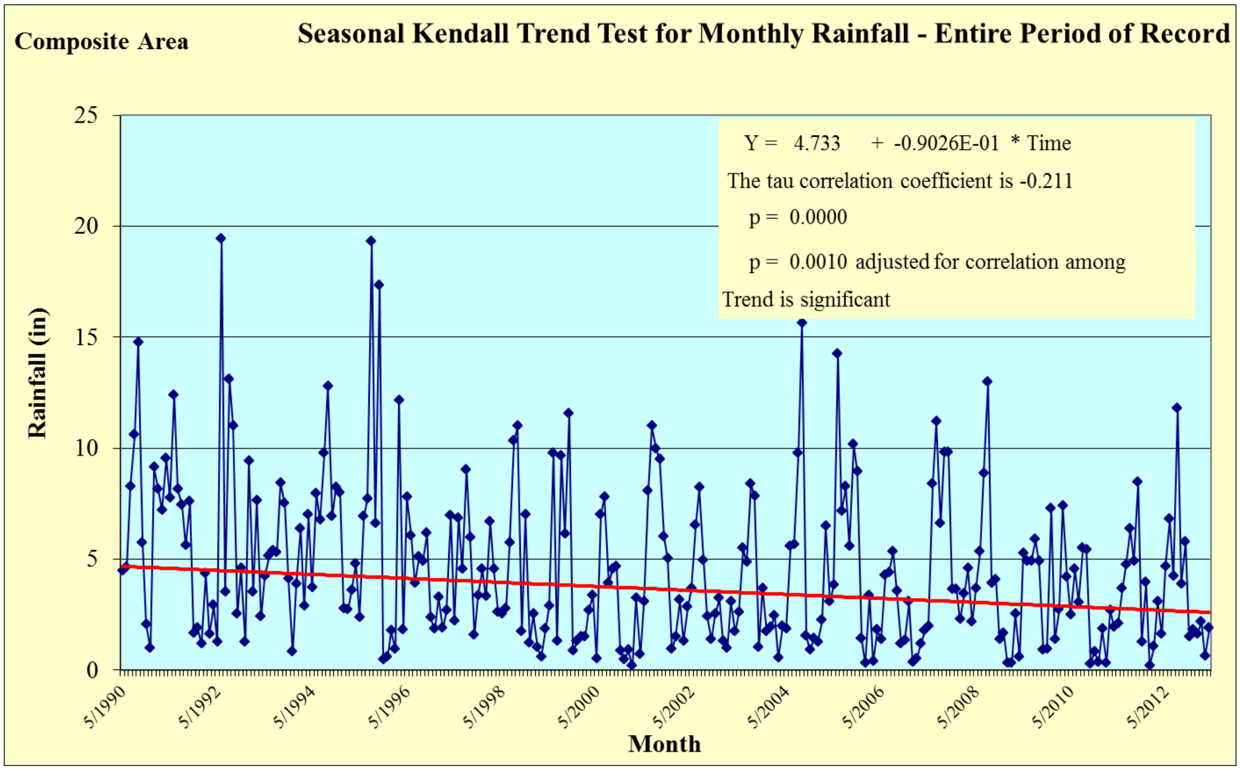


Figure 3-38. Trend analysis for period of record monthly rainfall.



3.6.1.3 TP Trend. Table 3-70 presents the observed annual median and 60-month median TP concentrations and differences from the reference period median concentration. The Composite Area TP concentration trend is presented in **Figure 3-39**. 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 3-39** denotes a reduction in loads.

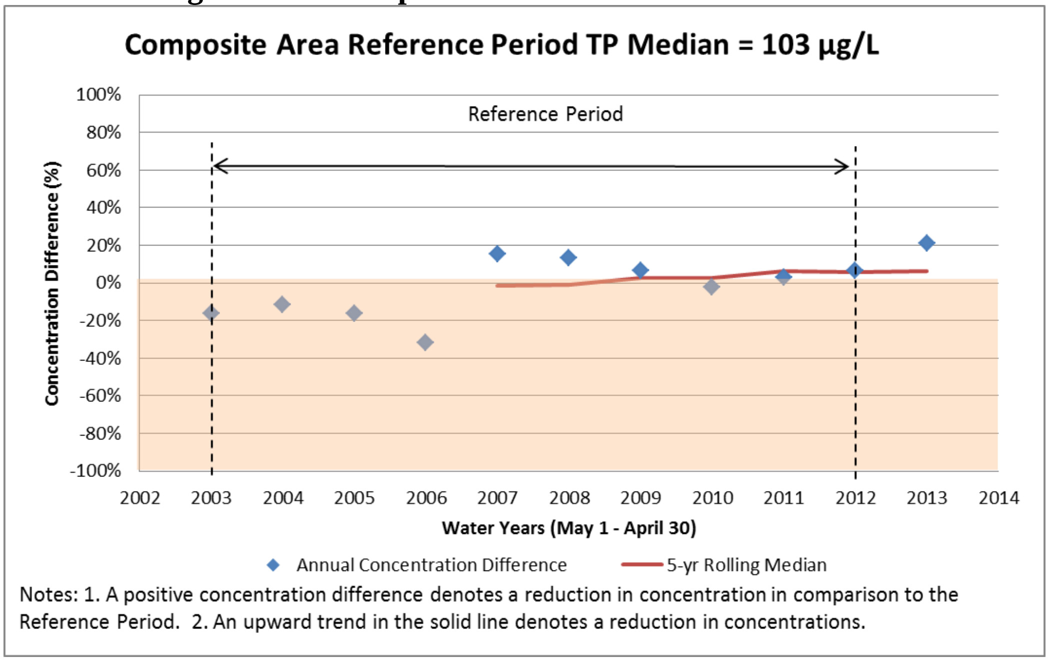
Table 3-70. Composite Area TP measurements and calculations. (Reference Period: WY2003-2012).

Water Year	Annual TP Median Concentration, µg/L	Annual Difference From Reference Period Median	TP 60-month Median Concentration, µg/L	5-yr Rolling Median Difference
2003	120	-17%		
2004	115	-12%		
2005	120	-17%		
2006	136	-32%		
2007	87	16%	105	-1%
2008	90	13%	104	-1%
2009	96	7%	101	2%
2010	106	-2%	100	3%
2011	100	3%	97	6%
2012	97	6%	97	6%
2013	82	21%	97	6%

Notes

1. Reference period median = 103 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 3-39. Composite Area TP concentration trend.



3.6.1.4 TN Trend. Table 3-71 presents the observed annual median and 60-month median TN concentrations and differences from the reference period median concentration. The Composite Area TN concentration trend is presented in **Figure 3-40**. 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 3-40** denotes a reduction in loads.

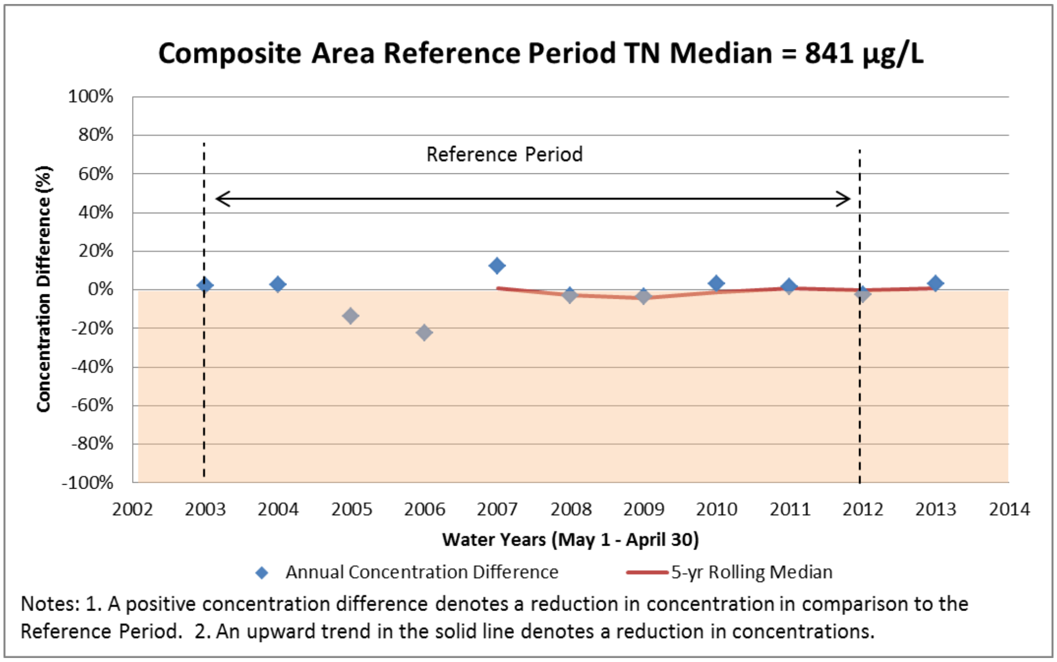
Table 3-71. Composite Area TN measurements and calculations. (Reference Period: WY2003-2012).

Water Year	Annual TN Median Concentration, µg/L	Annual Reduction From Reference Period Median	TN 60-month Median Concentration, µg/L	5-yr Rolling Median Difference
2003	823	2%		
2004	820	2%		
2005	956	-14%		
2006	1030	-22%		
2007	738	12%	834	1%
2008	867	-3%	863	-3%
2009	869	-3%	876	-4%
2010	815	3%	850	-1%
2011	830	1%	833	1%
2012	864	-3%	844	0%
2013	813	3%	834	1%

Notes

1. Reference period median = 841 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 3-40. Composite Area TN concentration trend.



3.6.2 Source Control Effectiveness

Based on a review of multiple analyses, District staff estimated basin-specific nutrient reductions relative to the Reference Period values for TP and TN anticipated as a result of implementation of collective source controls within the sub-watershed. Please refer to Appendix C for a detailed description of the rationale to develop the reductions.

3.6.3 The TP 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 for the Composite Area was based on the historical monthly median 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 are described in the following sections. The associated TP performance determination process is presented as a flowchart in **Figure 1-3**.

3.6.3.1 The Annual Concentration Target Assessment 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 Composite Area and its basins is presented in **Table 3-72**.

Table 3-72. Summary of the Annual Concentration Targets for TP for the Composite Area and its basins.

Sub-watershed	Basin	TP Source Control Reduction Goal for Target	Reference Period TP Median Concentration, µg/L	TP Annual Concentration Target, µg/L
North Fork St. Lucie River	Five Mile Creek	11%	150	133
	Platts Creek	10%	195	176
	C-105	0%	37	37
	C-107	0%	36	36
	PSL Ditch 6	8%	95	87
	Hog Pen Slough	0%	57	57
	Elkcam Waterway	0%	56	56
South Fork St. Lucie River	Fern Creek	17%	99	82
	Frazier Creek	0%	74	74
	Coral Gardens Ditch	11%	141	126
South Coastal	Salerno Creek	0%	36	36
	Manatee Creek	8%	253	234
	Willoughby Creek	0%	21	21
Basin 4-5-6	Danforth Creek	18%	171	141
	Bessey Creek	15%	206	176
North Mid-Estuary	Warner Creek	0%	23	23
South Mid-Estuary	North Airport Ditch	0%	80	80
Composite Area		***10%***	***103***	***93***

Notes:
The Annual Concentration Targets and Limits are the bases for the performance indicators.
The Annual Concentration Target is a distribution of monthly concentrations, represented here by the median concentration of the distribution.
The source control reduction goals are presented for reference and are rounded for ease in presentation.
Source control reduction goals for the Annual Target account for reasonable BMP effectiveness, consideration of TMDL and historical median concentration.
Source control reduction goal for Target is relative to historical median concentration.

For the Composite Area and its basins, the inherent uncertainties associated with sampling tidally-influenced tributaries requires an alternative approach than was used in the other SLRW sub-watersheds. Long-term median monthly concentrations can be calculated for the Composite Area and its basins. However, 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.

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 Composite Area, 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 3-41**).

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:

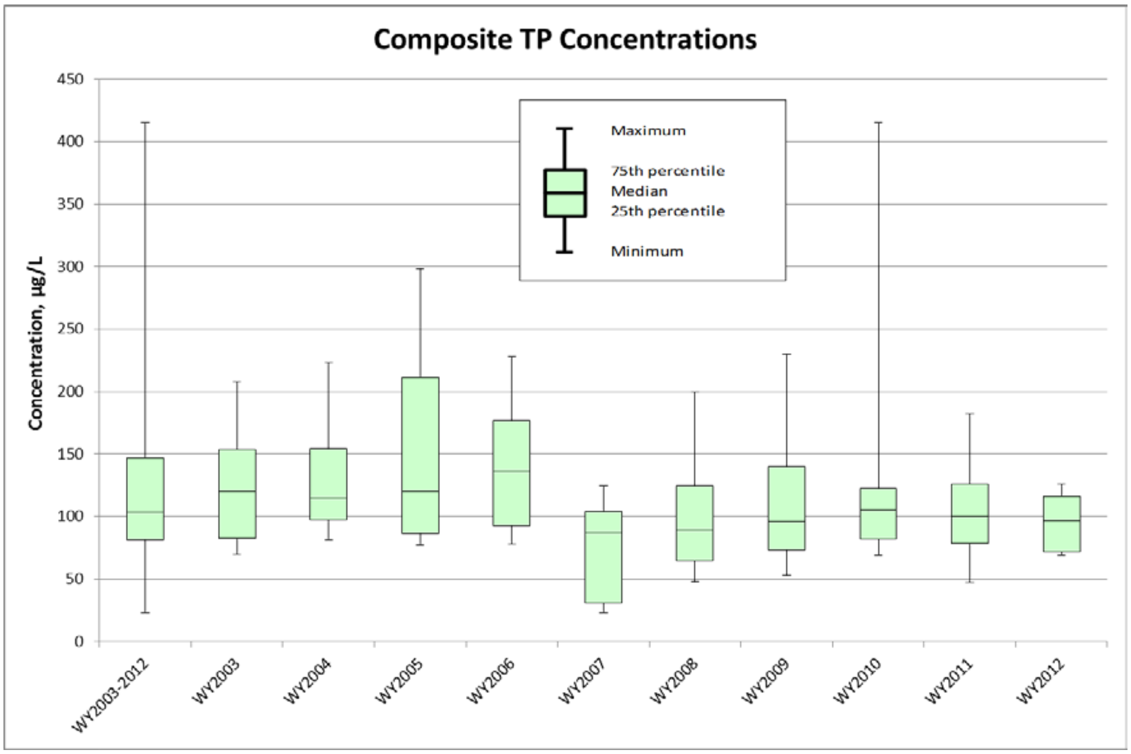
H_1: probability [x > y] ≠ 50 percent the given percentile of the Evaluation Year data set is different (larger or smaller) from the same percentile of the Reference Period data set (a 2-tailed test)

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 3-41. Comparison of WY2003-2012 monthly TP data for the Composite Area.



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[11], 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 $W_{rs} = m_W$

[11] See Appendix E for the algorithm to use if the number of monthly samples in the Evaluation Year is less than 10.

$Z_{rs} = (W_{rs} + 0.5 – m_W) / s_{Wt}$ 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 <u>significantly greater than</u> the Reference Period, i.e., to investigate the 2^{nd} alternative hypothesis, H_2: probability [x > y] > 50 percent, using a 1-tailed test.
      i. 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}.
      ii. 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.
      iii. 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 assessment. In light of the seasonality of the monthly data, a minimum of at least one monthly sample each quarter per basin for at least 75 percent of the basins 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 WY2003 are compared to the Reference Period data, with no reduction for source controls, in **Figure 3-42**.

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 40E-63, and as proposed in the other Northern Everglades 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 (28.02 to 67.26 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 assessment 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.

Figure 3-42. Example application of the rank-sum test to the Composite Area.

Month	TP Conc, µg/L	Compared against WY2003 Initial Rank	Occurrences	Final rank, r	r^2
200205	144	93	3	93.67	8773.44
200206	191	110	2	110.50	12210.25
200207	208	115	2	115.50	13340.25
200208	149	98	2	98.50	9702.25
200209	155	102	2	102.50	10506.25
200210	145	96	2	96.50	9312.25
200211	96	51	4	51.75	2678.06
200212	72	15	3	15.67	245.44
200301	70	13	2	13.50	182.25
200302	83	33	2	33.50	1122.25
200303	82	30	3	30.67	940.44
200304	84	35	3	35.67	1272.11

… (continues for intermediate months) …

201105	88	40	3	40.67	1653.78
201106	73	18	3	18.67	348.44
201107	113	74	2	74.50	5550.25
201108	105	66	2	66.50	4422.25
201109	126	81	2	81.50	6642.25
201110					
201111					
201112					
201201					
201202	69	10	3	10.67	113.78
201203					
201204					
Evaluation Year 2003					
May	144	93	3	93.67	8773.44
June	191	110	2	110.50	12210.25
July	208	115	2	115.50	13340.25
August	149	98	2	98.50	9702.25
September	155	102	2	102.50	10506.25
October	145	96	2	96.50	9312.25
November	96	51	4	51.75	2678.06
December	72	15	3	15.67	245.44
January	70	13	2	13.50	182.25
February	83	33	2	33.50	1122.25
March	82	30	3	30.67	940.44
April	84	35	3	35.67	1272.11

Reference Period median = 103 µg/L
W_{rs} = 809.9
m_W = 750.0
Since $W_{rs} > m_W$, $Z_{rs} = (W_{rs} – 0.5 – m_W) / s_{Wt}$
$Z_{5\%}$ = 1.645

WY2003 median = 120 µg/L
$\text{sum}[(R_k)^2]$ = 642,117.1
s_{wt} = 117.899
Z_{rs} = 0.504   p-value = 0.307

Decision:** **Even though the test statistic W_{rs} for WY2003 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 WY2003 distribution <u>is not significantly greater</u> than the Reference Period distribution.

A comparison of the monthly TP concentrations for each of the individual water years to the WY2003-2012 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 3-73**. While the monthly median concentrations for five water years were greater than the Reference Period median, only one of the water year's distributions (WY2006) was systematically larger than the Reference Period's distribution, and all of the water years of the Reference Period met the one-in-three year annual test.

Table 3-73. Summary of the rank-sum tests for the Composite Area for TP.

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?
2003	No	No	Yes
2004	No	No	Yes
2005	No	No	Yes
2006	No	Yes	Yes
2007	Yes	No	Yes
2008	Yes	No	Yes
2009	Yes	No	Yes
2010	No	No	Yes
2011	Yes	No	Yes
2012	Yes	No	Yes
All	***50%***	***10%***	***100%***

Note: "WY" = Water Year and "RP" = Reference Period

An example application with the TP Annual Concentration Target can be made against the WY2013 data. Since the WY2013 median TP concentration (82 µg/L) is less than the Annual Concentration Target (93 µg/L), the Composite Area would have achieved the Target performance metric without consideration of the spread of the distributions.

3.6.3.2 The Annual Concentration Limit Assessment for TP

For the Composite Area and its basins, 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 WY2003-2012 Reference Period, reduced by the basin-specific source control nutrient reduction goals, are recommended as the Annual Concentration Limits for the Composite Area and its basins (**Table 2-74**). 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.

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 (28.02 to 67.26 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 assessment 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.

An example application with the TP Annual Concentration Limit can be made against the WY2013 data. Since the WY2013 maximum TP concentration (101 µg/L) was less than the Annual Concentration Limit (344 µg/L), the Composite Area would have achieved the Limit performance metric.

Table 3-74. Annual Concentration Limit for TP for the Composite Area and its basins.

Sub-watershed	Basin	TP Source Control Reduction Goal for Limit	Reference Period TP Maximum Concentration, µg/L	TP Annual Concentration Limit, µg/L
North Fork St. Lucie River	Five Mile Creek	18%	1,168	963
	Platts Creek	15%	1,140	969
	C-105	35%	125	81
	C-107	31%	179	124
	PSL Ditch 6	12%	387	339
	Hog Pen Slough	11%	320	286
	Elkcam Waterway	12%	316	278
South Fork St. Lucie River	Fern Creek	26%	252	187
	Frazier Creek	11%	185	165
	Coral Gardens Ditch	16%	495	415
South Coastal	Salerno Creek	12%	102	90
	Manatee Creek	12%	1,277	1,130
	Willoughby Creek	22%	194	151
Basin 4-5-6	Danforth Creek	26%	477	351
	Bessey Creek	23%	302	234
North Mid-Estuary	Warner Creek	10%	125	112
South Mid-Estuary	North Airport Ditch	21%	350	278
Composite Area		***17%***	***415***	***344***

Notes:
The source control reduction goals are presented for reference and are rounded for ease in presentation.
Source control reduction goals for the Annual Limit account for reasonable BMP effectiveness, consideration of TMDL and historical maximum concentration.
Source control reduction goal for Limit is relative to historical maximum concentration.
Annual Concentration Targets and Limits are rounded to whole ppb and/or three significant digits, which may have revised % reduction slightly.

3.6.4 The TN Performance Metric Methodology

The proposed TN 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 for the Composite Area was based on the historical monthly median concentrations for the Reference Period, reduced by basin-specific source control reduction goals. The Annual Concentration Limit was based on the Reference Period's maximum observed monthly concentration, reduced by basin-specific source control reduction goals. The two components of the TN performance metric are described in the following sections. The associated TN performance determination process is presented as a flowchart in **Figure 1-3**.

3.6.4.1 The Annual Concentration Target Assessment 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 Composite Area and its basins is presented in **Table 3-75**.

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 assessment. In light of the seasonality of the monthly data, a minimum of at least one monthly sample each quarter per basin for at least 75 percent of the basins during the Evaluation Year is recommended for using the rank-sum test.

Table 3-75. Summary of the Annual Concentration Targets for TN for the Composite Area and its basins.

Sub-watershed	Basin	TN Source Control Reduction Goal for Target	Reference Period TN Median Concentration, µg/L	TN Annual Concentration Target, µg/L
North Fork St. Lucie River	Five Mile Creek	0%	721	720
	Platts Creek	11%	810	720
	C-105	13%	831	725
	C-107	7%	771	720
	PSL Ditch 6	6%	768	720
	Hog Pen Slough	10%	804	720
	Elkcam Waterway	12%	816	720
South Fork St. Lucie River	Fern Creek	14%	1,002	859
	Frazier Creek	0%	711	711
	Coral Gardens Ditch	16%	1,137	958
South Coastal	Salerno Creek	11%	813	720
	Manatee Creek	18%	1,619	1,320
	Willoughby Creek	14%	835	720
Basin 4-5-6	Danforth Creek	13%	1,030	892
	Bessey Creek	11%	1,096	980
North Mid-Estuary	Warner Creek	11%	810	720
South Mid-Estuary	North Airport Ditch	17%	866	722
Composite Area		***10%***	***841***	***757***

Notes:
The Annual Concentation Targets and Limits are the basis for the performance indicators.
The Annual Concentration Target is a distribution of monthly concentrations, represented here by the median concentration of the distribution.
The source control reduction goals are presented for reference and are rounded for ease in presentation.
Source control reduction goals for the Annual Target account for reasonable BMP effectiveness, consideration of TMDL and historical median concentration.
Source control reduction goals for TN also account for background TN concentrations, as represented by 90% of the historical TON concentration.
Source control reduction goal for Target is relative to historical median concentration.
Annual Concentration Targets and Limits are rounded to whole ppb and/or three significant digits, which may have revised % reduction slightly.

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. 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 (28.02 to 67.26 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 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 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 3-43**). A comparison of the monthly TN concentrations for each of the individual water years to the WY2003-2012 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 3-76**. While the monthly median concentrations for five water years were greater than the Reference Period median, only Water Year 2006 distribution was systematically larger than the Reference Period's distribution, and all of the water years of the Reference Period met the one-in-three year annual test.

Figure 3-43. Comparison of WY2003-2012 monthly TN data for the Composite Area.

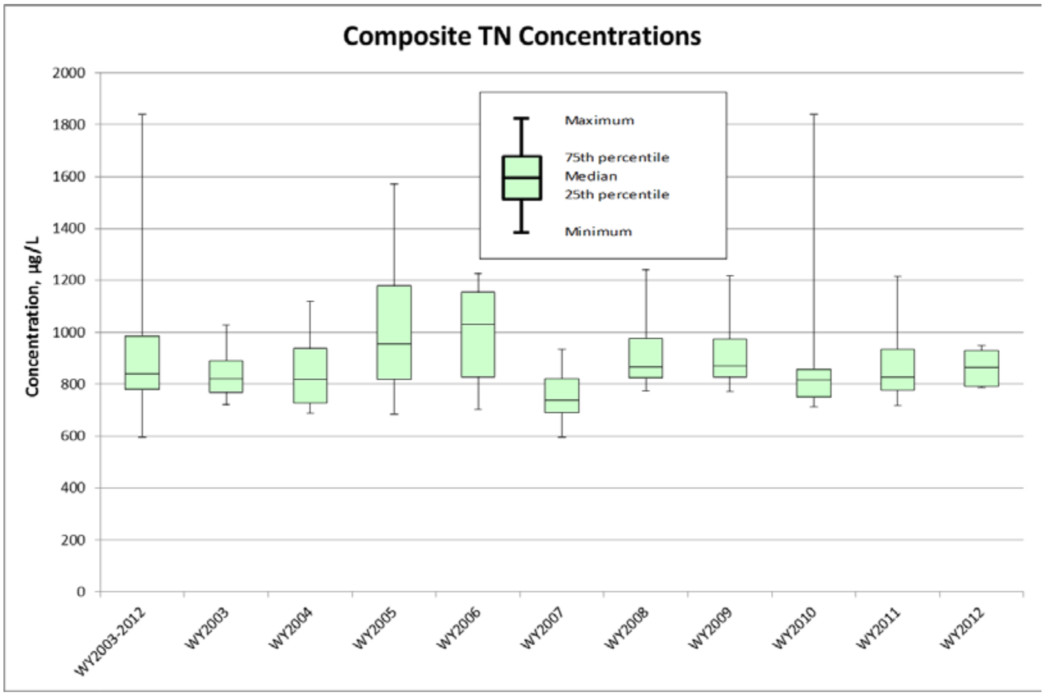


Table 3-76. Summary of the rank-sum tests for the Composite Area Reference Period for TN.

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?
2003	Yes	No	Yes
2004	Yes	No	Yes
2005	No	Yes	Yes
2006	No	Yes	Yes
2007	Yes	No	Yes
2008	No	No	Yes
2009	No	No	Yes
2010	Yes	No	Yes
2011	Yes	No	Yes
2012	No	No	Yes
All	***50%***	***20%***	***100%***

Note: "WY" = Water Year and "RP" = Reference Period

An example application with the TN Annual Concentration Target can be made against the WY2013 data. Although the WY2013 median TN concentration (813 µg/L) is above the Annual Concentration Target (757 µg/L), since Z_{rs} (1.490) $\leq$ Z_{crit} (1.645) the Composite Area would have achieved the Target performance metric.

3.6.4.2 The Annual Concentration Limit Determination for TN

For the Composite Area and its basins, the second part of the performance metric methodology will compare monthly concentrations during the Evaluation Year to an Annual Concentration Limit. 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 3-77**).

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 (28.02 to 67.26 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 assessment 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.

An example application with the TN Annual Concentration Limit can be made against the WY2013 data. Since the WY2013 maximum TN concentration (1,149 µg/L) was less than the Annual Concentration Limit (1,630 µg/L), the Composite Area would have achieved the Limit performance metric.

Table 3-77. Annual Concentration Limit for TN for the Composite Area and its basins.

Sub-watershed	Basin	TN Source Control Reduction Goal for Limit	Reference Period TN Maximum Concentration, µg/L	TN Annual Concentration Limit, µg/L
North Fork St. Lucie River	Five Mile Creek	12%	4,161	3,660
	Platts Creek	12%	5,022	4,430
	C-105	11%	1,681	1,500
	C-107	13%	1,601	1,400
	PSL Ditch 6	15%	1,835	1,560
	Hog Pen Slough	11%	2,856	2,550
	Elkcam Waterway	11%	2,416	2,150
South Fork St. Lucie River	Fern Creek	11%	2,861	2,540
	Frazier Creek	14%	1,703	1,460
	Coral Gardens Ditch	11%	2,805	2,500
South Coastal	Salerno Creek	14%	1,274	1,100
	Manatee Creek	14%	4,044	3,460
	Willoughby Creek	13%	2,165	1,880
Basin 4-5-6	Danforth Creek	11%	1,683	1,500
	Bessey Creek	8%	1,473	1,350
North Mid-Estuary	Warner Creek	12%	1,764	1,560
South Mid-Estuary	North Airport Ditch	13%	1,424	1,240
Composite Area		***11%***	***1,840***	***1,630***

Notes:
The Annual Concentation Targets and Limits are the basis for the performance indicators.
The source control reduction goals are presented for reference and are rounded for ease in presentation.
Source control reduction goals for TN also account for background TN concentrations, as represented by 90% of the historical TON concentration.
Annual Concentration Targets and Limits are rounded to whole ppb and/or three significant digits, which may have revised % reduction slightly.
Source control reduction goals for the Annual Limit account for reasonable BMP effectiveness, consideration of TMDL and historical maximum concentration.
Source control reduction goals for Limit are relative to historical maximum concentration.

3.6.5 Relationship Between Composite Area Performance Determination and Basin Performance Determination

If the Composite Area performance metrics are not achieved, a determination of the basin-specific performance metrics shown in **Tables 3-72, 3-74, 3-75** and **3-77** above, using the same methodology as described in Section 3.6.3, would be warranted, and could assist in prioritizing any necessary follow-up actions.

Furthermore, twelve additional basins are being monitored for TP and TN concentration and will be compared to the composite Annual Concentration Target and an Annual Concentration Limit to evaluate whether development of an individual metric would be warranted. The conceptual proposal is that if a basin exceeds the composite metric and increasing trends are observed development of an individual metric would be warranted.

