SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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

DRAFT – TECHNICAL SUPPORT DOCUMENT: LAKE OKEECHOBEE WATERSHED PERFORMANCE MEASURE METHODOLOGIES

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

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ACRONYMS AND ABBREVIATIONS

AAF	area adjustment factor
ac	acre
ac-ft and AF	acre feet
BMP	best management practice
CAFO	concentrated animal feeding operation
CERP	Comprehensive Everglades Restoration Plan
CERPRA	Comprehensive Everglades Restoration Plan Regulatory Act
cfs	cubic feet per second
Conc	concentration
District	South Florida Water Management District
EAA	Everglades Agricultural Area
EBCWD	East Beach Water Control District
ECP	Everglades Construction Project
ERP	Environmental Resource Permit
ESWCD	East Shore Water Control District
F.A.C.	Florida Administrative Code
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FECR	Fisheating Creek
FLUCCS	Florida Land Use, Cover, and Forms Classification Systems
F.S.	Florida Statutes
ft	feet
FWM	flow-weighted mean
GIS	geographic information system
IFAS	University of Florida's Institute of Food and Agricultural Sciences
in	inches

kg	kilogram(s)
lb and #	pound
ln	natural logarithm
LOPA	Lake Okeechobee Protection Act
LOPP	Lake Okeechobee Protection Plan
LOOP	Lake Okeechobee Operating Permit
LOWOD	Lake Okeechobee Works of the District
MA	moving average
mt	metric tons
NEEPP	Northern Everglades and Estuaries Protection Program
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
R^2	coefficient of determination
SFCD	South Florida Conservancy District
SFWMD	South Florida Water Management District
SSDD	South Shore Drainage District
STA	stormwater treatment area
SWIM	Surface Water Improvement and Management
ppb	parts per billion
TCNS	Taylor Creek-Nubbin Slough
TMDL	Total Maximum Daily Load
TN	total nitrogen
TP	total phosphorus
UCL	upper confidence limit
USGS	United States Geological Survey
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
µg/L	microgram per liter

WAM	Watershed Assessment Model
WOD	Works of the District
WY	water year, extending from May 1 to April 30 and identified by the calendar year when the water year ends, e.g., WY2010 extended from May 1, 2009 to April 30, 2010
yr	year

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 (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. 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. The portion of the SWIM Act relating specifically to Lake Okeechobee was subsumed and eventually became the NEEPP (373.4595 F.S.). The NEEPP mandates complementary source control programs by the three coordinating agencies (the Florida Department of Environmental Protection (FDEP or Department), the District and the Florida Department of Agriculture and Consumer Services (FDACS)), encompassing an expanded Lake Okeechobee Watershed, and the St. Lucie River Watershed and the Caloosahatchee River Watershed. The NEEPP states that "by January 1, 2004 the District shall submit to the Department a permit modification to the Lake Okeechobee structure permits to incorporate proposed changes necessary to ensure that discharges through the structures covered by this permit achieve state water quality standards, including the total maximum daily load established in accordance with S. 403.067. These changes shall be designed to achieve such compliance with state water quality standards no later than January 1, 2015". Total phosphorus (TP) is the pollutant of concern for Lake Okeechobee while TP and total nitrogen have been identified as pollutants of concern for the St. Lucie River and Caloosahatchee River Watersheds. In response to these legislative changes, the District must amend the 1989 Chapter 40E-61, F.A.C., to effectuate the NEEPP requirements.

One of the fundamental components of the Regulatory Source Control Program is water quality performance metrics coupled with water quality monitoring. The water quality performance metrics currently specified in Chapter 40E-61, F.A.C, are not in alignment with the Total Phosphorus Total Maximum Daily Load goals established in the NEEPP (140 metric tons per year (mt/yr) TP load, including 35 mt/yr due to atmospheric deposition). The performance metrics for the 1989 Chapter 40E-61, F.A.C. were concentration based limits from individual parcels within the watershed and were aligned with the 360 mt/yr TP load SWIM Plan target for Lake Okeechobee. Further, the NEEPP mandates that monitoring be conducted at representative sites to verify the effectiveness of the source control programs.

This *Draft Technical Support Document* presents 14 preliminary water quality performance metrics recommended for consideration in amendments to Chapter 40E-61, F.A.C., as presented in **Table 1-1**. These performance metrics estimate the TP 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 measure methodologies". When the performance measures are discussed as a whole, the term "basin" will be used to describe the sub-watersheds, summary basins, and hydrologic units. The resulting 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 TP loads incorporating hydrologic variability based on a representative base period dataset. Performance indicators are also generally TP loads incorporating hydrologic variability based on a representative reference period. However, performance indicators are recommended when all the criteria for establishing a performance measure are not met. Performance metrics 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. For areas where no performance measure methodology is being proposed for reasons described in Section 3.0

of this report the water quality will be assessed annually to determine if there is an increasing trend. The NEEPP establishes that a Memorandum of Understanding shall be executed among the agencies to ensure a complementary approach. The current MOU was executed in 2011.

Table 1-1. Lake Okeechobee Watershed TP Load Performance Metrics.

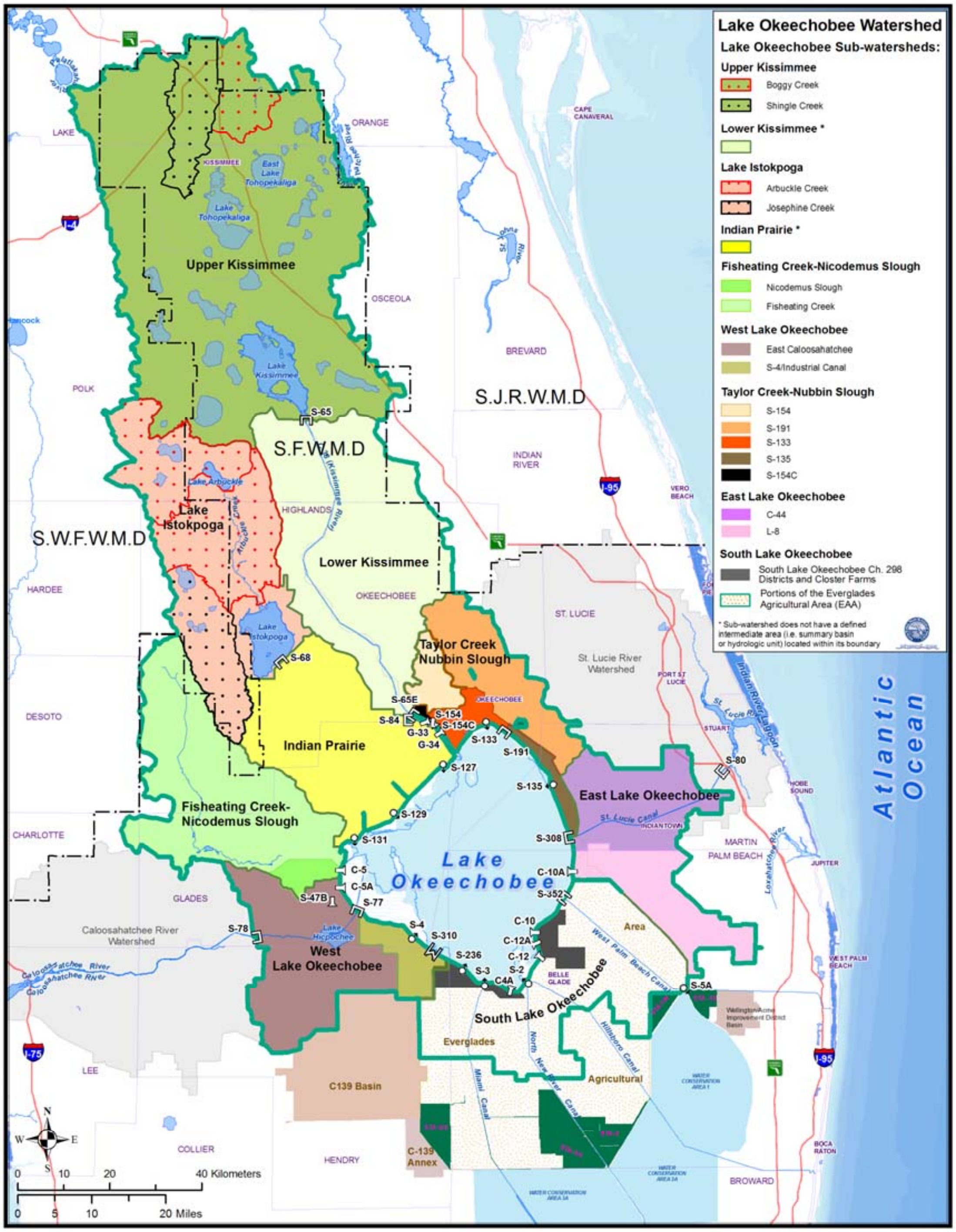
Basin	Performance Measure or Performance Indicator	Base Period	Base Period Median Load mt	Recommended Source Control Reduction
S-133	Performance Measure	WY1977-1986	7.4	25%
S-154	Performance Measure	WY1977-1984	8.3	35%
S-191	Performance Measure	WY1977-1988	89.7	40%
Lower Kissimmee	Performance Measure	WY1977-1990	56.1	30%
C-44	Performance Measure	WY2000-2010	52.9	35%
L-8	Performance Measure	WY1995-2003	17.1	20%
Indian Prairie	Performance Measure	WY1989-2001	67.6	30%
Fisheating Creek	Performance Measure	WY1998-2008	67.6	30%
S-4/Industrial Canal	Performance Measure	WY1993-2001	17.6	30%
East Caloosahatchee	Performance Measure	WY1982-1990	54.9	30%
Arbuckle Creek	Performance Indicator	WY1997-2007	38.8	0%
Josephine Creek	Performance Indicator	WY1997-2004	3.0	0%
Boggy Creek	Performance Indicator	WY2001-2008	5.0	0%
Shingle Creek	Performance Indicator	WY1999-2007	17.4	0%

Notes:

1. No performance metric will be assigned to the S-135, S-154C and Nicodemus Slough basins. However, the water quality from these basins will be assessed annually to determine if there is an increasing trend.
2. See Section 3.9 for a summary of the South Lake Okeechobee Sub-watershed performance measure metrics.

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

Figure 1-1. Sub-watershed level map of the Lake Okeechobee Watershed.



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1.2 Performance Measures Methodologies Development

In order to develop these performance measure methodologies, the following general activities were conducted.

1. Monthly and annual runoff and TP load for each basin within the watershed were calculated based on available historical data through Water Year 2010 (WY2010) for appropriate 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 the method 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 a Thiessen polygon weighting method was developed.
3. A base period (for performance measures) or reference period (for performance indicators) was selected for each basin. The base period or reference period is the benchmark period of historical observed data on which performance metrics are 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 eliminated through data adjustments); and being free of unexplained outliers in the rainfall, flow, or load data.
4. Ninety TP load annual prediction equations were examined for each basin to determine which equation would better estimate the base period or reference period TP annual 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 or reference period, and the presence of overparameterization.

5. Nutrient reductions were estimated based on work completed in the development of the watershed protection plans for Lake Okeechobee, St. Lucie River, and Caloosahatchee River (Bottcher 2006 and SWET 2008). These reductions are based on implementation of regulations and best management practices (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). For the Lake Istokpoga and Upper Kissimmee tributaries, in order to estimate requirements for TP reduction due to source controls, the first step was to review historic water quality data against the numeric nutrient criterion (120 µg/l for TP) (Chapter 62.302, F.A.C.). Maintaining base period or reference period levels was considered reasonable when the period of record median flow weighted mean (FWM) TP concentration was below this criterion.
6. Since the goal of the performance metrics is to evaluate the effectiveness of the source control programs, independent from regional water quality treatment construction projects (e.g., stormwater treatment area), this *Draft Technical Support Document* provides a methodology to 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 will be similar to the adjustment used in the Everglades Agricultural Area (EAA) under Chapter 40E-63, F.A.C. The same methodology will be used for future regional projects after they become operational.

1.3 Annual Performance Determination

Total phosphorus loads measured in discharges at each basin outlet structure, 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 Target and the Annual Load Limit are further defined in Section 2.5. In general, the Target represents the expected level of load or concentration resulting from the regulatory source control implementation. In the case of many performance measures the Target level varies annually to account for rainfall. The Limit represents the upper 90 percent confidence limit of a Target. Previous regulatory programs have established this as an acceptable level to balance assurance that exceedance is not due to random variation and also the resource is protected from exceptionally high annual levels.

The Target and Limit are applied in combination to evaluate annual and longer-term success in meeting required levels. The Limit is an effective indicator for a single year's levels, but it may not detect a less drastic shift or trend increase above regulated levels. Therefore a Target test is also applied, which approximates the 90% confidence level on three consecutive years of data. If the source controls are performing as expected, random variation will result in annual levels with equal chance of being above and below the Target. The statistical logic of a three year Target test equating to an 87.5% confidence level is explained by the following "coin flip" analogy.

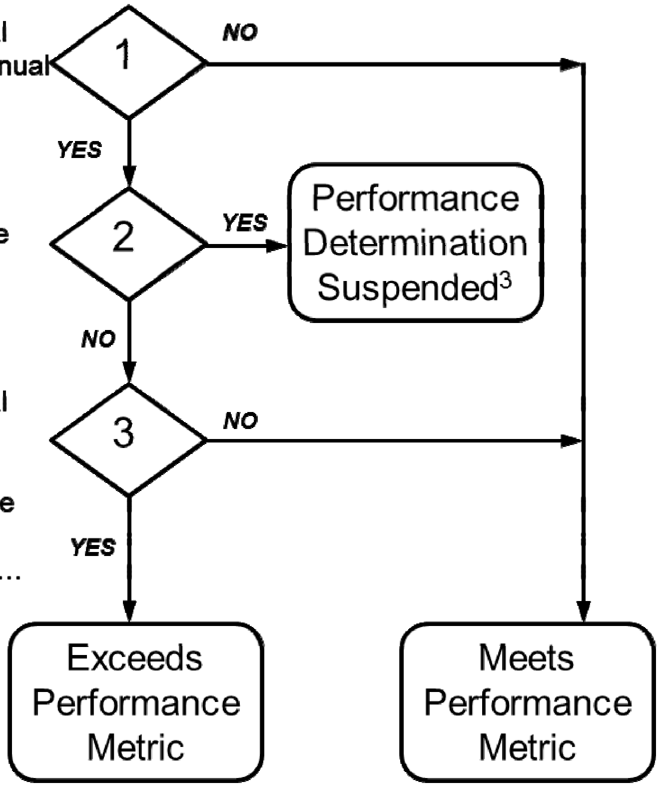
- A single year the Target is exceeded, there is a 50% chance that source controls are performing as expected.
- For two consecutive years to both be above the Target there is still a 25% chance that source controls are performing as expected.
- For a third consecutive year to exceed the Target, only a 12.5% chance exists that the source controls are performing and random variation is causing the exceedance. This equates to 87.5% confidence that levels are exceeding expectations.

Figure 1-2. Flowchart - annual performance determination.

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.
2. The Annual Load Target is adjusted for Regional Projects, if applicable.
3. If the Annual Load Target is exceeded in a May 1 through April 30 period, and the District determines that 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, without an intervening May 1 through April 30 period in which the basin has been determined to meet its performance measure, even though the three periods may be interrupted by periods of suspension.
4. The Annual Load Limit is adjusted for Regional Projects, if applicable.

Tables 1.2 through 1.15 present the performance metrics for each of the 14 basins with adequate water quality and flow data for the development of performance metrics. The metrics 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. **Figures 1-3 through 1-16** provide comparisons of the *scaled* load data with the proposed targets and limits for the base (or reference) periods. Scaled means that the annual loads of the base (or reference) period are decreased by the Recommended Source Control Reduction, thus the graph depicts the fit of the prediction.

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, or ln(rainfall), if applicable
- P = 12-month total rainfall for the previous water year (inches), or ln(rainfall), if applicable
- P_m = average value of the predictor (previous rain) in the base period, or ln(previous rain), 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, or ln(skewness), if applicable
- S_m = the average value of the rainfall skewness in the base period, or ln(skewness), if applicable
- SE_p = standard error of the prediction (mt, ln(mt) or sqrt(mt) as applicable)

Table 1-2. S-133 Summary Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
7.4	5.5	79%	25%	30.03	77.63

$$\text{Target} = -200.98003 + 19.638\ X + 29.41568\ P + 30.52657\ C$$

$$\text{Limit} = \text{Target} + 1.43976\ SE$$

$$SE = 3.88541\ [\ 1 + 1/10 + 3.01635\ (X-X_m)^2 + 4.00198\ (P-P_m)^2 + 10.51972\ (C-C_m)^2 + 0.38068\ (X-X_m)\ (P-P_m) + 2.9188\ (X-X_m)\ (C-C_m) + 8.67534\ (P-P_m)\ (C-C_m)\ ]^{0.5}$$

[1] Based on adjusted rainfall values
X = ln(Rain) and X_m = the mean of the log transformed annual rain for the base period
P = ln(Prior Year's Rain) and P_m = the mean of the log transformed prior year's rain for the base period

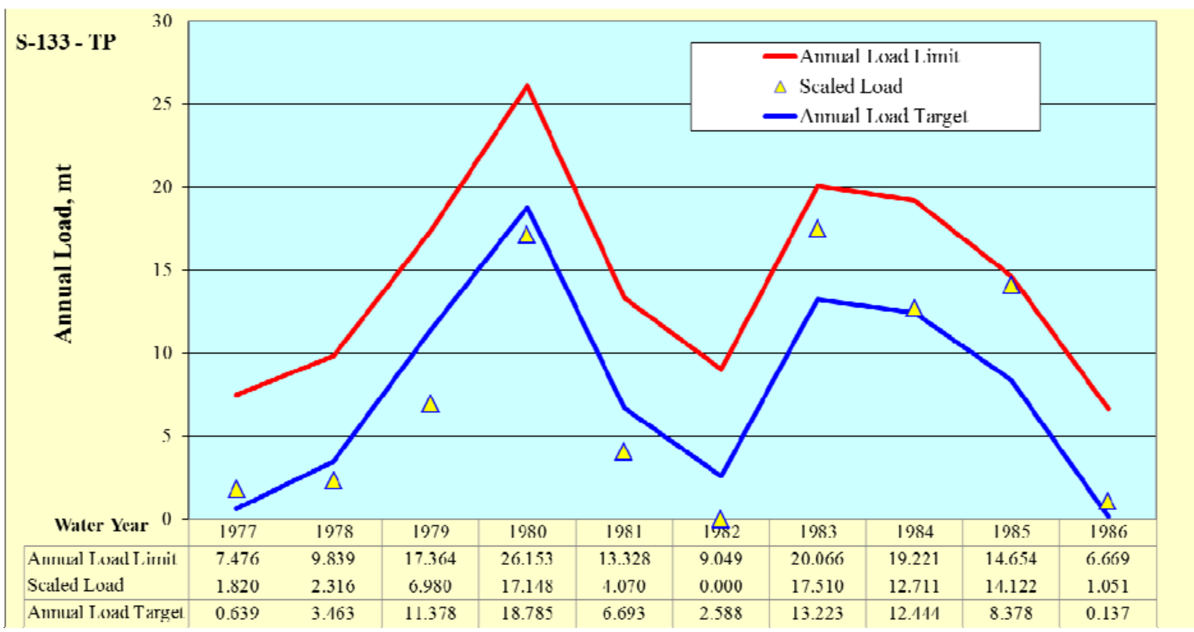


Figure 1-3. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the S-133 Summary Basin based on a 25% load reduction.

Table 1-3. S-154 Summary Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
8.3	5.4	80%	35%	30.06	56.20
Target = exp (-5.20573 + 0.16556 X)					
Limit = Target * exp (1.43976 SE)					
$SE = 0.74134 [1 + 1/8 + (X-X_m)^2 / 485.64409]^{0.5}$					

Water Year	1977	1978	1979	1980	1981	1982	1983	1984
Annual Load Limit	9.189	11.412	35.956	111.333	2.918	17.868	219.770	17.926
Scaled Load	0.710	4.194	16.319	24.570	1.935	4.331	97.284	6.422
Annual Load Target	2.874	3.617	11.488	32.926	0.795	5.751	60.253	5.770

Figure 1-4. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the S-154 Summary Basin based on a 35% load reduction.

Table 1-4. S-191 Summary Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall Minimum inches	 Maximum inches
149.5	89.7	89%	40%	36.49	63.56
Target = -692.35612 + 210.9038 X + 84.89757 C					
Limit = Target + 1.38303 SE					
$SE = 13.99487 [1 + 1/12 + 3.1233 (X-X_m)^2 + 2.11893 (C–C_m)^2 + 1.54068 (X-X_m) (C–C_m)]^{0.5}$					

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

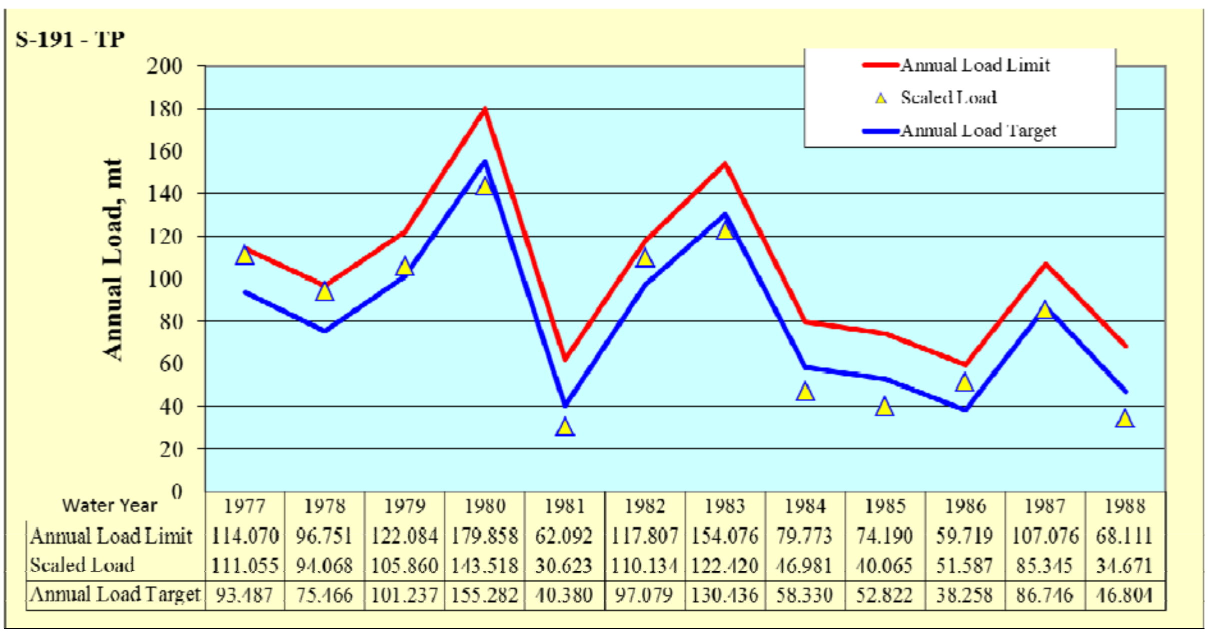
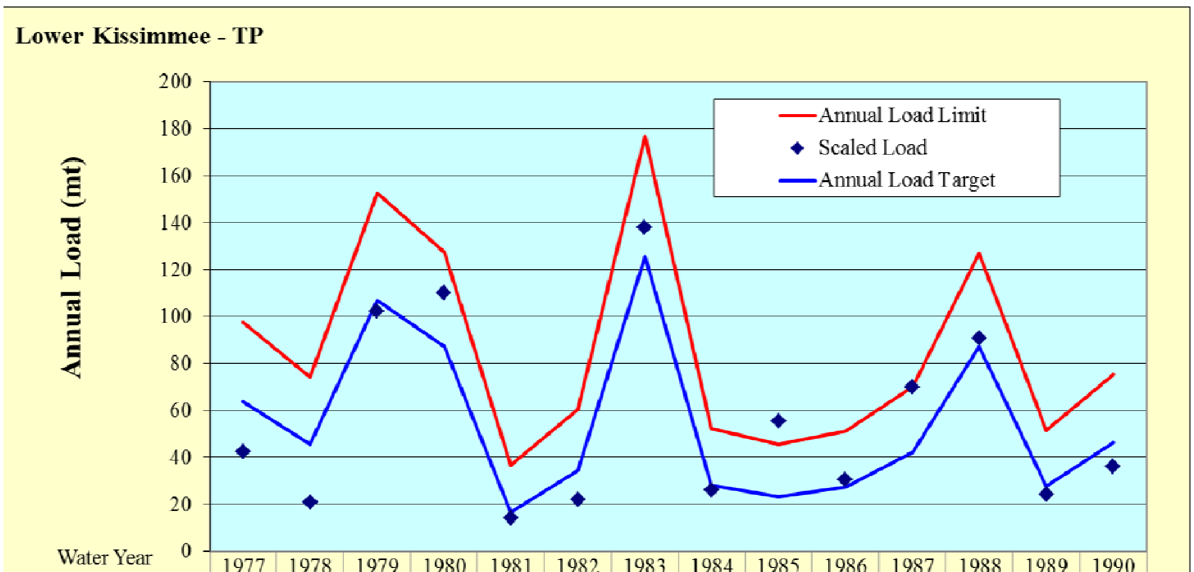


Figure 1-5. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the S-191 Summary Basin based on a 40% load reduction.

Table 1-5. Lower Kissimmee Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall Minimum inches	Base Period Rainfall Maximum inches
56.1	39.2	75%	30%	39.33	61.84
Target = $[-8.42963 + 0.31747\ X\ ]^2$					
Limit = $[\ \mathrm{sqrt}(\mathrm{Target}) + (1.35622\ \mathrm{SE})\ ]^2$					
SE = $1.33557\ [\ 1 + 1/14 + (X-X_m)^2\ /\ 641.63129\ ]^{0.5}$					



Water Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Annual Load Limit	97.550	74.281	152.473	127.241	36.596	60.315	176.826	52.088	45.616	51.218	70.280	127.090	51.608	75.207
Scaled Load	42.512	20.834	102.425	110.102	13.996	22.112	138.121	26.171	55.481	30.512	70.048	90.648	24.114	35.973
Annual Load Target	63.841	45.460	106.771	87.164	16.456	34.486	125.505	28.101	23.157	27.432	42.306	87.045	27.732	46.191

Figure 1-6. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Lower Kissimmee Sub-watershed based on a 30% load reduction.

Table 1-6. C-44 Hydrologic Unit TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
52.9	34.4	84%	35%	29.81	61.40
Target = exp [-6.33102 + 2.47876 X + 0.32418 S]					
Limit = Target * exp (1.39682 SE)					
$SE = 0.28227 [1 + 1/11 + 2.17743 (X-X_m)^2 + 0.37715 (S-S_m)^2 - 0.19128 (X-X_m)(S-S_m)]^{0.5}$					

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

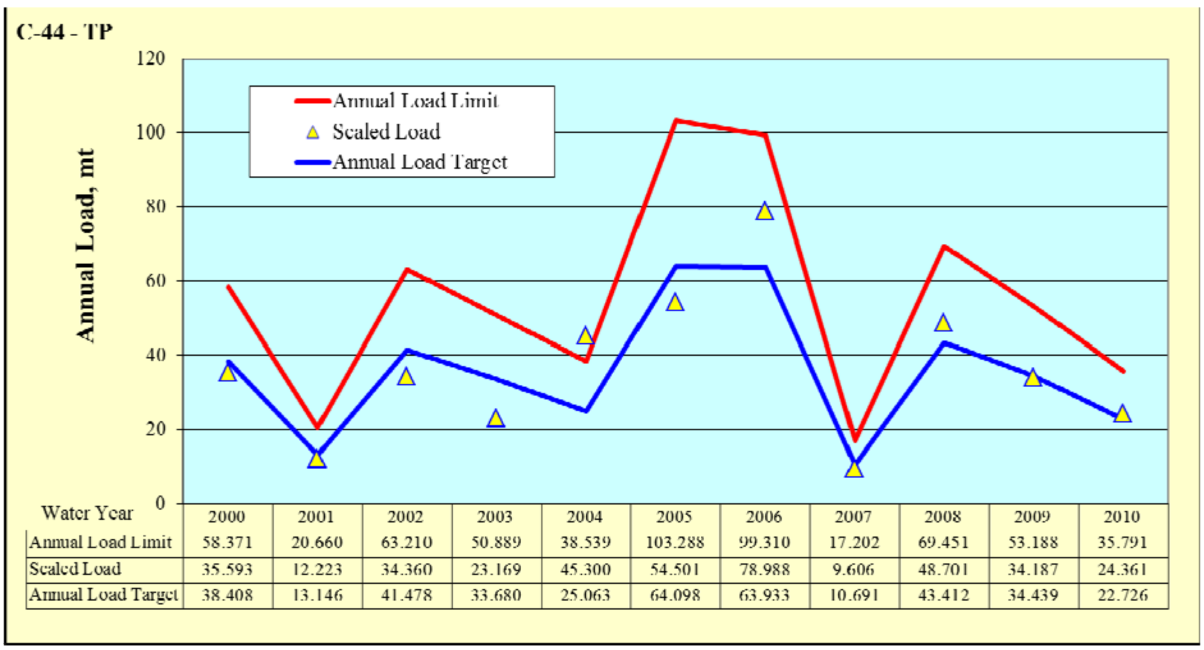


Figure 1-7. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the C-44 Hydrologic Unit based on a 35% load reduction.