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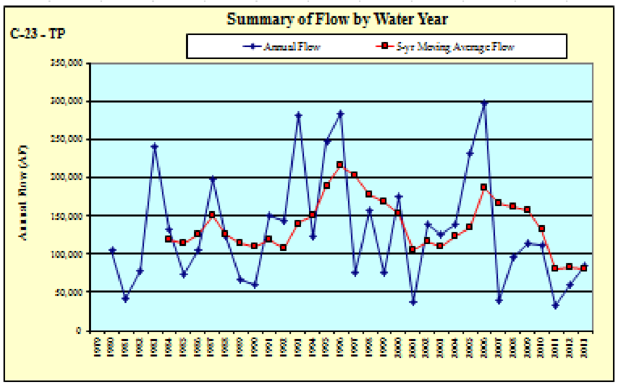
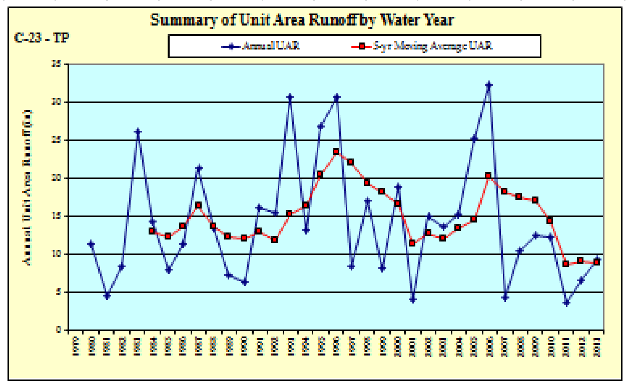
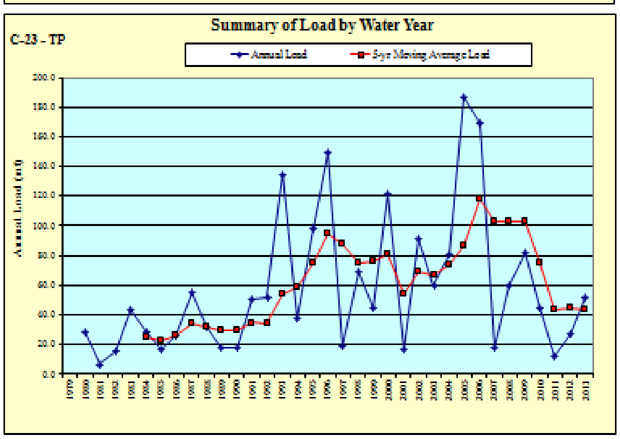
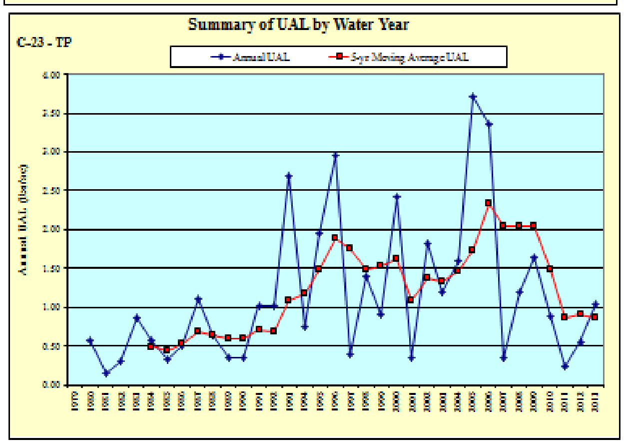
APPENDIX A - SUPPLEMENTAL INFORMATION FOR THE DERIVATION OF THE PERFORMANCE METRIC METHODOLOGIES FOR THE BASINS OF THE ST. LUCIE RIVER WATERSHED

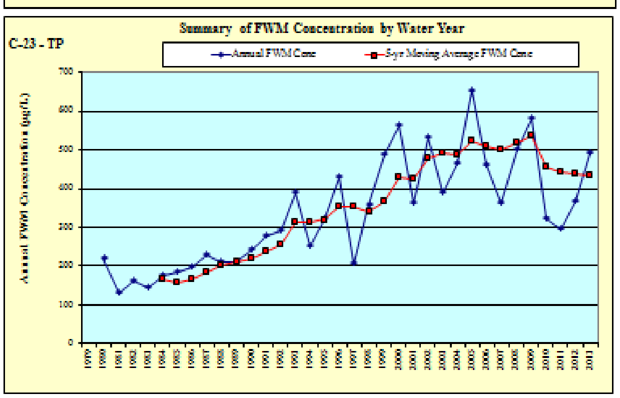
C-23 SUB-WATERSHED

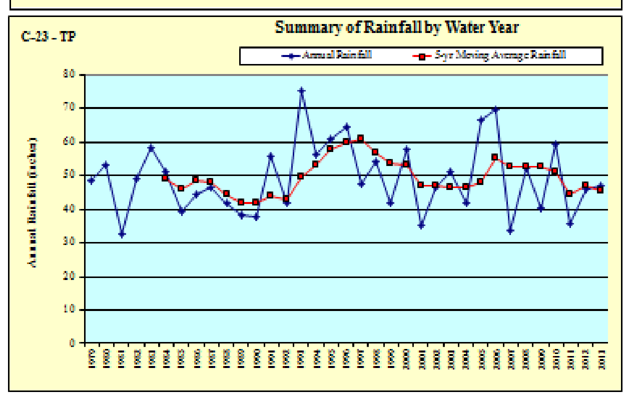


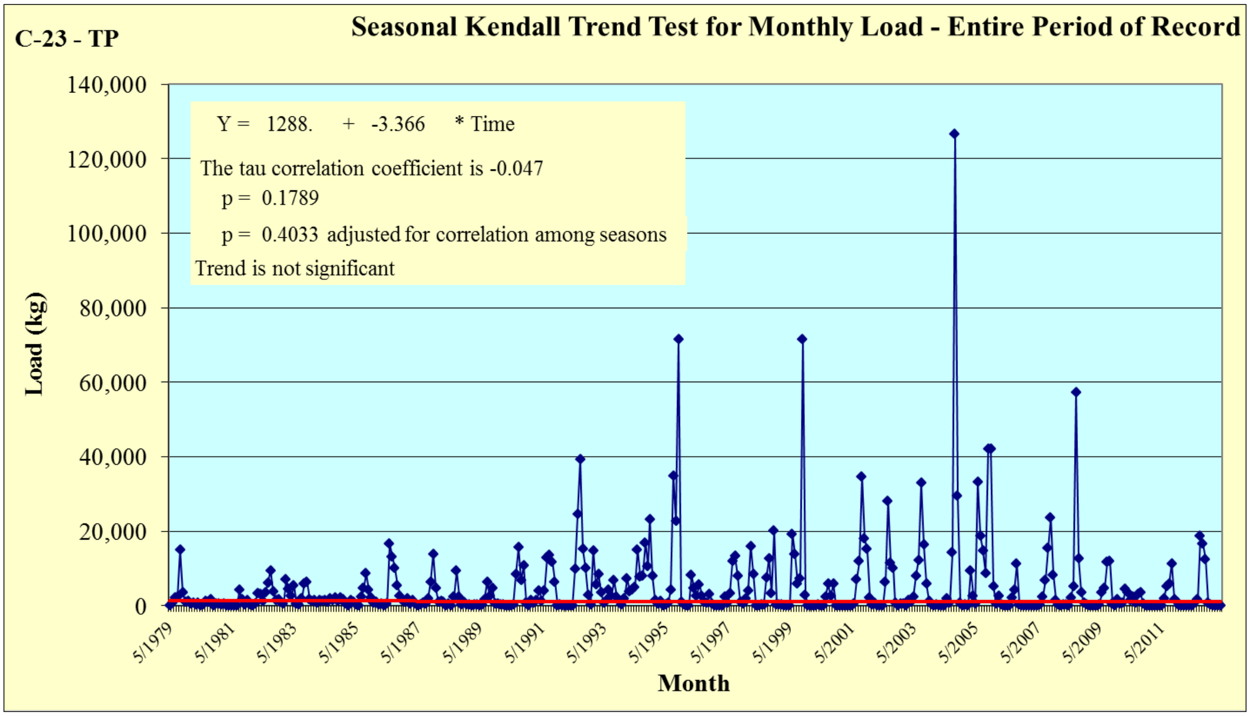











C-23 - TP
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 1288. + -3.366 * Time
The tau correlation coefficient is -0.047
p = 0.1789
p = 0.4033 adjusted for correlation among seasons
Trend is not significant
Load (kg)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1979
5/1981
5/1983
5/1985
5/1987
5/1989
5/1991
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5/1997
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5/2001
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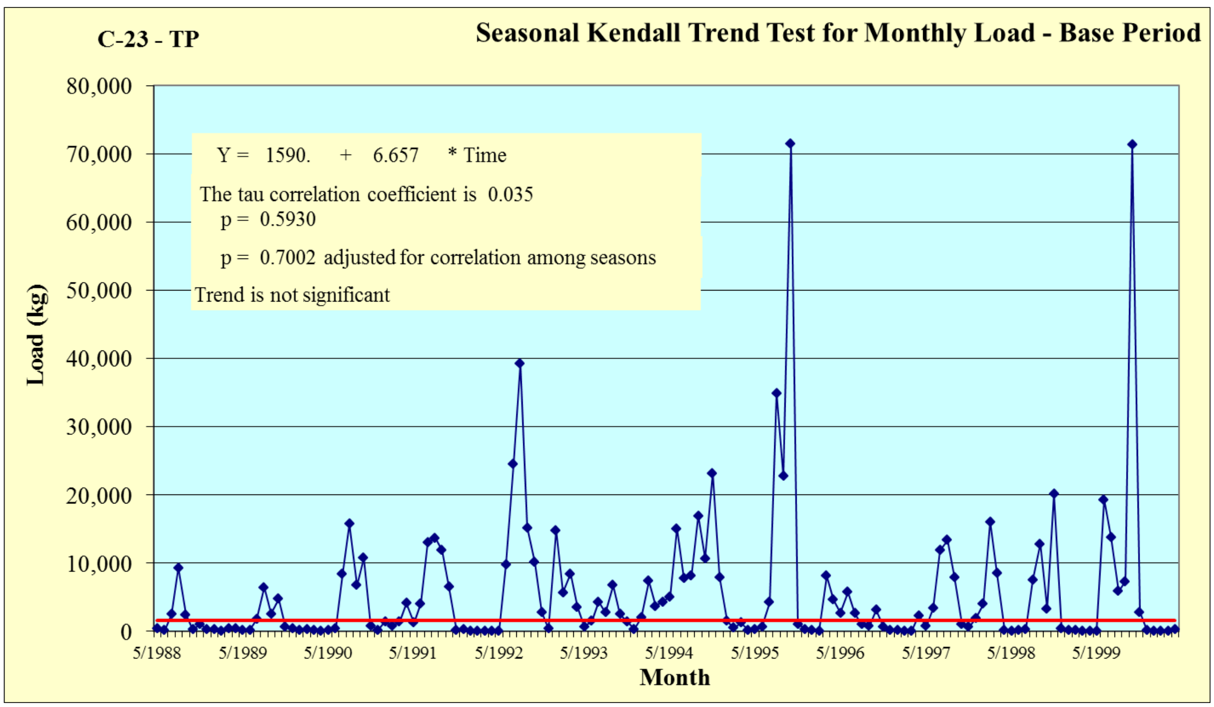
5/2005
5/2007
5/2009
5/2011
Month


C-23 - TP
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 1590. + 6.657 * Time
The tau correlation coefficient is 0.035
p = 0.5930
p = 0.7002 adjusted for correlation among seasons
Trend is not significant
Load (kg)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
5/1988
5/1989
5/1990
5/1991
5/1992
5/1993
5/1994
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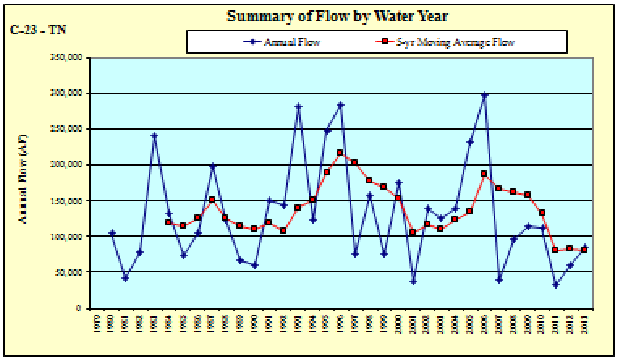
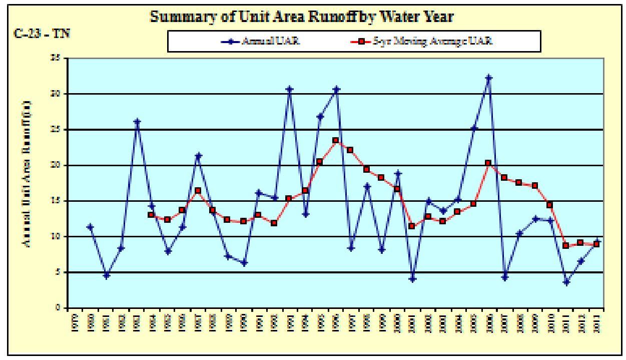
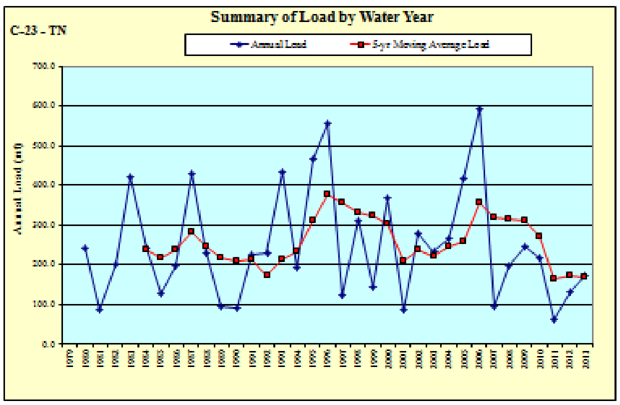
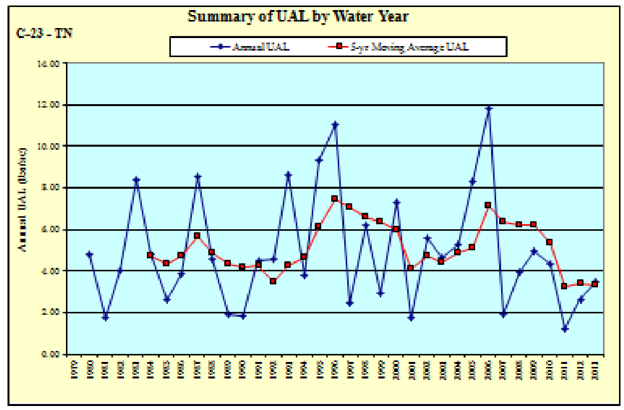
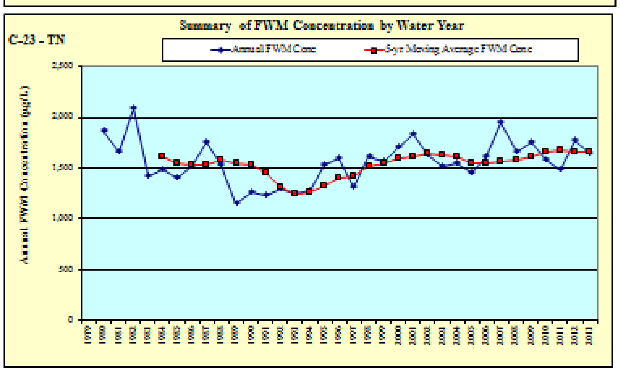
5/1997
5/1998
5/1999
Month

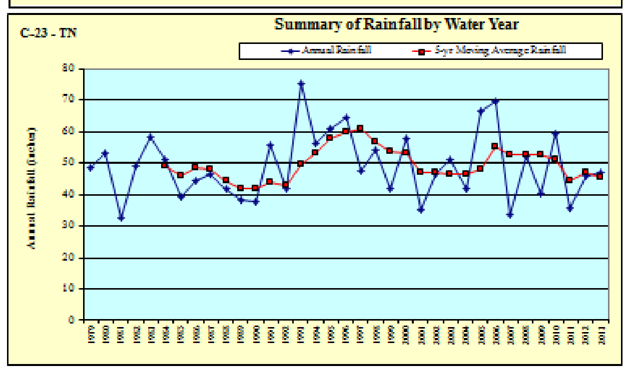

Summary of Flow by Water Year
C-23 - TN
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

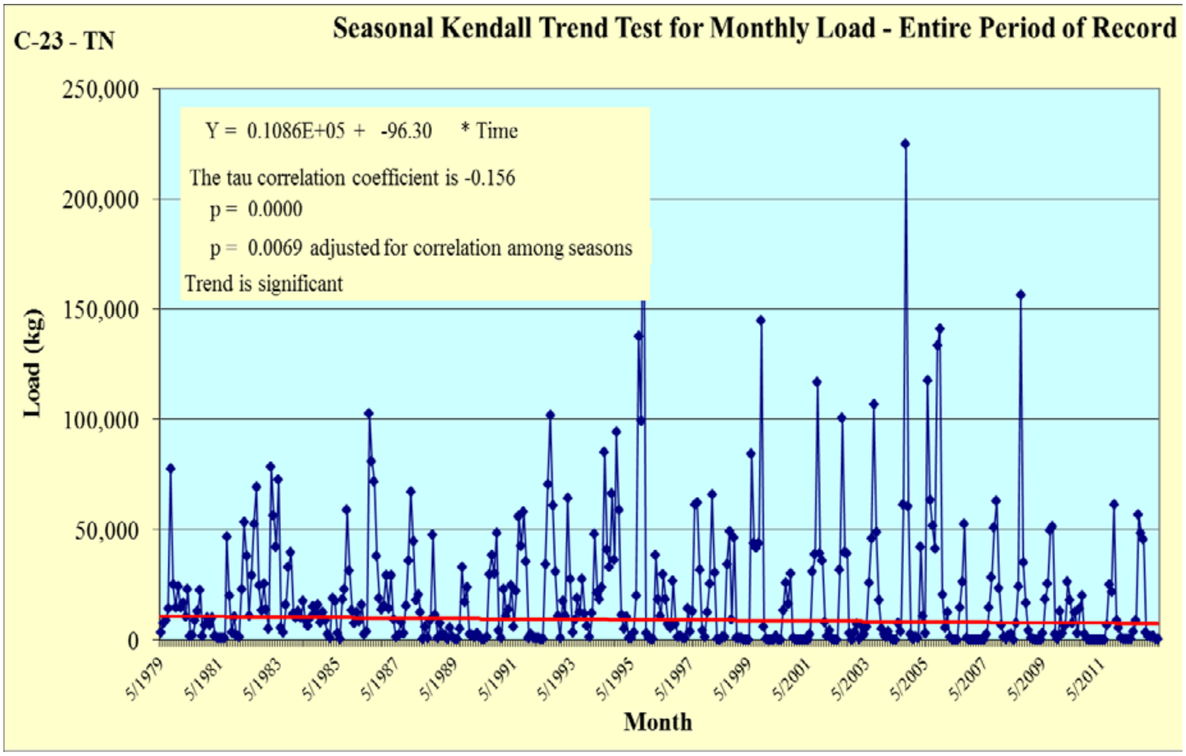

Summary of Unit Area Runoff by Water Year
C-23 - TN
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in)

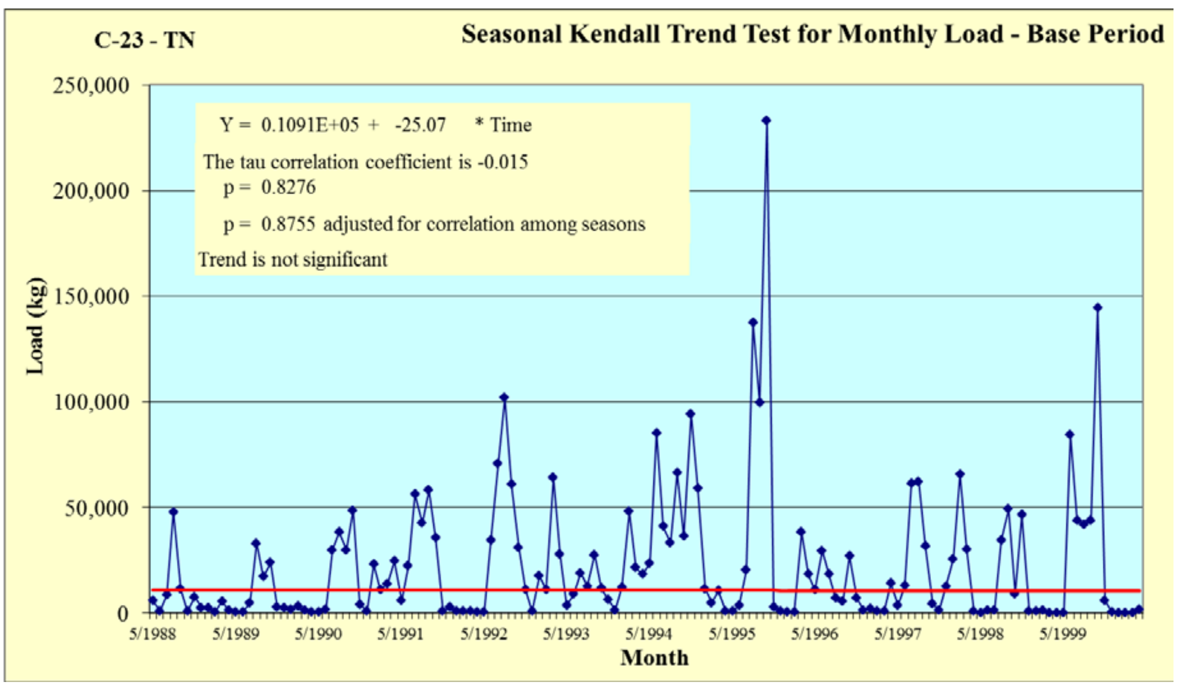

Summary of Load by Water Year
C-23 - TN
Annual Load
5-yr Moving Average Load
Annual Load (mt)

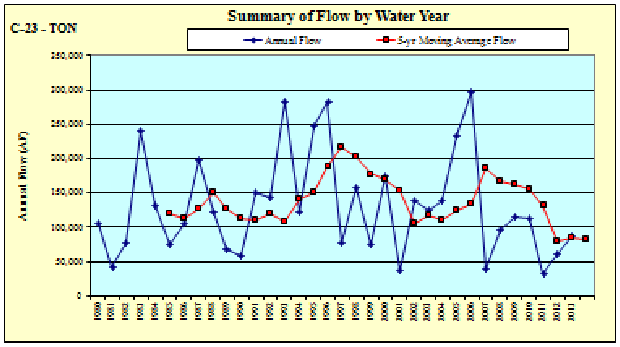

Summary of UAL by Water Year
C-23 - TN
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)

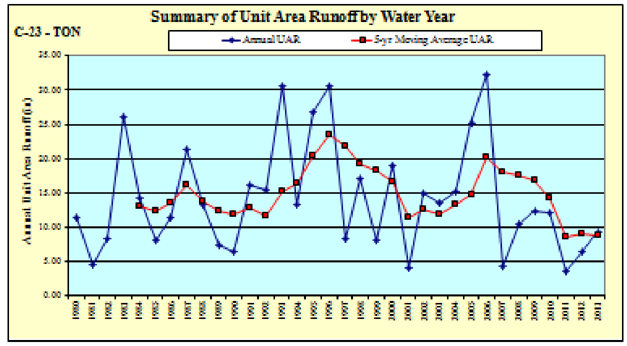

Summary of FWM Concentration by Water Year
C-23 - TN
Annual FWM Conc
5-yr Moving Average FWM Conc

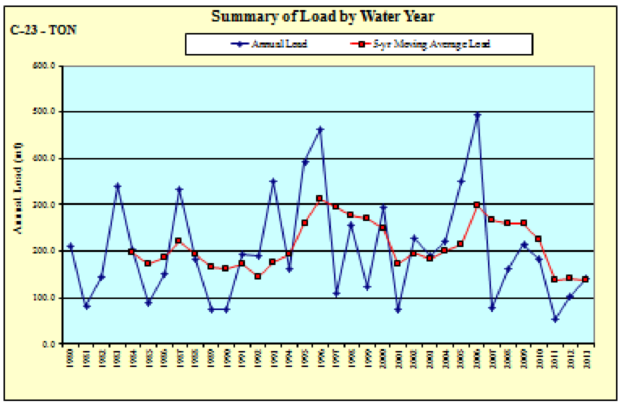

Summary of Rainfall by Water Year
C-23 - TN
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

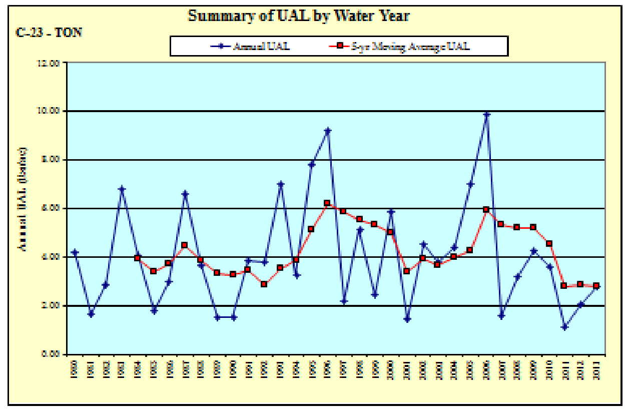

C-23 - TN
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 0.1086E+05 + -96.30 * Time
The tau correlation coefficient is -0.156
p = 0.0000
p = 0.0069 adjusted for correlation among seasons
Trend is significant
Load (kg)
250,000
200,000
150,000
100,000
50,000
0
5/1979
5/1981
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
Month

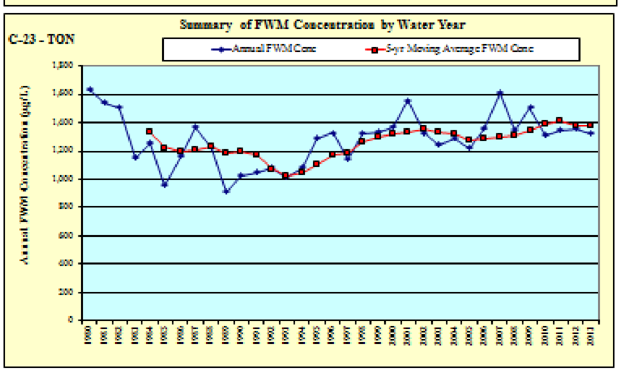

C-23 - TN
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 0.1091E+05 + -25.07 * Time
The tau correlation coefficient is -0.015
p = 0.8276
p = 0.8755 adjusted for correlation among seasons
Trend is not significant
Load (kg)
250,000
200,000
150,000
100,000
50,000
0
5/1988
5/1989
5/1990
5/1991
5/1992
5/1993
5/1994
5/1995
5/1996
5/1997
5/1998
5/1999
Month

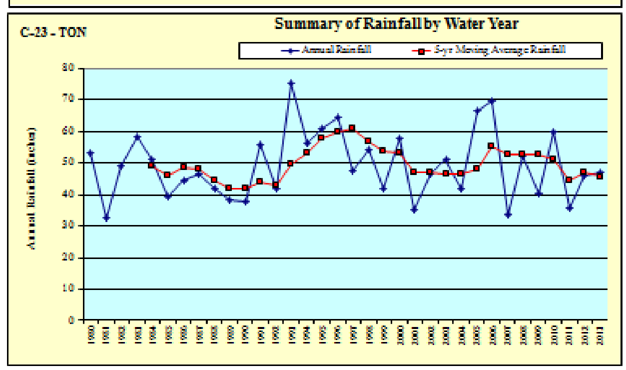

C-23 - TON
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

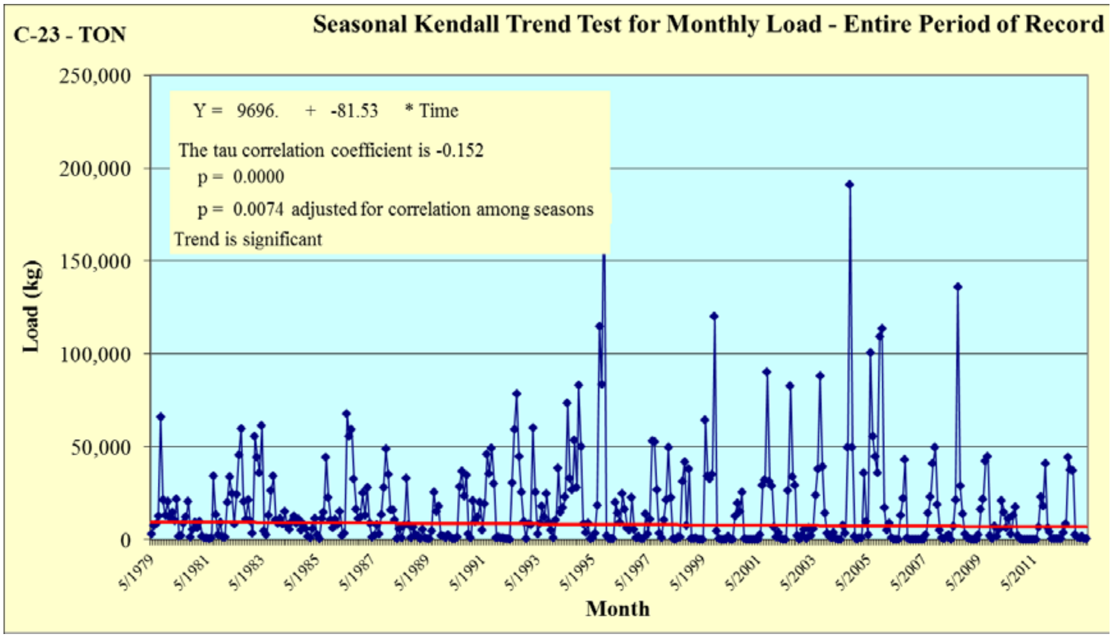

C-23 - TON
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR

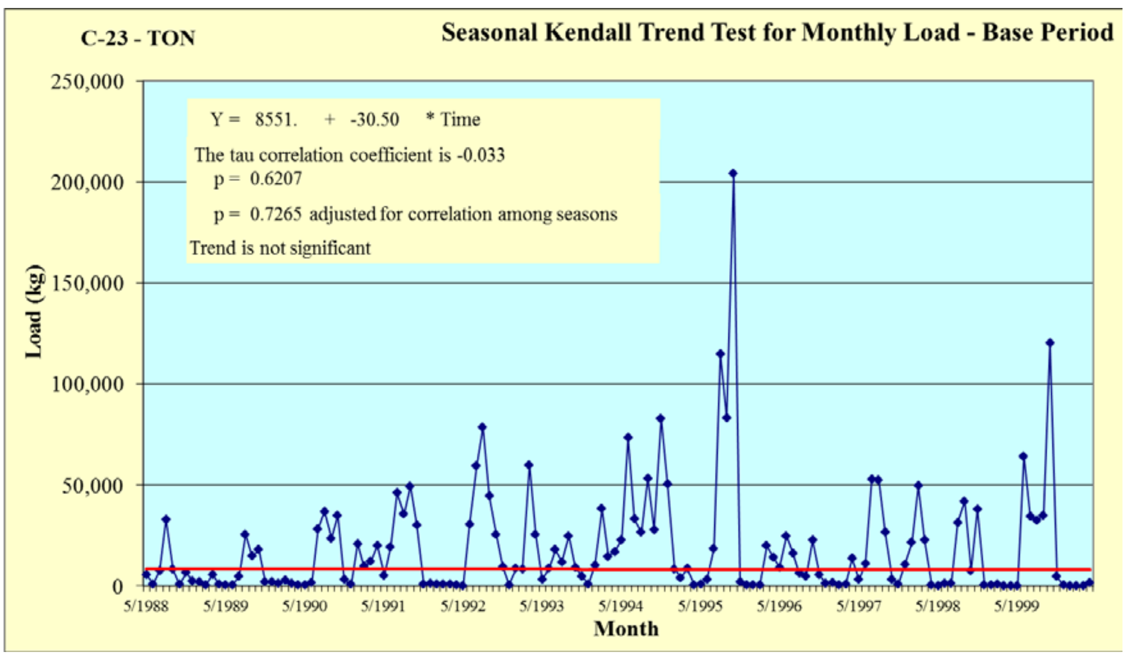

C-23 - TON
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)


C-23 - TON
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL


C-23 - TON
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc

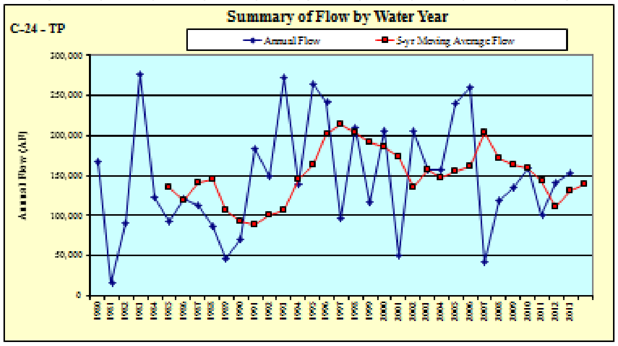

C-23 - TON
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

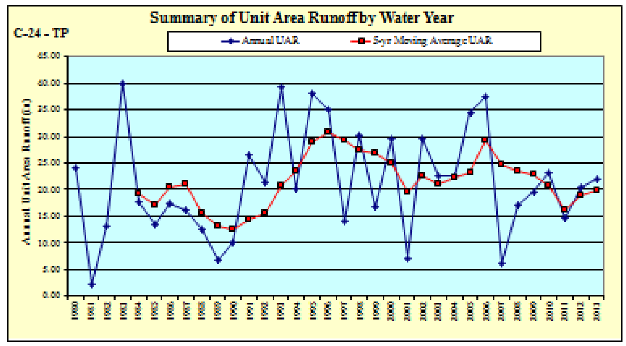

C-23 - TON
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 9696. + -81.53 * Time
The tau correlation coefficient is -0.152
p = 0.0000
p = 0.0074 adjusted for correlation among seasons
Trend is significant
Load (kg)
250,000
200,000
150,000
100,000
50,000
0
5/1979
5/1981
5/1983
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
Month

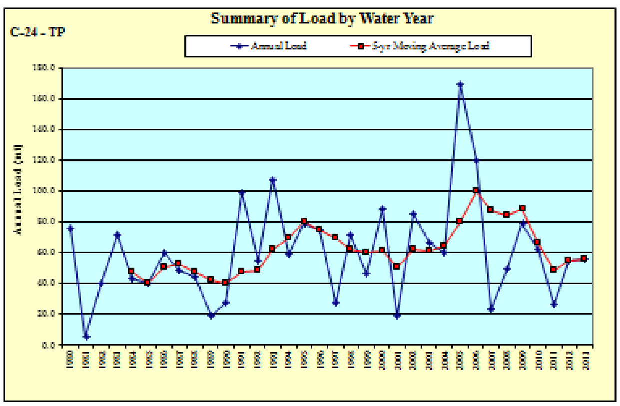

C-23 - TON
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 8551. + -30.50 * Time
The tau correlation coefficient is -0.033
p = 0.6207
p = 0.7265 adjusted for correlation among seasons
Trend is not significant
Load (kg)
250,000
200,000
150,000
100,000
50,000
0
5/1988
5/1989
5/1990
5/1991
5/1992
5/1993
5/1994
5/1995
5/1996
5/1997
5/1998
5/1999
Month

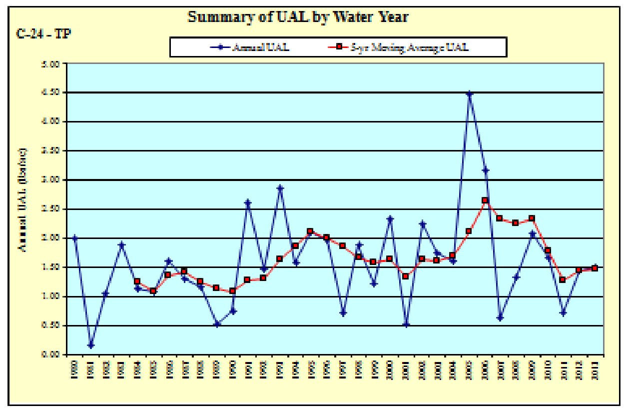
C-24 SUB-WATERSHED

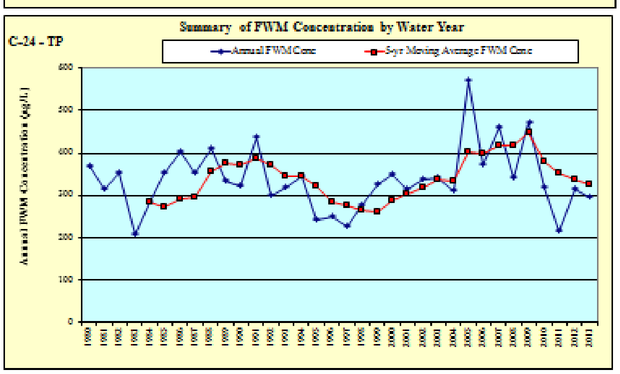
Annual Flow and Nutrient Levels

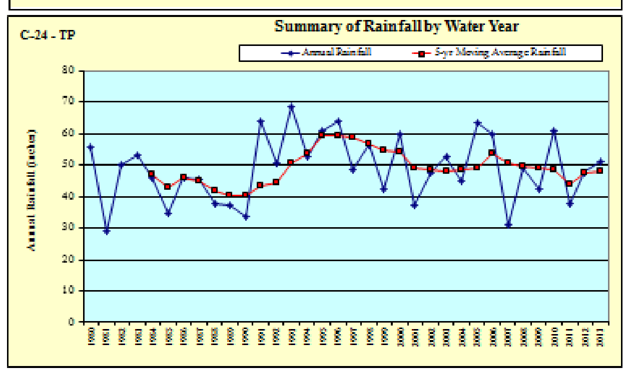


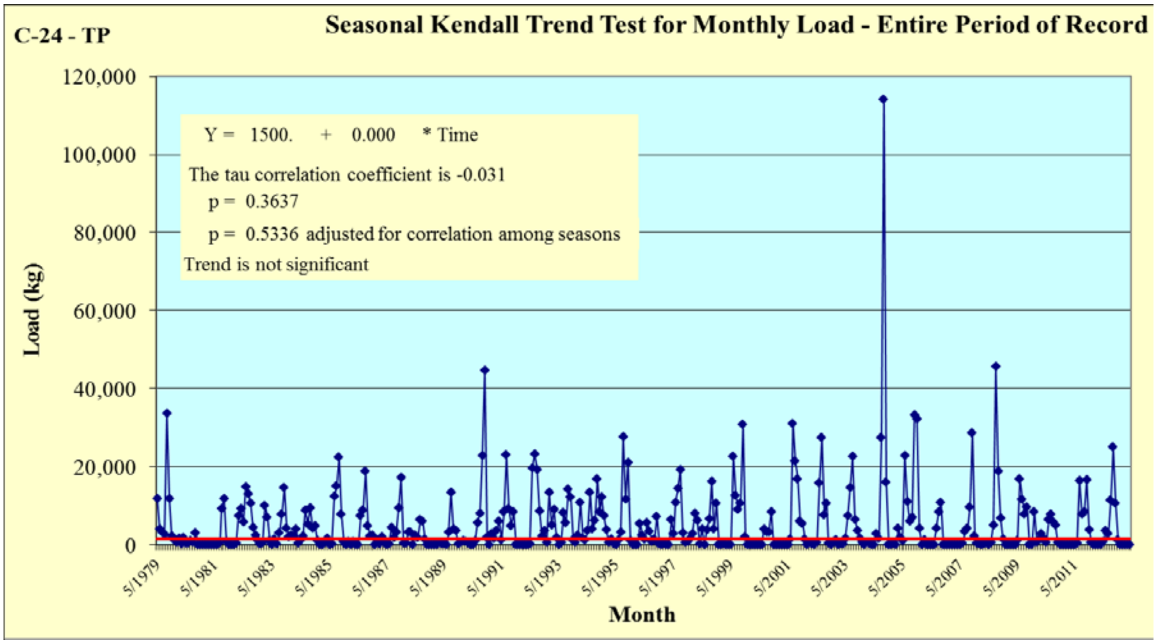


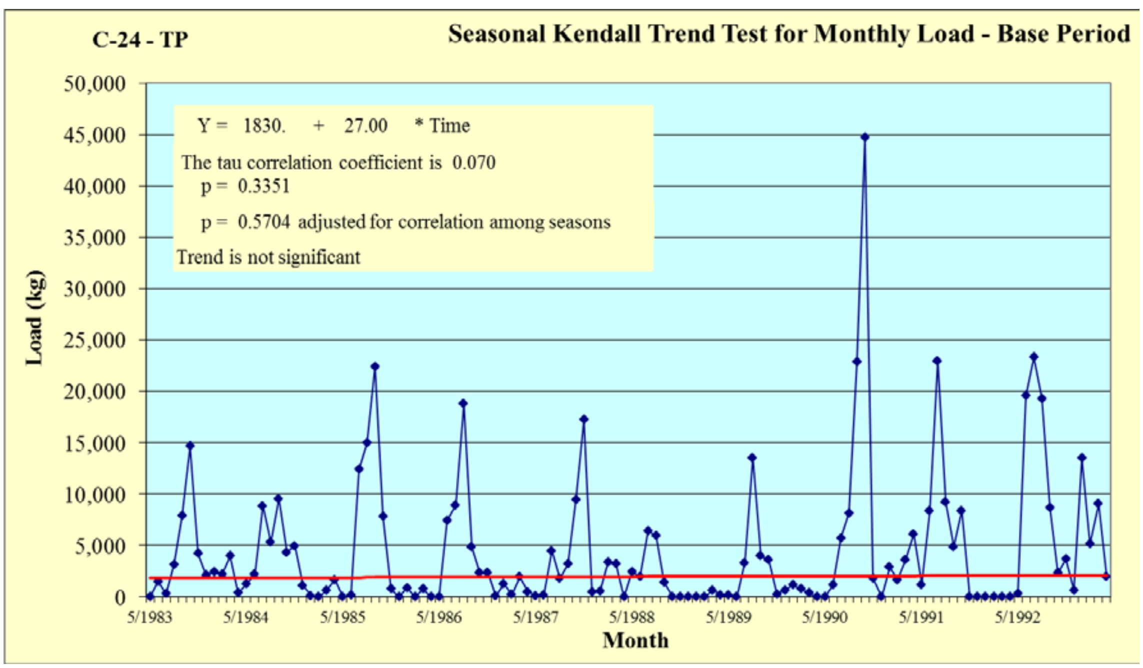


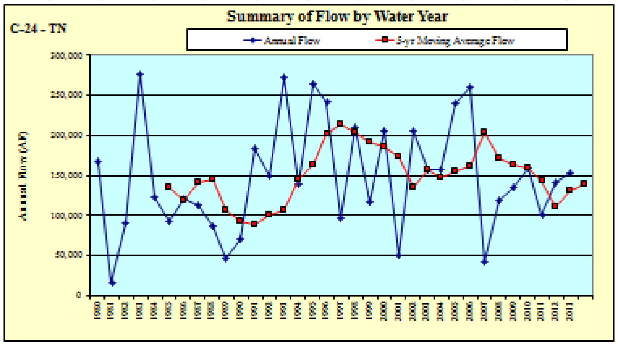


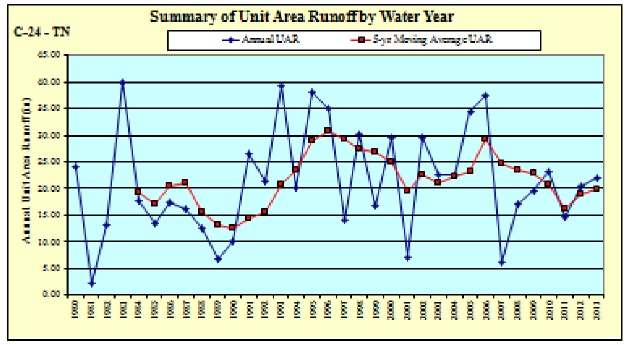


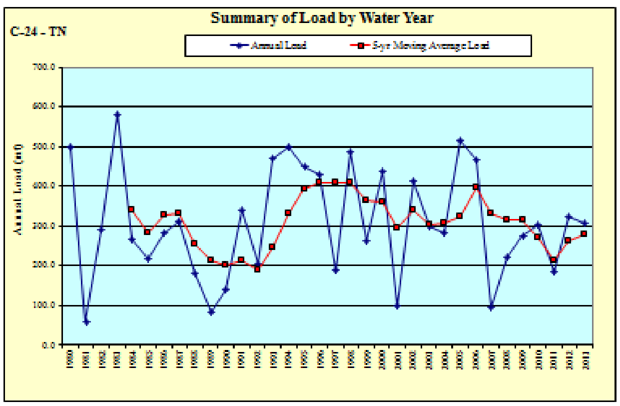


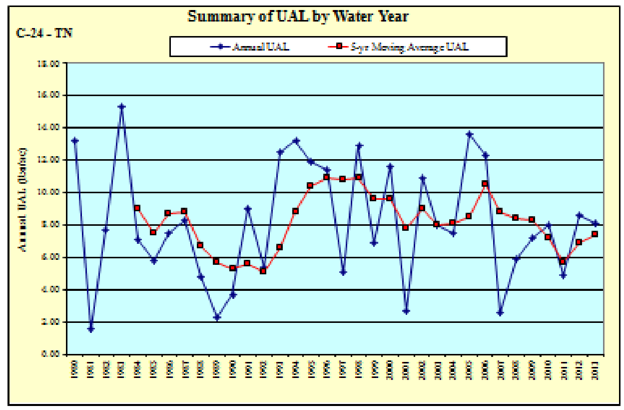

C-24 - TP
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 1500. + 0.000 * Time
The tau correlation coefficient is -0.031
p = 0.3637
p = 0.5336 adjusted for correlation among seasons
Trend is not significant
Load (kg)
Month
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1979
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

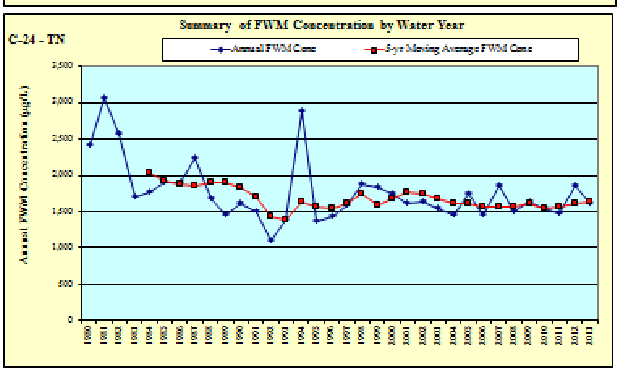

C-24 - TP
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 1830. + 27.00 * Time
The tau correlation coefficient is 0.070
p = 0.3351
p = 0.5704 adjusted for correlation among seasons
Trend is not significant
Load (kg)
Month
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
5/1983
5/1984
5/1985
5/1986
5/1987
5/1988
5/1989
5/1990
5/1991
5/1992

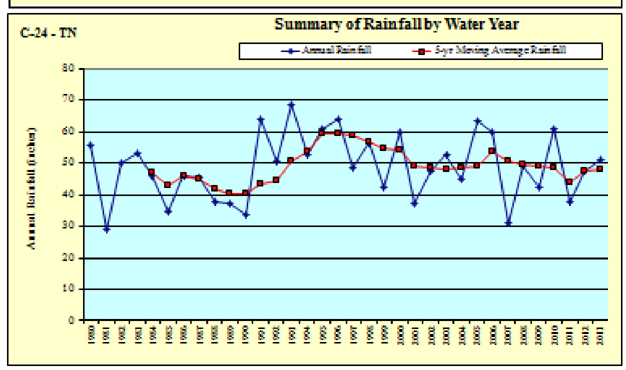

C-24 - TN
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual flow (AF)
300,000
250,000
200,000
150,000
100,000
50,000
0

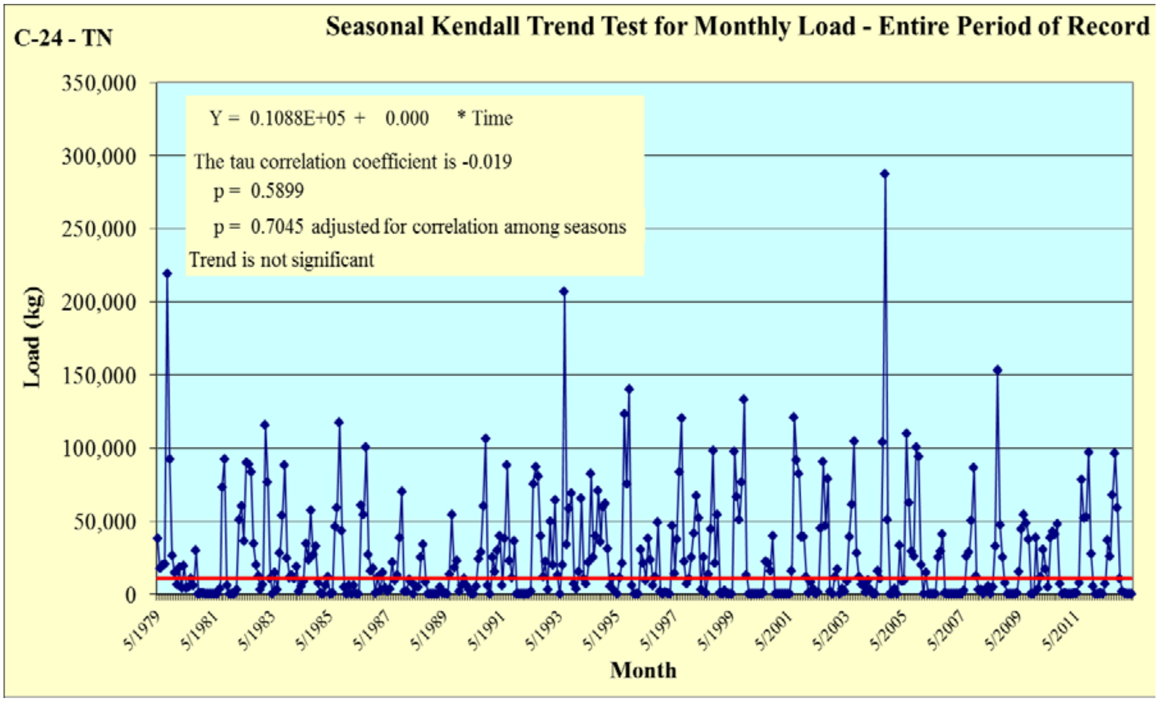

C-24 - TN
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in)

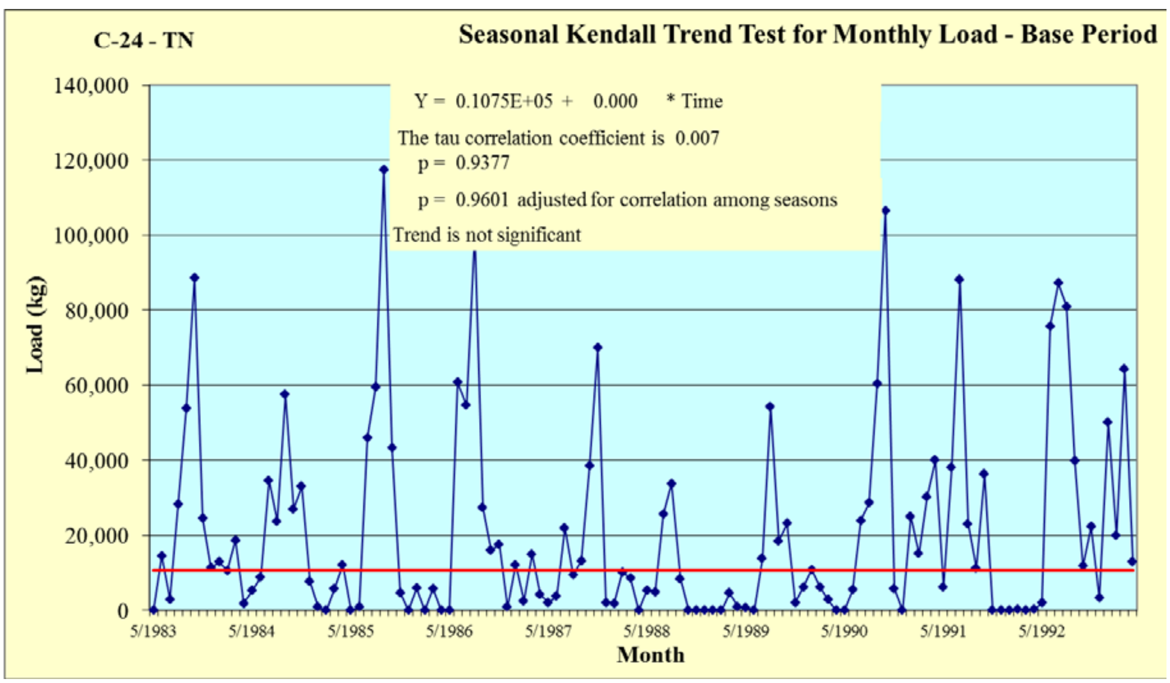

C-24 - TN
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0

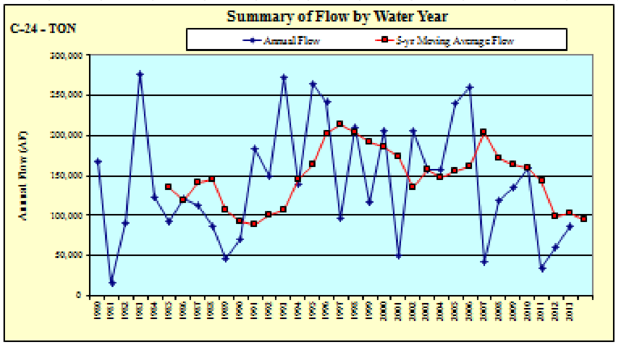

C-24 - TN
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00

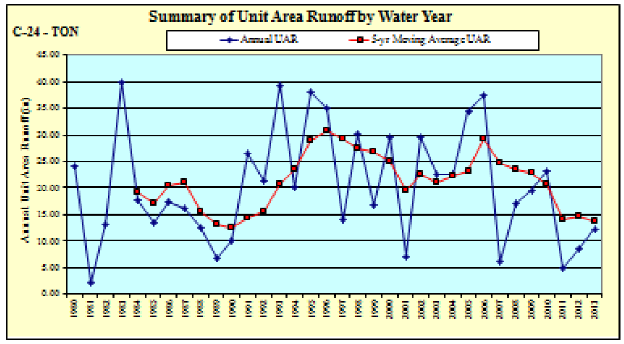

C-24 - TN
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)
3,500
3,000
2,500
2,000
1,500
1,000
500
0

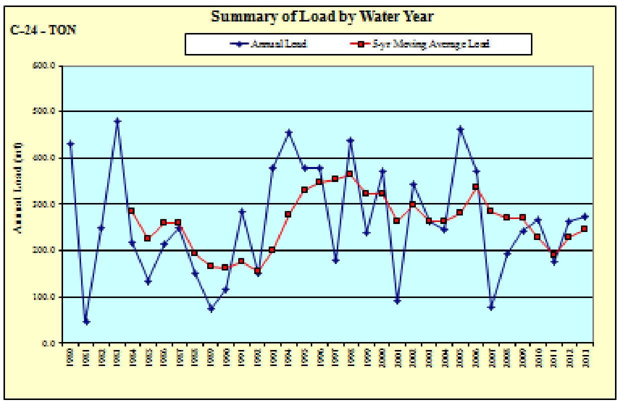

C-24 - TN
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)
80
70
60
50
40
30
20
10
0

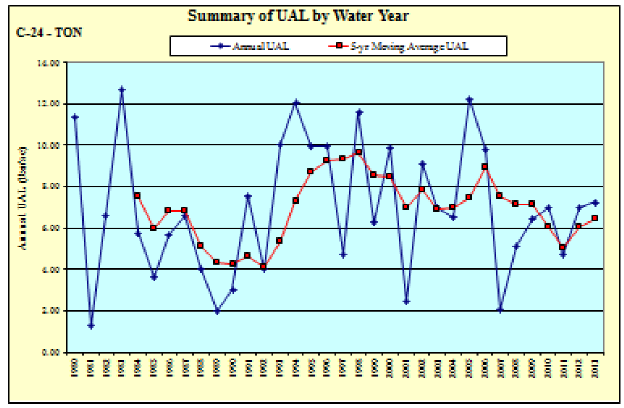

C-24 - TN
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 0.1088E+05 + 0.000 * Time
The tau correlation coefficient is -0.019
p = 0.5899
p = 0.7045 adjusted for correlation among seasons
Trend is not significant
Load (kg)
Month
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
5/1979
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

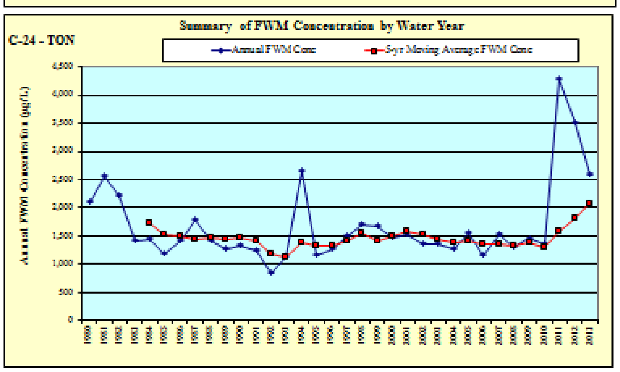

C-24 - TN
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 0.1075E+05 + 0.000 * Time
The tau correlation coefficient is 0.007
p = 0.9377
p = 0.9601 adjusted for correlation among seasons
Trend is not significant
Load (kg)
Month
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1983
5/1984
5/1985
5/1986
5/1987
5/1988
5/1989
5/1990
5/1991
5/1992

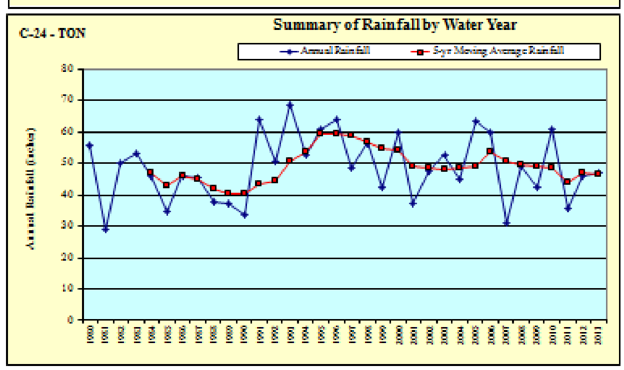

C-24 - TON
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

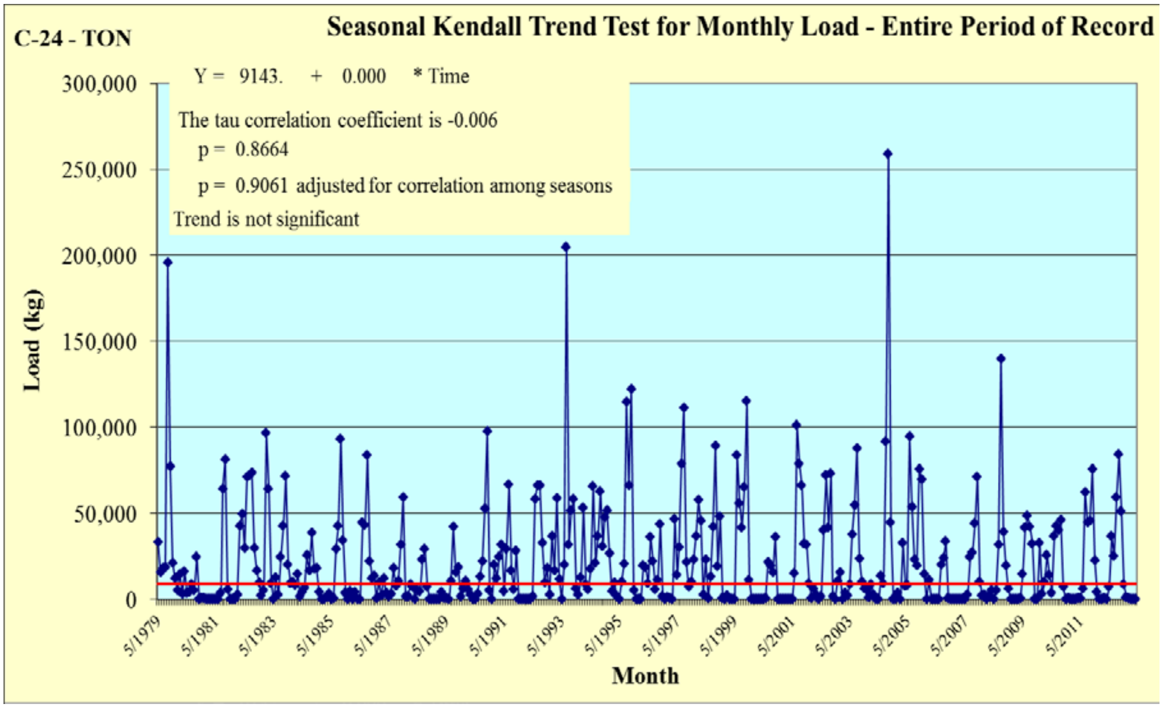

C-24 - TON
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR

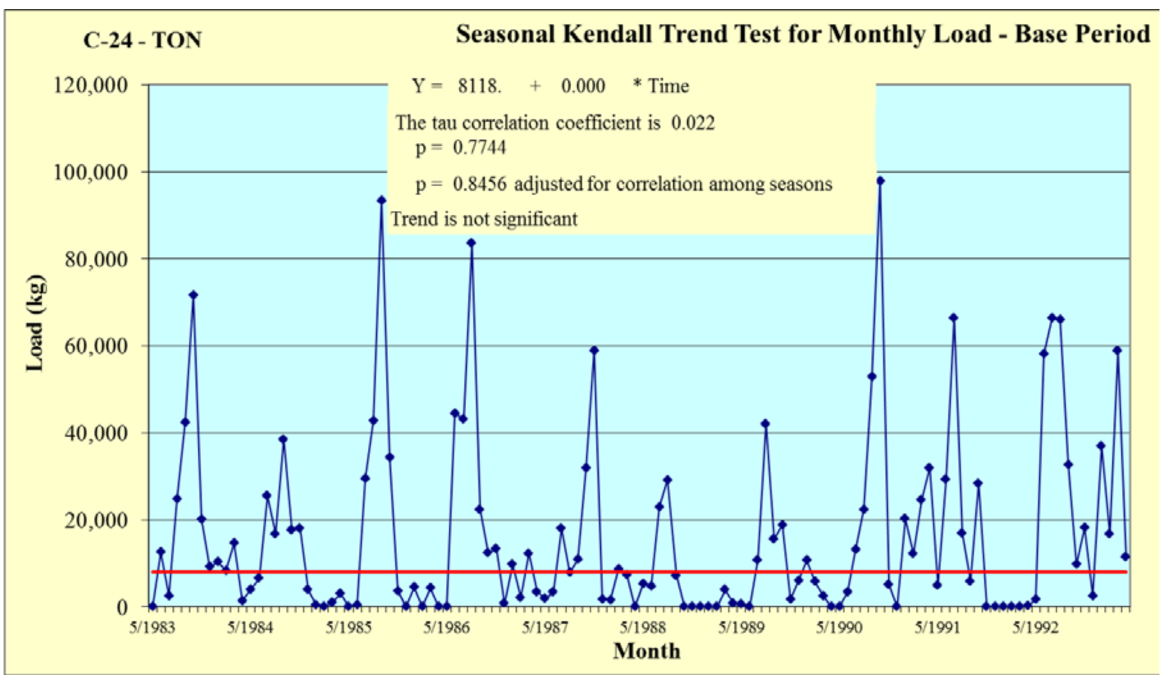

C-24 - TON
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load


C-24 - TON
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL


C-24 - TON
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc


C-24 - TON
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall


C-24 - TON
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 9143. + 0.000 * Time
The tau correlation coefficient is -0.006
p = 0.8664
p = 0.9061 adjusted for correlation among seasons
Trend is not significant
Load (kg)
300,000
250,000
200,000
150,000
100,000
50,000
0
5/1979
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
Month


C-24 - TON
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 8118. + 0.000 * Time
The tau correlation coefficient is 0.022
p = 0.7744
p = 0.8456 adjusted for correlation among seasons
Trend is not significant
Load (kg)
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1983
5/1984
5/1985
5/1986
5/1987
5/1988
5/1989
5/1990
5/1991
5/1992
Month

Calculation of Net Basin Nutrient Loads for the C-24 Sub-watershed

C-24 Sub-watershed Flows

I_{C24} = total inflow to the C-24 Sub-watershed
= Q_{G81In}
Q_{G81In} = G-81 inflows from the C-25 Sub-watershed

O_{C24} = total outflow from the C-24 Sub-watershed
= $Q_{G81Out} + Q_{S49}$
Q_{G81Out} = G-81 outflows to the C-25 Sub-watershed
Q_{S49} = S-49 discharges

PT_{C24} = pass through flow
= minimum (I_{24C} , O_{C24})

B_{EC} = net basin flow produced by local rainfall and runoff
= O_{C24} - PT_{C24}

C-24 Sub-watershed Loads

OL_{C24} = total outflow nutrient load
= $Q_{G81Out} * C_{G81Out} + Q_{S49Out} * C_{S49Out}$
C_{G81Out} = G-81 nutrient outflow concentration
C_{S49} = S-49 nutrient concentration

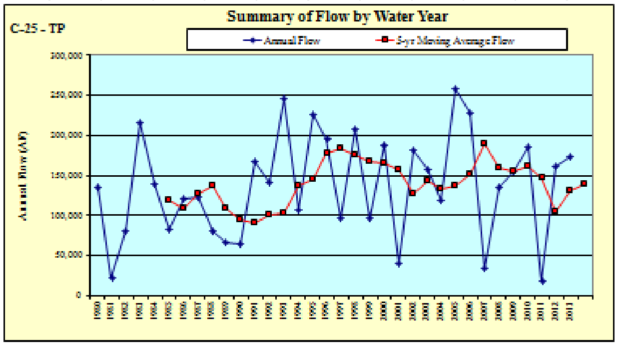
PTL_{C24} = pass through nutrient load
= $PT_{C24} * C_{In}$
C_{In} = flow weighted mean inflow concentration
= G-81 nutrient outflow concentration

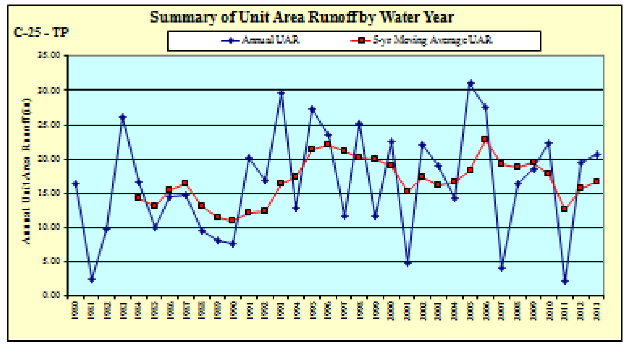
BL_{C24} = net basin load produced by local rainfall and runoff
= OL_{C24} - PTL_{C24}

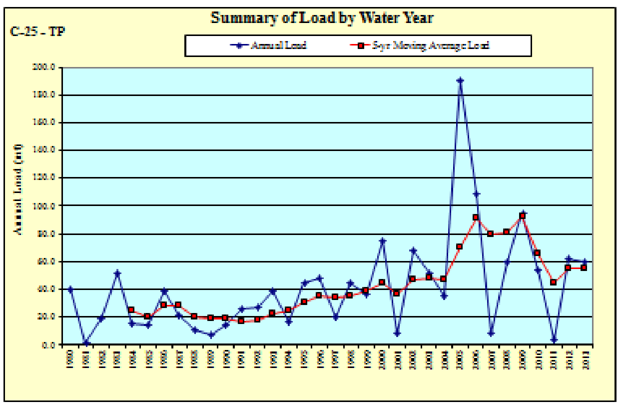
Missing water quality data at G-81 was assumed to be adequately represented by measured and estimated water quality data at S-99.

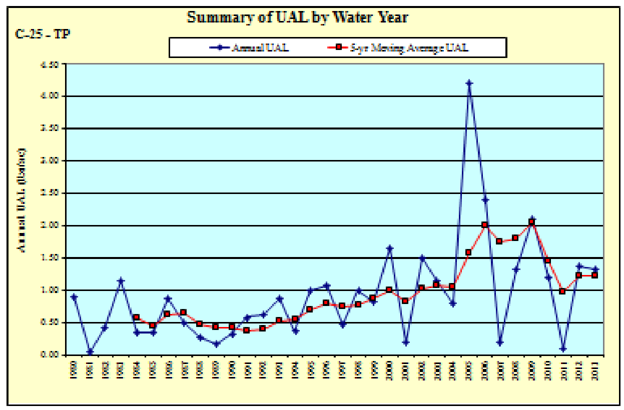
C-25 SUB-WATERSHED

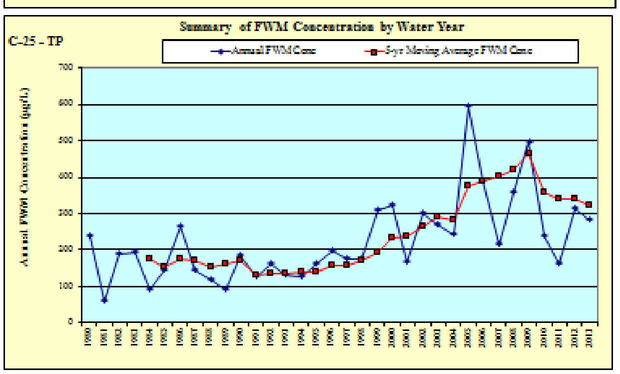
Annual Flow and Nutrient Levels

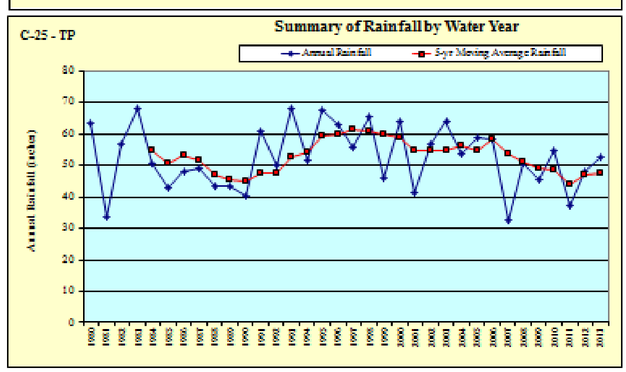


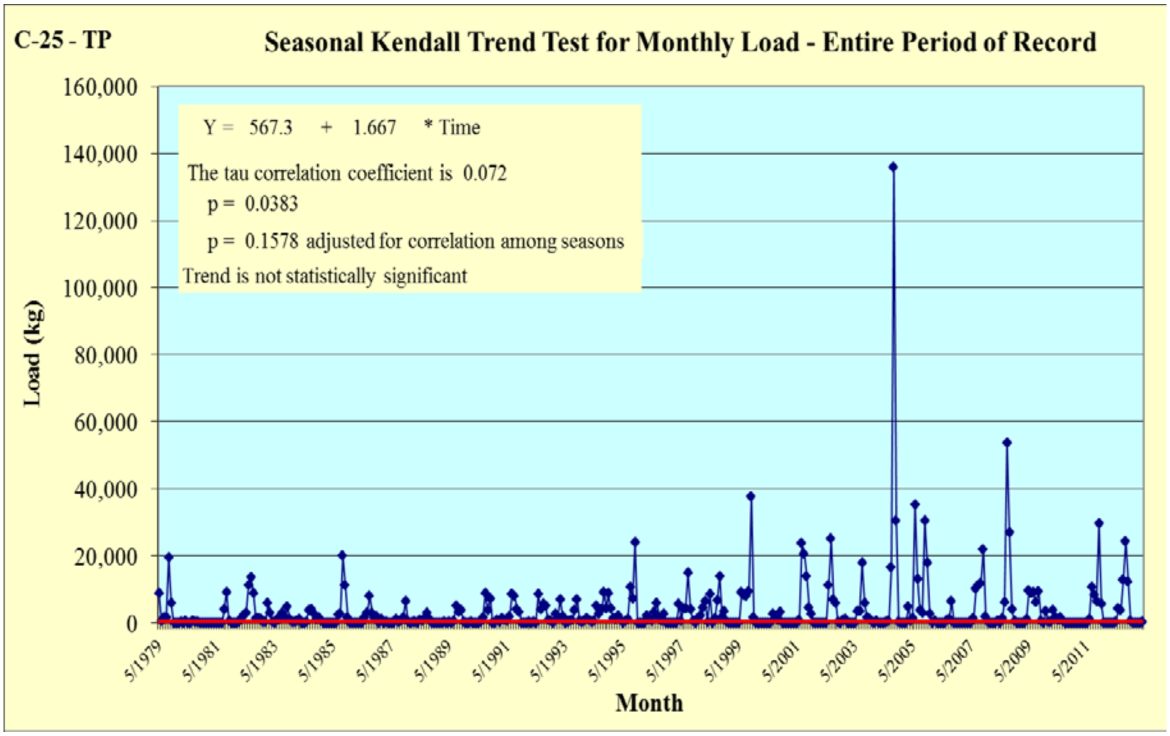


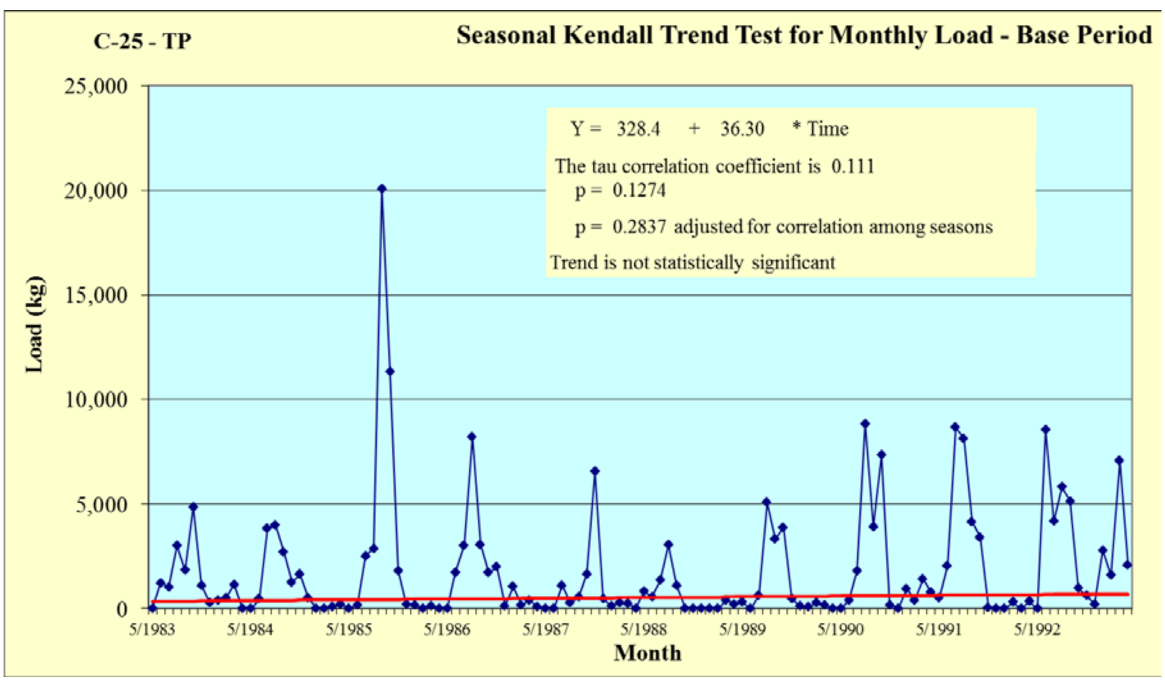


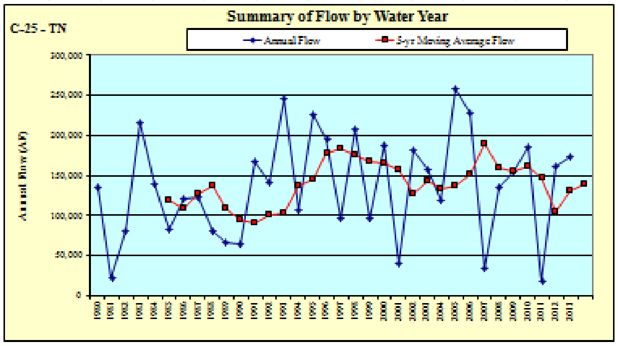


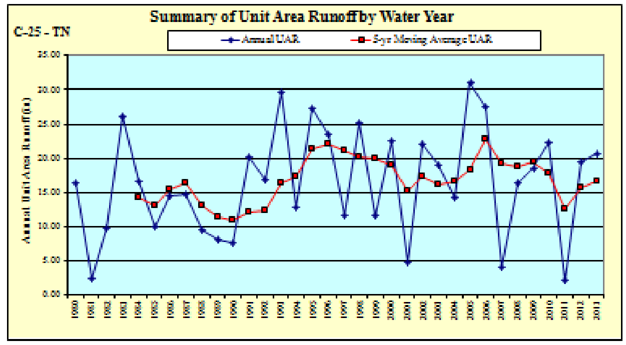


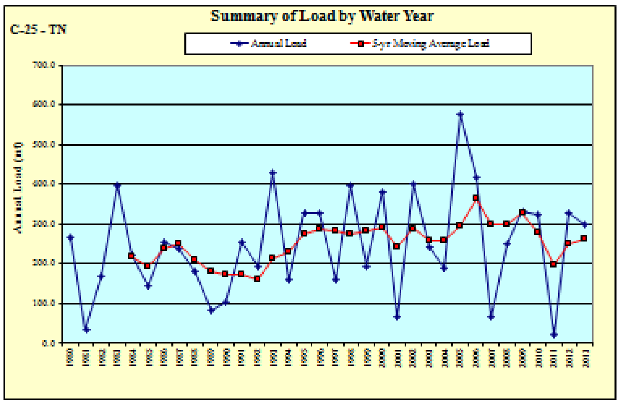


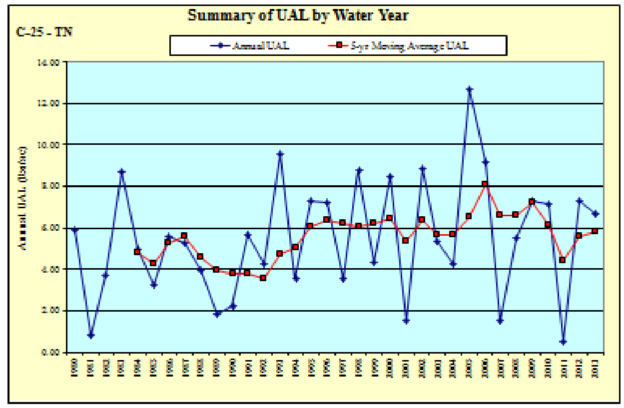

C-25 - TP
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 567.3 + 1.667 * Time
The tau correlation coefficient is 0.072
p = 0.0383
p = 0.1578 adjusted for correlation among seasons
Trend is not statistically significant
Load (kg)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1979
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
Month