Table 1-7. L-8 Summary Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall[1]	
				Minimum inches	Maximum inches
17.1	13.7	84%	20%	41.28	72.35

$$\text{Target} = (-5.06793 + 0.08241\,X - 1.54007\,S + 6.93876\,C)^2$$

$$\text{Limit} = [\,\text{sqrt}(\text{Target}) + (1.47588\,SE)\,]^2$$

$$SE = 0.46154\,[\,1 + 1/9 + 0.00211\,(X-X_m)^2 + 0.98133\,(S-S_m)^2 + 14.63127\,(C-C_m)^2 - 0.0005\,(X-X_m)\,(S-S_m) + 0.19976\,(X-X_m)\,(C-Cm) - 4.37464\,(S-S_m)\,(C-C_m)\,]^{0.5}$$

[1] Based on adjusted rainfall values

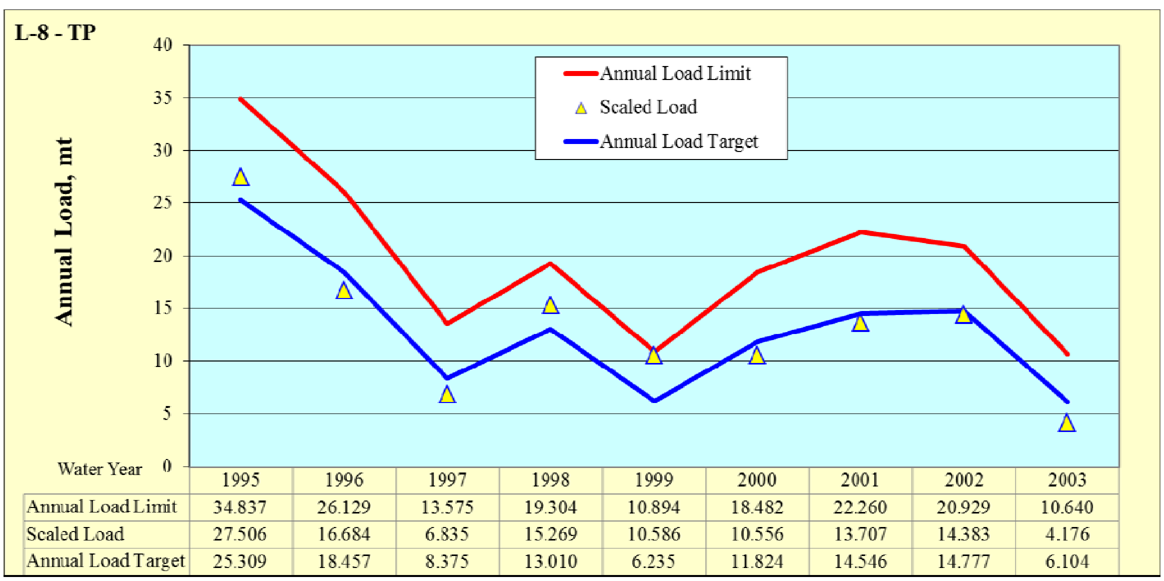


Figure 1-8. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the L-8 Summary Basin based on a 20% load reduction.

Table 1-8. Indian Prairie Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
67.6	47.3	91%	30%	30.55	49.29

$$\text{Target} = \exp(-12.83843 + 4.02124\,X + 1.76267\,C)$$

$$\text{Limit} = \text{Target} * \exp(1.37218\,SE)$$

$$SE = 0.20346\,[\,1 + 1/13 + 3.91995\,(X-X_m)^2 + 3.19741\,(C-C_m)^2 + 4.34342\,(X-X_m)\,(C-C_m)\,]^{0.5}$$

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

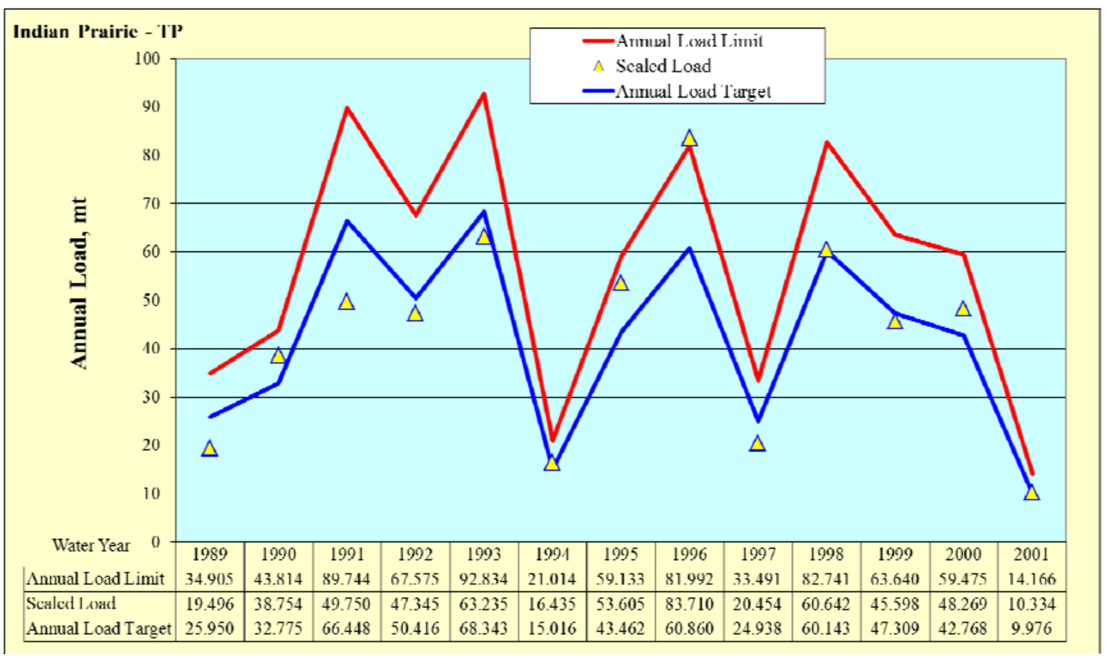


Figure 1-9. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Indian Prairie Sub-watershed based on a 30% load reduction.

Table 1-9. Fisheating Creek Summary Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
67.6	47.3	54%	30%	33.31	78.23
Target = -340.30489 + 99.44445 X					
Limit = Target + 1.38303 SE					
$SE = 23.82794 [1 + 1/11 + (X-X_m)^2 / 0.59477]^{0.5}$					

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

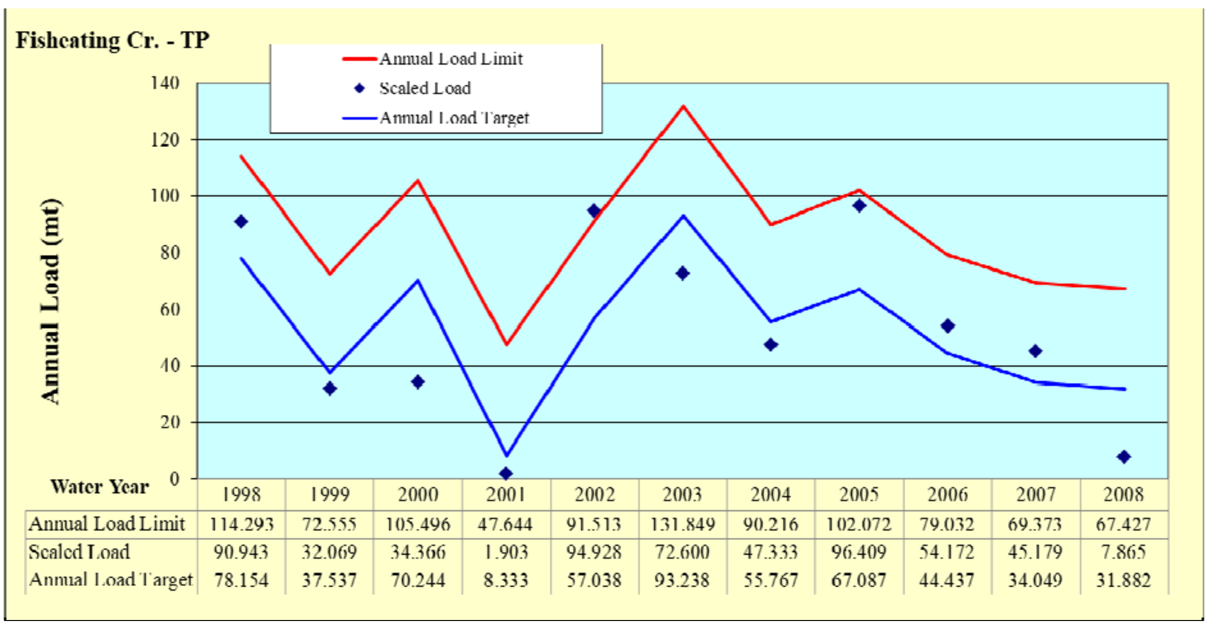


Figure 1-10. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Fisheating Creek Summary Basin based on a 30% load reduction.

Table 1-10. S-4/Industrial Canal Hydrologic Unit TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
17.6	14.3	76%	30%	26.95	62.81
Target = -14.62787 + 0.41452 X + 8.44621 C					
Limit = Target + 1.43976 SE					
SE = 3.02608 [1 + 1/9 + 0.00112 (X-X$_m$)^2 + 2.03794 (C–C$_m$)^2 + 0.00884 (X-X$_m$) (C–C$_m$)]$^{0.5}$					

$$Target = -14.62787 + 0.41452\,X + 8.44621\,C$$

$$Limit = Target + 1.43976\,SE$$

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

[1] Based on adjusted rainfall values

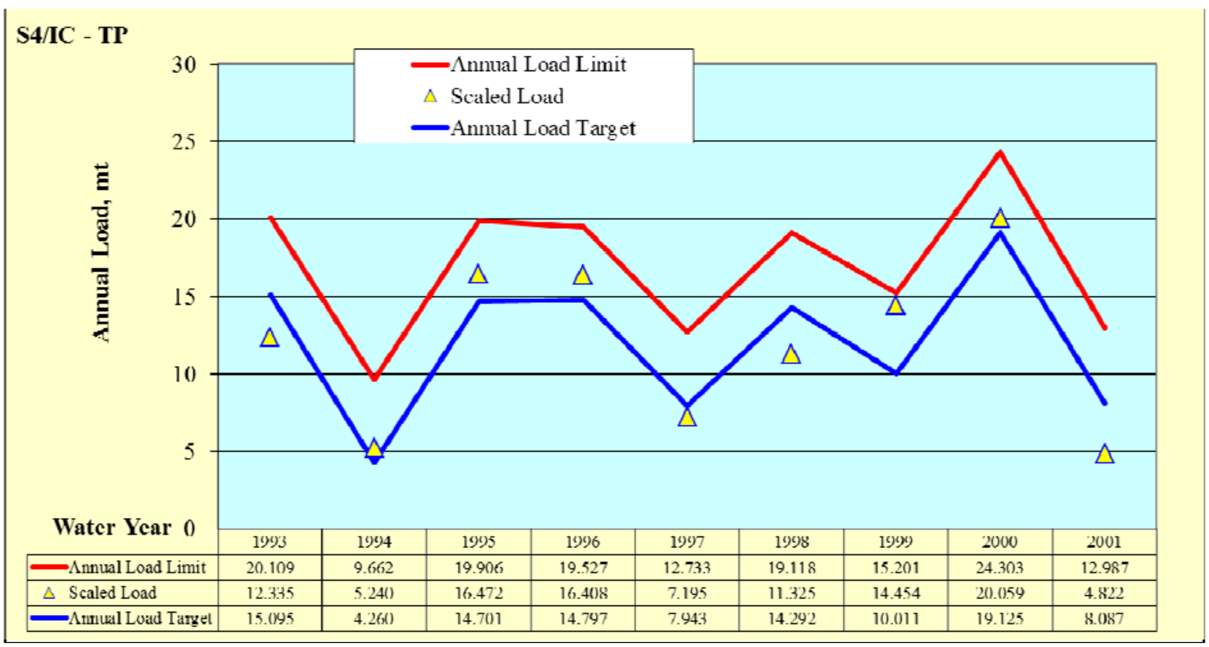


Figure 1-11. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the S-4/Industrial Canal Hydrologic Unit based on a 30% load reduction.

Table 1-11. East Caloosahatchee Hydrologic Unit TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall Minimum inches	Base Period Rainfall Maximum inches
54.9	38.5	73%	30%	42.29	72.47

$$\text{Target} = -136.788 + 3.61027\ X$$

$$\text{Limit} = \text{Target} + 1.41492\ SE$$

$$SE = 21.79613\ [\ 1 + 1/9 + (X - X_m)^2 / 675.50602\ ]^{0.5}$$

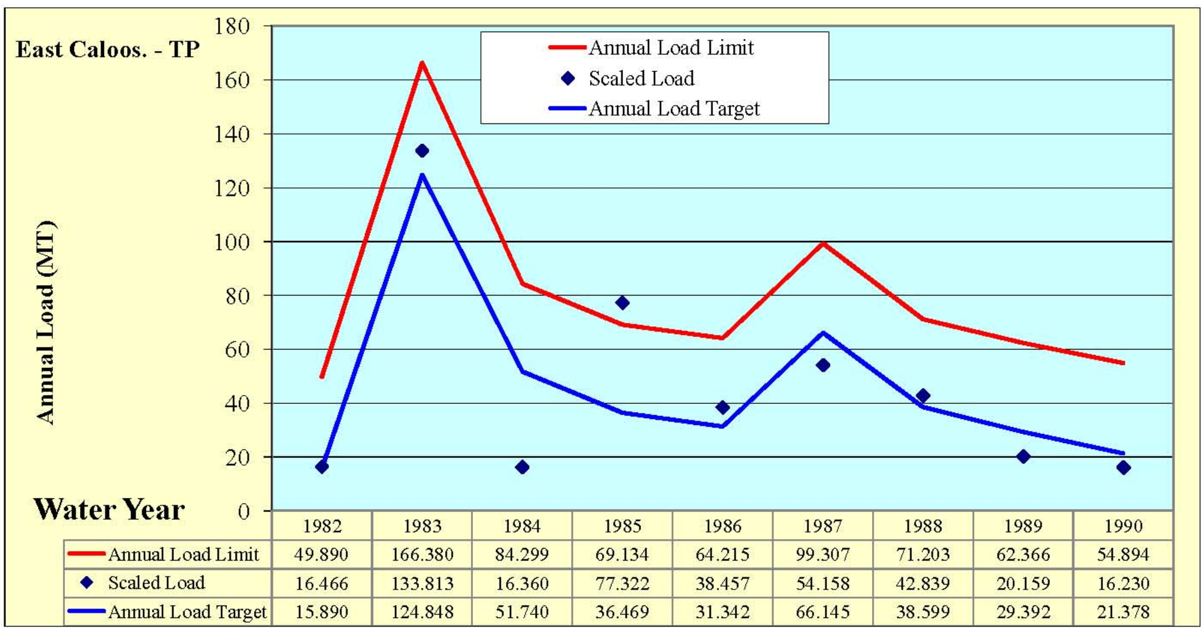
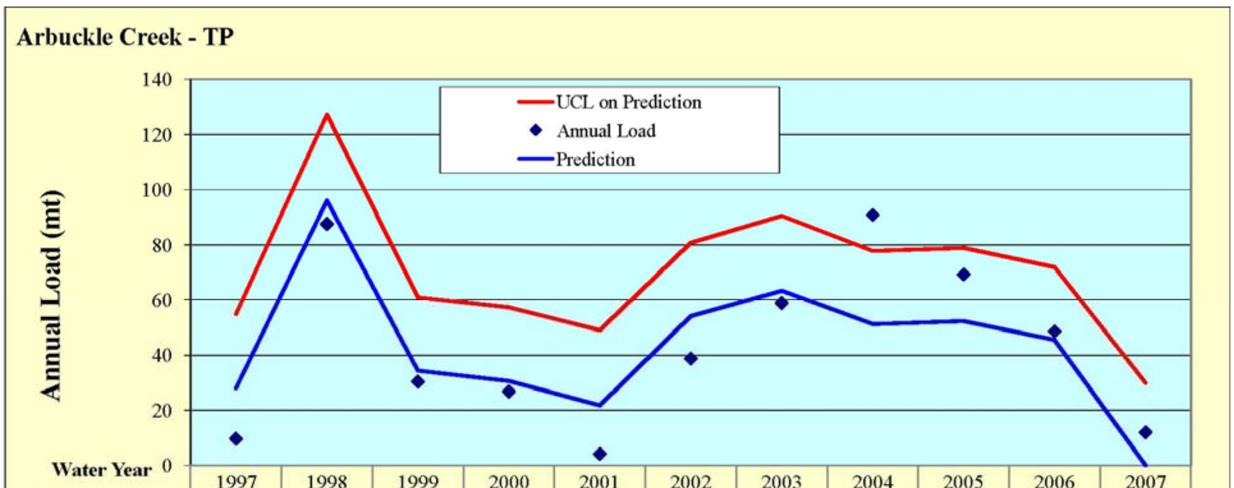


Figure 1-12. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the East Caloosahatchee Hydrologic Unit based on a 30% load reduction.