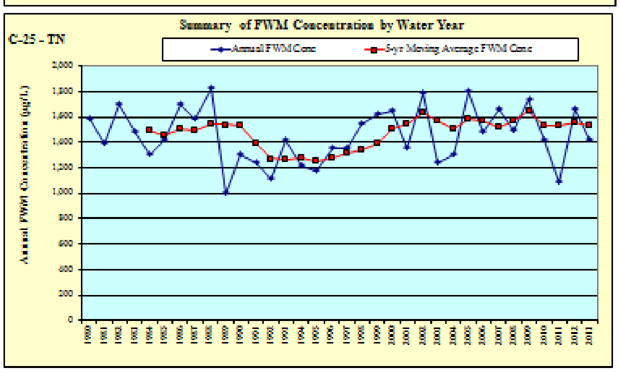

C-25 - TP
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 328.4 + 36.30 * Time
The tau correlation coefficient is 0.111
p = 0.1274
p = 0.2837 adjusted for correlation among seasons
Trend is not statistically significant
Load (kg)
25,000
20,000
15,000
10,000
5,000
0
5/1983
5/1984
5/1985
5/1986
5/1987
5/1988
5/1989
5/1990
5/1991
5/1992
Month

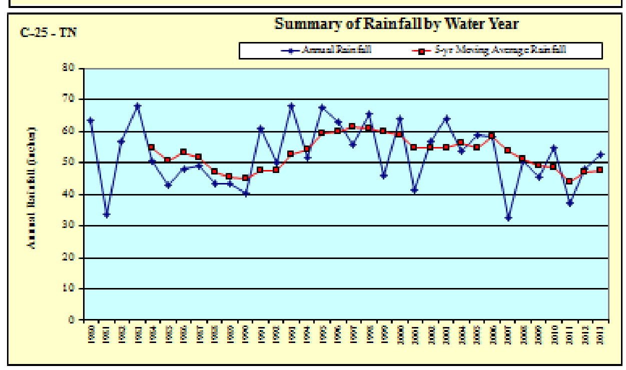

C-25 - TN
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

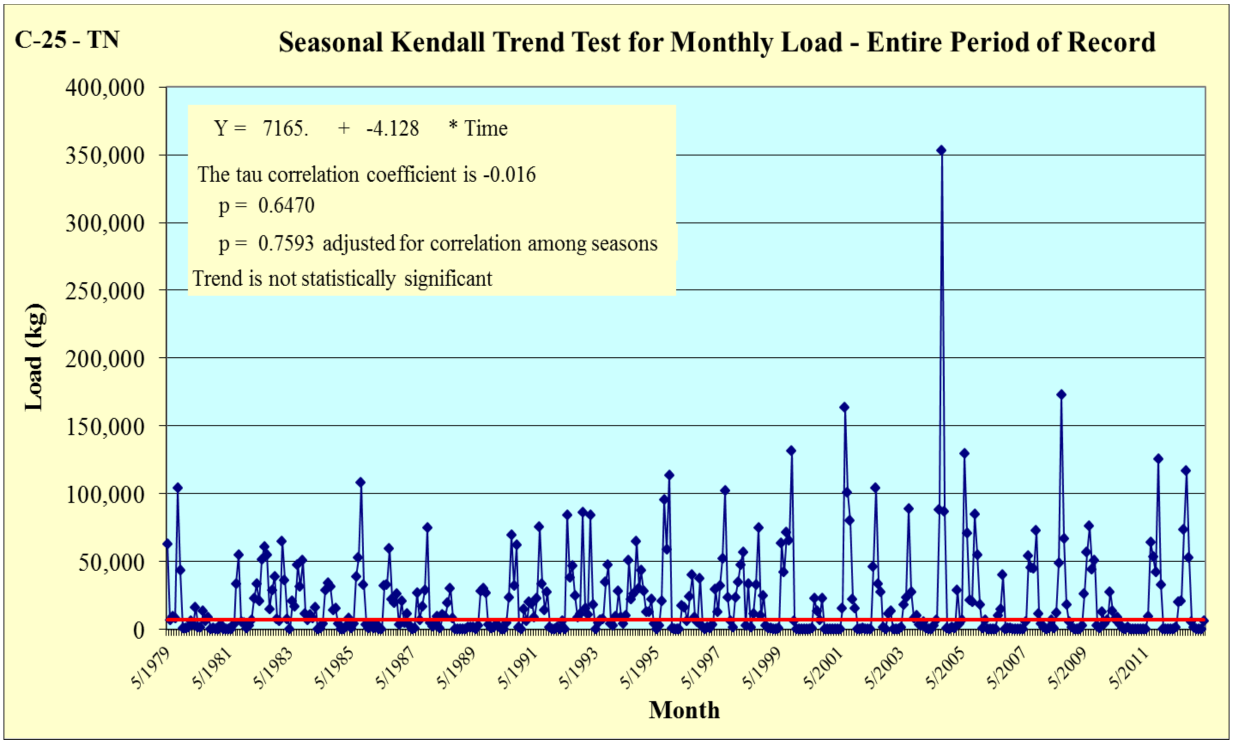

C-25 - TN
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in)

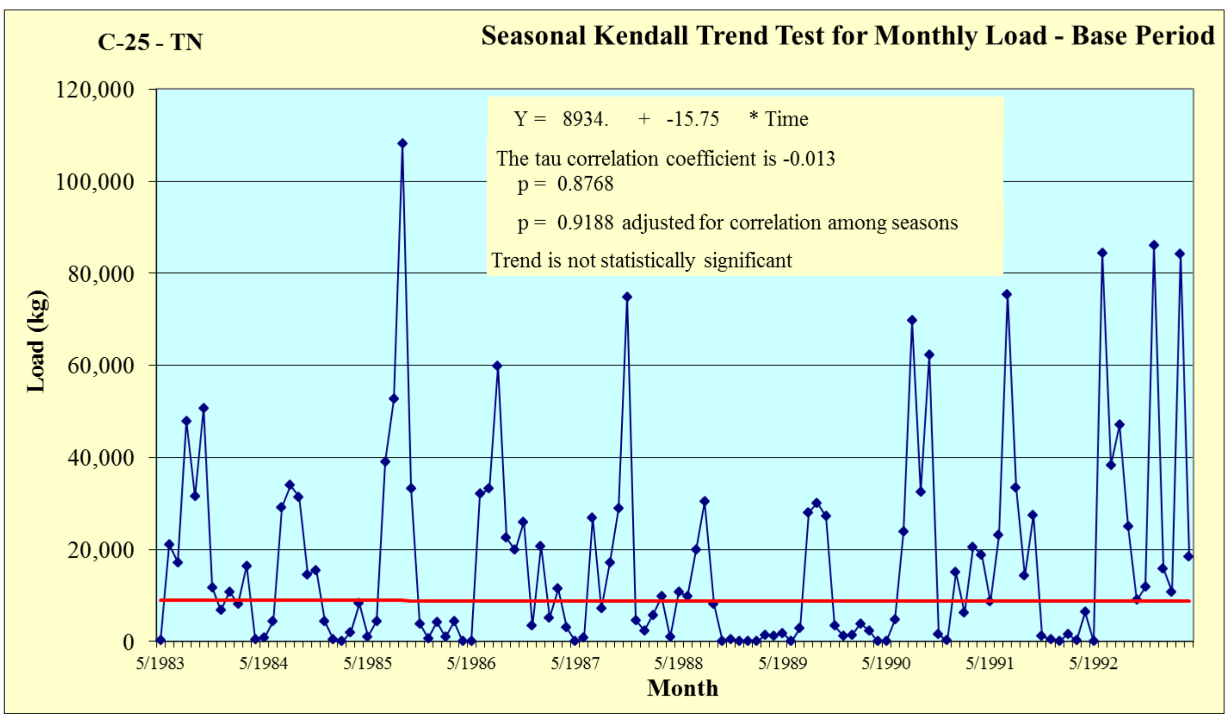

C-25 - TN
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)

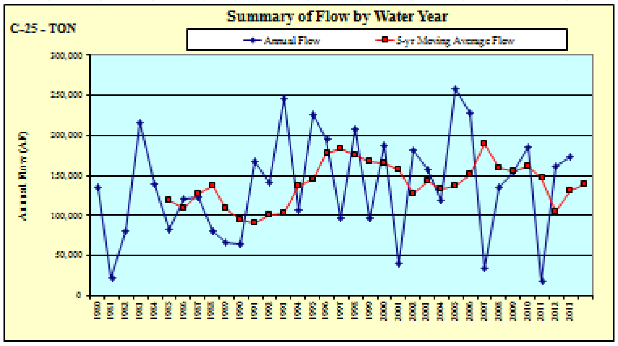

C-25 - TN
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)

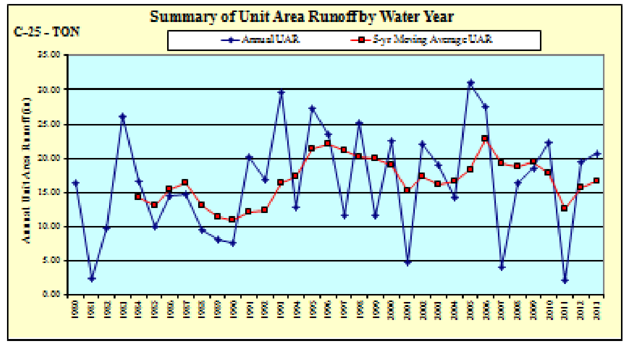

C-25 - TN
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)

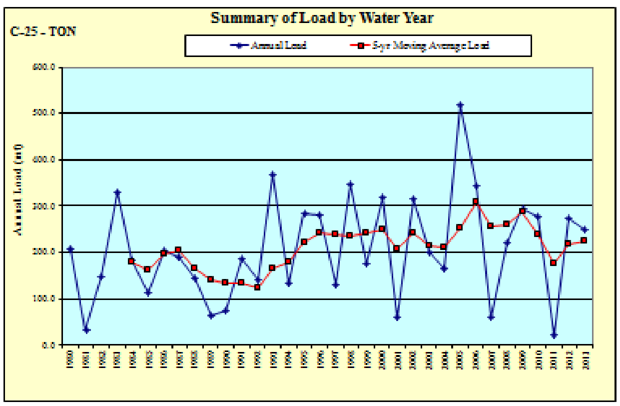

C-25 - TN
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

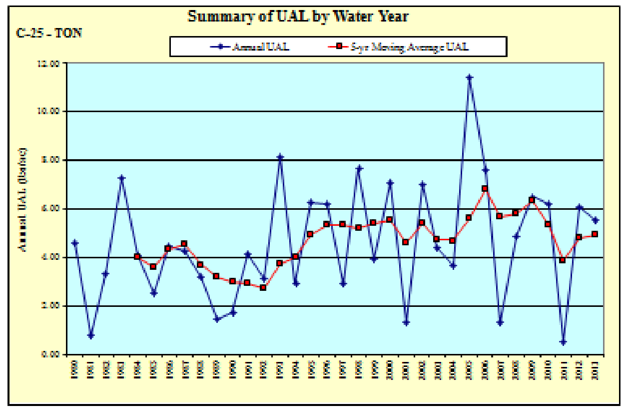

C-25 - TN
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 7165. + -4.128 * Time
The tau correlation coefficient is -0.016
p = 0.6470
p = 0.7593 adjusted for correlation among seasons
Trend is not statistically significant
Load (kg)
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
5/1979
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
Month

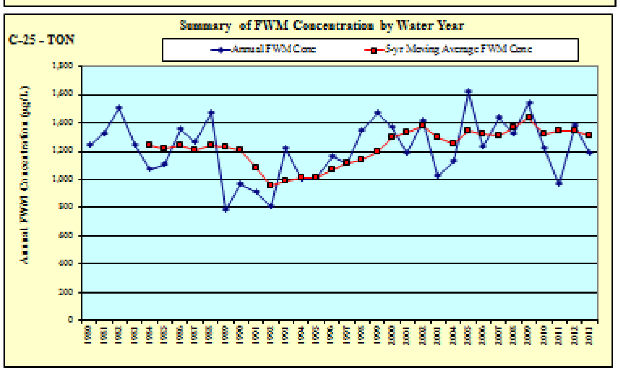

C-25 - TN
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 8934. + -15.75 * Time
The tau correlation coefficient is -0.013
p = 0.8768
p = 0.9188 adjusted for correlation among seasons
Trend is not statistically significant
Load (kg)
0
20,000
40,000
60,000
80,000
100,000
120,000
5/1983
5/1984
5/1985
5/1986
5/1987
5/1988
5/1989
5/1990
5/1991
5/1992
Month

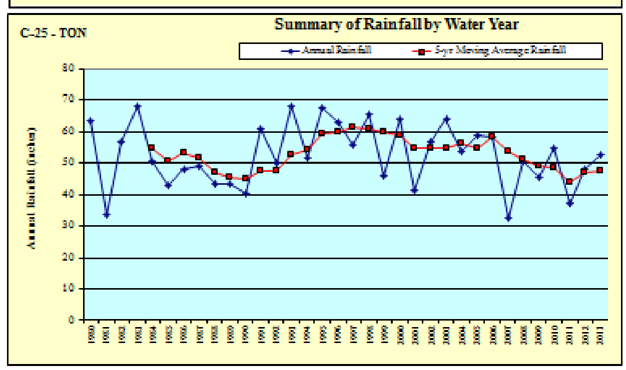

Summary of Flow by Water Year
C-25 - TON
Annual Flow
5-yr Moving Average Flow
Annual flow (AF)

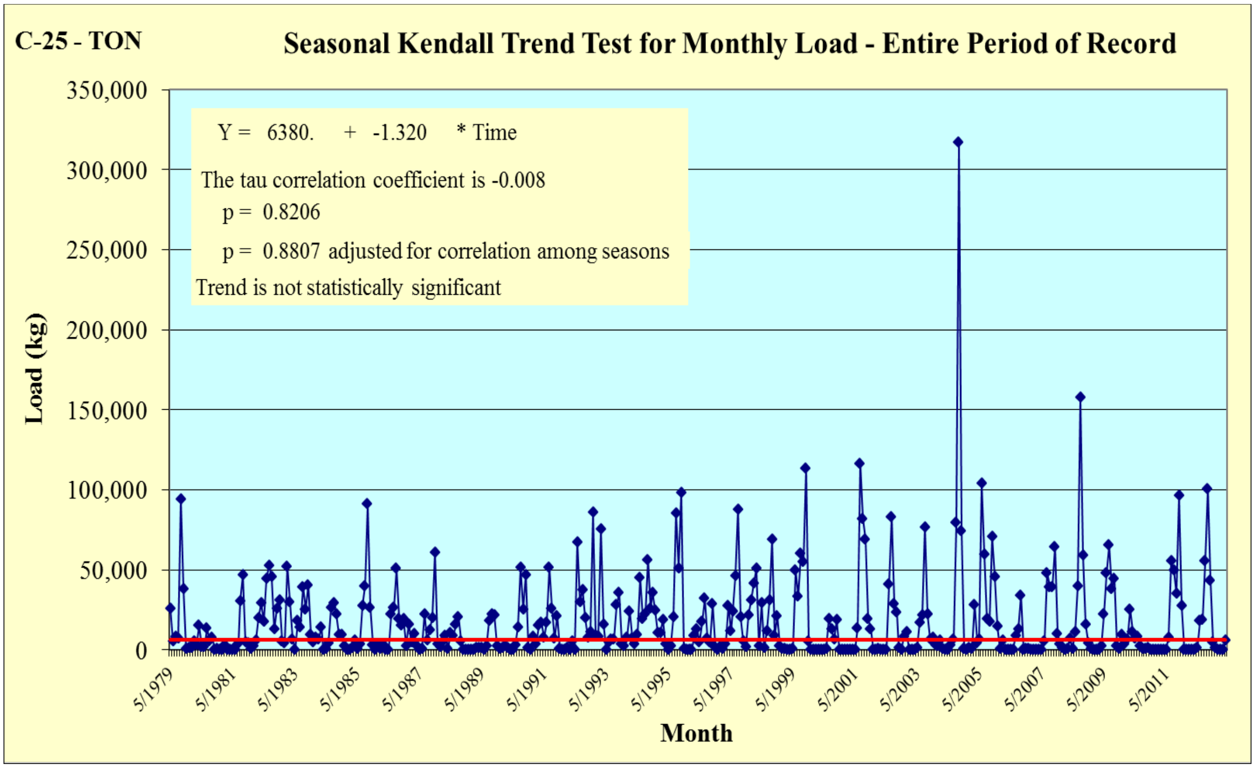

Summary of Unit Area Runoff by Water Year
C-25 - TON
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in)

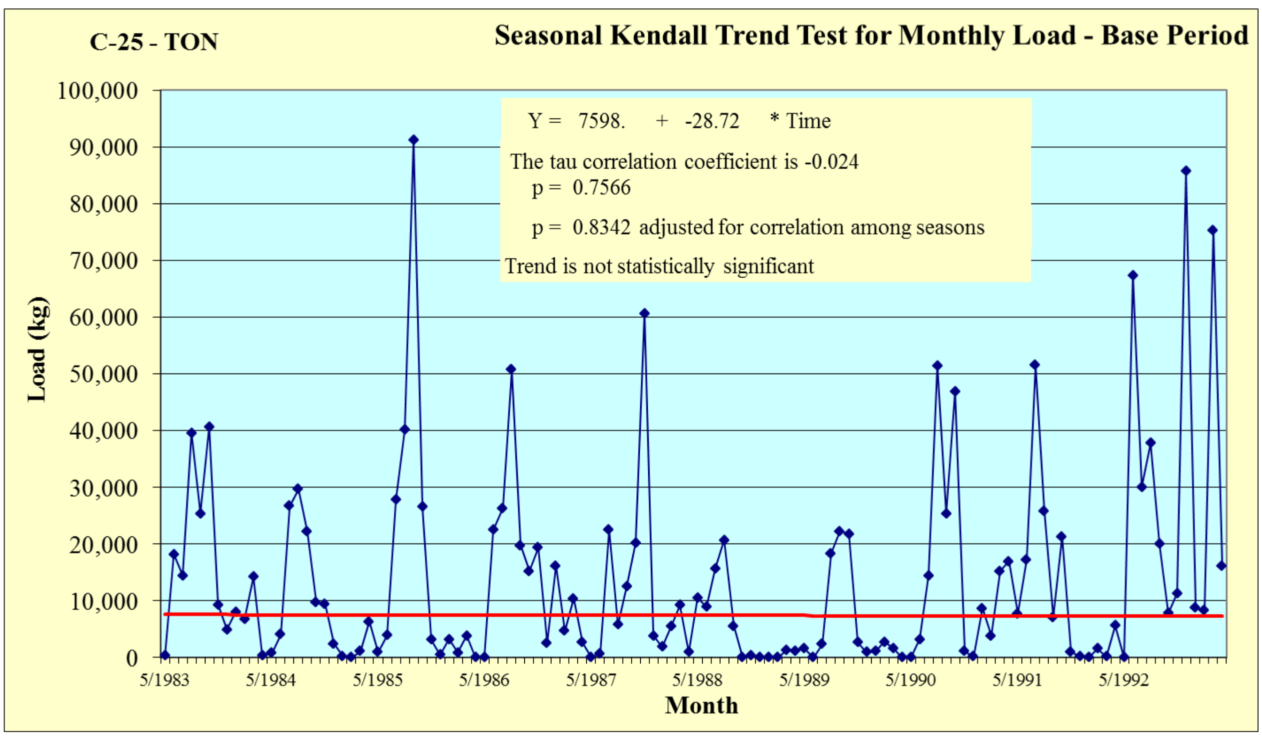

Summary of Load by Water Year
C-25 - TON
Annual Load
5-yr Moving Average Load
Annual Load (mt)


Summary of UAL by Water Year
C-25 - TON
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)


Summary of FWM Concentration by Water Year
C-25 - TON
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)


Summary of Rainfall by Water Year
C-25 - TON
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)


C-25 - TON
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 6380. + -1.320 * Time
The tau correlation coefficient is -0.008
p = 0.8206
p = 0.8807 adjusted for correlation among seasons
Trend is not statistically significant
Load (kg)
Month
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
5/1979
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


C-25 - TON
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 7598. + -28.72 * Time
The tau correlation coefficient is -0.024
p = 0.7566
p = 0.8342 adjusted for correlation among seasons
Trend is not statistically significant
Load (kg)
Month
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
5/1983
5/1984
5/1985
5/1986
5/1987
5/1988
5/1989
5/1990
5/1991
5/1992

Calculation of Net Basin Nutrient Loads for the C-25 Sub-watershed

C-25 Sub-watershed Flows

I_{C25} = total inflow to the C-25 Sub-watershed
= Q_{G81In}
Q_{G81In} = G-81 inflows from the C-24 Sub-watershed

O_{C25} = total outflow from the C-25 Sub-watershed
= $Q_{G81Out} + Q_{S50}$
Q_{G81Out} = G-81 outflows to the C-24 Sub-watershed
Q_{S50} = S-50 discharges

PT_{C25} = pass through flow
= minimum (I_{25C} , O_{C25})

B_{EC} = net basin flow produced by local rainfall and runoff
= $O_{C25} - PT_{C25}$

C-25 Sub-watershed Loads

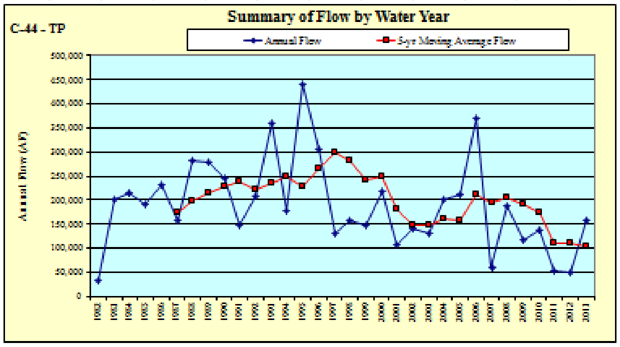
OL_{C25} = total outflow nutrient load
= $Q_{G81Out} * C_{G81Out} + Q_{S50Out} * C_{S50Out}$
C_{G81Out} = G-81 nutrient outflow concentration
C_{S50} = S-50 nutrient concentration

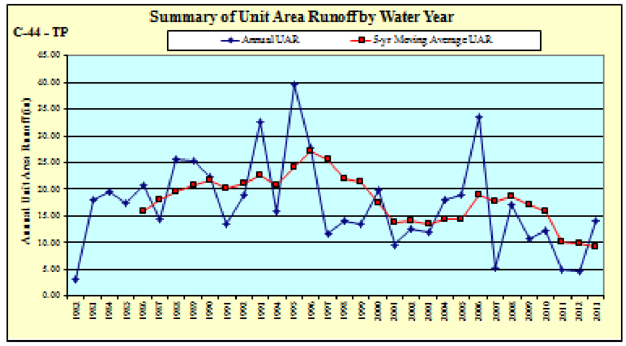
PTL_{C25} = pass through nutrient load
= $PT_{C25} * C_{In}$
C_{In} = flow weighted mean inflow concentration
= G-81 nutrient outflow concentration

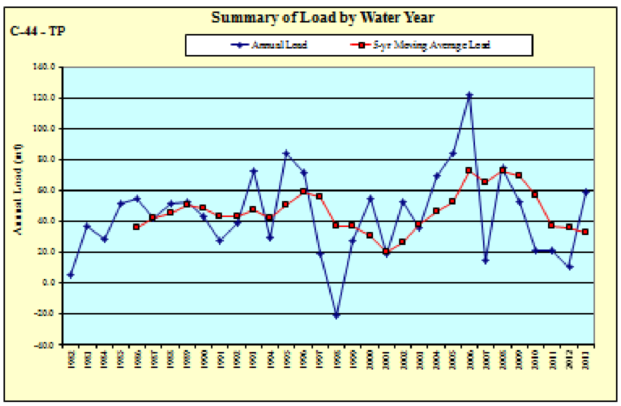
BL_{C25} = net basin load produced by local rainfall and runoff
= $OL_{C25} - PTL_{C25}$

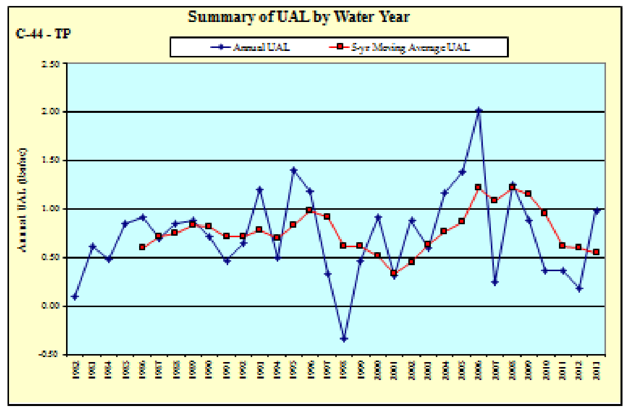
Missing water quality data at G-81 was assumed to be adequately represented by measured and estimated water quality data at S-99.

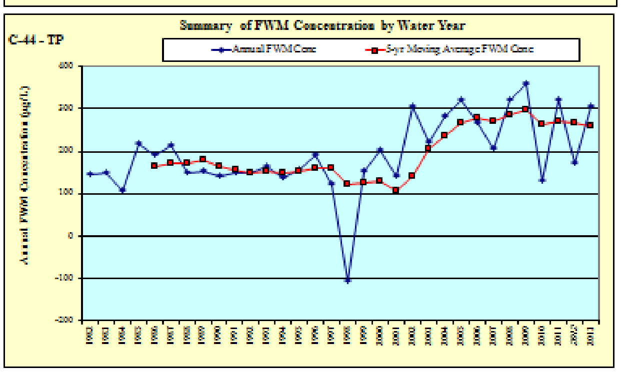
C-44 Sub-watershed

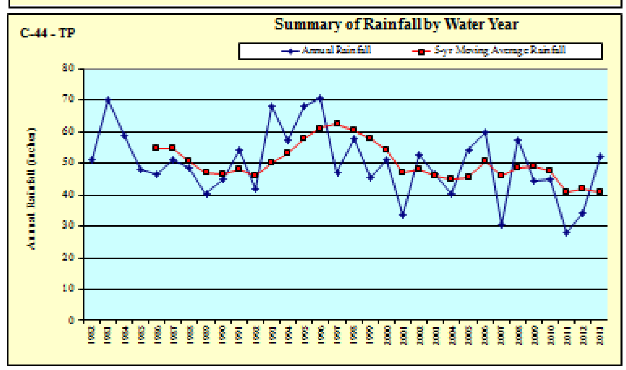


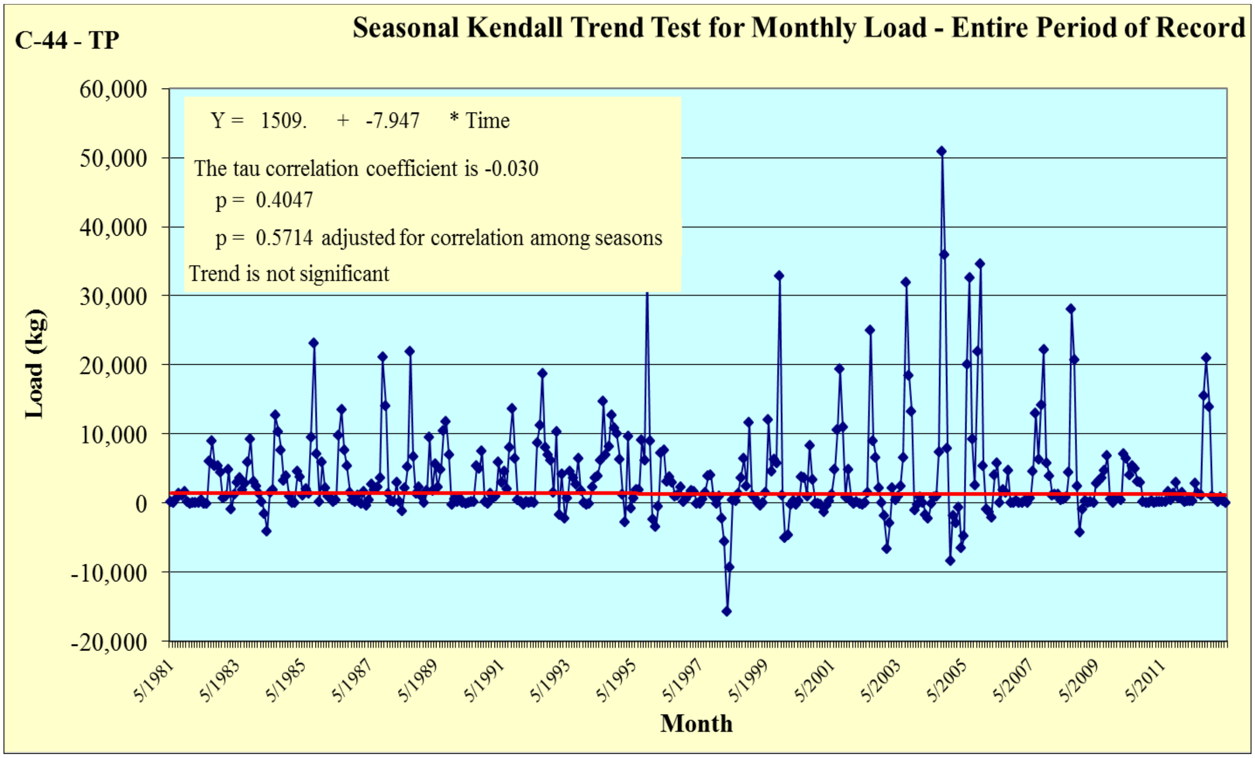


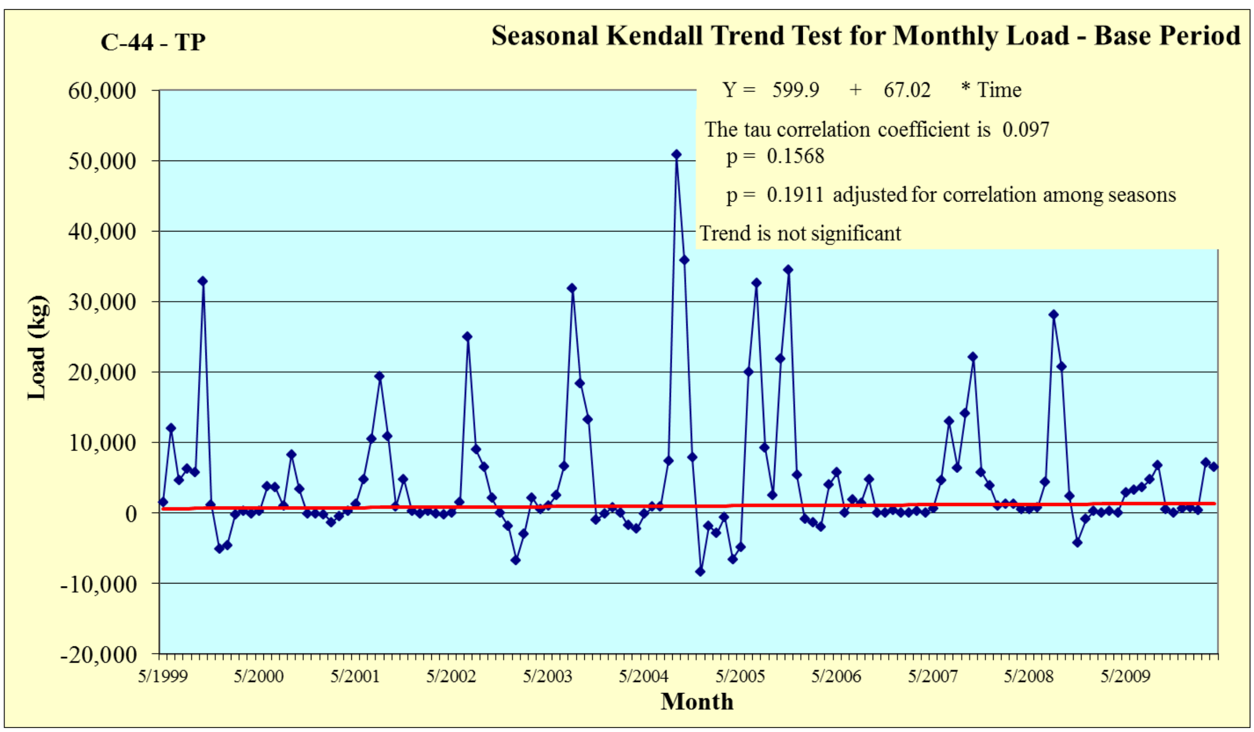


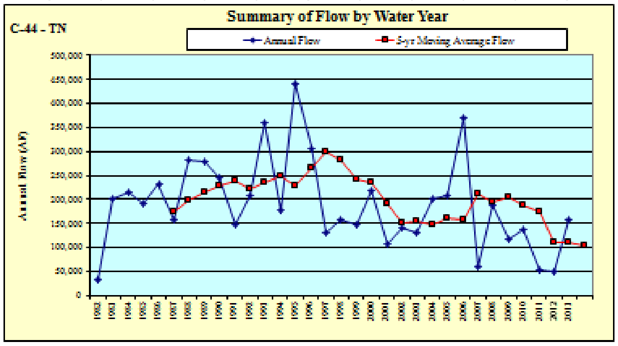


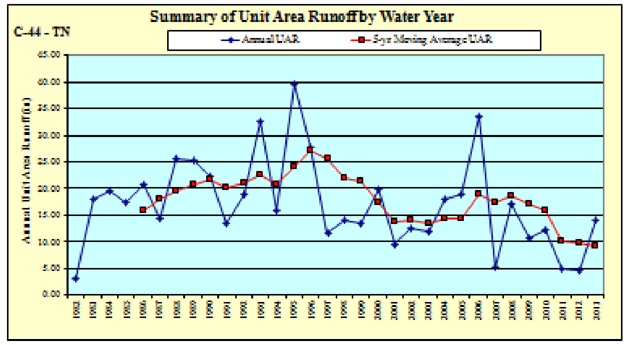


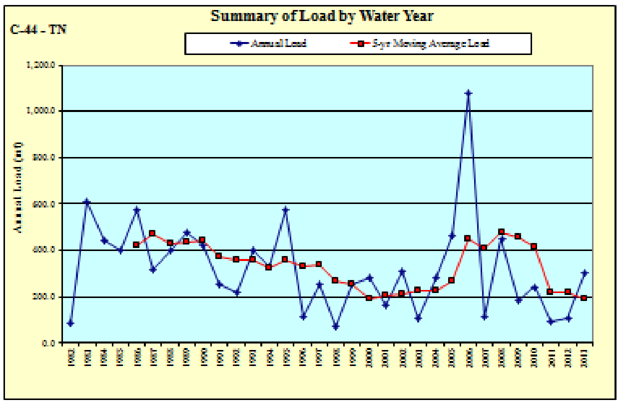


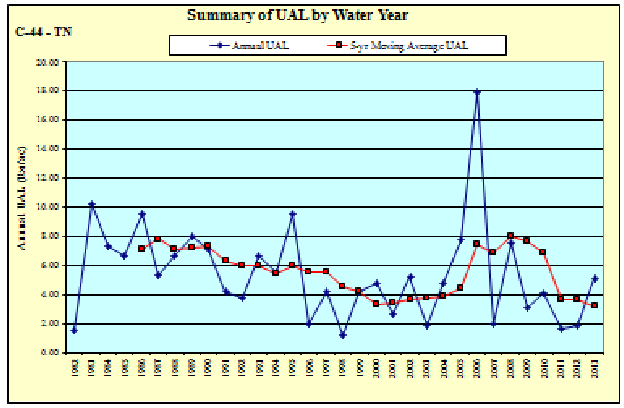

C-44 - TP
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 1509. + -7.947 * Time
The tau correlation coefficient is -0.030
p = 0.4047
p = 0.5714 adjusted for correlation among seasons
Trend is not significant
Load (kg)
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
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
Month

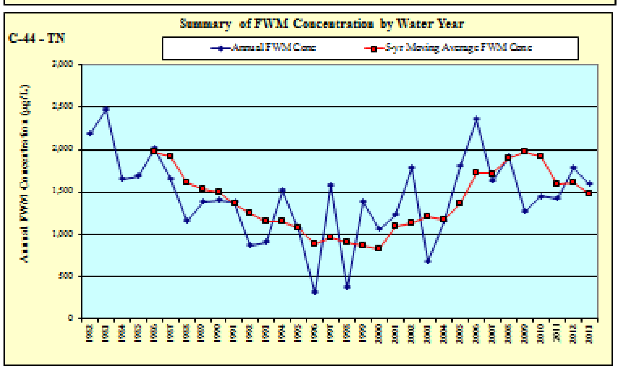

C-44 - TP
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 599.9 + 67.02 * Time
The tau correlation coefficient is 0.097
p = 0.1568
p = 0.1911 adjusted for correlation among seasons
Trend is not significant
Load (kg)
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
5/1999
5/2000
5/2001
5/2002
5/2003
5/2004
5/2005
5/2006
5/2007
5/2008
5/2009
Month

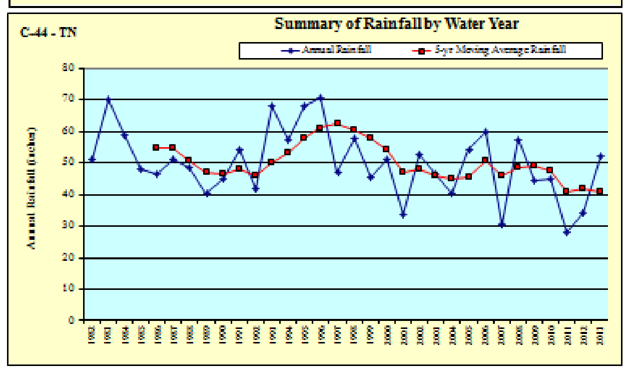

C-44 - TN
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

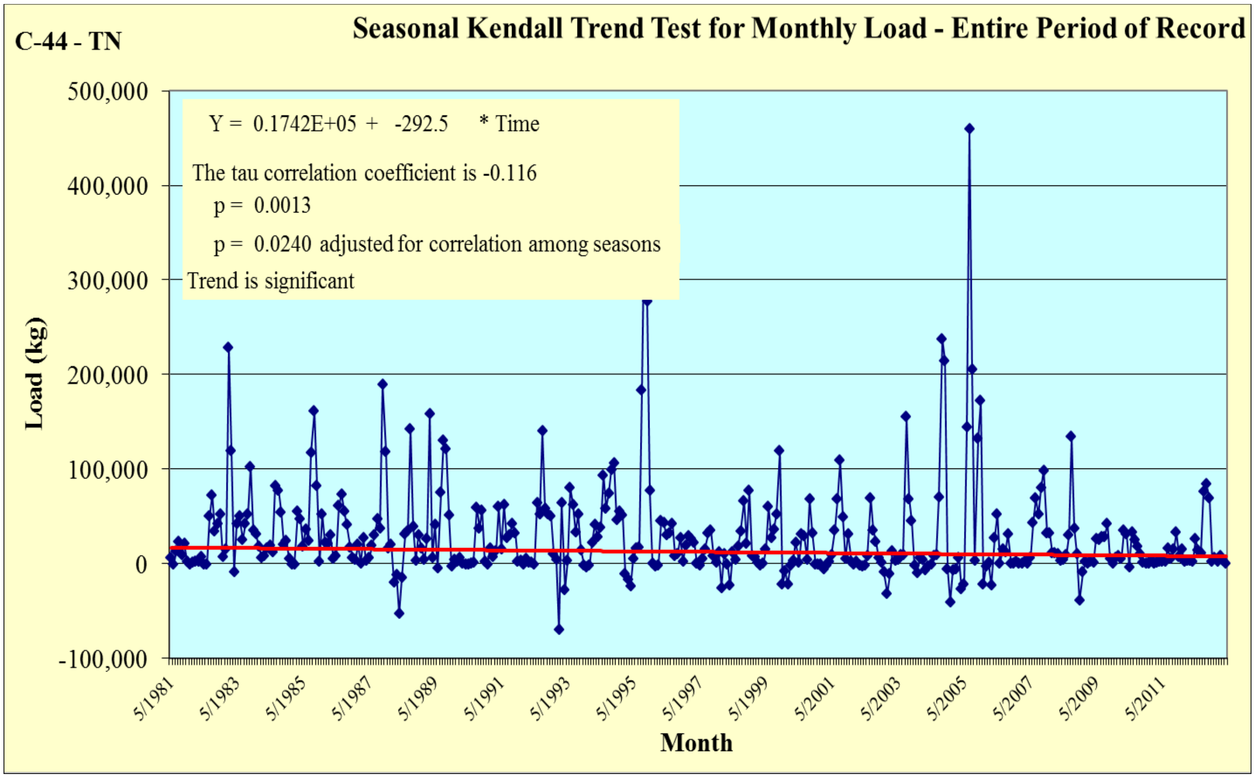

C-44 - TN
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in)

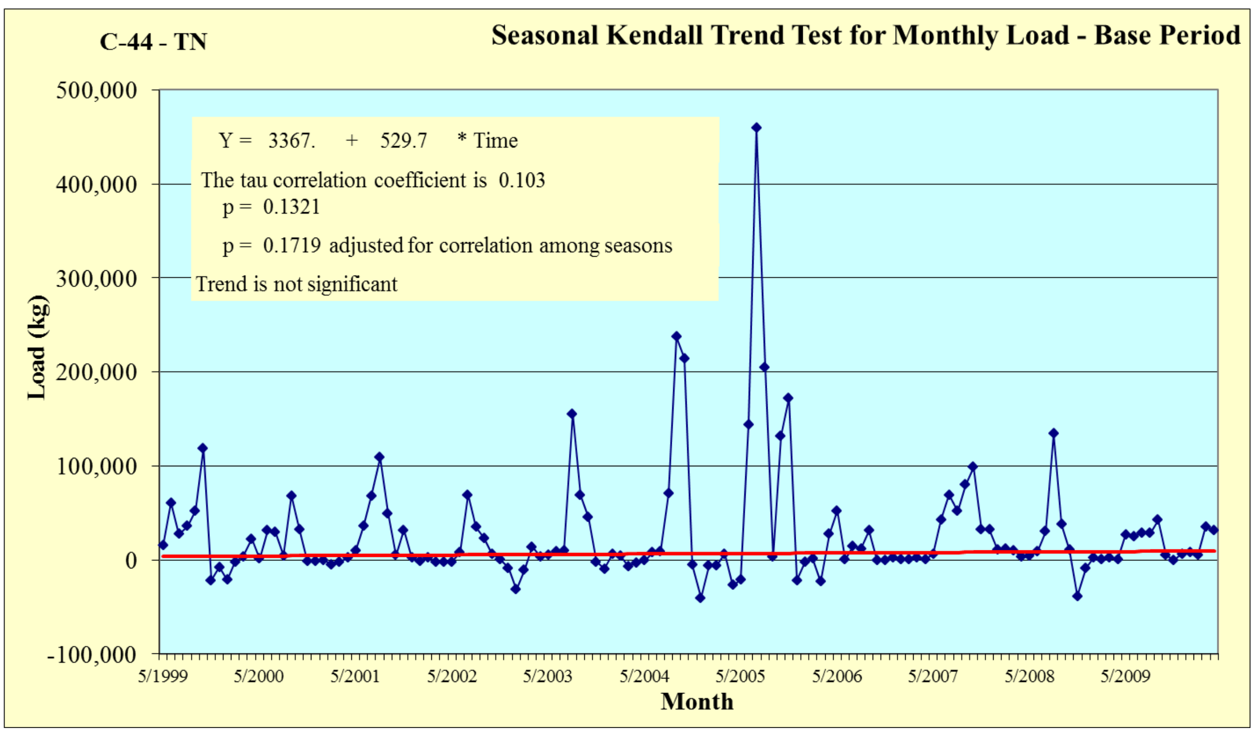

C-44 - TN
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)

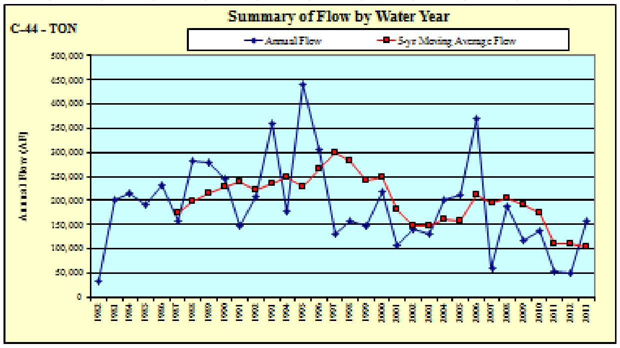

C-44 - TN
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)

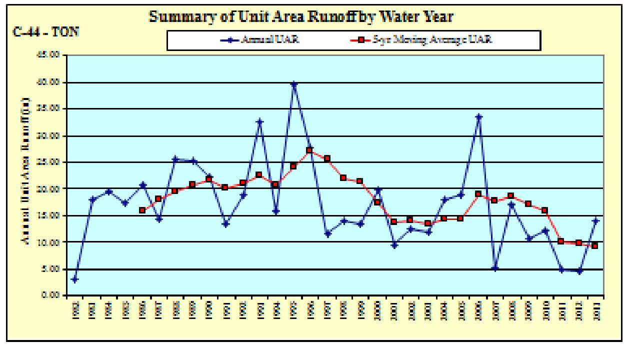

C-44 - TN
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)

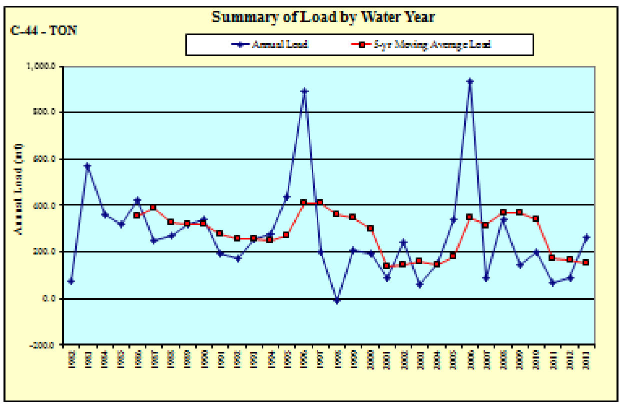

C-44 - TN
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

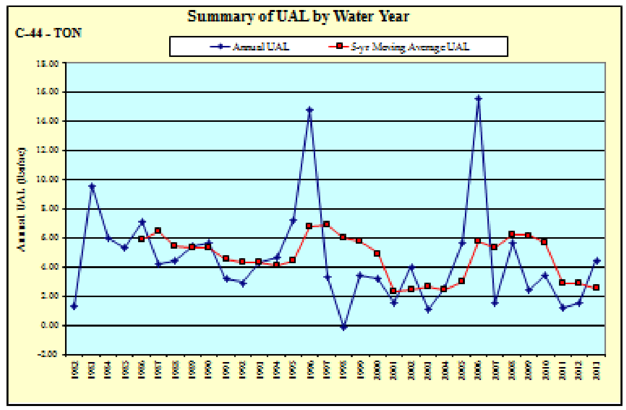

C-44 - TN
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 0.1742E+05 + -292.5 * Time
The tau correlation coefficient is -0.116
p = 0.0013
p = 0.0240 adjusted for correlation among seasons
Trend is significant
Load (kg)
500,000
400,000
300,000
200,000
100,000
0
-100,000
5/1981
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
Month

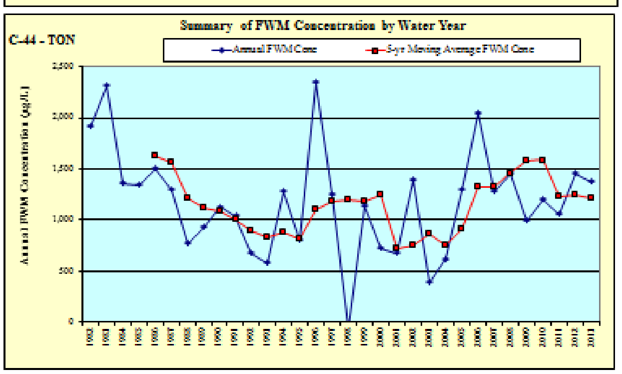

C-44 - TN
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 3367. + 529.7 * Time
The tau correlation coefficient is 0.103
p = 0.1321
p = 0.1719 adjusted for correlation among seasons
Trend is not significant
Load (kg)
500,000
400,000
300,000
200,000
100,000
0
-100,000
5/1999
5/2000
5/2001
5/2002
5/2003
5/2004
5/2005
5/2006
5/2007
5/2008
5/2009
Month

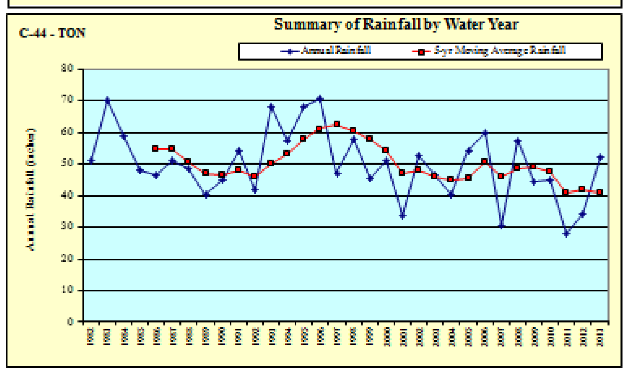

C-44 - TON
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

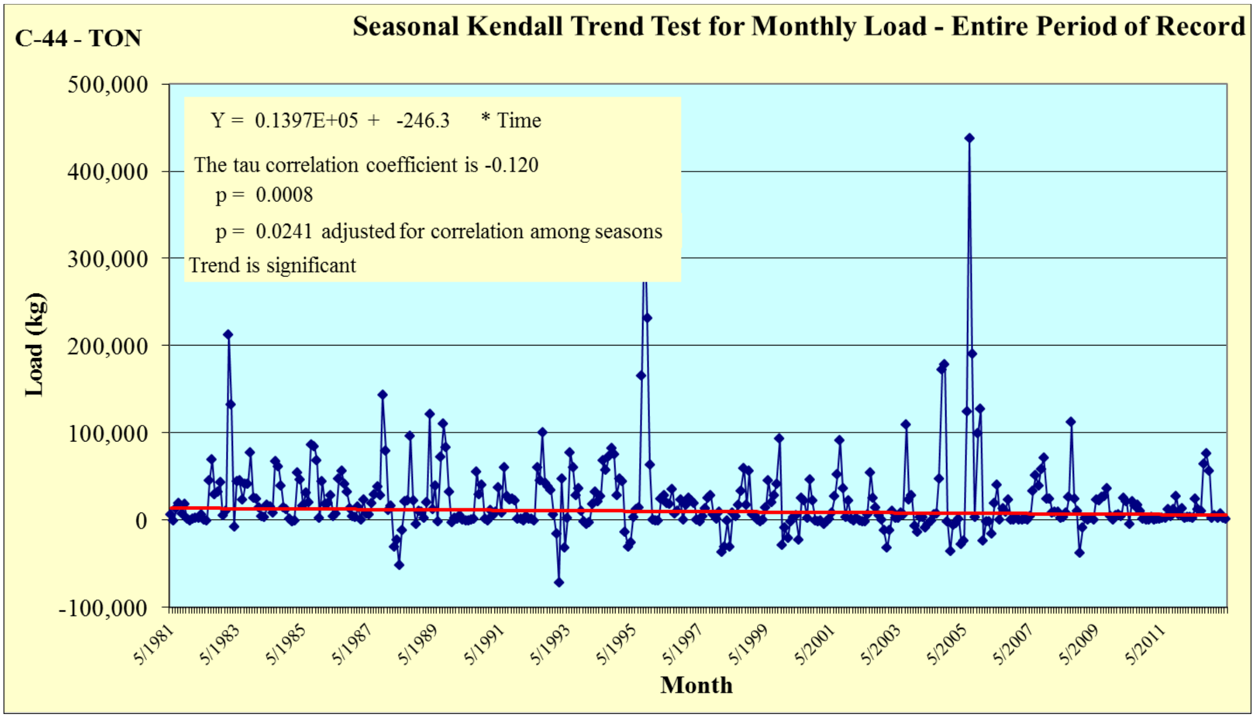

C-44 - TON
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in)

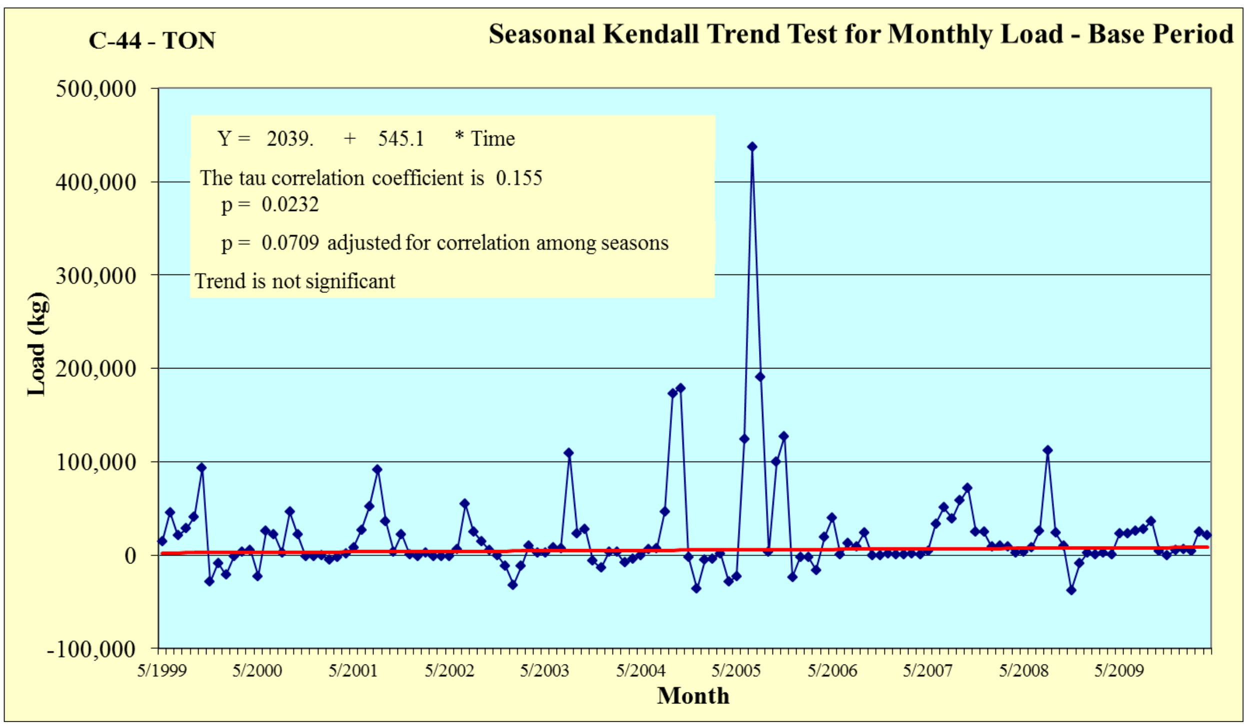

C-44 - TON
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load
Annual Load (mt)


C-44 - TON
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)


C-44 - TON
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)


C-44 - TON
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)


C-44 - TON
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 0.1397E+05 + -246.3 * Time
The tau correlation coefficient is -0.120
p = 0.0008
p = 0.0241 adjusted for correlation among seasons
Trend is significant
Load (kg)
500,000
400,000
300,000
200,000
100,000
0
-100,000
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
Month


C-44 - TON
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 2039. + 545.1 * Time
The tau correlation coefficient is 0.155
p = 0.0232
p = 0.0709 adjusted for correlation among seasons
Trend is not significant
Load (kg)
500,000
400,000
300,000
200,000
100,000
0
-100,000
5/1999
5/2000
5/2001
5/2002
5/2003
5/2004
5/2005
5/2006
5/2007
5/2008
5/2009
Month

Calculation of Net Basin Nutrient Loads for the C-44 Sub-watershed

C-44 Sub-watershed Unit Flows

$Q_{S\text{-}308In}$ = S-308 discharges from Lake Okeechobee to C-44
$Q_{S\text{-}308Out}$ = S-308 discharges C-44 to Lake Okeechobee
$Q_{S\text{-}80}$ = S-80 discharges from C-44 to St. Lucie Estuary
$I_{C\text{-}44}$ = total inflow to C-44
= $Q_{S\text{-}308In}$
$O_{C\text{-}44}$ = total outflow from C-44
= $Q_{S\text{-}308Out} + Q_{S\text{-}80}$
$PT_{C\text{-}44}$ = pass-through flow for C-44
= minimum $(I_{C\text{-}44}, O_{C\text{-}44})$
$B_{C\text{-}44}$ = net basin flow produced by local rainfall and runoff
= $O_{C\text{-}44} – PT_{C\text{-}44}$

C-44 Sub-watershed Loads

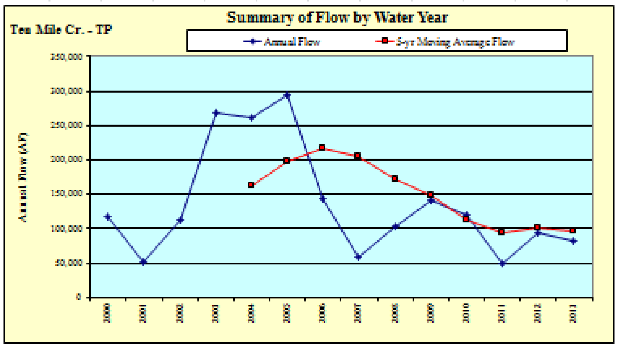
C_{In} = total inflow concentration
= total inflow load to C-44 / total inflow to C-44
= $(Q_{S\text{-}308In} * C_{S\text{-}308In}) / I_{C\text{-}44}$
$PTL_{C\text{-}44}$ = pass-through load for C-44
= $PT_{C\text{-}44} * C_{In}$
$C_{S\text{-}80}$ = S-80 concentration
$C_{S\text{-}308}$ = S-308 concentration
$OL_{C\text{-}44}$ = total outflow load from C-44
= $(Q_{S\text{-}80} * C_{S\text{-}80}) + (Q_{S\text{-}308Out} * C_{S\text{-}308})$
$BL_{C\text{-}44}$ = net basin load produced by local rainfall and runoff
= $OL_{C\text{-}44} – PTL_{C\text{-}44}$

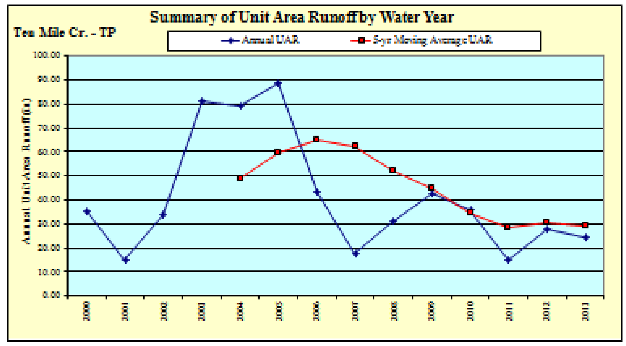
Comments:

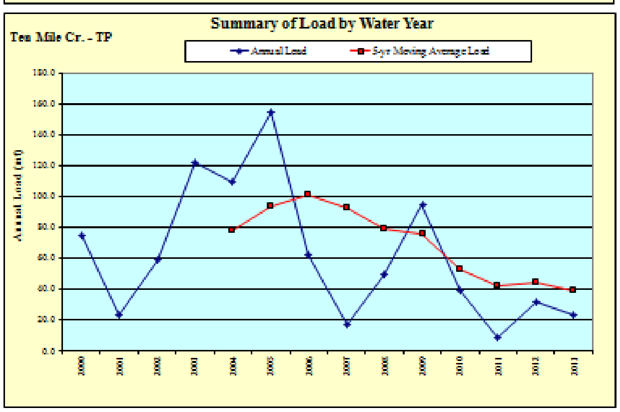
- The outflow concentration at S-308 to Lake Okeechobee ($C_{\mathbf{S\text{-}308}}$) should be the grab concentrations at S-308C, as these reflect discharges from the C-44 into the lake.
- However, the inflow concentrations at S-308 from Lake Okeechobee into the C-44 are the autosampler concentrations at S308C based on meeting with Cheol Mo on August 27, 2010.