Table 1-12. Arbuckle Creek Tributary TP Load Performance Indicator.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall Minimum inches	Base Period Rainfall Maximum inches
38.8	38.8	68%	0%	33.74	77.45
Target = -406.10066 + 115.44341 X					
Limit = Target + 1.38303 SE					
$SE = 18.27506\ [1 + 1/11 + (X-X_m)^2 / 0.46933]^{0.5}$					

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



Water Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
UCL on Prediction	54.827	127.336	60.956	57.341	49.076	80.765	90.544	77.777	78.883	71.924	29.915
Annual Load	9.748	87.642	30.417	26.846	4.264	38.802	58.961	90.876	69.319	48.603	12.087
Prediction	27.971	96.035	34.400	30.628	21.787	54.145	63.385	51.260	52.331	45.516	0.108

Figure 1-13. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Arbuckle Creek Tributary based on a 0% load reduction.

Table 1-13. Josephine Creek Tributary TP Load Performance Indicator.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
3.0	3.0	93%	0%	36.85	77.63
Target = -33.98677 + 9.49604 X					
Limit = Target + 1.43976 SE					
$SE = 0.68581\,[1 + 1/8 + (X-X_m)^2 / 0.40023]^{0.5}$					

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

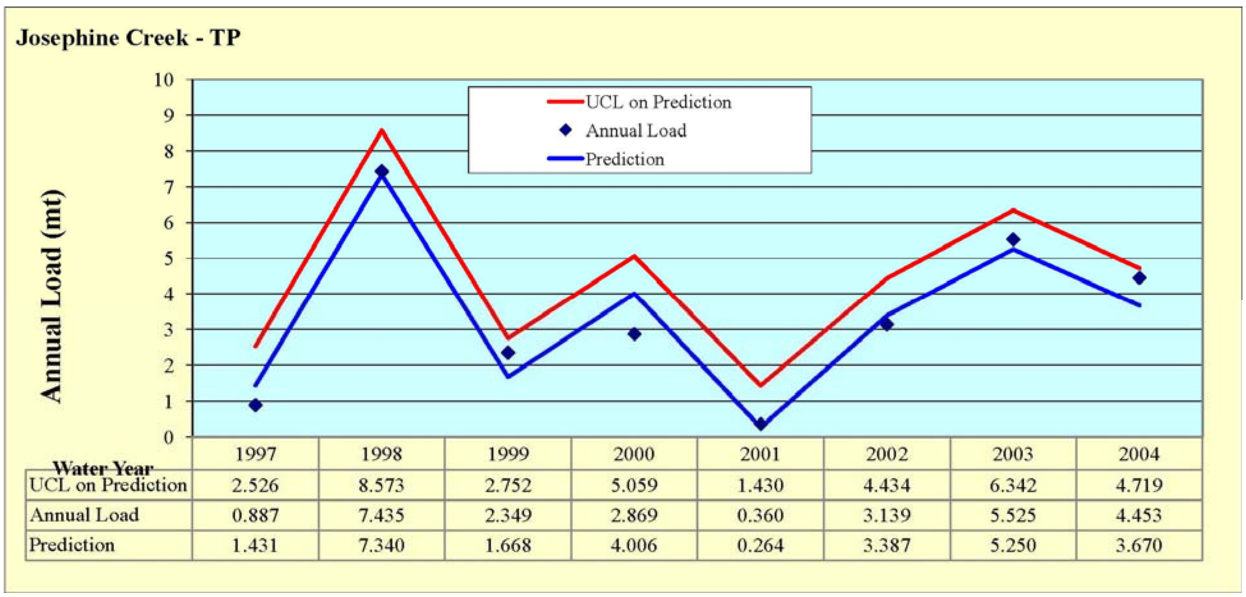


Figure 1-14. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Josephine Creek Tributary based on a 0% load reduction.

Table 1-14. Boggy Creek Tributary TP Load Performance Indicator.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall[1] Minimum inches	Base Period Rainfall[1] Maximum inches
5.0	5.0	98%	0%	32.89	71.83

$$\text{Target} = (-2.39491 + 0.05939\ X + 1.35719\ C)^2$$

$$\text{Limit} = [\ \text{sqrt}\ (\text{Target}) + (1.47588\ SE)]\ ^2$$

$$SE = 0.20722\ [1 + 1/8 + 0.0007\ (X\text{-}X_m)^2 + 3.58103\ (C–C_m)^2 + 0.0135\ (X\text{-}X_m)\ (C–C_m)]^{0.5}$$

[1] Based on adjusted rainfall values

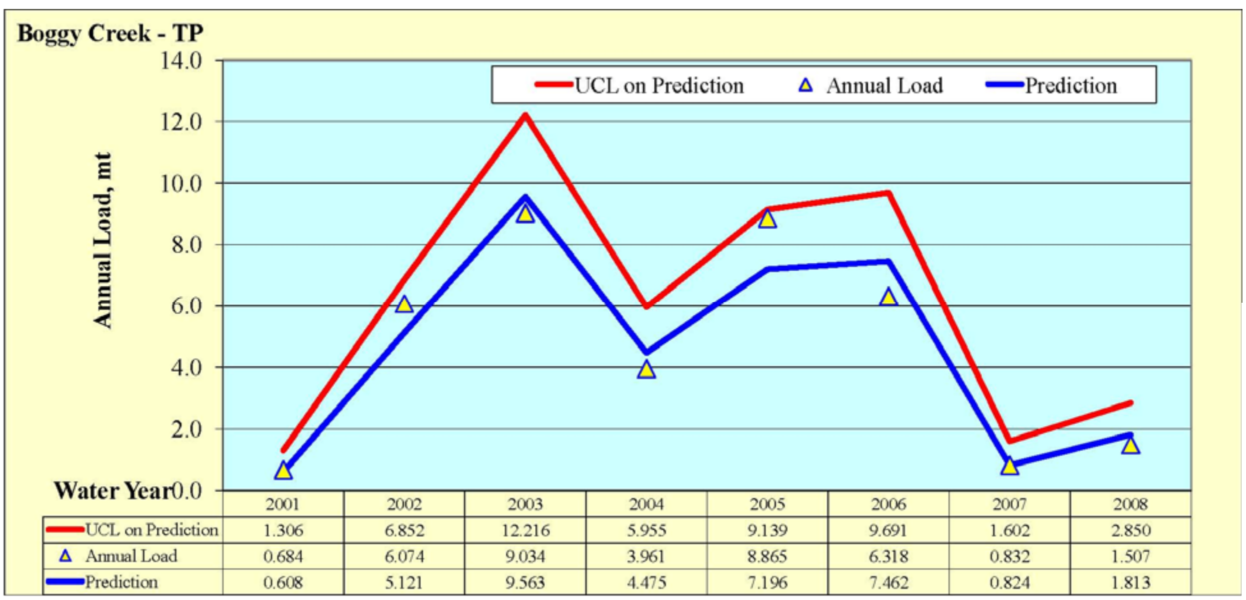


Figure 1-15. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Boggy Creek Tributary based on a 0% load reduction.

Table 1-15. Shingle Creek Tributary TP Load Performance Indicator.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R^2)	Recommended Source Control Reduction	Base Period Rainfall[1]	
				Minimum inches	Maximum inches
17.4	17.4	97%	0%	37.53	86.31

$$\text{Target} = -140.82331 + 43.29617\ X + 9.1697\ S$$

$$\text{Limit} = \text{Target} + 1.440\ SE$$

$$SE = 2.58225\ [1 + 1/9 + 1.7741\ (X\text{-}X_m)^2 + 0.52978\ (S - S_m)^2 + 0.10178\ (X\text{-}X_m)\ (S - S_m)]^{0.5}$$

[1] Based on adjusted rainfall values

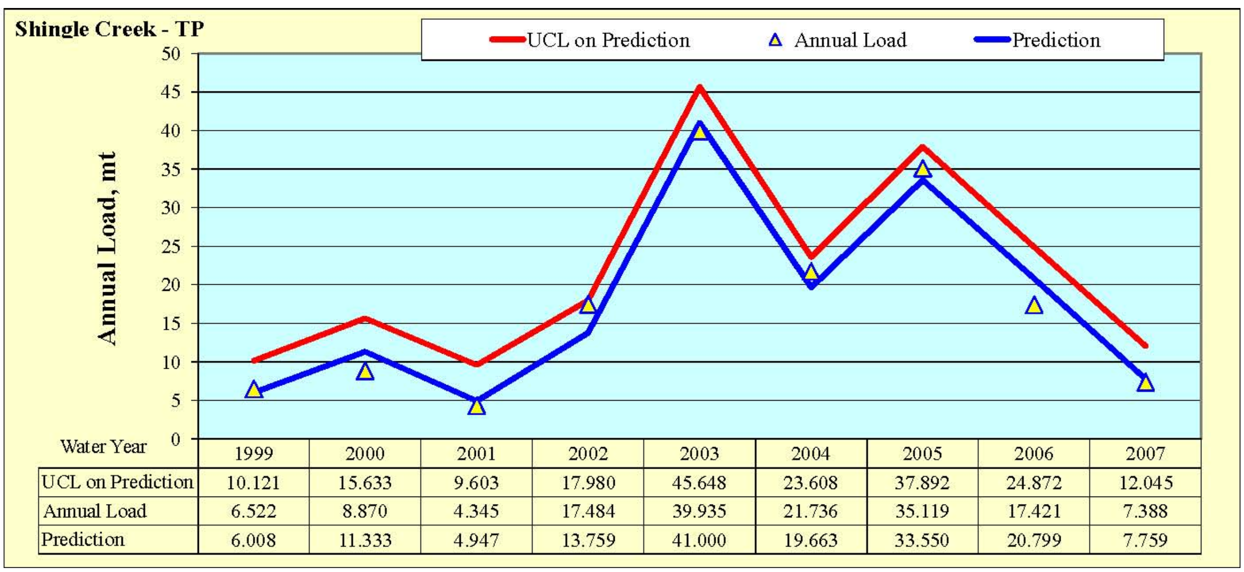


Figure 1-16. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Shingle Creek Tributary based on a 0% load reduction.

2. INTRODUCTION AND OBJECTIVES

This *Draft Technical Support Document* was developed in support of the District's Regulatory Source Control Program (Chapter 40E-61, F.A.C, also known as "Works of the District"). The program was established in 1989 in the Lake Okeechobee Watershed under the authority of the SWIM Act. Recent legislative changes have, among other things, directed complementary source control programs by the three coordinating agencies (the FDEP, the District and the FDACS), expanded the Lake Okeechobee Watershed, and expanded source control activities to include the St. Lucie River Watershed and the Caloosahatchee River Watershed.

In response to these legislative changes, the District must update the 1989 source control rule to effectuate the NEEPP requirements, including developing updated performance metrics. The statute directs that where water quality problems are detected despite the appropriate implementation of the BMPs a reevaluation of the BMPs shall be initiated. The performance metrics will ultimately be incorporated into Chapter 40-61, F.A.C., and will serve to meet the statutory requirement.

This *Draft Technical Support Document* presents quantitative methods for assessing the TP reductions in runoff resulting from the collective source control programs in the sub-watersheds, summary basins and hydrologic units within the Lake Okeechobee Watershed and portions of the Caloosahatchee River Watershed and St. Lucie River Watershed that overlap with the Lake Okeechobee Watershed boundary[1] **(Figure 2-1** and **Table 2-1)**. The quantitative methods are referred to as "performance measure methodologies".

[1] The performance measure methodologies for the Caloosahatchee River Watershed and St. Lucie River Watershed will be detailed in *Technical Support Documents* for those respective sub-watersheds, including the NEEPP required nitrogen component.

2.1 Organization of the Draft Technical Support Document

Section 1 of this *Draft Technical Support Document* provided an Executive Summary of the performance measure methodologies for the respective sub-watersheds, summary basins and hydrologic units within the Lake Okeechobee Watershed. Where possible, consistency was maintained with previously documented naming and delineations of these basins. However, this was not always possible as this expansive area has been referenced in a variety of prior documents using different terms, e.g., some summary basins in Lake Okeechobee documents are referred to as sub-watersheds in river watershed documents. Since some of the basins discussed in this document discharge to more than one watershed (i.e., to Lake Okeechobee and to a river watershed), a common terminology was used for those specific basins: "hydrologic units", for example, "C-44 Hydrologic Unit". However, when the methodology is discussed as a whole, the term "basin" will be used to describe sub-watersheds, summary basins and hydrologic units.

Section 2 provides general background information for the Project. **Section 3** summarizes the performance measure methodologies for basins of the Lake Okeechobee Watershed. **Appendix A** presents supplemental technical details of the individual basins. **Appendix B** presents the regression equations that serve as the foundation for the performance measures and performance indicators. **Appendix C** provides a summary of the flow and water quality stations used in developing the performance measure methodologies.

Figure 2-1. Sub-watershed level map of the Lake Okeechobee Watershed.

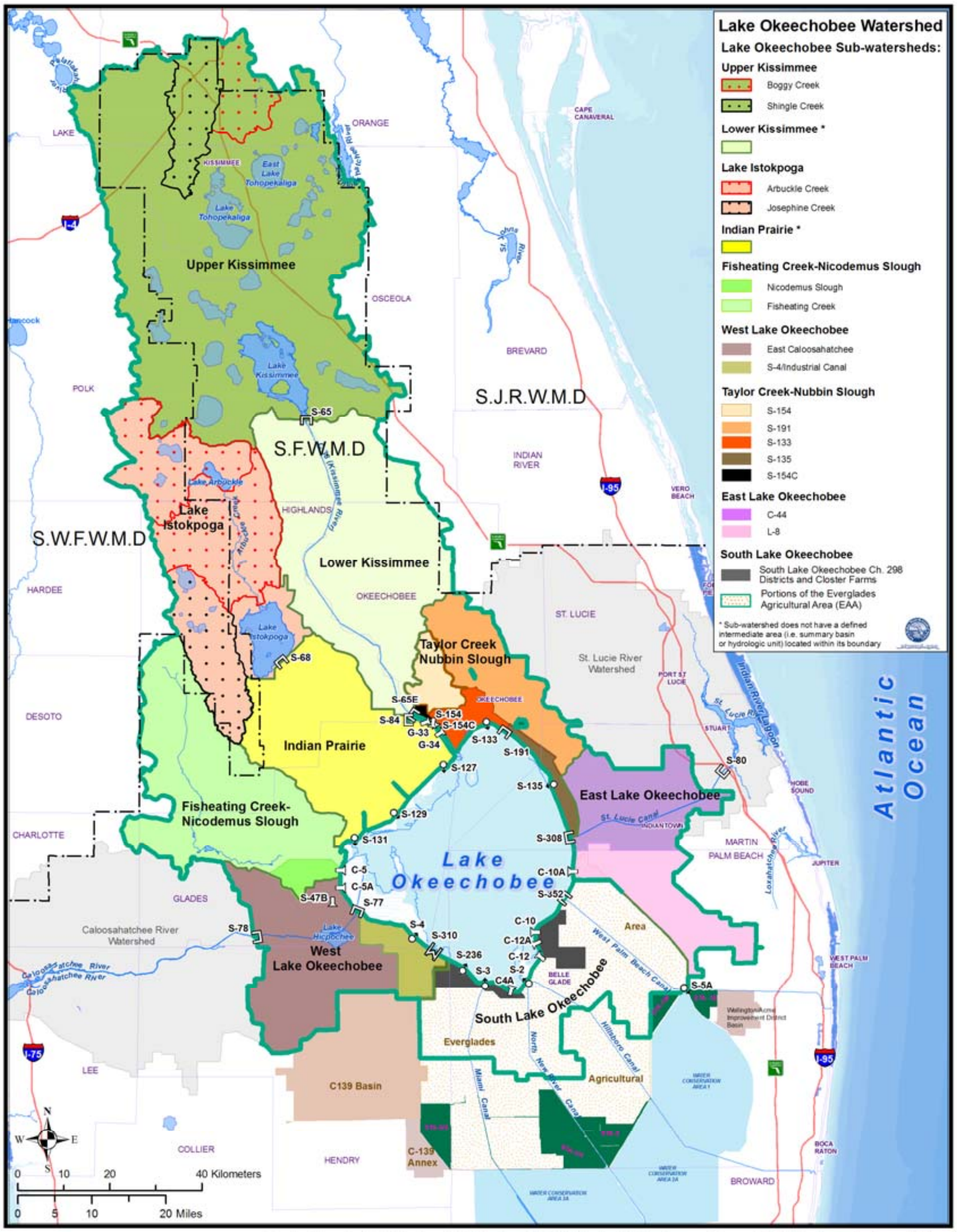


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Table 2-1. Summary table of basins within the Lake Okeechobee Watershed.