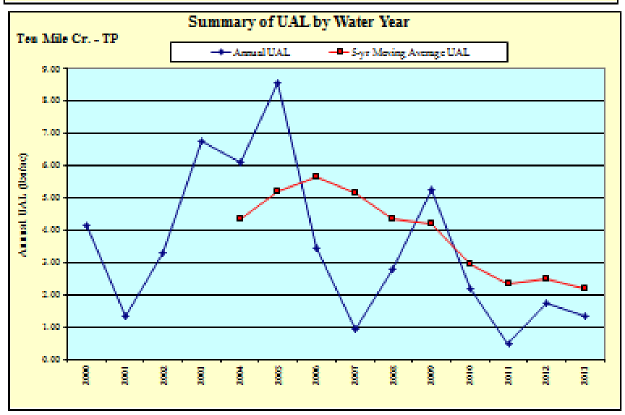
TEN MILE CREEK BASIN

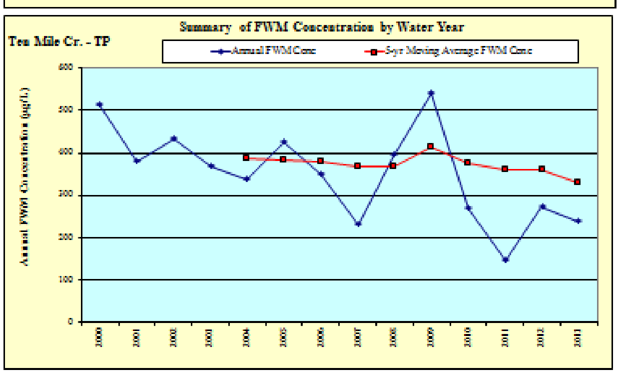
Annual Flow and Nutrient Levels

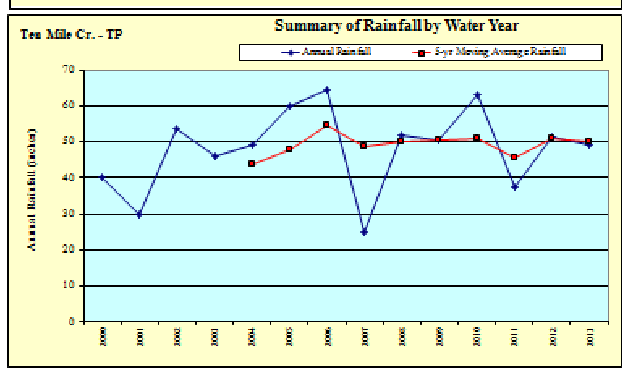


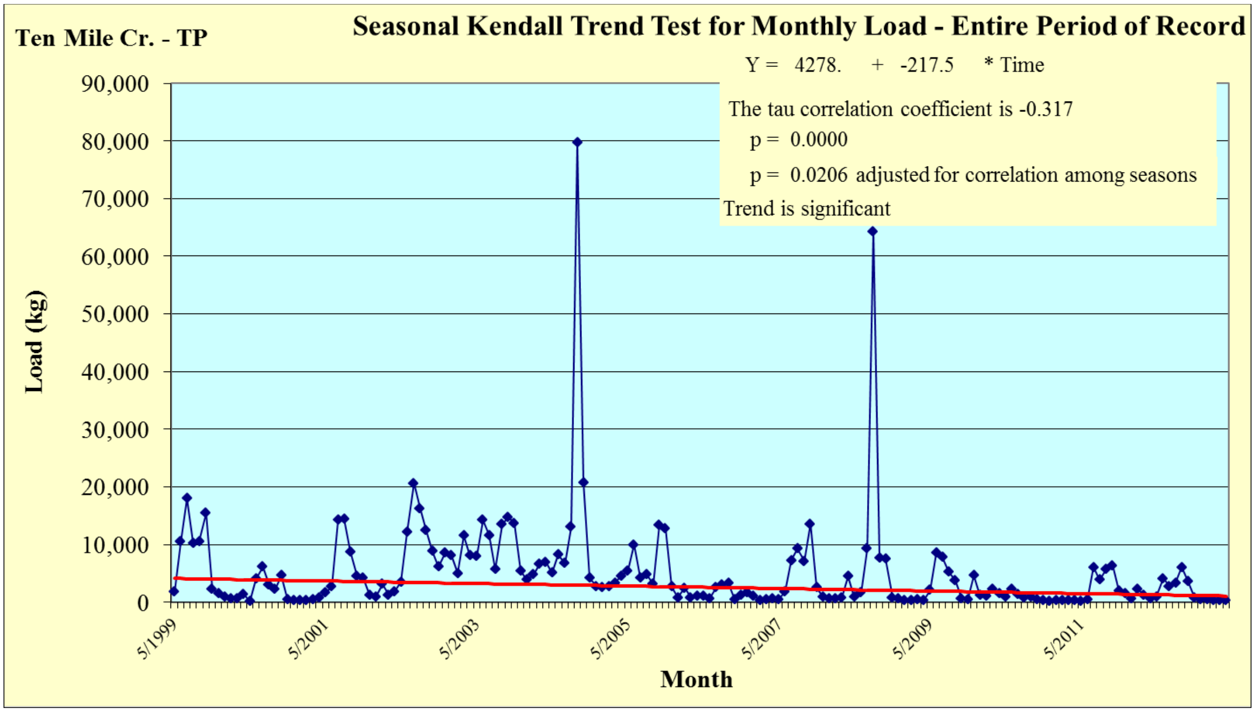


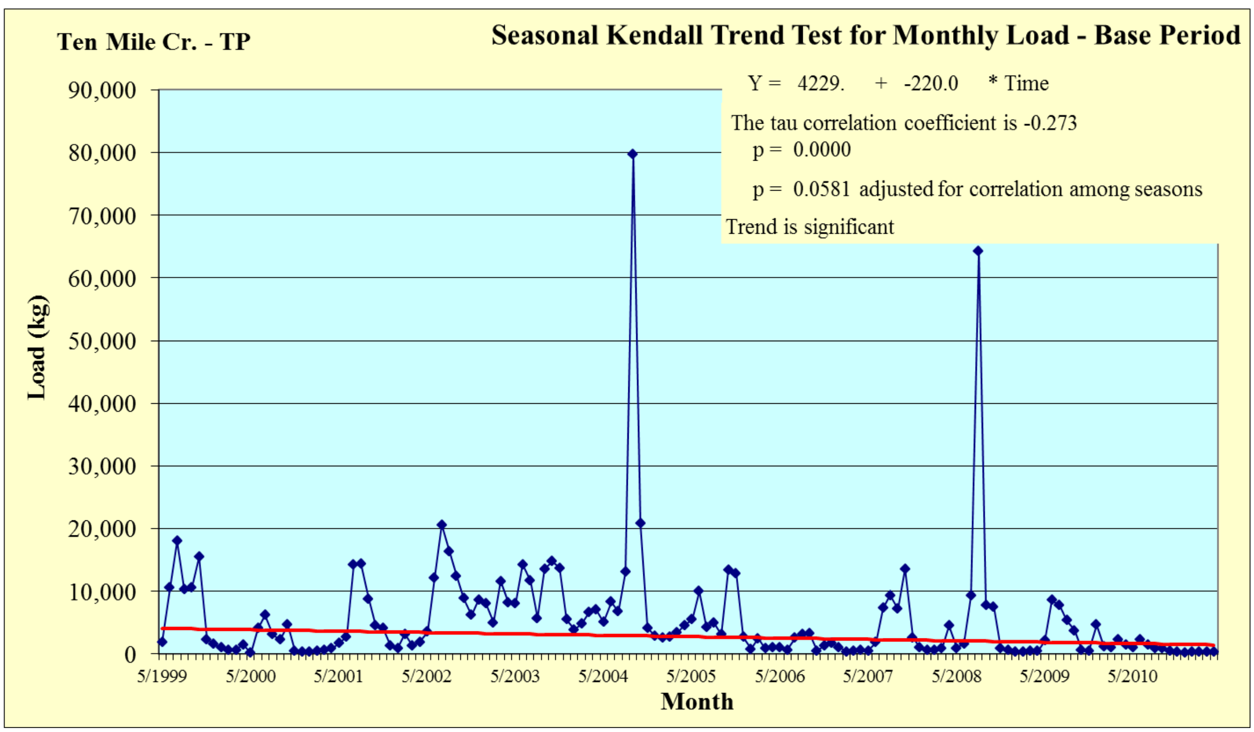


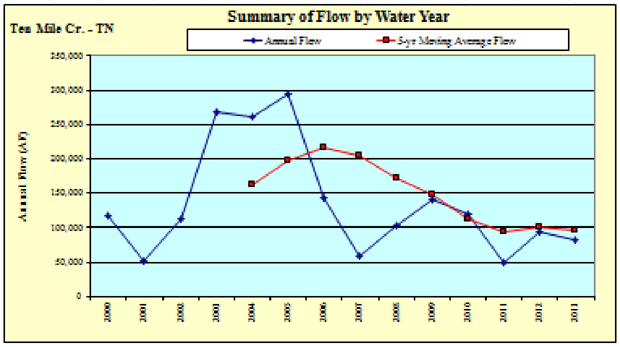


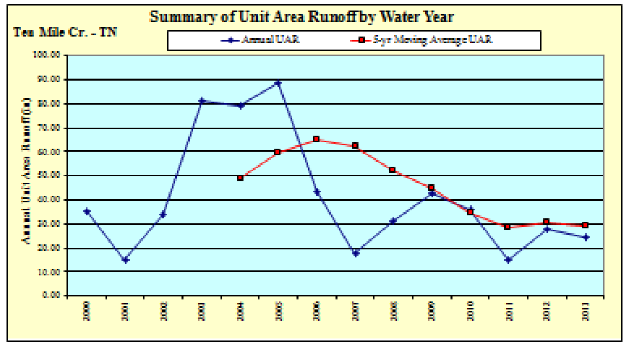


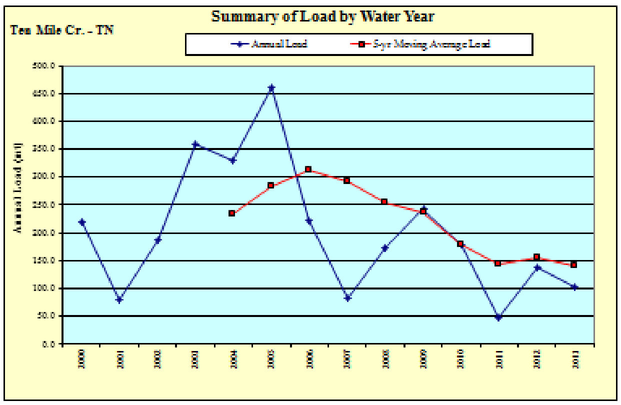


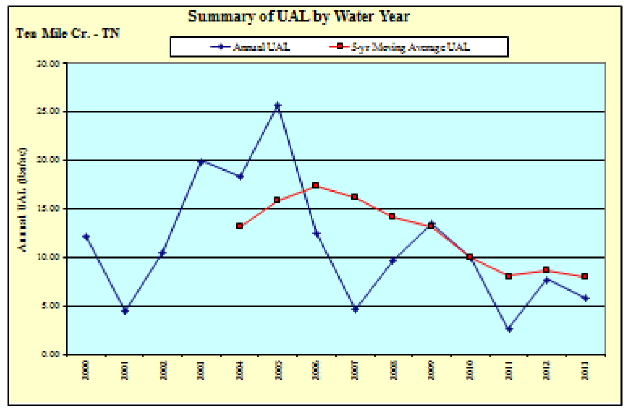

Ten Mile Cr. - TP
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 4278. + -217.5 * Time
The tau correlation coefficient is -0.317
p = 0.0000
p = 0.0206 adjusted for correlation among seasons
Trend is significant
Load (kg)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
5/1999
5/2001
5/2003
5/2005
5/2007
5/2009
5/2011
Month

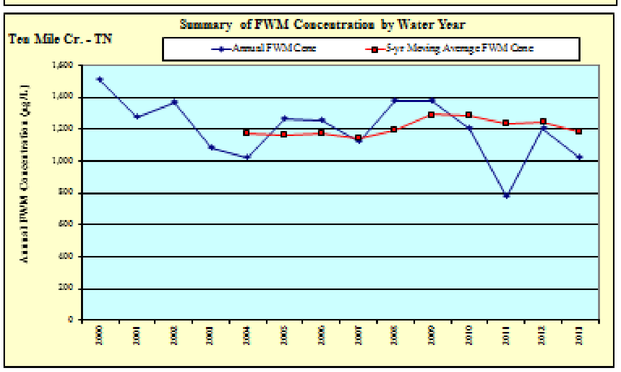

Ten Mile Cr. - TP
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 4229. + -220.0 * Time
The tau correlation coefficient is -0.273
p = 0.0000
p = 0.0581 adjusted for correlation among seasons
Trend is significant
Load (kg)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
5/1999
5/2000
5/2001
5/2002
5/2003
5/2004
5/2005
5/2006
5/2007
5/2008
5/2009
5/2010
Month

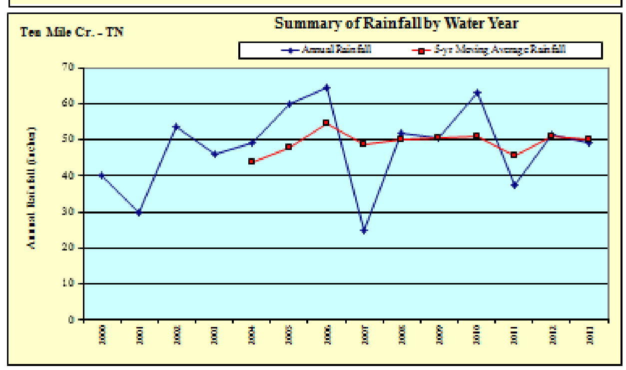

Summary of Flow by Water Year
Ten Mile Cr. - TN
Annual Flow
5-yr Moving Average Flow
Annual Flow (AF)

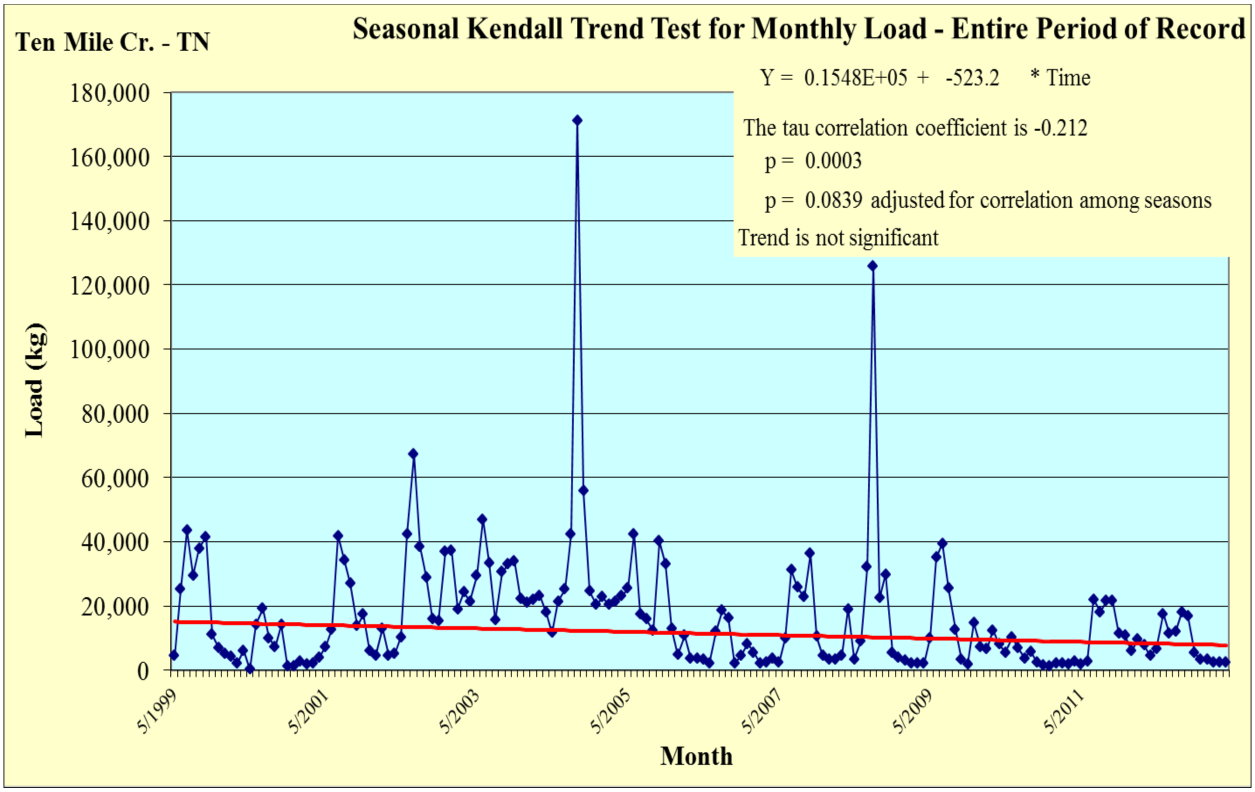

Summary of Unit Area Runoff by Water Year
Ten Mile Cr. - TN
Annual UAR
5-yr Moving Average UAR
Annual Unit Area Runoff (in)

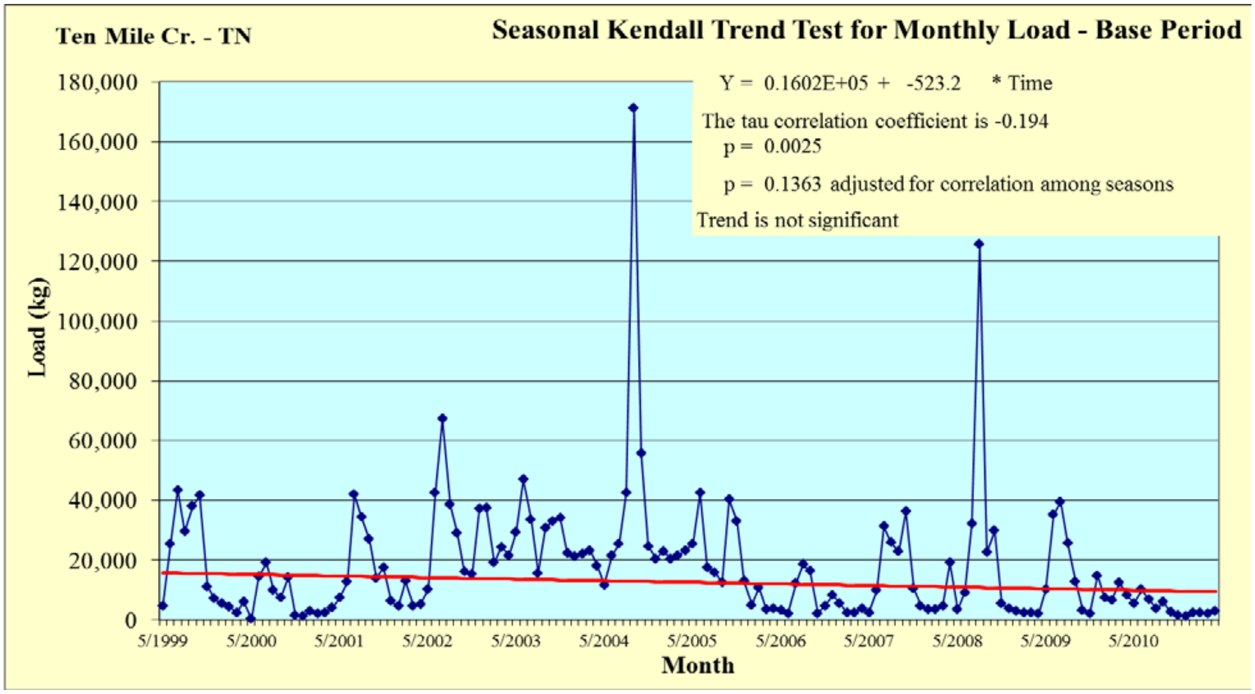

Summary of Load by Water Year
Ten Mile Cr. - TN
Annual Load
5-yr Moving Average Load
Annual Load (mt)

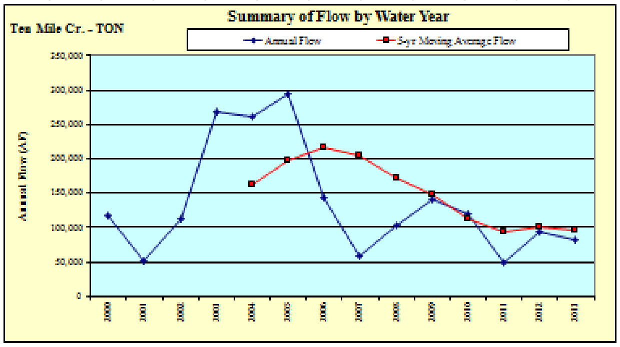

Summary of UAL by Water Year
Ten Mile Cr. - TN
Annual UAL
5-yr Moving Average UAL
Annual UAL (lbs/ac)

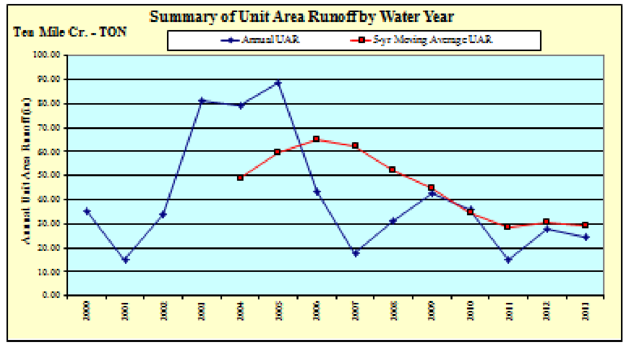

Summary of FWM Concentration by Water Year
Ten Mile Cr. - TN
Annual FWM Conc
5-yr Moving Average FWM Conc
Annual FWM Concentration (µg/L)

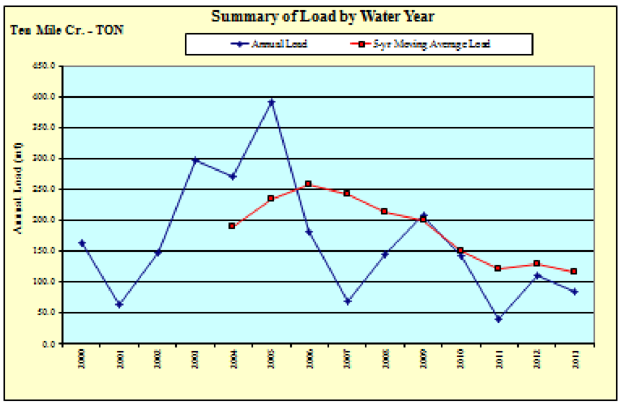

Summary of Rainfall by Water Year
Ten Mile Cr. - TN
Annual Rainfall
5-yr Moving Average Rainfall
Annual Rainfall (inches)

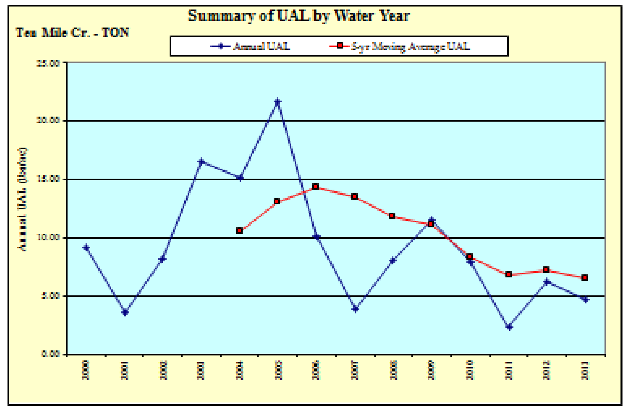

Ten Mile Cr. - TN
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 0.1548E+05 + -523.2 * Time
The tau correlation coefficient is -0.212
p = 0.0003
p = 0.0839 adjusted for correlation among seasons
Trend is not significant
Load (kg)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1999
5/2001
5/2003
5/2005
5/2007
5/2009
5/2011
Month

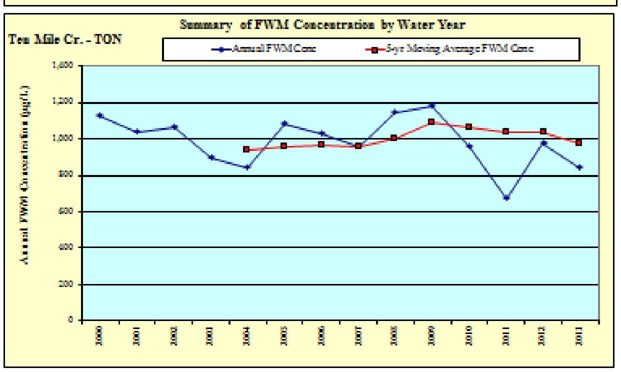

Ten Mile Cr. - TN
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 0.1602E+05 + -523.2 * Time
The tau correlation coefficient is -0.194
p = 0.0025
p = 0.1363 adjusted for correlation among seasons
Trend is not significant
Load (kg)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1999
5/2000
5/2001
5/2002
5/2003
5/2004
5/2005
5/2006
5/2007
5/2008
5/2009
5/2010
Month

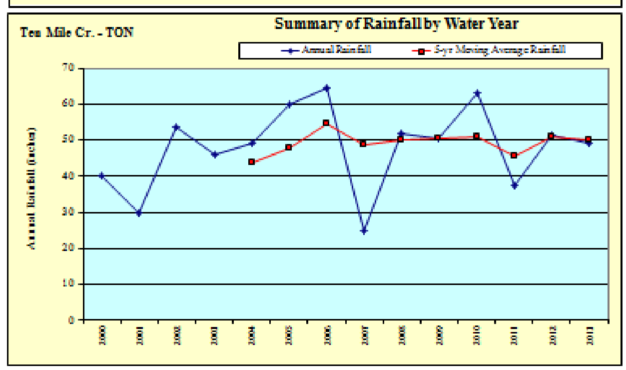

Ten Mile Cr. - TON
Summary of Flow by Water Year
Annual Flow
5-yr Moving Average Flow

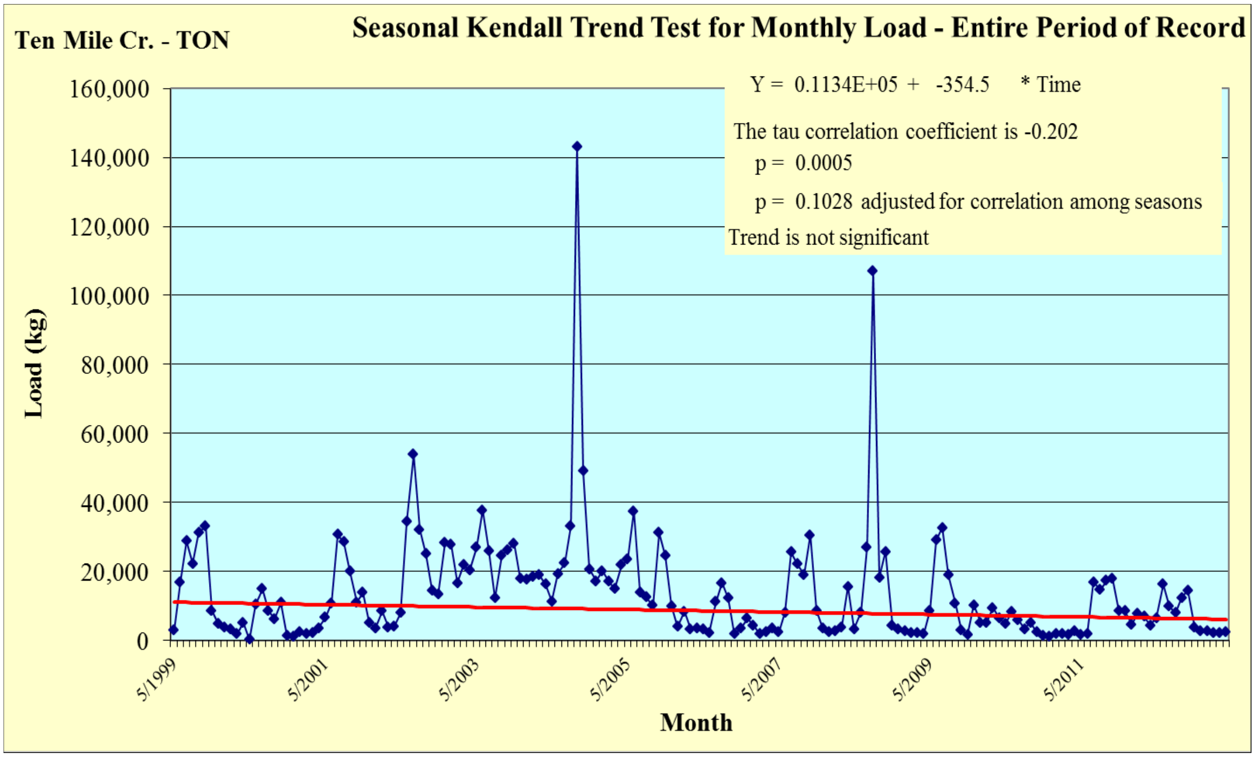

Ten Mile Cr. - TON
Summary of Unit Area Runoff by Water Year
Annual UAR
5-yr Moving Average UAR

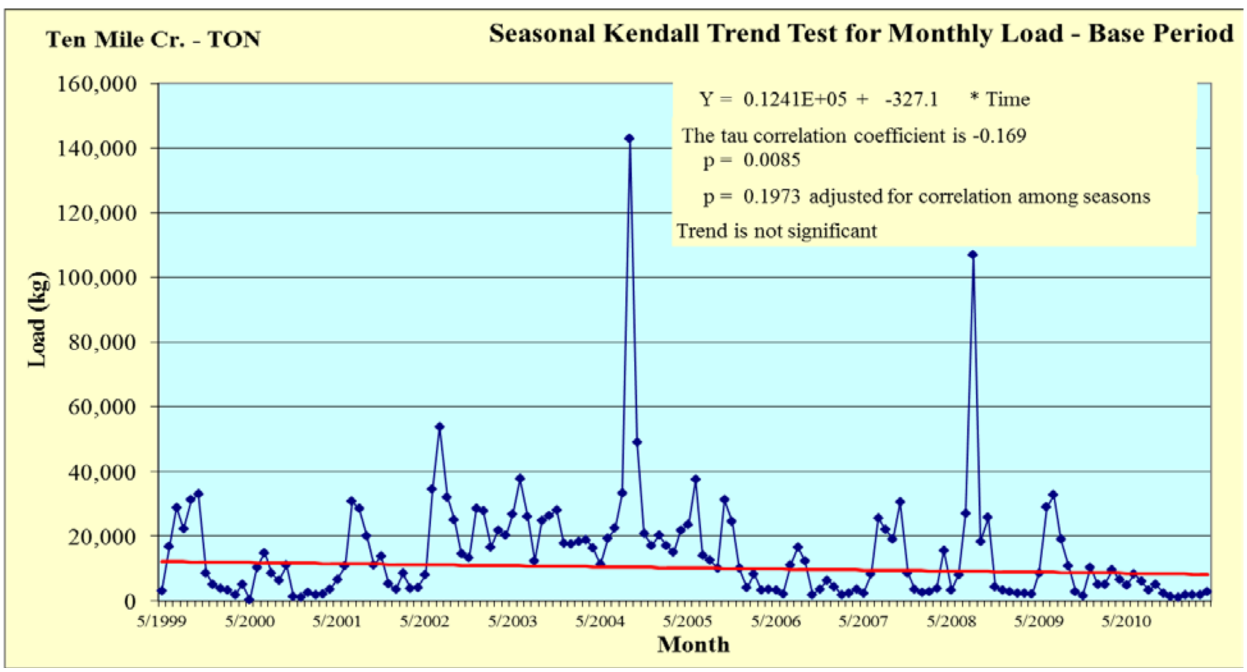

Ten Mile Cr. - TON
Summary of Load by Water Year
Annual Load
5-yr Moving Average Load


Ten Mile Cr. - TON
Summary of UAL by Water Year
Annual UAL
5-yr Moving Average UAL

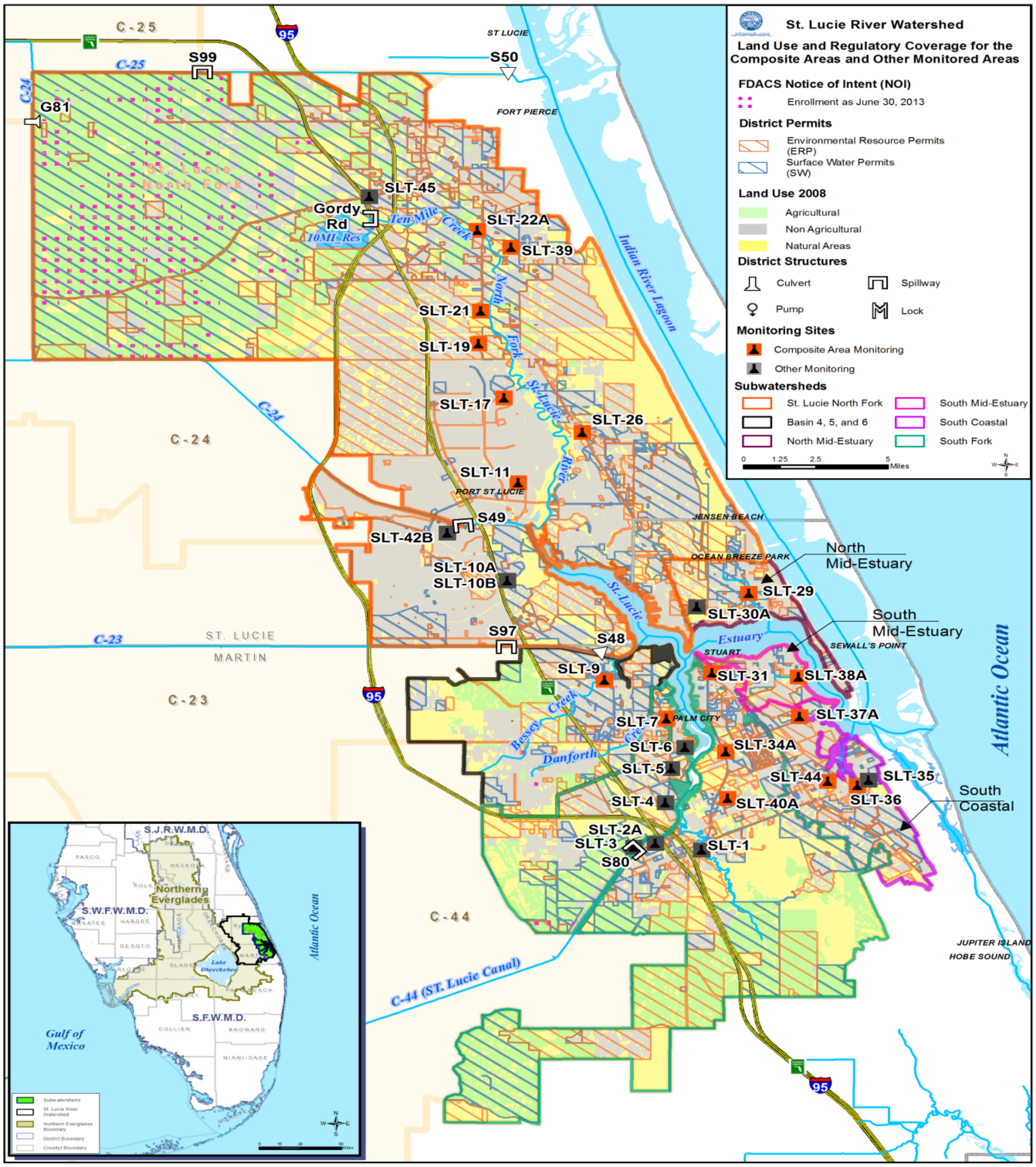

Ten Mile Cr. - TON
Summary of FWM Concentration by Water Year
Annual FWM Conc
5-yr Moving Average FWM Conc


Ten Mile Cr. - TON
Summary of Rainfall by Water Year
Annual Rainfall
5-yr Moving Average Rainfall

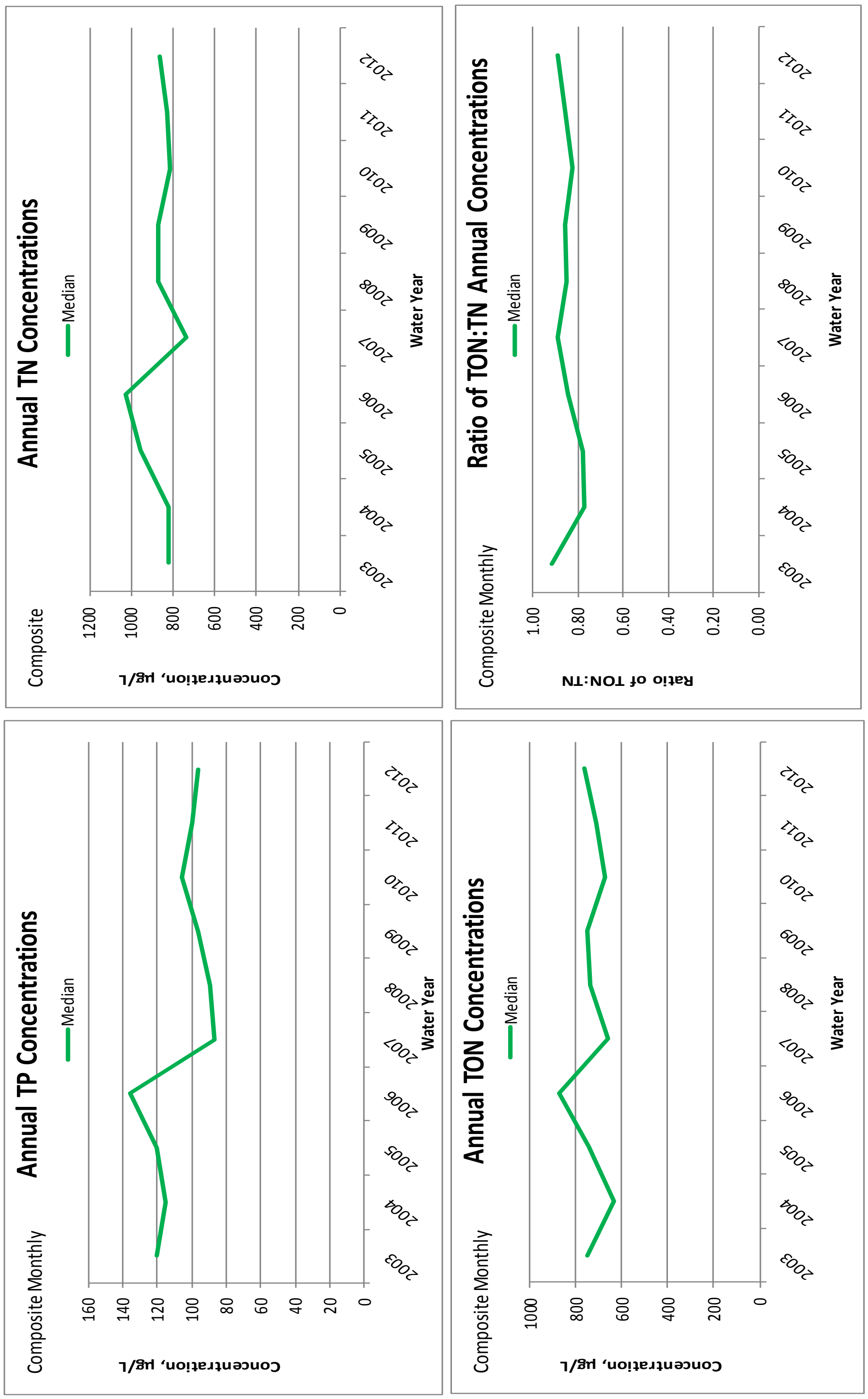

Ten Mile Cr. - TON
Seasonal Kendall Trend Test for Monthly Load - Entire Period of Record
Y = 0.1134E+05 + -354.5 * Time
The tau correlation coefficient is -0.202
p = 0.0005
p = 0.1028 adjusted for correlation among seasons
Trend is not significant
Load (kg)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1999
5/2001
5/2003
5/2005
5/2007
5/2009
5/2011
Month

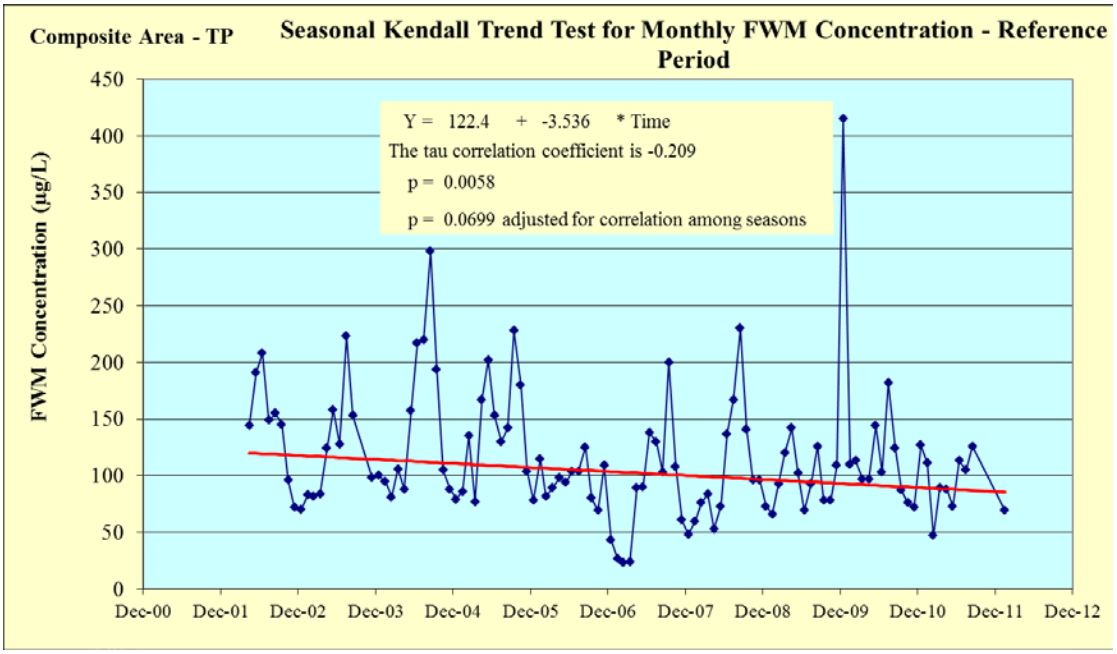

Ten Mile Cr. - TON
Seasonal Kendall Trend Test for Monthly Load - Base Period
Y = 0.1241E+05 + -327.1 * Time
The tau correlation coefficient is -0.169
p = 0.0085
p = 0.1973 adjusted for correlation among seasons
Trend is not significant
Load (kg)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5/1999
5/2000
5/2001
5/2002
5/2003
5/2004
5/2005
5/2006
5/2007
5/2008
5/2009
5/2010
Month

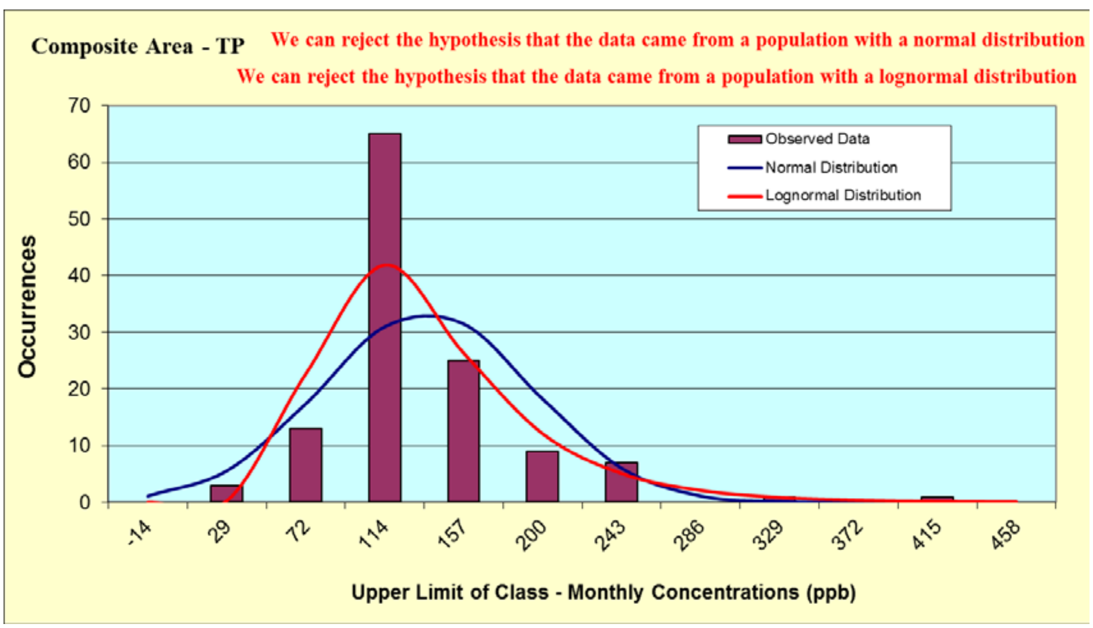
COMPOSITE AREA
Land Use Map (from District 2012)

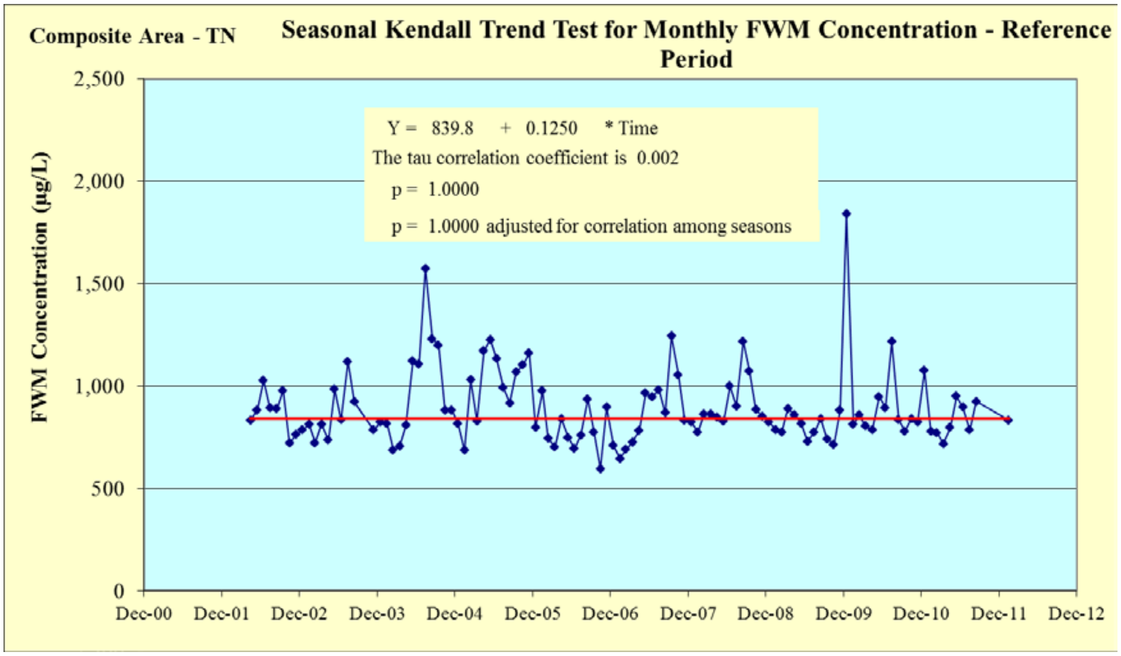


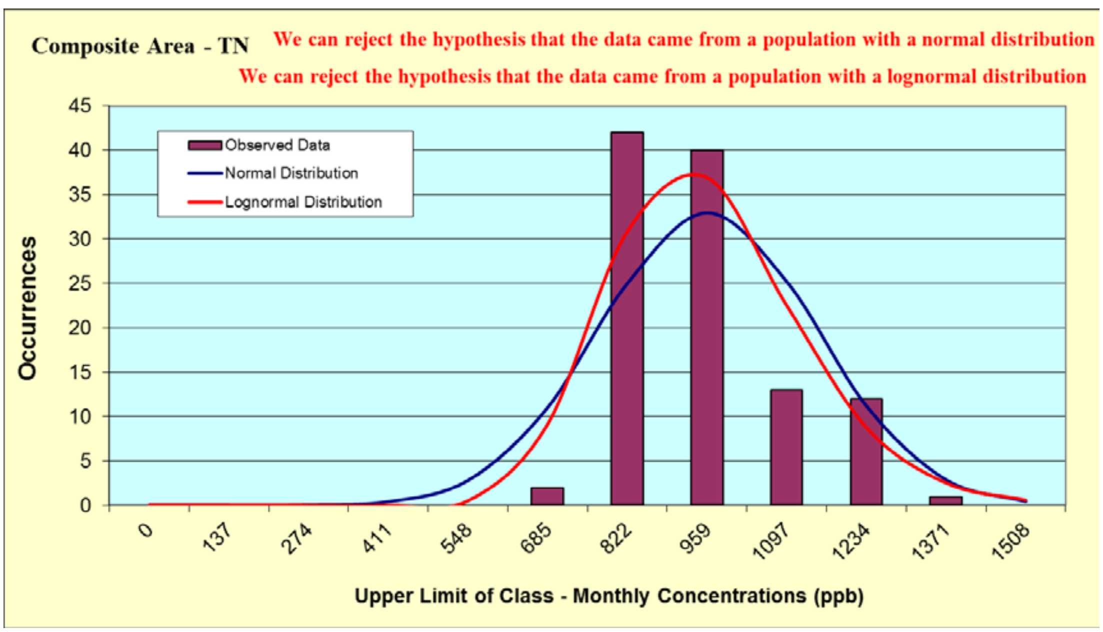
Annual summaries of Composite Area composite concentrations.

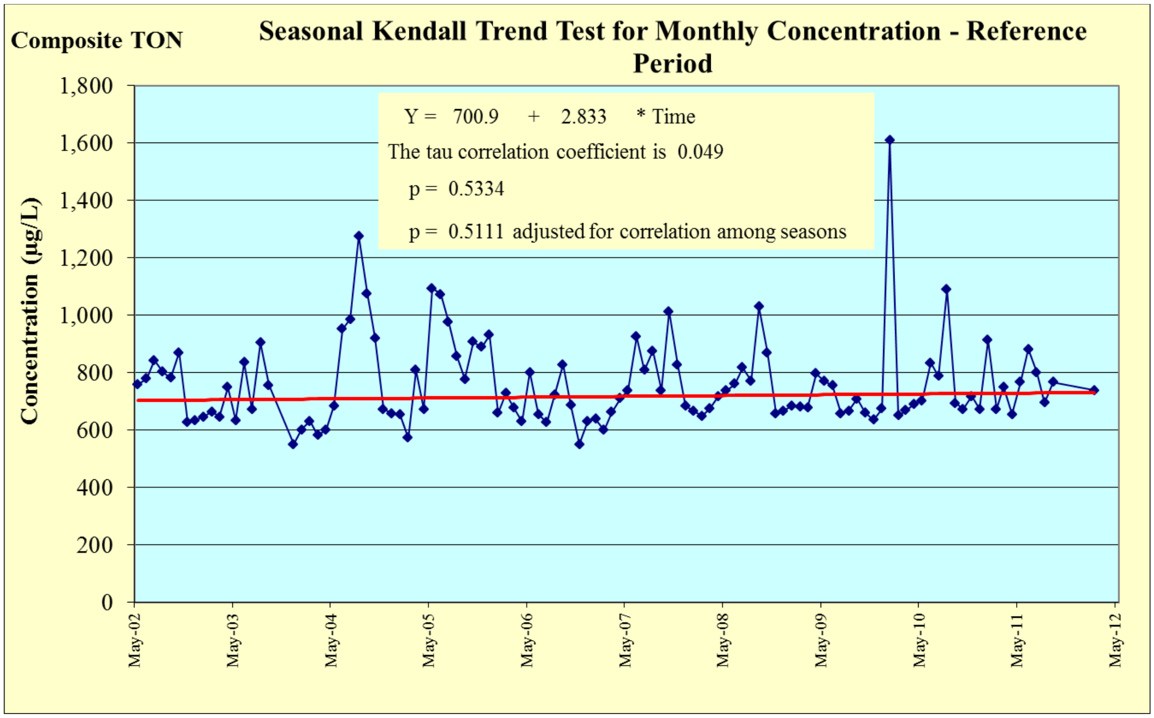



Composite Area - TP
Seasonal Kendall Trend Test for Monthly FWM Concentration - Reference Period
Y = 122.4 + -3.536 * Time
The tau correlation coefficient is -0.209
p = 0.0058
p = 0.0699 adjusted for correlation among seasons
FWM Concentration (µg/L)
450
400
350
300
250
200
150
100
50
0
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Dec-08
Dec-09
Dec-10
Dec-11
Dec-12


Composite Area - TP
We can reject the hypothesis that the data came from a population with a normal distribution
We can reject the hypothesis that the data came from a population with a lognormal distribution
Observed Data
Normal Distribution
Lognormal Distribution
Occurrences
70
60
50
40
30
20
10
0
-14
29
72
114
157
200
243
286
329
372
415
458
Upper Limit of Class - Monthly Concentrations (ppb)


Composite Area - TN
Seasonal Kendall Trend Test for Monthly FWM Concentration - Reference Period
Y = 839.8 + 0.1250 * Time
The tau correlation coefficient is 0.002
p = 1.0000
p = 1.0000 adjusted for correlation among seasons
FWM Concentration (µg/L)
2,500
2,000
1,500
1,000
500
0
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Dec-08
Dec-09
Dec-10
Dec-11
Dec-12


Composite Area - TN
We can reject the hypothesis that the data came from a population with a normal distribution
We can reject the hypothesis that the data came from a population with a lognormal distribution
Observed Data
Normal Distribution
Lognormal Distribution
Occurrences
45
40
35
30
25
20
15
10
5
0
0
137
274
411
548
685
822
959
1097
1234
1371
1508
Upper Limit of Class - Monthly Concentrations (ppb)



Composite Area

Water Year	TP				TN				TON			
	# 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
2003	12	123	120	115	12	843	823	838	12	733	754	728
2004	10	127	115	121	10	841	820	832	10	676	632	668
2005	12	145	120	131	12	1014	956	988	12	828	747	804
2006	12	139	136	131	12	999	1030	984	12	850	873	836
2007	12	75	87	64	12	751	738	745	12	676	658	671
2008	12	99	90	92	12	916	867	908	12	776	738	769
2009	12	112	96	103	12	907	869	899	12	763	749	756
2010	12	128	106	112	12	889	815	858	12	762	671	735
2011	12	105	100	99	12	872	830	862	12	763	710	755
2012	6	96	97	93	6	864	864	861	6	775	767	773
2013	12	92	82	89	12	842	813	834	12	722	699	715
WY2003-2012 Monthly Median			103				841				717	

Five Mile Creek

Water Year	TP				TN				TON				
	# 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	Coef of Variation	Median µg/L	Geometric Mean, µg/L
2003	12	239	185	204	12	865	869	835	12	728	0.25	715	706
2004	10	209	176	191	10	824	620	754	10	626	0.41	525	585
2005	10	224	164	190	10	900	756	824	10	662	0.39	614	620
2006	12	208	189	195	12	1030	945	992	12	846	0.26	810	822
2007	7	158	152	155	7	648	577	630	7	577	0.23	556	563
2008	6	181	153	161	6	729	592	685	6	594	0.30	548	576
2009	9	190	149	166	9	769	702	742	9	625	0.32	549	603
2010	11	255	146	185	10	1058	652	830	10	896	1.15	527	676
2011	9	133	127	131	9	669	637	656	8	575	0.20	556	565
2012	4	95	94	87	4	601	565	589	4	575	0.24	542	563
2013	11	131	125	127	11	765	746	754	11	650	0.12	650	646
POR Annual Average	9	184	151	163	9	805	696	754	9	668	0.35	599	630
WY2003-2012 monthly median		200	150	172		841	721	772		691	0.57	596	640

Platts Creek

Water Year	TP				TN				TON			
	# 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
2004	10	218	219	215	10	913	875	896	10	541	501	528
2005	12	229	205	223	12	932	945	893	12	597	532	554
2006	12	335	181	252	12	1417	968	1149	12	1155	718	885
2007	5	195	195	194	5	561	556	554	5	421	391	417
2008	3	188	177	187	3	1017	1124	984	3	738	811	710
2009	8	209	182	184	8	1065	909	964	8	836	668	755
2010	9	177	159	169	8	645	647	632	8	478	485	475
2011	9	228	234	224	9	677	641	671	9	460	415	444
2012	4	240	222	234	2	779	779	768	2	565	565	554
2013	11	163	165	161	10	885	917	861	10	605	573	583
POR Annual Average	8	218	194	204	8	889	836	837	8	639	566	590
WY2004-2012 monthly median		233	195	211		935	810	842		674	512	585

C-105

Water Year	TP				TN				TON			
	# 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
2003	12	50	40	43	12	883	813	854	12	858	791	828
2004	10	32	31	29	10	748	781	726	10	725	762	704
2005	11	44	42	39	11	803	816	777	11	777	800	751
2006	12	46	43	44	12	850	848	848	12	825	819	822
2007	11	40	28	36	11	859	837	850	11	825	821	817
2008	12	47	38	43	12	897	917	887	12	844	872	837
2009	12	60	59	55	11	862	837	855	11	829	807	820
2010	11	28	25	26	11	808	818	797	10	791	809	780
2011	8	27	26	26	8	810	833	806	8	794	814	790
2012	5	23	19	22	4	880	869	876	4	855	839	852
2013	12	27	23	24	12	752	744	750	12	733	729	731
POR Annual Average	11	38	34	35	10	832	828	821	10	805	806	794
WY2003-2012 monthly median		41	37	37		840	831	826		812	805	798

C-107

Water Year	TP				TN				TON			
	# 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
2003	12	52	36	42	12	761	792	755	12	733	749	728
2004	10	57	39	43	10	779	765	763	10	731	732	718
2005	12	61	43	49	12	939	796	900	12	860	725	832
2006	12	47	47	43	12	777	766	772	12	710	681	707
2007	11	45	40	43	11	864	821	850	11	806	801	793
2008	12	57	40	49	12	877	868	855	12	826	804	808
2009	12	42	34	38	11	786	734	769	11	746	711	734
2010	12	39	35	36	12	760	753	749	11	730	747	719
2011	12	28	27	28	12	754	712	748	12	719	696	715
2012	5	34	26	32	5	790	760	779	5	751	742	744
2013	11	46	23	34	11	785	705	766	11	738	687	727
POR Annual Average	11	46	35	40	11	806	770	791	11	759	734	748
WY2003-2012 monthly median		47	36	40		810	771	793		762	726	749

PSL Ditch 6

Water Year	TP				TN				TON			
	# 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
2003	8	122	114	118	8	792	745	781	8	700	693	694
2004	10	176	156	161	10	721	751	707	10	619	670	609
2005	10	144	112	115	10	993	794	932	10	854	687	805
2006	11	89	84	85	11	841	816	825	11	754	739	742
2007	5	145	123	136	5	966	955	948	5	895	844	877
2008	8	106	96	87	8	831	781	785	8	694	617	664
2009	11	110	91	89	10	794	730	775	10	680	660	671
2010	11	97	82	82	11	886	818	845	11	776	787	737
2011	5	60	63	59	5	657	671	656	5	613	628	612
2012	6	79	59	70	6	747	680	729	6	667	668	662
2013	12	62	57	60	12	714	693	703	12	614	598	608
POR Annual Average	9	108	94	97	9	813	767	789	9	715	690	698
WY2003-2012 monthly median		115	95	98		829	768	799		727	683	704

Hog Pen Slough

Water Year	TP				TN				TON			
	# 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
2003	12	74	53	64	12	754	729	747	12	655	605	648
2004	10	76	59	68	10	750	746	745	10	644	649	640
2005	10	96	68	80	10	1066	852	968	10	946	708	836
2006	12	61	55	59	12	857	845	844	12	752	711	740
2007	7	50	48	48	7	727	692	717	7	651	609	640
2008	9	58	52	56	8	922	886	913	8	754	684	746
2009	11	59	57	55	11	913	909	901	11	778	741	764
2010	10	60	57	60	10	747	750	746	9	639	641	638
2011	11	94	63	77	11	1095	878	1013	11	976	749	888
2012	4	51	51	50	4	747	709	741	4	645	623	639
2013	9	54	51	52	9	880	838	872	9	729	667	716
POR Annual Average	10	67	56	61	9	860	803	837	9	743	671	718
WY2003-2012 monthly median		70	57	62		869	804	836		755	682	722

Elkcam Waterway

Water Year	TP				TN				TON			
	# 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
2003	12	78	69	72	12	843	789	832	12	787	755	779
2004	10	64	65	62	10	872	843	868	10	773	814	763
2005	12	128	97	99	12	1194	1036	1122	12	1101	961	1025
2006	12	93	94	82	12	944	974	933	12	834	796	827
2007	11	47	44	42	11	793	749	776	11	750	677	734
2008	12	85	68	72	12	945	965	925	12	850	802	834
2009	12	64	46	56	11	800	759	793	11	745	726	740
2010	12	54	51	49	12	787	782	782	12	700	689	697
2011	12	44	33	37	12	721	702	712	12	680	682	674
2012	6	89	81	76	6	1032	1048	1010	6	921	954	909
2013	12	58	51	50	12	789	778	778	12	749	755	739
POR Annual Average	11	73	63	63	11	884	857	866	11	808	783	793
WY2003-2012 monthly median		74	56	62		888	816	862		810	746	788

Fern Creek

Water Year	TP				TN				TON			
	# 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
2004	9	91	65	78	8	923	856	895	8	847	799	829
2005	8	118	78	90	9	1011	997	985	9	887	878	867
2006	6	118	112	114	6	1018	1014	980	6	897	843	860
2007	1	86	86	86	1	1129	1129	1129	1	1070	1070	1070
2008	3	195	195	194	2	1331	1331	1328	2	1122	1122	1121
2009	10	126	122	110	9	1093	1084	1070	9	981	893	956
2010	5	116	51	89	5	1362	975	1219	5	1260	951	1081
2011	4	100	86	92	4	934	920	928	4	874	867	866
2012	2	191	191	190	2	2507	2507	2507	2	2421	2421	2419
2013	4	94	96	94	4	1084	1133	1077	4	993	1036	986
POR Annual Average	5	123	108	114	5	1239	1195	1212	5	1135	1088	1105
WY2004-2012 monthly median		120	99	102		1126	1002	1060		1020	918	953

Frazier Creek

Water Year	TP				TN				TON			
	# 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
2003	12	97	102	89	12	700	686	683	12	590	570	577
2004	6	57	54	55	6	551	520	539	6	506	501	500
2005	10	89	70	81	10	765	689	703	10	570	573	533
2006	12	107	96	101	12	896	825	851	12	654	617	643
2007	6	71	71	69	6	722	721	705	6	528	500	517
2008	11	80	79	77	10	775	745	736	10	704	647	672
2009	11	91	80	87	11	841	744	804	11	676	695	660
2010	11	75	72	74	11	781	775	770	11	727	662	715
2011	7	75	65	73	7	825	735	800	7	808	724	782
2012	3	48	50	48	3	572	585	570	3	557	575	553
2013	11	60	57	57	10	643	555	603	10	625	541	587
POR Annual Average	9	77	72	74	9	734	689	706	9	631	600	613
WY2003-2012 monthly median		84	74	79		768	711	732		644	617	620

Coral Gardens Ditch

Water Year	TP				TN				TON			
	# 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
2008	12	152	137	148	12	1247	1165	1234	12	873	806	857
2009	12	133	141	128	12	1051	1028	1043	12	839	798	826
2010	12	140	131	135	12	1092	1037	1078	12	845	783	826
2011	12	166	140	143	12	1253	1212	1210	12	1073	1091	1006
2012	5	184	183	175	5	1574	1296	1483	5	1409	1220	1276
2013	12	118	116	117	12	1081	1083	1073	12	830	793	821
POR Annual Average	11	149	141	141	11	1217	1137	1187	11	978	915	936
WY2008-2012 monthly median		151	141	141		1200	1137	1167		955	834	908

Salerno Creek

Water Year	TP				TN				TON			
	# 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
2008	11	55	50	51	11	935	961	924	11	733	745	729
2009	12	50	40	44	12	856	853	850	12	764	742	758
2010	12	32	30	31	12	778	756	773	11	702	662	696
2011	12	34	29	32	12	824	775	809	12	768	714	754
2012	3	35	36	35	3	784	779	783	3	702	698	702
2013	12	50	43	39	12	889	783	848	12	778	664	740
POR Annual Average	10	42	38	39	10	844	818	831	10	741	704	730
WY2008-2012 monthly median		42	36	38		843	813	832		740	691	733

Manatee Creek

Water Year	TP				TN				TON			
	# 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
2003	10	230	225	226	10	1403	1267	1365	10	858	714	795
2004	8	200	190	194	8	1381	1215	1352	8	732	745	731
2005	9	278	264	273	9	2233	1998	2120	9	905	920	895
2006	7	232	229	231	7	1917	1904	1905	7	921	943	919
2007	3	230	234	221	3	1294	1291	1244	3	867	890	844
2008	1	135	135	135	1	1397	1397	1397	1	910	910	910
2009	7	324	308	307	7	1787	1768	1765	7	846	824	837
2010	7	336	284	309	6	1552	1325	1476	6	818	755	795
2011	7	607	408	520	7	1751	1588	1649	7	1100	1012	1046
2012	2	298	298	294	1	1212	1212	1212	1	1094	1094	1094
2013	6	195	191	193	6	1197	1191	1194	6	977	976	974
POR Annual Average	6	278	251	264	6	1557	1469	1516	6	912	889	895
WY2003-2012 monthly median		300	253	270		1681	1619	1602		884	809	855

Willoughby Creek

Water Year	TP				TN				TON			
	# 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
2003	4	27	26	25	4	1055	1052	1054	4	454	448	452
2004	10	22	19	21	10	1340	1239	1256	10	512	501	508
2005	12	41	28	28	12	1197	1117	1138	12	525	504	521
2006	12	30	31	28	12	903	815	883	12	547	512	539
2007	12	19	17	18	12	848	847	840	12	545	522	537
2008	12	32	29	28	12	787	788	784	12	570	580	563
2009	12	26	22	23	11	813	742	789	11	563	523	553
2010	12	18	18	17	12	816	759	806	12	525	512	522
2011	12	17	16	17	12	752	700	741	12	546	538	542
2012	4	26	25	25	4	791	780	788	4	628	626	626
2013	12	22	22	21	11	729	708	725	11	538	565	531
POR Annual Average	10	26	23	23	10	912	868	891	10	541	530	536
WY2003-2012 monthly median		26	21	22		924	835	886		542	516	535

Danforth 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
2003	8	171	163	164	8	1002	926	982	8	784	744	765
2004	9	191	167	178	9	991	909	963	9	790	712	767
2005	5	277	233	259	5	1282	1300	1254	5	990	1037	965
2006	11	198	215	186	11	1161	1298	1123	11	988	1119	958
2007	2	123	123	123	2	1010	1010	1005	2	827	827	824
2008	1	333	333	333	1	1683	1683	1683	1	1502	1502	1502
2009	9	183	160	175	9	1086	1006	1064	9	851	735	831
2010	6	227	197	210	6	1177	1158	1168	6	965	938	958
2011	6	163	159	162	6	1036	1065	1030	6	851	916	839
2012	2	168	168	168	2	952	952	952	2	711	711	711
2013	9	176	150	167	9	1036	871	984	9	865	716	814
POR Annual Average	6	201	188	193	6	1129	1107	1110	6	920	905	903
WY2003-2012 monthly median		196	171	183		1098	1030	1070		887	885	861

Bessey 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
2003	4	198	199	197	4	1063	1023	1056	4	929	927	919
2004	3	206	214	198	3	1099	1071	1074	3	902	912	869
2005	4	222	224	221	4	1134	1173	1124	4	911	971	899
2006	9	195	194	192	9	1113	1145	1101	9	946	960	935
2007	1	185	185	185	1	1328	1328	1328	1	608	608	608
2008	5	228	227	224	5	1107	1105	1083	5	906	890	877
2009	5	256	259	254	5	1153	1103	1149	5	883	945	871
2010	1	200	200	200	1	998	998	998	1	806	806	806
2011	4	205	212	199	4	1066	1077	1064	4	865	863	863
2012	1	274	274	274	1	1047	1047	1047	1	845	845	845
2013	1	366	366	366	1	1573	1573	1573	1	1377	1377	1377
POR Annual Average	3	230	232	228	3	1153	1149	1145	3	907	919	897
WY2003-2012 monthly median		215	206	211		1109	1096	1097		898	895	883

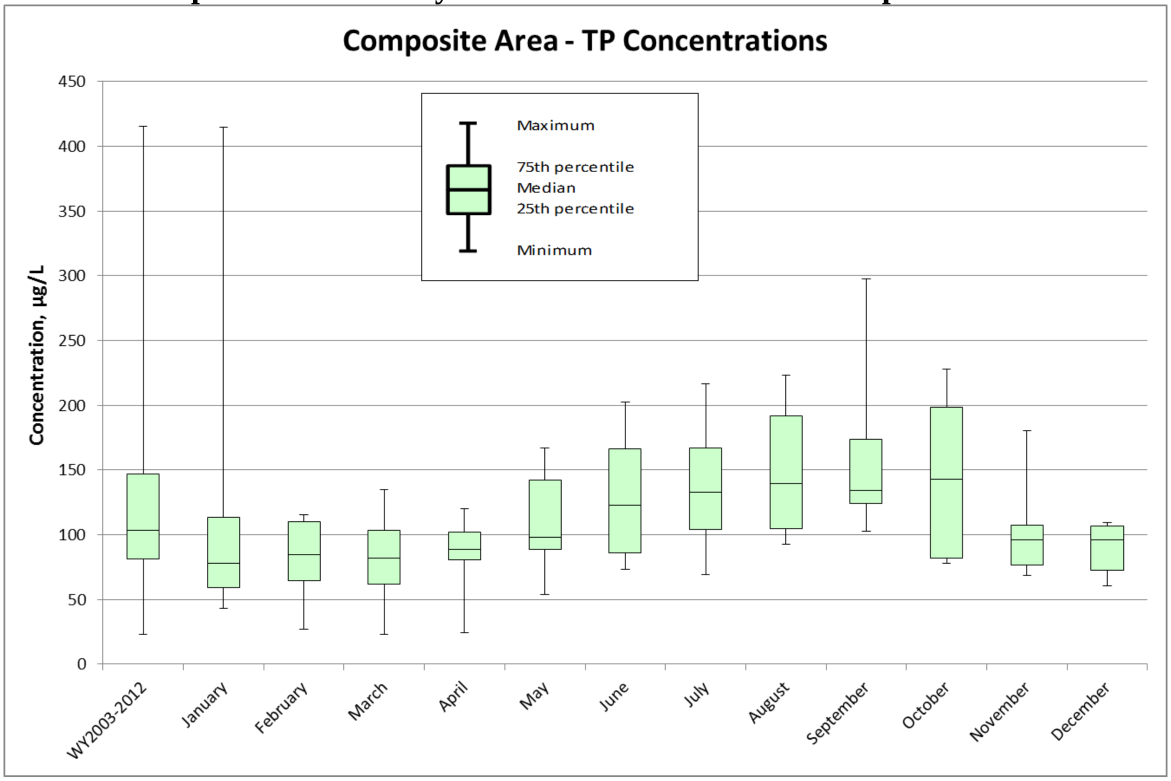
Warner Creek

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
2003	12	26	25	25	12	731	729	726	12	643	636	639
2004	9	29	24	27	9	828	752	802	9	740	662	707
2005	8	37	23	29	8	961	913	940	8	842	780	828
2006	11	35	33	34	11	1036	973	1023	11	894	866	882
2007	5	27	24	25	5	741	735	739	5	681	687	680
2008	9	26	21	23	9	988	1053	972	9	885	907	873
2009	9	28	23	26	9	1019	976	989	9	925	889	902
2010	8	17	15	15	8	737	729	731	7	683	642	676
2011	8	20	19	19	8	860	810	851	8	748	730	740
2012	1	64	64	64	1	1164	1164	1164	1	1034	1034	1034
2013	12	24	24	24	12	1045	774	981	12	948	742	898
POR Annual Average	8	30	27	28	8	919	873	902	8	820	779	805
WY2003-2012 monthly median		28	23	25		888	810	865		790	724	771

North Airport Ditch

Water Year	TP				TN				TON			
	# 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
2003	3	189	112	160	3	973	785	926	3	721	751	720
2004	5	109	73	96	5	870	788	851	5	764	702	736
2005	2	188	188	183	2	1027	1027	1014	2	826	826	818
2006	5	82	90	79	5	1026	995	1011	5	871	823	866
2007	3	72	76	69	3	887	881	873	3	779	817	768
2008	3	102	89	97	3	972	1037	959	3	761	686	749
2009	7	61	57	51	7	854	798	844	7	672	619	652
2010	2	68	68	68	2	859	859	859	2	772	772	771
2011	4	69	64	67	3	809	744	800	3	704	655	692
2012	0				0				0			
2013	3	75	81	75	3	905	909	903	3	780	731	776
POR Annual Average	3	101	90	94	3	918	882	904	3	765	738	755
WY2003-2012 monthly median		96	80	81		914	866	895		757	757	740

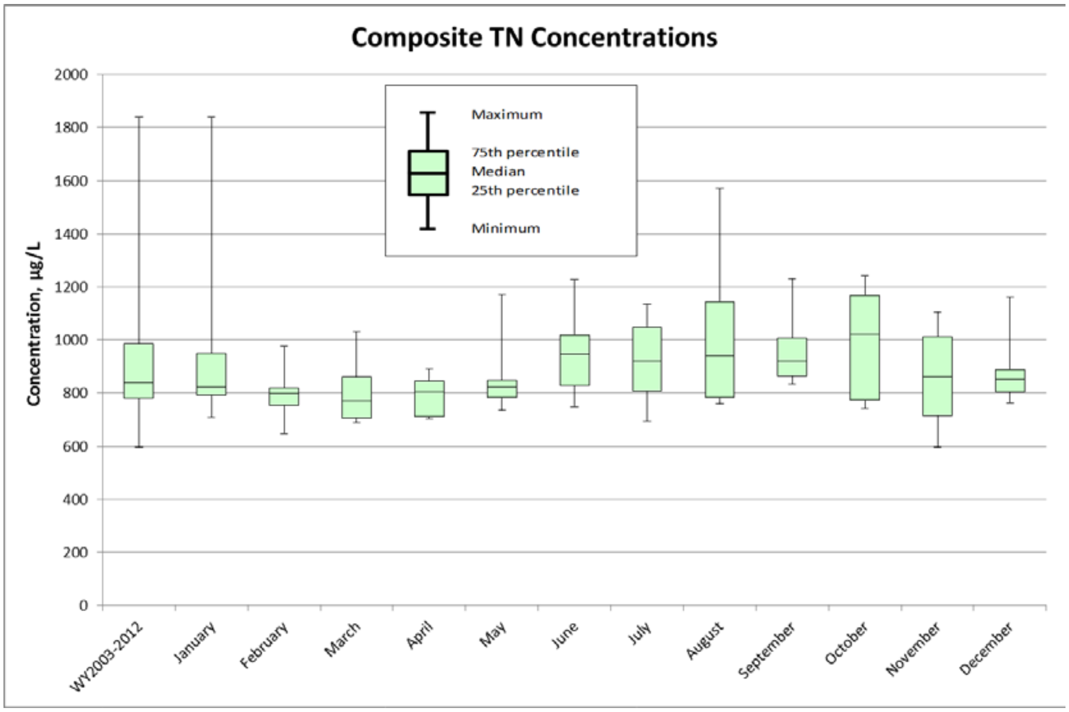
Comparison of monthly TP concentrations for the Composite Area.