Summary Basin or Hydrologic Unit	Area (acres)	Lake Okeechobee Watershed	St. Lucie River Watershed	Caloosahatchee River Watershed	Everglades Agricultrual Area
Upper Kissimmee Sub-watershed					
No Summary Basins	N/A				
Sub-watershed Total	***1,028,421***	√			
Lower Kissimmee Sub-watershed					
No Summary Basins	N/A				
Sub-watershed Total	***429,188***	√			
Taylor Creek-Nubbin Slough Sub-watershed					
S-191	119,402	√			
S-133	25,626	√			
S-135	17,756	√			
S-154	31,815	√			
S-154C	2,134	√			
Sub-watershed Total	***196,733***	√			
Lake Istokpoga Sub-watershed					
No Summary Basins	N/A				
Sub-watershed Total	***394,203***	√			
Indian Prairie Sub-watershed					
No Summary Basins	N/A				
Sub-watershed Total	***276,577***	√			
Fisheating Creek-Nicodemus Slough Sub-watershed					
Fisheating Creek	298,713	√			
Nicodemus Slough	19,329	√			
Sub-watershed Total	***318,042***	√			
West Lake Okeechobee Sub-watershed					
East Caloosahatchee	204,094	√		√	
S-4/Industrial Canal	42,145	√		√	
Sub-watershed Total	***246,240***	√		√	
South Lake Okeechobee Sub-watershed[1]					
715 Farms (Culv 12A)	3,302	√			√
East Beach WCD (Culv 10)	6,624	√			√
East Shore WCD (Culv 12)	8,416	√			√
S-2	106,371	√			√
S-3	62,946	√			√
South FL Conservancy D (S-236)	11,028	√			√
South Shore/So. Bay DD (Culv 4A)	4,134	√			√
S-5A Basin (S-352-WPB Canal)	119,443	√			√
Sub-watershed Total	***322,262***	√			√
East Lake Okeechobee Sub-watershed					
C-44[2]	132,572	√	√		
L-8 Basin (Culv 10A)	106,440	√			
Sub-watershed Total	***239,013***	√	√		

[1] Note: South Lake Okeechobee Areas is based on LOPP boundaries, all other boundaries are based on ArcHydro.

[2] Note: The area provided in this table for C-44 was obtained from Deliverable 6.1 Collective Source Control Performance Measures for C-23, C-24, C-25/25E, and C-44 Technical Report (dated September 2011; HDR 2011)

[3] Note: There are some minor differences between the acreages shown in Table 2-1 and the 2011 LOPP. L-61W was removed from the Indian Prairie Sub-watershed and is now included in the Fisheating Creek Summary Basin. Culvert 5Awas moved from the Nicodemus Slough Summary Basin to the East Caloosahatchee Hydrologic Unit. These changes were a result of a review of flow patterns in these areas.

Appendix D presents the methods used to establish recommended nutrient load reductions that could be reasonably expected to result from implementation of collective source control programs. **Appendix E** provides the details of the algorithm to be used to adjust the performance measures to account for regional projects. The Excel spreadsheets containing the specific analyses for the performance measures are included as **Attachment 1** to this *Draft Technical Support Document*.

2.2Authorization and Scope

This *Draft Technical Support Document: Lake Okeechobee Watershed Performance Measure Methodologies* constitutes Deliverable 3.5 of Contract 4600002337 - Performance Measure Methodologies for Collective Source Controls in the Lake Okeechobee and Caloosahatchee River Watersheds - between the District and Gary Goforth, Inc. dated January 31, 2011. The objective of this deliverable is to summarize the technical methods utilized for development of performance measures or performance indicators for the individual basins of the Lake Okeechobee Watershed. The *Draft Technical Support Document* contains a narrative step-by-step description of the performance measure methodologies, including:

- An explanation of how monitoring results will be evaluated against each basin's performance measures;
- A description of how the performance of the collective source control program within each basin will be assessed, consisting of the steps that will be taken at the completion of each water year to determine if a basin has achieved its performance measure.

This document was prepared by Gary Goforth, Inc., in association with L. Hornung Consulting, Inc., Soil & Water Engineering Technology, Inc. and staff of the South Florida

Water Management District, and complements work completed by others, including the following.

1. The performance measure for the East Caloosahatchee Hydrologic Unit, also referred to as the East Caloosahatchee Sub-watershed within the Caloosahatchee River Watershed, was based in part on historical data analyses conducted by HDR Engineering, Inc. as part of Contract No. ST061298 – WO08 (Data Analysis and Performance Measure Development for the St Lucie and the Caloosahatchee River Source Control Programs) with the South Florida Water Management District (HDR 2011b). Additional historical data analyses were conducted as part of this work effort to incorporate revised data.
2. The historical data analyses and performance measure methodology for the C-44 Hydrologic Unit, also referred to as the C-44 Sub-watershed of the St. Lucie River Watershed, were performed by HDR Engineering, Inc. as part of Contract No. ST061298 – WO08 (Data Analysis and Performance Measure Development for the St Lucie and the Caloosahatchee River Source Control Programs) with the South Florida Water Management District (HDR 2011a, HDR 2011c). Additional data analyses were conducted as part of this work effort to incorporate revised information.
3. The performance measure methodology for the Everglades Agricultural Area (EAA) Basin, which has overlapping boundaries with the South Lake Okeechobee Sub-watershed, was developed as part of Ch. 40E-63, F.A.C.
4. The proposed performance measure methodology for the Ch. 298 Districts and Closter Farms was developed by District staff with assistance from Gary Goforth, Inc. (Goforth et al. 2011).

2.3 Background

This *Draft Technical Support Document* summarizes the quantitative methods for assessing the collective performance of the source control programs for the basins within the Lake Okeechobee Watershed **(Figure 1-1**). The collective source control programs in place or being developed include the source control programs identified in **Table 2-2**.

2.3.1 History of Source Controls in the Lake Okeechobee Watershed

The following section describes over thirty years of federal, state and regional efforts leading up to the current source control programs in the Lake Okeechobee Watershed. A summary of the source control implementation time frame for the Lake Okeechobee Watershed is presented in **Table 2-3**.

PROGRAMS THAT BEGAN IN THE 1970s

Federal Clean Water Act

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

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 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 river watersheds.

[3]Applicable to only the Lake Okeechobee Watershed.

[4]Partially funded by FDEP.

[5]No reductions considered.

Table 2-3. Summary of the source control implementation time frame for the Lake Okeechobee Watershed.

Timeframe	Event
1970s	FDER Dairy regulatory programs begin
1972	Clean Water Act and Florida Water Resources Act
	South Florida Water Management District Stormwater Permitting Begins
1978	Florida Established Non-Point Source Management Programs
1981	Rural Clean Water Program Taylor Creek Headwaters
1984	FDER Biosolids/Domestic Wastewater Residuals Regulations
1985	Florida State stormwater rule adopted, retention ponds became required for new development
1986	New citrus groves were required to include onsite reservoirs for stormwater runoff.
1987	Surface Water Improvement and Management Act for Lake Okeechobee enacted
1987	FDER Dairy Rule for Lake Okeechobee Basin
1989	Chapter 40E-61, the Lake Okeechobee Works of the District Rule adopted by SFWMD
1990	National Pollutant Discharge Elimination System Programs
1992	Chapter 40E-63, the Everglades Agricultural Area Works of the District Rule adopted by SFWMD
1995	SFWMD Environmental Resource Permitting Regulatory Program adopted
1995	Kissimmee River Restoration Project
1999	Florida Watershed Restoration Act
2000	The Lake Okeechobee SWIM Act is revised to become the Lake Okeechobee Protection Act
2003	FDOH Septage Application requires Agricultural Use Plan
2003	FDACS adopts Rule 5M-3, the BMP rule for the priority basins S-191, S-154, S-65 D and S-65E.
2003	FDACS Land Application of Animal Wastes (Rule 5M-3)
2004	FDOH Wastewater Master Plans
2005	The geographic area of the Lake Okeechobee Protection Act is expanded to include the Upper Kissimmee and the Lake Istokpoga Sub-watersheds.
2006	FDACS expands BMP rule 5M-3 to the entire Lake Okeechobee Watershed
2007	The LOPA is revised to become the Northern Everglades and Estuaries Protection Program
2007	FDACS Urban Turf Fertilization Rule (Rule 5E-1.003)
2011	FDACS amends BMP Rule 5M-3 to the entire Northern Everglades
Beyond 2012	Elimination of land application of biosolids
	Proposed FDEP Numeric Nutrient Criteria

In response to assessments and research from the Area-wide Water Quality Planning Program performed under Section 208 of the Clean Water Act, Florida began implementing programs to minimize nonpoint sources of pollution in the late 1970s. In 1987, the Clean Water Act was amended to add Section 319 which required states to develop nonpoint source management programs. Florida began full implementation of its revised nonpoint source management program in 1989 following submission, review, and approval by USEPA (FDEP 1999).

Florida Dairy Programs

In the Lake Okeechobee Watershed, the dairy lagoon regulatory program was implemented by the Federal Soil and Water Conservation Service (which is now the Natural Resource Conservation Service) in the 1970s and required wastewater retention onsite. In 1987, this program was followed by the FDEP dairy rule (Rule 17-6.330) which required specific BMPs for dairies in the Lake Okeechobee Drainage Basin, which at the time consisted of the Lower Kissimmee, Taylor Creek-Nubbin Slough, Fisheating Creek-Nicodemus Slough, Indian Prairie and South Lake Okeechobee Sub-watersheds. During this time there was also a dairy buyout program which was a voluntary program where the state purchased a deed restriction on dairy properties which decided to close instead of implementing the BMPs required under Rule 17-6.330. The deed restriction prevents these properties from being used as a dairy operation.

In 1996, Rule 17-6.330 was superseded by Rule 62-670, the Feedlot and Dairy Wastewater Treatment and Management program, 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. Rule 62-670 had additional requirements for dairies operating in the Lake Okeechobee Drainage Basin which was defined as it had been under Rule 17-6.330.

USEPA finalized the CAFO Rule in 2003 under the Clean Water Act which required all large animal feed 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 Industrial Waste permits to NPDES permits.

PROGRAMS THAT BEGAN IN THE 1980s

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.

The Lake Okeechobee Operating Permit (LOOP) was issued to SFWMD by FDEP in 1983. The LOOP required the management of water in the Everglades Agricultural Area (EAA) in the South Lake Okeechobee Sub-watershed for nutrient reduction and flood protection purposes.

Federal Rural Clean Water Program

In the 1980s the Rural Clean Water Program provided financial and technical assistance to private landowners and operators having control of rural land. The assistance was provided through long-term contracts to install best management practices in project areas which had critical water quality problems resulting from agricultural activities. In 1981, there were 63,109 acres included in the Rural Clean Water Program within fourteen projects in the Taylor Creek-Nubbin Slough Sub-watershed, including dairy farms, beef cattle pastures that were extensively ditched for improved surface drainage, and areas within one-quarter of a mile from a waterway. BMPs which excluded dairy cows and beef cattle from waterways and to control wastewater runoff from dairy barns were installed. In 1988 the program was expanded to include dairies in the Lower Kissimmee Sub-watershed.

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 Lake Okeechobee 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 the nutrient loading to Lake Okeechobee. Biosolids provide a low cost agricultural fertilizer. If land application is prohibited, fertilization may be reduced due to economic factors.

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 were required to include detention reservoirs in their surface water management plans.

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

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

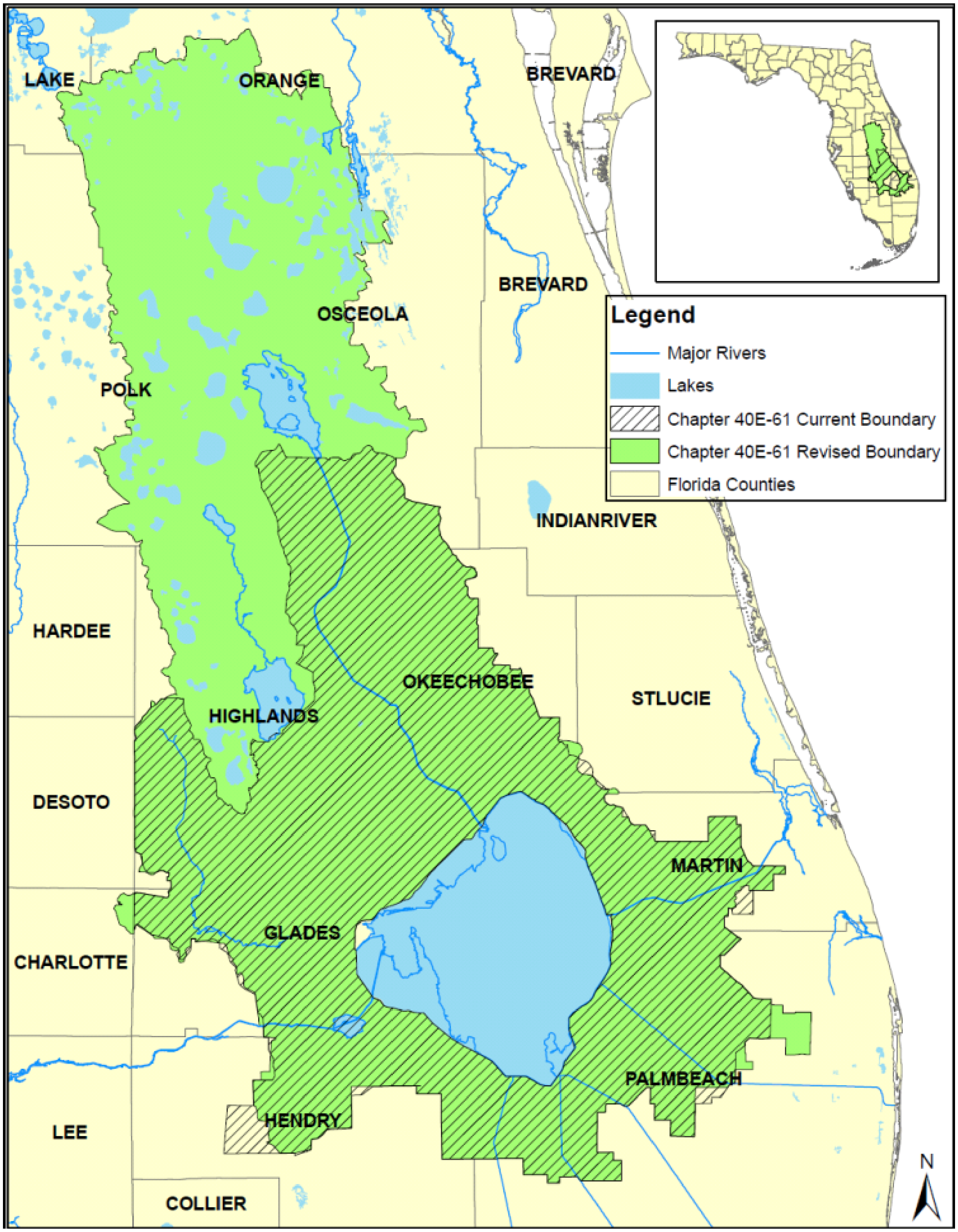
In 1987, the State of Florida enacted the Surface Water Improvement and Management (SWIM) Act. This Act required the water management districts to develop and implement plans for restoring and protecting degraded water bodies in the state. The Lake Okeechobee SWIM Plan was prepared by the SFWMD in 1989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

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

In 1989, the District adopted Rule 40E-61 regulating phosphorus surface water discharges from certain land uses in the Lake Okeechobee Watershed. At that time, the program included the Lower Kissimmee, Indian Prairie, Fisheating Creek-Nicodemus Slough, South

Lake Okeechobee, East Lake Okeechobee, West Lake Okeechobee, and Taylor Creek/Nubbin Slough Sub-watersheds (see **Figure 2-2**). Approximately 800 permits were issued on parcels of land five (5) acres and greater for the following land uses: improved pasture, heifer farms, vegetable farms, hog farms, poultry farms, goat farms, urban stormwater, golf courses, sugar cane, horse farms, nurseries, land spreading of sludge (biosolids), and sod farms. At the time the rule became effective, the assumption was that landowners were in compliance until their monitoring data indicated otherwise. The permits set a concentration based discharge limit based on the load reductions set forth under the SWIM plan. The Lake Okeechobee Works of the District (LOWOD) permits required a simple statement from permit holders on how they planned to control phosphorus. The majority of the permits included statements such as "I will use low phosphorus fertilizer". Farm-level grab sample monitoring was required and was funded by the SFWMD. Monitoring funds were limited and the number of landowners required to implement additional BMPs for not meeting the TP concentration limit was relatively few. Performance was measured at the parcel level and it has been difficult to determine the overall program performance in reducing phosphorus loading.

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



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.

Federal Kissimmee River Restoration Project

The Kissimmee River Restoration and the Kissimmee River Headwaters Revitalization Projects were jointly authorized in the 1992 Water Resources Development Act. The primary goal of the Kissimmee River Restoration Project is to reestablish the ecological integrity of the river-floodplain system, which is defined as, “the capability of supporting and maintaining a balanced, integrated, adaptive community having species composition, diversity, and functional organization comparable to that of natural habitat of the region” (Karr and Dudley, 1981). Restoration of ecological integrity requires reconstruction of the physical form of the river (i.e., canal backfilling, removal of water control structures, and elimination of secondary drainage ditches, levees, and roads) and reestablishment of historical (pre-channelization) hydrologic (i.e., discharge and stage) characteristics.

Successful completion of the Kissimmee River Restoration Project and associated projects has critical implications for other ecosystem restoration projects in South Florida. For example, the restoration project should increase phosphorus retention within the Kissimmee River system through restoration of floodplain wetlands, thus removing a portion of phosphorus loads that would otherwise reach Lake Okeechobee.

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

The 1994 Everglades Forever Act defined that Stormwater Treatment Areas and BMP implementation for the Everglades Construction Project basins are the best available technology for achieving interim phosphorus water quality goals for the Everglades Protection Area. In order to carry out these activities, the Everglades Forever Act mandated the creation of an Everglades Program, including a regulatory component to oversee implementation of BMPs. The District promulgated Chapter 40E-63, F.A.C., which details the scope of the Everglades Regulatory Program for the Everglades Agricultural Area (a portion of which is located in the South Lake Okeechobee Sub-watershed) and the C-139 basins. In this rule, the District describes the implementation procedures and compliance measures for the BMP program mandated in the Everglades Forever Act including (1) enforcing implementation of BMPs, (2) conducting a water quality monitoring program to evaluate the effectiveness of BMPs, (3) tracking area-wide phosphorus loads, and (4) developing a mandatory BMP research program for phosphorus and other water quality parameters of concern.

SFWMD Environmental Resource Permit program

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

Florida Watershed Restoration Act

The Florida Watershed Restoration Act of 1999 established and implemented TMDLs and encouraged the implementation of agricultural BMPs. In response to the Act, the Cow/Calf

BMP Manual was developed and adopted in 1999, updated in 2007, and followed by development of BMP manuals for other land uses. The BMP manuals were developed by a collaboration of multiple organizations and representatives of Federal, State, and local governments.

PROGRAMS THAT BEGAN IN THE 2000s

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

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

In 2005, LOPA was revised further and the Upper Kissimmee and Lake Istokpoga Sub-watersheds were included in the Lake Okeechobee Watershed boundary. The 2005 revisions to LOPA directed that phosphorus load reductions be achieved through a phased program of implementing long-term solutions based on the Lake Okeechobee TMDL of 140 metric tons for TP (105 metric tons from contributing sub-watersheds and 35 from atmospheric deposition).

In 2007, LOPA was subsumed by Northern Everglades and Estuaries Protection Program (NEEPP), which further refined the responsibilities of the coordinating agencies to achieve TP reduction objectives faster. The objectives included (1) continued implementation of existing regulations and incentive-based BMPs, (2) development and implementation of improved BMPs, (3) improvement and restoration of hydrologic function of natural and managed systems, and (4) use of alternative technologies for nutrient reduction. In addition, changes were identified for Chapter 40E-61, F.A.C. to incorporate NEEPP mandates that modify the boundary of the program through the inclusion of the Upper Kissimmee Sub-watershed, Lake Istokpoga Sub-watershed, Caloosahatchee River Watershed, and St. Lucie River Watershed; see **Figure 2-2** for proposed revisions to the boundary of 40E-61.

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) 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 Lake Okeechobee Watershed 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 LOWOD program.

BEYOND 2011

The 2011 Lake Okeechobee Protection Plan (LOPP) update provides detailed information on near term and long term activities. These activities include such items as continued implementation of BMP programs, dispersed water management projects, wetland projects, aquifer storage and recovery, parcel level chemical treatment, and the development of stormwater treatment areas and reservoirs. More information about specific projects and programs can be found in the LOPP and subsequent updates.

2.4 Regulatory Framework

The SFWMD's regulatory source control program began in the Lake Okeechobee Watershed with the SWIM Plan, which was required by the 1987 SWIM legislation (Chapter 373.4595, Florida Statutes (F.S.)). The history of this program and the changes to the legislation which mandated the program was discussed above in Section 2.3.1.

After these legislative changes, the SFWMD began the process of revising LOWOD regulatory source control program rule to be compatible with current initiatives. The goal is to have a regulatory source control program that is an ongoing program of BMPs implemented through the issuance of permits for agricultural and non-agricultural land uses (new and existing). The rule will be a comprehensive program of BMP plan approval, verification of implementation through field visits, and data evaluation; and be complementary to the FDACS and FDEP state-wide source control programs. The SFWMD will develop a performance metric for the collective source control programs. Performance measures ensure consistent implementation of BMPs, measure actual phosphorus reductions, and allow for the detection of water quality problems so that BMPs can be re-evaluated if necessary.

This *Draft Technical Support Document* describes the methodologies for initial proposed performance measures that, once finalized, will be used to determine whether the collective source control programs for the Lake Okeechobee Watershed are meeting the objectives of the NEEPP. This approach requires annual calculation of the TP load leaving the outfall structures from each basin.

Because of the critical importance of the Kissimmee-Lake Okeechobee-Everglades ecosystem, many programs work in concert to protect the water resources of the region as a whole. For basins which discharge to more than one watershed, this *Draft Technical Support Document* describes the relationships between the source control programs in those areas.

2.4.1 Total Maximum Daily Loads

Source controls are one of several restoration tools used to support the achievement of the Lake Okeechobee TMDL for TP of 140 metric tons per year (mt/yr), as defined in Chapter 62-304.700, F.A.C.[2]

The FDEP issued an operating permit to the District that contains TP discharge limits for the structures discharging into Lake Okeechobee (Lake Okeechobee Operating Permit (LOOP); FDEP 2007). The LOOP requires the District to conduct annual evaluations to determine progress towards achieving the TMDL and associated "regional target phosphorus loads". The "regional target phosphorus loads" established by the LOOP are 5-yr average annual TP loads for the structures discharging into Lake Okeechobee, grouped into four regions (**Table 2-4**).

[2] For the purposes of this document only the adopted state Lake Okeechobee TMDL was considered.

Table 2-4. FDEP Lake Okeechobee Operating Permit regional grouping (modified from FDEP 2007 to show regional TP load targets).

WATERSHED	STRUCTURES
Northern Region 5-year moving average annual (MA) load = 78.59 mtons	S-65E, S-71, S-72, S-84, S-127, S-129, S-131, S-133, S-135, S-154C, S-154, S-191, CU-5, C-38W/CULVERT A/G-33, G-207, G-208, L-59E/G-34, L-59W/G-74, L-60E/G-75, L-60W/G-76, L-61E, HP-7, Inflow 1, Inflow2, Inflow 3, Fisheating Creek/FECSR78[2]
Southern Region 5-year moving average annual (MA) load = 9.56 mtons	S-2, S-3, S-4, S-354, Industrial Canal, S-352, S-236, Culvert 12[3], Culvert 4A[3], Culvert 10[3], Culvert 12A[3], S-351
Eastern Region 5-year MA load = 16.84 metric tons	CU-10A, S308[2]
Western Region 5-year MA load = 0.01 metric tons	S-77[2], CU-5A[2]

[1]This table contains structures which contribute flows and loads to Lake Okeechobee. The structures have been grouped into 4 regions and a target load has been calculated for each region. For purposes of calculations associated with the target load, data from all of the structures identified in the region should be utilized.

[2]Identifies structures that are monitored through this permit.

[3] Identifies structures which are authorized through a separate permit but are included in the target load calculation for a particular region.

The relationship between the TMDL regulatory framework defined in the LOOP and the performance measure methodologies contained 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. Basin-specific contrasts are clarified in the subsequent section.

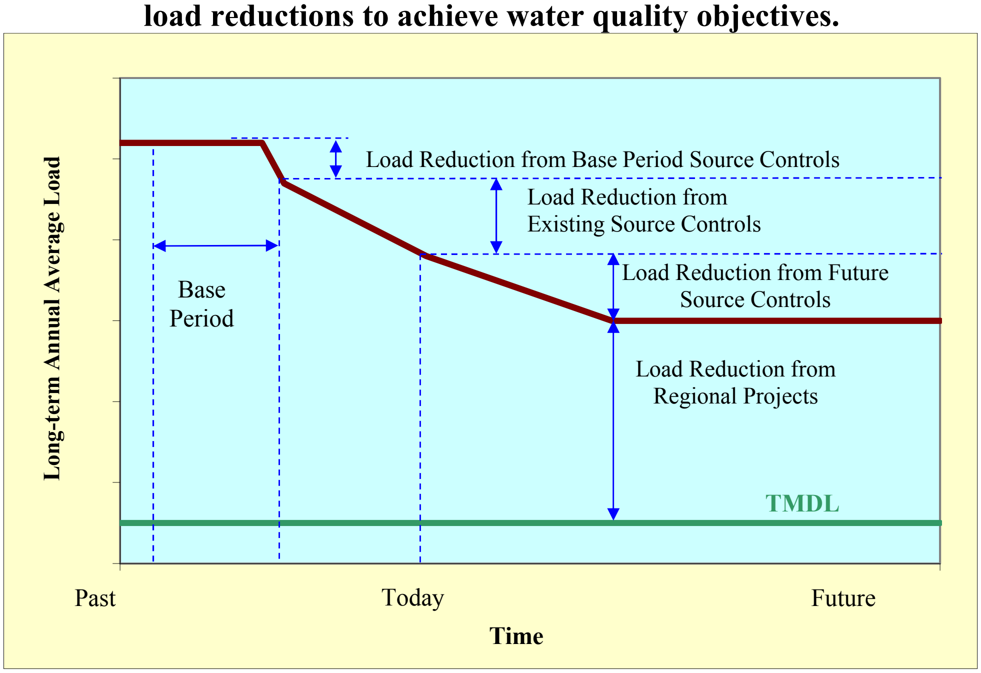
Similarities. A common feature between most of the approaches described herein and the TMDL regulatory framework defined in the LOOP is the requirement for an <u>annual assessment</u> of TP loads. For the performance methodologies, the exceptions are when adequate historical data were not available for development of a load-based performance measure, and in some cases a load-based performance indicator was derived. Another common feature between the approaches described herein and the LOOP is the use of the Water Year (May to April) as the averaging interval for reporting nutrient loads.

General Contrasts. General differences between the TMDL regulatory framework defined in the LOOP and the proposed Lake Okeechobee Watershed (LOW) performance measure methodologies are described below.

1. **Achievement of the Lake Okeechobee TMDL.**

LOOP. The load targets within the LOOP are designed to achieve the Lake TMDL based on load reductions resulting from all initiatives described in the LOPP, including source control and regional projects (SFWMD 2011a). Collectively, source control measures and regional projects described in the LOPP are intended to work in concert to meet the applicable TMDL and other water quality objectives (see **Figure 2-3**).

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



LOW Performance Measure Methodology. The performance measure methodologies described herein only consider source controls which do not by themselves achieve the TMDL for Lake Okeechobee. The goal for the collective TP source control programs in the Lake Okeechobee Watershed will be based on TP load reductions that can reasonably be expected to be achieved through full implementation of BMPs.

2. Location of monitoring stations.

LOOP. In the LOOP, 40 structures that discharge into Lake Okeechobee are grouped into four regions (**Table 2-4**), and each region has a target phosphorus load.

LOW Performance Measure Methodology. The Lake Okeechobee Watershed is divided into sub-watersheds, summary basins and hydrologic units to represent discharge from a defined area. These do not always correspond to the four regions of the LOOP, and hence, the regional target phosphorus loads of the LOOP cannot always be compared directly to the grouping of structures used in the Lake Okeechobee Watershed performance measures. A complete cross reference of the LOOP structures is presented in **Table 2-5**.

3. The receiving body or bodies and location of the monitoring stations used for the annual assessment.

LOOP. In the LOOP, the TP load target is assessed against the observed loads from permitted structures that discharge into Lake Okeechobee, e.g. S-77 of the East Caloosahatchee Hydrologic Unit.

LOW Performance Measure Methodology. The performance measures and performance indicators described herein establish annual TP targets for the basin runoff regardless of discharge direction. In other words, the performance measure evaluates the source control program regardless of where the runoff discharges to. For example, the methodology for the East Caloosahatchee Hydrologic Unit includes TP loads at S-77 (which discharges into Lake Okeechobee) combined with TP loads at S-78 (which discharges into the Caloosahatchee River). A comparison of the receiving waters considered in the LOOP and those considered in the performance methodologies described herein is presented in **Table 2-6**.

Table 2-5. Cross-reference of LOOP and Lake Okeechobee Watershed structures.