Comparison of Composite Area monthly TP concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

Month	Month values signficantly different from Reference Period values?
January	Yes
February	Yes
March	Yes
April	No
May	No
June	No
July	Yes
August	Yes
September	Yes
October	No
November	No
December	No

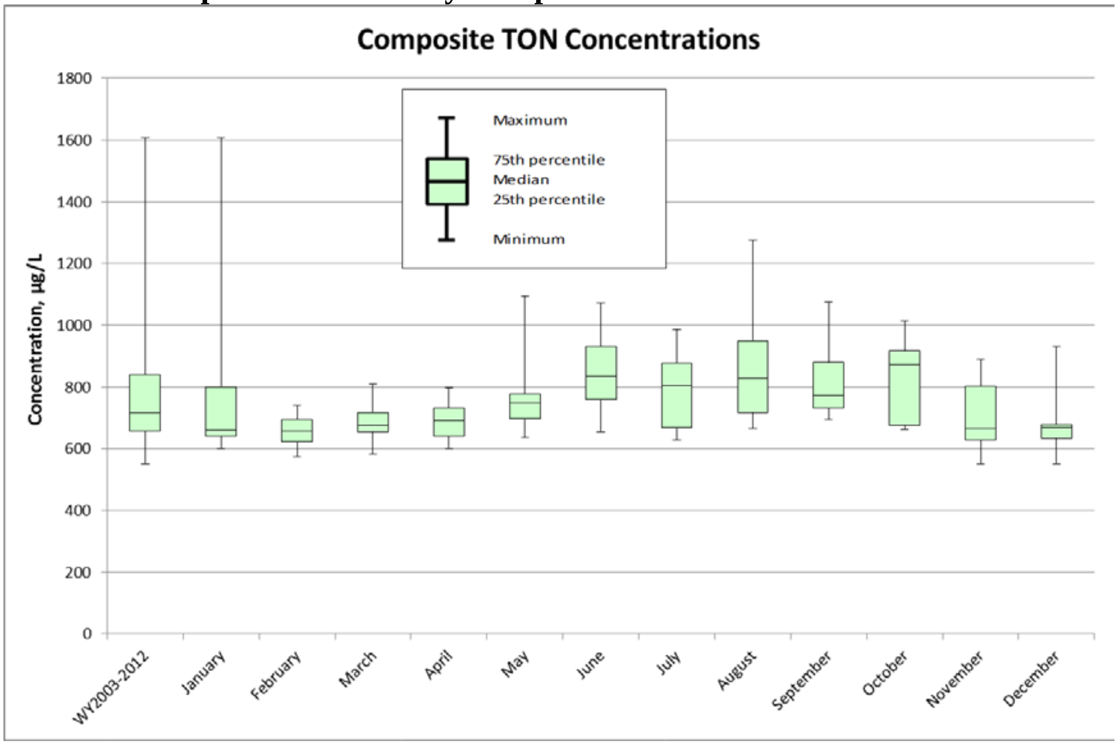
Comparison of monthly Composite Area TN concentrations.



Comparison of monthly Composite Area TN concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

Month	Month values signficantly different from Reference Period values?
January	No
February	Yes
March	Yes
April	Yes
May	No
June	No
July	No
August	No
September	Yes
October	No
November	No
December	No

Comparison of monthly Composite Area TON concentrations.



Comparison of monthly Composite Area TON concentrations to entire Reference Period concentrations using the Wilcoxon rank-sum test at a 5 percent significance level.

Month	Month values signficantly different from Reference Period values?
January	No
February	Yes
March	No
April	No
May	No
June	Yes
July	No
August	Yes
September	Yes
October	No
November	No
December	Yes

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 C-23, C-24, C-25 and C-44 Sub-watersheds, and for the Ten Mile Creek basin. Water control structures include 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 nutrient load calculations are collected by automatic samplers or grab samples for the C-23, C-24, C-25 and C-44 Sub-watersheds and for the Ten Mile Creek basin. Current raw water sample collecting methods at structures utilized in the St. Lucie River Watershed basins nutrient load calculation are listed in **Table B-2**.

For basins within the Composite Area, data collection sites are identified in **Table B-3**.

Rainfall stations are presented in **Tables B-4 and B-5**.

Table B-1. Database keys for structure flow data.

Sub-watershed / Basin	Structure	DBKEY	Type*	Period of Record		Frequency of Collection
				Begin	End	
C-23	S-48	JM106	CR10	8/15/1995	Present	Daily
C-24	S-49	JW223	PREF	1/1/1979	Present	Daily
	G-81	VG483	TELE	4/14/2003	Present	Daily
		16564	NA	9/26/1995	9/3/1998	Daily
		06887	DWR	1/2/1987	9/25/1995	Daily
C-25	S-99	15783	TELE	5/20/1994	Present	Daily
		07744	SP01	4/22/1987	5/19/1994	Daily
		04856	NA	1/1/1979	4/21/1987	Daily
	S-50	16535	NA	5/31/1995	Present	Daily
		04388	NA	1/1/1979	5/30/1995	Daily
	G-81	VG483	TELE	3/30/1997	Present	Daily
		16564	NA	9/26/1995	3/29/1997	Daily
		06887	DWR	1/2/1987	9/25/1995	Daily
C-44	S-80	JW224	PREF	1/1/1979	Present	Daily
	S-308	15626	PREF	1/1/1983	Present	Daily
North Fork / Ten Mile Creek	Gordy Rd Structure	JW239	NA	7/28/1999	Present	Daily

* Flow data type: as defined in DBHYDRO

PREF	PREFERRED VALUE
CR10	CAMPBELL SCIENTIFIC INC. MEASUREMENT AND CONTROL MODULE
TELE	TELEMETRY (RADIO NETWORK)
NA	NOT APPLICABLE
SP01	SOLID STATE LOGGER
DWR	DAILY WATER READING (MANUALLY RECORDED OBSERVATION)

Table B-2. Sampling methods for structure water quality data.

Sub-watershed / Basin	Structure or Station	TP Collection Site ID	Period of Record		Data Collection Frequency
			Begin	End	
C-23	S-48	C23S48	8/15/1995	Present	Monthly
C-24	S-49	C24S49	1/19/1979	Present	Monthly
	G-81	NA	NA	NA	
C-25	S-99	C25S99		Present	
	S-50	C25S50	1/19/1979	Present	Monthly
	G-81	NA	NA	NA	
C-44	S-80	C44S80	1/19/1979	Present	Weekly
	S-308	S308C	7/16/1981	Present	Bi-weekly
North Fork / Ten Mile Creek	Gordy Rd Structure	GORDYRD	8/18/1999	Present	Weekly

Table B-3. Water quality data sources in the Composite Area.

Sub-watershed / Basin		Flow Stations	WQ Stations
North Fork	Five Mile Creek	Five Mile Canal (USGS)	SLT-22/22A
	Platts Creek	unmonitored	SLT-39
	C-105	SLT21_W	SLT-21
	C-107	SLT19_W	SLT-19
	PSL Ditch 6	SLT17_W	SLT-17
	Hog Pen Slough	SLT26_W	SLT-26
	Elkcam Waterway	unmonitored	SLT-11
South Fork	Fern Creek	SLT40_W	SLT-40
	Frazier Creek	SLT31_W	SLT-31
	Coral Gardens Ditch	unmonitored	SLT-34A
Basins 4-5-6	Danforth Creek	SLT7_W	SLT-07
	Bessey Creek	SLT9_W	SLT-09
North Mid-Estuary	Warner Creek	SLT29_W	SLT-29
South Mid-Estuary	North Airport Ditch	unmonitored	SLT-38
South Coastal	Salerno Creek	unmonitored	SLT-44
	Manatee Creek	SLT36_W	SLT-36
	Willoughby Creek	SLT37A_W	SLT-37/37A

Table B-4. Rainfall stations and weights for the sub-watersheds: WY1976-1990

Sub-watershed / Basin	Station	Weight
NORTH MID- ESTUARY	S80_R	1.00000
SOUTH MID- ESTUARY	S80_R	1.00000
BASIN 4, 5, and 6	S80_R	1.00000
C-23	S135_R	0.23119
	S80_R	0.24455
	OPAL_R	0.02099
	FT PIERC_R	0.01602
	COW CREE_R	0.48724
C-24	OPAL_R	0.08214
	MOBLEY_R	0.04184
	FT PIERC_R	0.13535
	COW CREE_R	0.74066
C-25	MOBLEY_R	0.09849
	FT PIERC_R	0.01308
	COW CREE_R	0.36530
	VERO TOW_R	0.27089
	ROCK K_R	0.25224
C-44	S135_R	0.48721
	S80_R	0.46282
	PAHOKEE1_R	0.04997
NORTH FORK	S80_R	0.14731
	FT PIERC_R	0.69365
	COW CREE_R	0.15759
	VERO TOW_R	0.00144
SOUTH COASTAL	S80_R	1.00000
SOUTH FORK	S80_R	1.00000

Table B-5. Rainfall stations and weights for the sub-watersheds: WY1991-2013

Sub-watershed / Basin	SITE	Weight
BASIN 4, 5, and 6	S80_R	0.2469
	S97_R	0.7531
NORTH MID- ESTUARY	S80_R	0.0836
	S97_R	0.9164
SOUTH MID- ESTUARY	S80_R	0.7968
	S97_R	0.2032
C-23	BLUEGOOS_R	0.5921
	COW CREE_R	0.2833
	OPAL_R	0.0210
	S49_R	0.0096
	S97_R	0.0433
	S135_R	0.0236
	FTP FS_R	0.0271
C-24	BLUEGOOS_R	0.1213
	COW CREE_R	0.4312
	FTP FS_R	0.2762
	MOBLEY_R	0.0418
	OPAL_R	0.0821
	S49_R	0.0474
C-25	COW CREE_R	0.2966
	FT_PIERC_R	0.0078
	FTP FS_R	0.1246
	MOBLEY_R	0.0985
	ROCK K_R	0.2522
	VERO_TOW	0.2203
C-44	BLUEGOOS_R	0.1086
	PAHOKEE1_R	0.0500
	S135_R	0.4315
	S80_R	0.3653
	S97_R	0.0447
NORTH FORK	FT_PIERC_R	0.2972
	FTP FS_R	0.3110
	S49_R	0.3041
	S97_R	0.0876
	BLUEGOOS_R	0.0002
SOUTH COASTAL	S80_R	1.0000
SOUTH FORK	S80_R	0.9847
	S97_R	0.0153
Ten Mile Creek	FT_PIERC_R	0.040
	FTP FS_R	0.960
Composite Area	BLUEGOOS_R	0.0001
	FT PIERC_R	0.1859
	FTP FS_R	0.1945
	S49_R	0.1902
	S80_R	0.2939
	S97_R	0.1355

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 River Watershed 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

During the preliminary development of the performance metrics for the SLRW, the 1988 land use coverage was recommended and found to be most representative of the base periods selected for the C-25/25E and C-24 sub-watersheds. The 2004 land use was recommended and found to be most representative of the base periods selected for the C-44 and C-23 sub-watersheds, and 2008 for Ten Mile Creek and the St. Lucie Tributaries (SLTs) (HDR, 2011), (**Table C-1**). The land use coverage for the C-23 was refined based on the 1988 land use coverage found to be most representative of the base period selected compared to the 2004 land use coverage utilized during the preliminary development of the performance metrics for the SLRW in 2011.

For the C-23, C-24, C-25/25E, and C-44 Sub-watersheds, a comparison of land uses between 1988 and 2004 is presented in **Table C-2**. This comparison was presented in the preliminary development of the performance metrics for the SLRW, (HDR, 2011), and further refined here based on improved sub-watershed boundaries, (ADA, 2012).

Once the land use coverage for the entire St. Lucie 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. Performance Metrics Benchmark Time Periods

Sub-watershed/Basin	Base/Reference Period	LU Year
C-23	WY 1989 - 2000	1988
C-24	WY 1984 - 1993	1988
C-25/25E	WY 1984 - 1993	1988
C-44	WY 2000 - 2010	2004
Ten Mile Creek	WY 2000 - 2011	2008
Composite Area	WY 2003 - 2012	2008

Table C-2. Comparison of 1988 and 2004 land use data (from SFWMD).

Land Use Category	FLUCCS	Acreage								TP UAL	TP Loads (kg)								TN UAL	TN Loads (kg)							
		C-23		C-24		C-25/25E		C-44		(lb/ac)	C-23		C-24		C-25/25E		C-44		(lb/ac)	C-23		C-24		C-25/25E		C-44	
		1988	2004	1988	2004	1988	2004	1988	2004		1988	2004	1988	2004	1988	2004	1988	2004		1988	2004	1988	2004	1988	2004	1988	2004
Residential Low Density	1100	576	1,566	60	682	77	259	2,786	1,848	0.49	128	348	13	151	17	57	619	411	4.29	1,121	3,047	117	1,326	149	503	5,422	3,596
Residential Medium Density	1200	13	304	0	2,565	148	123	419	315	1.40	8	193	0	1,629	94	78	266	200	6.24	36	860	0	7,260	418	348	1,185	892
Residential High Density	1300	0	0	0	261	1	4	95	187	3.00	0	0	0	355	2	5	129	254	9.36	0	0	0	1,107	5	17	402	793
Commercial and Services	1400	0	9	0	40	0	0	129	204	1.40	0	6	0	25	0	0	82	130	8.58	0	35	0	155	0	0	503	796
Industrial	1500	8	48	0	55	16	47	365	81	2.40	9	53	0	60	17	51	397	88	7.80	29	171	0	196	55	166	1,290	286
Extractive	1600	0	412	0	0	0	312	0	0	0.66	0	123	0	0	0	94	0	0	5.46	0	1,019	0	0	0	774	0	0
Institutional	1700	77	662	0	22	0	1	13	98	2.40	84	720	0	24	0	1	14	106	5.46	192	1,639	0	54	1	2	33	242
Recreational	1800	0	135	0	666	0	0	100	210	0.96	0	59	0	290	0	0	43	91	5.46	0	335	0	1,648	0	0	247	519
Open Land	1900	1,110	10	3,798	75	62	1	217	149	0.28	141	1	482	9	8	0	28	19	3.12	1,570	14	5,375	106	88	2	307	211
Improved Pasture	2110	41,461	33,236	40,529	32,128	37,830	18,301	30,163	23,185	1.90	35,732	28,644	34,930	27,680	32,603	15,772	25,996	19,982	8.66	162,826	130,527	159,169	126,175	148,567	71,871	118,458	91,054
Unimproved Pastures	2120	2,665	5,024	2,127	6,064	269	3,032	0	2,168	0.92	1,112	2,097	888	2,531	112	1,265	0	905	4.29	5,186	9,776	4,139	11,801	523	5,900	0	4,218
Woodland Pastures	2130	0	8,259	0	6,890	4	3,167	0	6,458	0.88	0	3,297	0	2,750	2	1,264	0	2,578	3.20	0	11,980	0	9,995	6	4,595	0	9,368
Row Crops	2140	22	1,696	775	1,316	3	346	2,412	5,593	4.50	46	3,462	1,583	2,686	5	705	4,923	11,416	11.70	118	9,002	4,115	6,983	14	1,834	12,800	29,682
Field Crops	2150	0	1,577	0	835	0	1,188	0	391	2.96	0	2,121	0	1,122	0	1,597	0	526	5.17	0	3,695	0	1,956	0	2,783	0	916
Sugar Cane	2156	0	0	0	0	0	0	6,450	2,627	0.63	0	0	0	0	0	0	1,843	751	6.24	0	0	0	0	0	0	18,257	7,436
Citrus	2210	29,628	32,461	10,455	15,838	31,024	52,383	41,055	42,940	1.80	24,190	26,504	8,536	12,931	25,330	42,769	33,521	35,060	6.63	89,100	97,623	31,442	47,630	93,300	157,533	123,468	129,137
Other Groves	2230	0	17	0	0	0	0	0	0	2.30	0	18	0	0	0	0	0	0	7.02	0	55	0	0	0	0	0	0
Cattle Feeding Operations	2310	0	105	0	0	0	0	0	0	8.96	0	425	0	0	0	0	0	0	42.16	0	2,001	0	0	0	0	0	0
Poultry Feeding Operations	2320	0	0	0	44	0	0	0	63	1.50	0	0	0	30	0	0	0	43	7.80	0	0	0	157	0	0	0	221
Tree Nurseries	2410	0	154	0	55	0	158	0	85	2.90	0	202	0	73	0	208	0	112	9.36	0	653	0	236	0	670	0	362
Sod Farms	2420	0	0	0	0	0	0	0	294	2.52	0	0	0	0	0	0	0	336	7.02	0	0	0	0	0	0	0	936
Ornamentals	2430	0	0	0	25	0	21	0	268	2.90	0	0	0	33	0	28	0	352	9.36	0	0	0	107	0	91	0	1,136
Specialty Farms	2500	0	0	0	0	0	0	0	29	1.82	0	0	0	0	0	0	0	24	6.24	0	0	0	0	0	0	0	81
Horse Farms	2510	0	54	0	14	0	0	719	592	1.82	0	45	0	12	0	0	594	488	12.48	0	305	0	80	0	0	4,073	3,349
Dairies	2520	58	419	210	0	141	652	0	0	9.38	NA	NA	NA	NA	NA	NA	0	0	15.60	NA	NA	NA	NA	NA	NA	0	0
Aquaculture	2540	0	69	0	23	0	0	0	0	0.70	0	22	0	7	0	0	0	0	7.80	0	245	0	82	0	0	0	0
Fallow Cropland	2610	0	217	0	0	0	2	0	0	0.70	0	69	0	0	0	1	0	0	5.46	0	537	0	0	0	5	0	0
Rangeland	3000	68	1,527	532	220	1,747	637	1,326	6,243	0.28	9	194	68	28	222	81	168	793	3.20	99	2,215	771	319	2,534	924	1,924	9,057
Abandoned Groves	3230	0	0	0	0	0	1	0	173	0.70	0	0	0	0	0	0	0	55	5.46	0	0	0	0	0	2	0	429
Upland Forests	4000	7,038	2,690	8,000	1,265	13,720	1,028	8,320	11,641	0.28	NA	NA	NA	NA	NA	NA	1,057	1,479	1.95	NA	NA	NA	NA	NA	NA	7,359	10,297
Water	5000	718	1,782	1,029	1,236	720	3,443	7,630	2,128	0.05	16	40	23	28	16	78	173	48	0.70	229	568	328	393	229	1,096	2,429	677
Wetlands	6000	26,180	16,019	15,536	12,155	12,535	12,723	29,338	15,225	0.01	119	73	70	55	57	58	133	69	1.17	13,894	8,501	8,245	6,451	6,653	6,752	15,570	8,080
Barren Land	7000	679	1,096	20	296	639	990	255	1,097	0.75	231	373	7	101	217	337	87	373	5.46	1,682	2,715	49	734	1,582	2,453	632	2,717
Transportation	8100	0	438	98	501	117	572	157	611	1.65	0	328	74	375	87	428	117	457	7.18	0	1,427	320	1,630	379	1,861	510	1,989
Communication	8200	6	10	0	0	0	5	0	6	0.48	1	2	0	0	0	1	0	1	4.68	13	22	0	0	0	10	0	12
Utilities	8300	566	877	202	102	673	331	769	7,809	0.48	123	191	44	22	147	72	167	1,700	4.68	1,202	1,863	430	217	1,430	703	1,632	16,577
Total		110,874	110,874	83,373	83,373	99,725	99,725	132,717	132,717		61,950	69,609	46,718	53,018	58,936	64,951	70,358	78,847		279,287	292,833	216,488	228,802	257,921	262,897	318,488	337,071
										Difference	11%		12%		9%		11%			5%		5%		2%		6%	

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-3** (see the column labeled, “Existing Unit Load (lbs-P/ac/yr”).

Table C-3. 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	Total P	Estimated	Total P after
Primary Agricultural Land Use				(lbs-P/ac/yr)	Load (tons)	% Reduction	Reduction (tons)
	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-4 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-4. 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 St. Lucie 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-5 and C-6** present nutrient UALs used in the development of the St. Lucie River and St. Lucie 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-7**). 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-8**.

Table C-5. 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-6. 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-7. BMPs assumed to be implemented for estimates of nutrient load reductions.

Land Use	Citrus	Improved Pastures	Residential and Urban	Other agriculture
Watershed Acreage Percentage	23 %	21 %	16 %	15 %
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 • 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 • 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:* • Cover crops • Sediment traps

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

Table C-8. 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 St. Lucie River Watershed TP and TN 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 St. Lucie 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 SLRWPP 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-9) 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. Some adjustments were initially considered for basins with base periods preceding implementation of source control programs, such as the C-24 basin (WY1984-1993), and for basins with partial implementation of source control programs during the base period, such as the C-44 basin (WY2000-2010), however, these adjustments were later removed since the effects of implementation were not reflected in the water quality data. For the Ten Mile Creek basin (WY2000-2011), and the eastern basins where the composite area metric was developed WY2003-2012), 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 C.3.d.

For the C25 basin the observed unit area load during the base period was substantially lower than the modeled unit area load, and the unit area load for other basins (which had similar land uses). Considering the low levels that had been observed during the base period and the current levels, it was considered that a zero percent reduction which would entail reverting to historic levels was reasonable (base period median of 0.41 ppb in comparison to a WY2000-2010 median of 1.26 lb/ac).

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-9**; the spreadsheets associated with the recommended reductions are included in Attachment 1.

Table C-9. 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				
C-23	10	49	30	30
C-24	10	49	30	30
C-44	9	53	33	35
C-25/25E	10	48	30	0
Ten Mile Creek	10	52	34	35
Composite Area	3	30	17	10
Total Nitrogen				
C-23	9	45	26	25
C-24	9	45	25	25
C-44	8	48	28	30
C-25/25E	9	46	26	0
Ten Mile Creek	9	52	31	30
Composite Area	2	56	38	10

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 Composite Area, 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 C-23, C-24, C-25, C-44 and Ten Mile Creek 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 Composite Area and Its Tributaries

Available water quality data collected by the District were used. Data are collected at selected individual tributaries bi-weekly when flowing and when conductivity is less than 2500 µmhos/cm to minimize tidal influences. The procedure to estimate the nutrient reductions was as follows:

Derivation of the Annual Concentration Target

- Initial source control reduction goals were developed for each basin were developed based on the individual land use source control effectiveness ranges for each basin based on "Typical" load reductions indicated in the St. Lucie Watershed Protection Plan (SFWMD, FDEP and FADCS 2009).

- The nutrient TMDL concentrations presented in the Final TMDL report (FDEP 2008), were considered to adjust the reductions goals: If the historical monthly median concentration was below the TMDL concentration (TP = 81 µg/L and TN = 720 µg/L) a goal of zero percent was established, representing maintenance of existing conditions. If a Typical Reduction resulted in indicators below the TMDL concentration, the indicators were capped at the TMDL.
- For TN, there was an additional 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. If Typical Reductions resulted in a TN level below 90 percent of the associated TON level, the indicators were capped at 90 percent TON.
- Adjustments to the source control reduction goals were made based on best professional judgment to account for the following:
    1. Although monitoring data are generally reported to be collected during discharge conditions, if the observed nutrient concentrations were substantially lower than those simulated by the model based on existing land uses, it was considered reasonable to conservatively adjust the reductions, or require maintaining historic levels only.
    2. 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.

- After review of the intermediate results, and in further consideration of the above caveats, the Composite Area 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 38 percent (“Typical Reduction”) to 10 percent.
    - In consideration of the composite 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.
    - 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 (115 ppb). The median of the composite area was 103 ppb, which yields a resulting ratio of 103/115=0.8936. 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 TN, the tributaries’ cumulative flow-weighted mean concentration during the reference period was 841 ppb. The median of the composite area was 873 ppb, which yields a resulting ratio of 841/873=0.9633. 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 Manatee Creek was 847 ppb, however after the sub-watershed reduction goal was revised to 10 percent, the tributary reductions were proportionately revised and the resulting Target concentration was adjusted to 1,321 ppb.

The resulting Annual Concentration Targets and reduction goals are presented in **Table C-10**.

Table C-10. Estimates of the Annual TP and TN Concentration Targets for the Composite Area.

Basin	TP Source Control Reduction Goal for Target	Reference Period TP Median Concentration, µg/L	TP Annual Concentration Target, µg/L	TN Source Control Reduction Goal for Target	Reference Period TN Median Concentration, µg/L	TN Annual Concentration Target, µg/L
Five Mile Creek	11%	150	133	0%	721	720
Platts Creek	10%	195	176	11%	810	720
C-105	0%	37	37	13%	831	725
C-107	0%	36	36	7%	771	720
PSL Ditch 6	8%	95	87	6%	768	720
Hog Pen Slough	0%	57	57	10%	804	720
Elkcam Waterway	0%	56	56	12%	816	720
Fern Creek	17%	99	82	14%	1,002	859
Frazier Creek	0%	74	74	0%	711	711
Coral Gardens Ditch	11%	141	126	16%	1,137	958
Salerno Creek	0%	36	36	11%	813	720
Manatee Creek	8%	253	234	18%	1,619	1,320
Willoughby Creek	0%	21	21	14%	835	720
Danforth Creek	18%	171	141	13%	1,030	892
Bessey Creek	15%	206	176	11%	1,096	980
Warner Creek	0%	23	23	11%	810	720
North Airport Ditch	0%	80	80	17%	866	722
Composite Area	***10%***	***103***	***93***	***10%***	***841***	***757***

Notes:

1. The Reference Period for the Composite Area is WY2003-2012.
2. 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.
3. 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 TMDL levels.
   b. 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 four tributaries.

2. After review of the intermediate results, and in further consideration of the cavaets, the "Typical" reduction goals were adjusted. The composite Limit was adjusted in proportion to the tributaries Limits adjustment in the same manner as for the Target derivation.

The resulting Annual Concentration Limits and reduction goals are presented in **Table C-11**.

Table C-11. Estimates of the Annual Concentration Limits for the Tidal Caloosahatchee and Coastal Caloosahatchee Sub-watersheds.

Basin	TP Source Control Reduction Goal for Limit	Reference Period TP Maximum Concentration, µg/L	TP Annual Concentration Limit, µg/L	TN Source Control Reduction Goal for Limit	Reference Period TN Maximum Concentration, µg/L	TN Annual Concentration Limit, µg/L
Five Mile Creek	18%	1,168	963	12%	4,161	3,660
Platts Creek	15%	1,140	969	12%	5,022	4,430
C-105	35%	125	81	11%	1,681	1,500
C-107	31%	179	124	13%	1,601	1,400
PSL Ditch 6	12%	387	339	15%	1,835	1,560
Hog Pen Slough	11%	320	286	11%	2,856	2,550
Elkcam Waterway	12%	316	278	11%	2,416	2,150
Fern Creek	26%	252	187	11%	2,861	2,540
Frazier Creek	11%	185	165	14%	1,703	1,460
Coral Gardens Ditch	16%	495	415	11%	2,805	2,500
Salerno Creek	12%	102	90	14%	1,274	1,100
Manatee Creek	12%	1,277	1,130	14%	4,044	3,460
Willoughby Creek	22%	194	151	13%	2,165	1,880
Danforth Creek	26%	477	351	11%	1,683	1,500
Bessey Creek	23%	302	234	8%	1,473	1,350
Warner Creek	10%	125	112	12%	1,764	1,560
North Airport Ditch	21%	350	278	13%	1,424	1,240
Composite Area	***17%***	***415***	***344***	***11%***	***1,840***	***1,630***

Notes:

1. The Reference Period for the Composite Area is WY2003-2012.
2. The Annual Concentration Limit is the maximum observed monthly concentration during the reference period, adjusted by the nutrient reduction goal.
3. Source control reduction goals for TN also account for background TN concentrations, as represented by 90 percent of the historical TON concentration.
4. Target and Limit concentrations are rounded to whole ppb and/or three significant digits, which may have slightly revised the percent reduction.

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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.

   b. Calculate the area adjustment factor (AAF)

   AAF = (total basin area minus area of regional project) / (average area in Base Period)

   c. 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

APPENDIX E – WILCOXON RANK SUM EQUATIONS FOR SMALL SAMPLE SIZES (<10)

If the number of monthly samples during any Evaluation Year is ten or less, the rank sum algorithm will require modification.

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 results of the test are evaluated.
   a. If the statistic W_{rs} for the Evaluation Year is within the values of the $W_{0.05,n}$ in **Table E-1**, 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 less than or equal to the mean of W_{rs} in Table E-1, we can conclude that the Evaluation Year's data are not significantly greater than the Reference Period.

c. If W_{rs} for the Evaluation Year is greater than the Upper W_{rs} in Table E-1, we can conclude that the Evaluation Year's data are significantly greater than the Reference Period.

Table E-1. Values of the Lower and Upper $W_{0.05,n}$ for use in Evaluating against the Reference Period (m=112).

Sample Size, n	Lower W_{rs}	Mean W_{rs}	Upper W_{rs}
9	397.2	549.0	700.8
8	338.2	484.0	629.8
7	280.7	420.0	559.3
6	225.0	357.0	489.0
5	170.9	295.0	419.1
4	119.0	234.0	349.0
3	74.8	174.0	273.2

ATTACHMENT 1 – ASSOCIATED EXCEL SPREADSHEETS

The following Excel spreadsheets containing the relevant data analyses are attached by reference to this Draft *Technical Support Document*.

C-23 Sub-watershed spreadsheets:

PM1 Stats C23 TP – 12 18 2013

PM2 Stats C23 TP - 12 18 2013

PM1 Stats C23 TN - 12 18 2013

PM2 Stats C23 TN - 12 18 2013

PM1 Stats C23 TON - 12 18 2013

PM2 Stats C23 TON - 12 18 2013

C-23 Sub-watershed SKT files

C-24 Sub-watershed spreadsheets:

PM1 Stats C24 TP – 12 18 2013

PM2 Stats C24 TP – 12 18 2013

PM1 Stats C24 TN - 12 18 2013

PM2 Stats C24 TN – 12 18 2013

PM1 Stats C24 TON - 12 18 2013

PM2 Stats C24 TON – 12 18 2013

C-24 Sub-watershed SKT files

C-25 Sub-watershed spreadsheets:

PM1 Stats C25 TP - 12 18 2013

PM2 Stats C25 TP – 12 18 2013

PM1 Stats C25 TN - 12 18 2013

PM2 Stats C25 TN – 12 18 2013

PM1 Stats C25 TON - 12 18 2013

PM2 Stats C25 TON – 12 18 2013

C-25 Sub-watershed SKT files

C-44 Sub-watershed spreadsheets:

PM1 Stats C44 TP – 12 18 2013

PM2 Stats C44 TP - 12 18 2013

PM1 Stats C44 TN - 12 18 2013

PM2 Stats C44 TN - 12 18 2013

PM1 Stats C44 TON - 12 18 2013

PM2 Stats C44 TON - 12 18 2013

C-44 Sub-watershed SKT files

Ten Mile Creek Sub-watershed spreadsheets:

PM1 Stats TMC TP – 12 18 2013

PM2 Stats TMC TP – 12 18 2013

PM1 Stats TMC TN - 12 18 2013

PM2 Stats TMC TN – 12 18 2013

PM1 Stats TMC TON - 12 18 2013

PM2 Stats TMC TON – 12 18 2013

TMC SKT files

Composite Area spreadsheets:

PM1 Stats Composite rainfall – 12 18 2013

PM1 Stats Composite TP – 12 18 2013

PM1 Stats Composite TN – 12 18 2013

PM1 Stats Composite TON – 12 18 2013

(12-18-2013) PI One SLT Composite

Composite Sub-watershed SKT files

Nutrient reduction spreadsheets

(11-13-13) BMP REDUCTION C-23_1988 LU

(11-13-13) BMP REDUCTION C-24_LU 1988 LU

(11-13-13) BMP REDUCTION C-25_C-25E_LU 1988

(11-13-13) BMP REDUCTION C-44_2004 LU

(03-08-13) BMP REDUCTION TMC_LU 2008