LOOP Region	Structures	Lake Okeechobee Watershed Sub-watershed	Summary Basin or Hydrologic Unit
Northern Region	S-133	Taylor Creek/Nubbin Slough Sub-watershed	S-133 Summary Basin
	S-135		S-135 Summary Basin
	S-154		S-154 Summary Basin
	S-154C		S-154C Summary Basin
	S-191		S-191 Summary Basin
	S-65E	Lower Kissimmee Sub-watershed & Upper Kissimmee Sub-watershed	
	S-71, S-72, S-84, S-127, S-129, S-131, C-38W/Culvert A/G-33, L-59E/G-34, L-59W/G-74, L-60E/G-75, L-60W/G-76, L-61E	Lake Istokpoga and Indian Prairie Sub-watersheds	
	Fisheating Creek/FECSR78	Fisheating Creek / Nicodemus Slough Sub-watershed	Fisheating Creek Summary Basin
	Culvert 5		Nicodemus Slough Summary Basin
	HP-7	Not included (Note 1)	
	Inflow 1		
	Inflow 2		
	Inflow 3		
	G-207	Not included (Note 2)	
	G-208		
Southern Region	S-2, S-3, S-351, S-352, S-354	South Lake Okeechobee Sub-watershed	EAA Basin (40E-61)
	Culvert 4A, Culvert 10, Culvert 12, Culvert 12A, S-236		Ch. 298 Districts
	S-4, Industrial Canal (S-310)	West Lake Okeechobee Sub-watershed	S-4 / Industrial Canal Hydrologic Unit
Western Region	S-77		East Caloosahatchee Hydrologic Unit
	Culvert 5A		East Caloosahatchee Hydrologic Unit
Eastern Region	S-308	East Lake Okeechobee Sub-watershed	C-44 Summary Basin
	Culvert 10A		L-8 Summary Basin

Notes:

1. Excluded from the LOW performance measure due to insufficient data
2. Excluded from the LOW performance measure since these structures convey water supply inflow to the sub-watershed, and the conveyed TP loads are subtracted out as flow through

Table 2-6. Comparison of LOOP and Lake Okeechobee Watershed receiving waters and consideration of pass-through loads.

Sub-watershed	Summary Basin or Hydrologic Unit	LOOP Receiving Water	Basin Receiving Waters	Pass - Through Loads?
Taylor Creek/Nubbin Slough	S-133	Lake Okeechobee	Lake Okeechobee	No
Taylor Creek/Nubbin Slough	S-135	Lake Okeechobee	Lake Okeechobee	No
Taylor Creek/Nubbin Slough	S-154	Lake Okeechobee	Lake Okeechobee	No
Taylor Creek/Nubbin Slough	S-154C	Lake Okeechobee	Lake Okeechobee	No
Taylor Creek/Nubbin Slough	S-191	Lake Okeechobee	Lake Okeechobee	No
Lower Kissimmee Sub-watershed		Lake Okeechobee	Lake Okeechobee	Yes
East Lake Okeechobee	C-44	Lake Okeechobee	Lake O, St Lucie River and Estuary	Yes
East Lake Okeechobee	L-8	Lake Okeechobee	Lake O, EAA, C-51W, STA-1 Inflow Works, City of West Palm Beach Catchment Area	Yes
Indian Prairie Sub-watershed		Lake Okeechobee	Lake Okeechobee	Yes
Fisheating Creek/Nicodemus Slough	Fisheating Creek	Lake Okeechobee	Lake Okeechobee	No
Fisheating Creek/Nicodemus Slough	Nicodemus Slough	Lake Okeechobee	Lake Okeechobee	No
Lake Istokpoga Sub-watershed		Lake Okeechobee	Lake Okeechobee	No
Upper Kissimmee Sub-watershed		Lake Okeechobee	Lake Okeechobee	No
West Lake Okeechobee	S-4 / Industrial Canal	Lake Okeechobee	Lake Okeechobee, East Caloosahatchee Hydrologic Unit	Yes
West Lake Okeechobee	East Caloosahatchee	Lake Okeechobee	Lake Okeechobee, S-4 / Industrial Canal Hydrologic Unit, Caloosahatchee River	Yes
South Lake Okeechobee	EAA Basin (40E-63)	Lake Okeechobee	Lake Okeechobee, L-8 Canal, STAs, Everglades Protection Area	Yes
South Lake Okeechobee	Ch 298 Districts	Lake Okeechobee	Lake Okeechobee	No

4. Treatment of pass-through loads.

LOOP. The LOOP target loads are based on total TP loads discharged into Lake Okeechobee from the permitted structures. As such, there is no differentiation between basin runoff loads, and those loads that pass through the basin from upstream sources.

LOW Performance Measure Methodology. In contrast, the proposed approach presented herein differentiates between basin runoff loads, and those loads that pass through the basin from upstream sources. For example, S-65E of the Lower Kissimmee Sub-watershed discharges a combination of basin stormwater runoff and deliveries to Lake Okeechobee from sources outside the summary basin, e.g., the Upper Kissimmee Sub-watershed. These pass-through loads are outside the control of the collective source control programs within the basin and in some cases are covered under source control programs of the upstream basin. Specific calculations are included to separate the pass-through loads such that only basin runoff loads are compared against the performance measure for the summary basin. The basins that account for pass-through loads are presented in **Table 2-6.**

5. **Different evaluation periods.**

LOOP. In the LOOP, progress towards attainment of the TMDL is based on a five-year moving average of TP loads measured at the permitted structures that discharge into Lake Okeechobee.

LOW Performance Measure Methodology. In contrast, the proposed performance measures 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 a two-part (Target/Limit) methodology[3].

i. One part of the methodology, the Annual Load Target, evaluates whether the basin's runoff loads are below or above the median load observed during an appropriate Base Period, adjusted for hydrologic variability. Performance relative to the Target is based upon the results from three consecutive years.

ii. The second part of the methodology, the Annual Load Limit, evaluates whether a basin's runoff loads are below or above the upper 90 percent confidence limit on the predicted Annual Load Target. A single year's result determines performance relative to the Limit.

6. **Different Base Periods for Derivation of Targets.**

[3] In those basins where insufficient data precluded establishment of a performance measure, an annual performance indicator was established. The characteristics of the performance indicators are described in Sections 3.6 and 3.8.

LOOP. For the TMDL, the target loads were estimated from models using flows for the 27-year period of record from 1973 through 1999.

LOW Performance Measure Methodology. The performance measure methodologies described in this document used measured flow and water quality data for basin-specific base periods, ranging from eight years to fourteen years in duration, that were selected based on criteria described in Section 1.2.

7. **Consideration of hydrologic variability.**

LOOP. The LOOP targets are static and are not adjusted for hydrologic variability. However, the derivation and application of the LOOP targets attempted to account for hydrologic variability in two aspects:

i. The targets were derived from a long-term (27 years) period of flows that occurred during a wide range of meteorological conditions, and
ii. The targets are assessed against 5-year moving average TP loads.

LOW Performance Measure Methodology. The performance measure methodologies described herein explicitly account for hydrologic variability through the use of one or more annual rainfall characteristics to derive the Annual Load Targets and Annual Load Limits.

Basin-specific contrasts are highlighted below.

1. **Lower Kissimmee Sub-watershed.** For the purpose of the Lake Okeechobee Watershed performance measure, pass-through TP loads measured at S-65 are subtracted from TP loads measured at S-65E in order to calculate the Lower Kissimmee Sub-watershed runoff contribution. No such distinction between the

Upper Kissimmee Sub-watershed and Lower Kissimmee Sub-watershed is made in the LOOP.

2. **Indian Prairie Sub-watershed.** Structures G-207 and G-208 pump water from Lake Okeechobee as necessary to maintain adequate levels in the area's canals. As such, they do not contribute to the Indian Prairie Sub-watershed basin runoff, and are not included in the sub-watershed's performance measure. However, these structures are included in the Northern Region of the LOOP, although positive TP loading into the lake has never been reported for these structures. Four minor structures (HP-7, Inflow-1, Inflow-2 and Inflow-3) are located along the east and west banks of the C-41 Canal downstream of S-71, although flow and water quality are not monitored at these structures. Flow and water quality monitoring was initiated downstream of these structures in the C-41 Canal at a location known as C41H78, but the first year of reported TP loading data was not available until WY2010. Therefore, because insufficient data were available, these minor structures were excluded from the derivation of the performance measure for the Indian Prairie Sub-watershed.

3. **West Lake Okeechobee Sub-watershed.** The water control structures that discharge from the West Lake Okeechobee Sub-watershed are included in two different regions (Southern and Western regions) as defined by the LOOP (see **Table 2-5**).

4. **South Lake Okeechobee Sub-watershed**. The performance for the South Lake Okeechobee Sub-watershed described in this document considers the performance measures adopted under 40E-63, F.A.C. and the draft performance measures for the Chapter 298 Districts. In contrast, the LOOP considers the S-4/Industrial Canal Hydrologic Unit part of the Southern Region, whereas for this document the S-4/Industrial Canal Hydrologic Unit is considered part of the West Lake Okeechobee Sub-watershed.

2.4.2 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 2-7**, reprinted from the *Lake Okeechobee Protection Plan 2011 Update* (SFWMD et al. 2011a). The objective of the LOPP is to reduce loads to the lake sufficient to achieve the TMDL. In the LOPP, two general types of source controls are identified for each of the sub-watersheds:

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

It should be noted that the objective of the regulatory source control program considered for this project is to reduce loads in runoff by implementing onsite BMPs. The relationship between the 2011 LOPP planning level estimates and the performance measure 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. The exceptions are when adequate historical data were not available for development of a load-based performance measure, and in some cases a load-based performance indictor was derived.

Table 2-7. Estimates of TP Load reductions in the Lake Okeechobee Watershed (from SFWMD et al 2011a).

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

Sub-watershed	Watershed Baseline Data				Current Activities								Near-Term P Reduction Activities (2011 to 2013) (5)		P Reduction Strategies (6)			
					Owner and Cost share Implemented BMPs (1)		Watershed P Control Projects (2)		Regional Public Works Projects (3)		Other Regional and Sub-Regional Projects (4)							
	Area (acres)	Average Annual Discharge (Measured) (2001-2009) (Acre-ft)	Average Annual P Load (Measured)(2001-2009) (Mtons)	Average Annual P Conc. (Calculated) (2001-2009) (ppb)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Remain. Conc. (ppb)	Adjusted Remain. Load* (Mtons)
Upper Kissimmee (S-65)	1,021,674	853,368	97	92	0	97	0	97	13	84	0	84	0	83	30	53	50	53
Lower Kissimmee (S-65A,B,C,D,E)	429,283	359,254	57	129	18	39	7	33	8	25	0	25	6	19	6	13	30	13
Taylor Creek/Nubbin Slough (S-191,154,133,135	198,299	146,900	105	578	18	87	19	68	5	63	2	60	20	40	35	5	30	5
Lake Istokpoga (S-68)	392,147	290,826	40	110	0	39	0	39	0	39	2	38	0	37	27	11	30	11
Indian Prairie Basins (12 basins)	294,147	219,581	101	373	10	91	0	91	0	91	8	82	9	74	66	8	30	8
Fisheating Creek & Nicodemus Slough	315,007	295,324	86	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)	237,631	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 measure methodologies are described below.

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

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

   LOW Performance Measure Methodology. The performance measures and performance indicators described herein establish annual TP targets for the basins, and include TP loads from structures that do not discharge into the lake. For example, the methodology for the East Caloosahatchee Hydrologic Unit includes TP loads at S-77 (which discharges into Lake Okeechobee) combined with TP loads at S-78 (which discharges into the Caloosahatchee 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.

   LOW Performance Measure Methodology. The algorithms used to calculate pass-through loads for the proposed approach are described in Section 2.6.1. 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 and will not impact the annual performance determination of the downstream basin.

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.

LOW Performance Measure Methodology. The goal for the collective TP source control programs in the Lake Okeechobee Watershed will be based on TP load reductions that can reasonably be expected to be achieved through full implementation of BMPs. The performance measure methodologies described herein are used to make annual performance determinations to establish if the BMPs implemented within individual basins are achieving the TP load reductions that can be expected. Unlike the planning-level estimates in the 2011 LOPP, the performance measures 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.

LOW Performance Measure Methodology. In contrast, the proposed performance measures 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[4] which evaluates loads annually and over a three year period.

5. **Different Base Periods for Derivation of Targets.**

   LOPP. For the 2011 LOPP, the baseline loads were established for the 9-year base period of January 1, 2001 through December 1, 2009.

   LOW Performance Measure Methodology. The performance measure methodologies described in this document use measured flow and water quality data for basin-specific base periods, ranging from eight to fourteen years. These base periods were selected based on the criteria described in Section 1.2, including because they precede implementation of most source controls.

6. **Consideration of hydrologic variability.**

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

   LOW Performance Measure Methodology. When possible with the available data, the recommended performance measure methodologies explicitly account for hydrologic variability through prediction equations that use one or more annual rainfall characteristics.

[4] In those basins where insufficient data precluded establishment of a performance measure, an annual performance indicator was established. The characteristics of the performance indicators are described in Sections 3.6 and 3.8.

7. **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).

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

2.5 Definitions

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

(1) "Annual Load Target" means the component of the two-part performance measure methodology that evaluates whether a basin's runoff TP load levels are below or above the central measure (e.g., median) of the TP load level of an appropriate reference period, adjusted for hydrologic variability.

(2) "Annual Load Limit" means the component of the two-part performance measure methodology that evaluates whether a basin's runoff TP load levels are below or above the upper 90 percent confidence limit on the predicted Annual Load Target

(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 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 eliminated through data adjustments); and be free of unexplained outliers in the rainfall, flow, or load data.

(4) "Calendar Year" means the twelve months beginning January 1 and extending through December 31.

(5) "Evaluation Period" means the time period for which the observed TP loads 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 historical Base Period.

(6) "Evaluation Year" means the Water Year to be evaluated relative to the performance measure methodology.

(7) "Hydrologic unit" means a basin that discharges to more than one watershed, i.e., to Lake Okeechobee and to a river watershed.

(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 TP per year. Water quality concentration and water quantity (flow) data are required to calculate the phosphorus load discharged past the monitoring point, as defined by the following general equation:

TP Load (mass/time) =TP concentration (mass/volume) x flow (volume/time)

(9) "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.

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

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

(12) "Performance Indicator" means a numeric nutrient load goal that could be achieved through the implementation of source control programs for a basin where the criteria for establishing a performance measure are not met. A performance indicator may be based on available data (a reference period), and best professional judgment A performance indicator reflects the District's commitment to adaptive management and continuous improvement in nutrient reductions.

(13) "Performance Measure" means a numeric nutrient load 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.

(14) "Performance Measure 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.

(15) "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.

(16) "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.

(17) "Scaled loads" means the observed Base Period loads reduced by the recommended load reduction.

(18) "Sub-watershed" means lands that make up the contributing surface area for which the District has determined the water quality to be represented by specified monitoring sites.

(19) "Summary Basin" means an intermediate area which is located within one of nine sub-watersheds for which the District has determined the water quality to be represented by specified monitoring sites.

(20) "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.

2.6 Performance Measure Methodology

This section presents common elements of the proposed performance measure methodologies for basins having a minimum of eight years of concentration and flow data which adequately represent TP in discharge runoff during a wide range of hydrologic conditions. For basins that discharge to more than one receiving water body (e.g., the C-44 Hydrologic Unit discharges to both Lake Okeechobee and the St Lucie River/Estuary), the performance measures are based on the total discharge to all receiving waters.

2.6.1 Consideration of Pass-through Flow and Load

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

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

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

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

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

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

Pass through TP 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 TP 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.

2.6.2 Source Control Effectiveness

The effectiveness of source controls is ultimately measured by the reduction of nutrients in runoff. Conservative reduction estimates from the implementation of collective source control programs in comparison to a base period were developed. Source control programs are classified as non-point or point sources (**Table 2-2**). Note that reductions were not considered for programs whose nutrient load 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. For example, the FDACS Agricultural BMP Program includes nutrient management BMPs for agricultural operations, the Urban Turf Fertilizer Rule limits the phosphorus and nitrogen content of fertilizers in urban turf and lawns, and the biosolids and manure rules provide specific requirements for these nutrient sources. The BMPs upon which the nutrient load 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 Lake Okeechobee watershed are presented in **Table 2-8**.

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Table 2-8 BMPs assumed to be implemented for estimates of nutrient load reductions (based on Bottcher 2008)[1].

Land Use		Citrus	Improved Pastures	Residential and Urban	Dairies	Other agriculture
Watershed acreage Percentage	1995	7.0 %	22.4 %	6.9 %	0.5 %	18.3 %
	2008	4.6 %	21.4 %	13.0 %	0.2 %	23.3 %
Nutrient Mgt		*Typical:* • P: Soil testing • Includes implementation biosolids rule • Controlled application (timing & placement, fertigation) • Spill prevention *High End:* • Slow release fertilizer	*Typical:* • P: Soil testing • Includes implementation of biosolids rule, the animal manure implementation rule, and the septage application rule • Spill prevention • Grass management[2] and rotational grazing • Reduced cattle density • Alternate water sources, shade, restricted placement of feeders, supplements, and water, fencing *High End:* • Slow release fertilizer	*Typical:* • Reduced fertilization in accordance with the Urban Turf Fertilizer Rule • Controlled application (timing & placement) • Spill prevention *High End:* • Florida Friendly Landscape	*Typical:* • P: Soil testing • Includes implementation of the CAFO rule, • Feed management • Grass management[2] and rotational grazing • Improved forage/sprayfield management - P balanced with high P uptake crop rotations *High End:* • Solids separation for offsite disposal • Add housing to move animals off field[3]	*Typical:* • P: Soil testing • Includes implementation of biosolids rule • Controlled application (timing & placement, fertigation) • Spill prevention *High End:* Slow release fertilizer
Water Mgt		*Typical:* Storm water detention/retention because of improved irrigation and drainage or ERP permitted systems *High End:* • Water reuse from existing retention/detention ponds • Wetland restoration	*Typical:* • Wetland restoration • Retention basin by working pens *High End:* • Stormwater detention/retention	*Typical:* Dry detention swales (0.25 inch) and wet detention (0.25 inch) *High End:* • ERP permitted systems, when required • Regional projects for dry detention and wet detention	*Typical:* • Improved Irrigation and Drainage Management • Wetland restoration *High End:* • Expanded waste storage ponds • Expanded sprayfields • Storm water detention/retention	*Typical:* Storm water detention/retention because of improved irrigation and drainage, flooded fields, and riser board control or ERP permitted systems *High End:* • Wetland restoration
Particulate Matter and Sediment Controls		*Typical:* • Grass management between trees • Sediment traps[1] *High End:* • Grassed swales	Note: Grass management will also apply to particulate matter and sediment controls	*Typical:* • Street sweeping • Sediment/baffle boxes	*Typical:* • Buffer strips Note: Grass management and improved forage/sprayfield management will also apply to particulate matter and sediment controls	*Typical:* • Cover crops • Sediment traps

[1]Based on telephone conversation with Dr. Bottcher on 08/30/12.
[2]Includes selecting the appropriate grass variety and mowing to ensure healthy and uniform grass coverage.
[3]Includes associated waste pond and sprayfield expansions (this BMP would also be considered a Water Management BMP)

A spreadsheet model, similar to the tool developed for the Lake Okeechobee, St. Lucie River, and Caloosahatchee Watershed Protection Plans, was developed to estimate nutrient load reductions for each basin. The basin reduction was calculated as the nutrient load reductions for each land use weighted by each land use acreage and unit area load (pounds/acre/year, lbs/ac/yr). The nutrient load reductions (percentage) per land use and unit area load coefficients were based on the technical documents produced for the Lake Okeechobee, the Caloosahatchee, and the St. Lucie River Watershed Protection Plans (Bottcher, 2006 and SWET 2008), respectively. Land use acreages reflected 1995 conditions and were compared to current land use acreages to verify that they were generally representative of current conditions, otherwise warranting adjustment.

It is recognized that there may be a great deal of variability in BMP effectiveness due to specific implementation, soil characteristics, assimilation, and nutrient responses. Therefore, ranges of effectiveness from “Low” (limited effectiveness) to “High” (optimal effectiveness), as well as, a “Typical” (most likely condition), were reviewed to determine those most appropriate. The typical reduction levels were adjusted to account for partial implementation of source control programs (or BMPs) in comparison to the base period and current water quality levels in consultation with District staff. Reductions were rounded to account for the inherent uncertainty in the data.

These reduction levels relative to the respective base periods provide a preliminary recommendation for development of performance measures. As additional information is obtained during the stakeholder technical review process, the nutrient load reduction percentages presented in **Table 2-9** may be refined. Please refer to Appendix D for additional clarification on the source control effectiveness methodology.

Table 2-9. Recommended TP load reduction percentages.

Basin	Recommended load reduction percent
S-133	25
S-154	35
S-191	40
Lower Kissimmee	30
C-44	35
L-8	20
Indian Prairie	30
Fisheating Creek	30
S-4/Industrial Canal	30
East Caloosahatchee	30

2.6.3 Significant Digits

The development of the performance measure 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 from the individual station source data using Thiessen weights provided by the District, and rounded to the nearest 0.001 inch.
- Monthly rainfall values were calculated as the sum of the daily values and rounded to the nearest 0.01 inch.
- Annual rainfall values were calculated as the sum of the monthly values and rounded to the nearest 0.01 inch.
- Structure/site flow source data were estimated from structure rating curves, and available at the nearest 0.01 cubic foot per second - day.
- Monthly runoff volumes were rounded to the nearest 0.1 acre foot (AF).

- Annual runoff volumes were calculated as the sum of the monthly values and rounded to the nearest 1 AF.
- TP 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).
- Monthly TP loads were calculated as the sum of the product of daily flow and daily concentration assigned by the load algorithm, then rounded to the nearest 0.1 kg.
- Annual TP loads were calculated as the sum of the monthly values and rounded to the nearest 0.001 metric ton (mt).
- Monthly flow-weighted mean TP concentrations were calculated from monthly flow and load values (rounded to the nearest 0.1 AF and 0.1 kg, respectively), and then rounded to the nearest 1 µg/L.
- Annual flow-weighted mean TP concentrations were calculated from annual flow and load values (rounded to the nearest 1 AF and 0.001 mt, respectively), and then rounded to the nearest 1 µg/L.
- In order to preserve the above precision,
  - calculations involving log and square root transformations were carried out to the fifth decimal place,
  - regression coefficients were carried out to the fifth decimal place, and
  - intermediate calculations were carried out to two more decimal places and then rounded to achieve the above significant digits.

2.6.4 Selecting the Regression Equation

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

Table 2-10. Regression equations evaluated to express annual TP 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

For the majority of the hydrologic basins within the Lake Okeechobee Watershed, a statistically significant prediction equation was found for annual load and an associated equation derived for the upper confidence limit (UCL), expressed as a function of the annual rainfall to account for hydrologic variability. If a suitable regression equation expressing TP levels as a function of hydrologic variability could not be identified, the basin was identified as needing a performance indicator.

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

1. **Outliers.** All annual values of the independent and dependent variables were screened for outliers, using the Maximum Normal Residuals technique (Snedecor and Cochran 1989). If a potential outlier was identified, the physical conditions that may have produced the value were investigated to assess whether the value should be retained in the analysis.

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

   residual = observed value minus the predicted value

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

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

3. **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.

4. **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.

5. **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.

6. **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 measure methodologies (typically 8-15). 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.

7. **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. In the case of the S-133 Summary Basin, the highest adjusted R^2 for a regression equation that did not contain prior year as a predictor variable was only 23 percent (compared to 79 percent when using a regression equation with prior year's rain as a predictor variable). Consistent with the guidance above, collinearity was checked for the Annual Load Target equation, and determined to be acceptable, in that there was no statistically significant correlation between annual rainfall and prior year's rainfall.

8. **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.

9. **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.

2.6.5 Exceedance Frequency Analysis

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 TP load is composed of two parts:

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

Since the performance determination contains two components that are applied simultaneously, the cumulative exceedance frequency for the method is greater than the exceedance frequencies of either of the individual components. 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. 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.[5]

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 described by the mean and standard deviation of the residuals observed by comparing the loads predicted using the regression equation and the actual loads during the Base Period.
5. 10,000-year sets of Annual TP Load Targets and Annual Load Limits were then generated using the appropriate equations.
6. A 10,000-year set of annual TP loads was generated by adding the calculated annual residual to the calculated Annual Load Target.
7. The 10,000-year set of annual TP loads was then compared to the Annual Load Target and the Annual Load Limit, and the cumulative exceedance frequency was calculated.

2.6.6 Strength and Defensibility

For each basin an evaluation was conducted and derived by reviewing the data (gaps and revisions), assumptions made in performance measure development, the quantitative statistics (R^2), etc. All of the basins that had load based performance measures were ranked high or moderate for their overall technical strength and defensibility.

[5] 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.

2.6.7 Regional Projects

A description of existing and proposed regional projects can be found in the 2011 Lake Okeechobee Protection Plan Update (SFWMD 2011a). Performance measures methodologies will account for regional projects in a similar manner as in Chapter 40E-63, F.A.C.:

- After completion of a regional project,
    - the basin's Annual Load Target will be reduced in proportion to the regional project acreage no longer contributing to basin runoff,
    - the basin's Annual Load Limit will be calculated using the Annual Load Target reduced as described above, and
    - the basin's Runoff Load will be adjusted to take into account the regional project's load reduction.
- Monitoring will be implemented at the inflow and/or outflow of the regional project, as needed to calculate the basin runoff load and the treatment occurring within the regional project.
- The basin's Annual Load Target per unit area will be the same before and after completion of regional projects.

Additional details regarding the algorithm to account for regional projects are presented in Appendix E.

2.6.8 Annual Performance Determination

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

1. **A model to estimate future TP loads.** The model estimates a future TP 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 TP 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 TP 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.

Total phosphorus runoff 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[6].

- **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.

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 Section 3.

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. Additional details regarding the calculations to account for regional projects are contained in Appendix E. System changes affecting the number or location of inflows and outflows, including regional

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

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 measure, that is, it will have not exceeded the collective median annual phosphorus loading that would have occurred during the Base Period, adjusted for hydrologic variability and adjusted for the source control load reduction goal.

4. 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.

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 rainfall for the Evaluation Year, the basin will be determined to have not met its performance measure, that is, it will have exceeded the annual phosphorus 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.

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 rainfall for the Evaluation Year, the basin will be determined to have not met its performance measure, 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.

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

3. PERFORMANCE MEASURE METHODOLOGIES FOR THE LAKE OKEECHOBEE WATERSHED

The following sections describe the performance measure methodologies of basins within the Lake Okeechobee Watershed.

- Section 3.1: Taylor Creek-Nubbin Slough Sub-watershed
- Section 3.2: Lower Kissimmee Sub-watershed
- Section 3.3: East Lake Okeechobee Sub-watershed
- Section 3.4: Indian Prairie Sub-watershed
- Section 3.5: Fisheating Creek-Nicodemus Slough Sub-watershed
- Section 3.6: Lake Istokpoga Sub-watershed
- Section 3.7: West Lake Okeechobee Sub-watershed
- Section 3.8: Upper Kissimmee Sub-watershed
- Section 3.9: South Lake Okeechobee Sub-watershed

A summary of the major characteristics of the performance measure methodologies for the basins of the Lake Okeechobee Watershed is presented in **Table 3-1**.

Table 3-1. Summary of Lake Okeechobee Watershed performance metrics.

Sub-watershed	Summary Basin or Hydrologic Unit	Base Period or Reference Period	Performance Metric	Pass - Through Loads?	Base Period or Reference Period Median Load, mt	Recommended Load Reduction Goal	Adjusted Rainfall in Performance Determination?
Taylor Creek/Nubbin Slough	S-133	WY1977-1986	PM	No	7.366	25%	Yes
Taylor Creek/Nubbin Slough	S-154	WY1977-1984	PM	No	8.272	35%	No
Taylor Creek/Nubbin Slough	S-191	WY1977-1988	PM	No	149.511	40%	Yes
Lower Kissimmee Sub-watershed		WY1977-1990	PM	Yes	56.061	30%	No
East Lake Okeechobee	C-44	WY2000-2010	PM	Yes	52.861	35%	Yes
East Lake Okeechobee	L-8	WY1995-2003	PM	Yes	17.134	20%	Yes
Indian Prairie Sub-watershed		WY1989-2001	PM	Yes	67.635	30%	Yes
Fisheating Creek/Nicodemus Slough	Fisheating Creek	WY1998-2008	PM	No	67.618	30%	No
Lake Istokpoga	Arbuckle Creek	WY1997-2007	PI	No	38.802	0%	No
Lake Istokpoga	Josephine Creek	WY1997-2004	PI	No	3.004	0%	No
Upper Kissimmee	Boggy Creek	WY2001-2008	PI	No	5.018	0%	Yes
Upper Kissimmee	Shingle Creek	WY1999-2007	PI	No	14.189	0%	Yes
West Lake Okeechobee	S-4 / Industrial Canal	WY1993-2001	PM	Yes	20.331	30%	Yes
West Lake Okeechobee	East Caloosahatchee	WY1982-1990	PM	Yes	54.939	30%	No

Notes:

1. PM = Performance Measure
   PI = Performance Indicator
2. No performance metric will be assigned to the S-135, S-154C and Nicodemus Slough basins. However, the water quality from these basins will be assessed annually to determine if there is an increasing trend.
3. See Section 3.9 for a summary of the South Lake Okeechobee Sub-watershed performance measure metrics.

3.1 Taylor Creek-Nubbin Slough Sub-watershed

In total, the Taylor Creek-Nubbin Slough Sub-watershed comprises 196,733 acres located directly north of Lake Okeechobee, and includes the town of Okeechobee Florida (**Figure 3-1**)[7]. The Taylor Creek-Nubbin Slough Sub-watershed is composed of 5 separate summary basins, S-191, S-135, S-133, S-154, and S-154C. Each of these basins has a distinct discharge point into Lake Okeechobee. Flow and water quality data from these stations were used to calculate the annual TP loads from each basin (flow and TP monitoring sites are identified in **Tables C-1** and **C-2**).

District staff identified the rainfall stations considered to be representative of the Taylor Creek-Nubbin Slough Sub-watershed and associated basins for the period WY1976-2010. A schematic of the Taylor Creek-Nubbin Slough Sub-watershed with the various rain stations is presented in **Figure 3-2.** Monthly rainfall data and weighting factors for the rainfall stations for each basin were developed and provided by the District. Weighting factors are shown in **Figure 3-2** for the individual basins. Annual summaries of rainfall values for each basin are presented in the Sections 3.1.1 through 3.1.5.

The following sections describe the derivation of the performance measure methodologies for the basins within the Taylor Creek-Nubbin Slough Sub-watershed.

[7] Areas used in this Technical Memorandum were calculated by the District; the areas vary somewhat from those reported in the March 2011 update to the Lake Okeechobee Protection Plan.

Figure 3-1. Taylor Creek-Nubbin Slough Sub-watershed boundary and discharge monitoring locations.

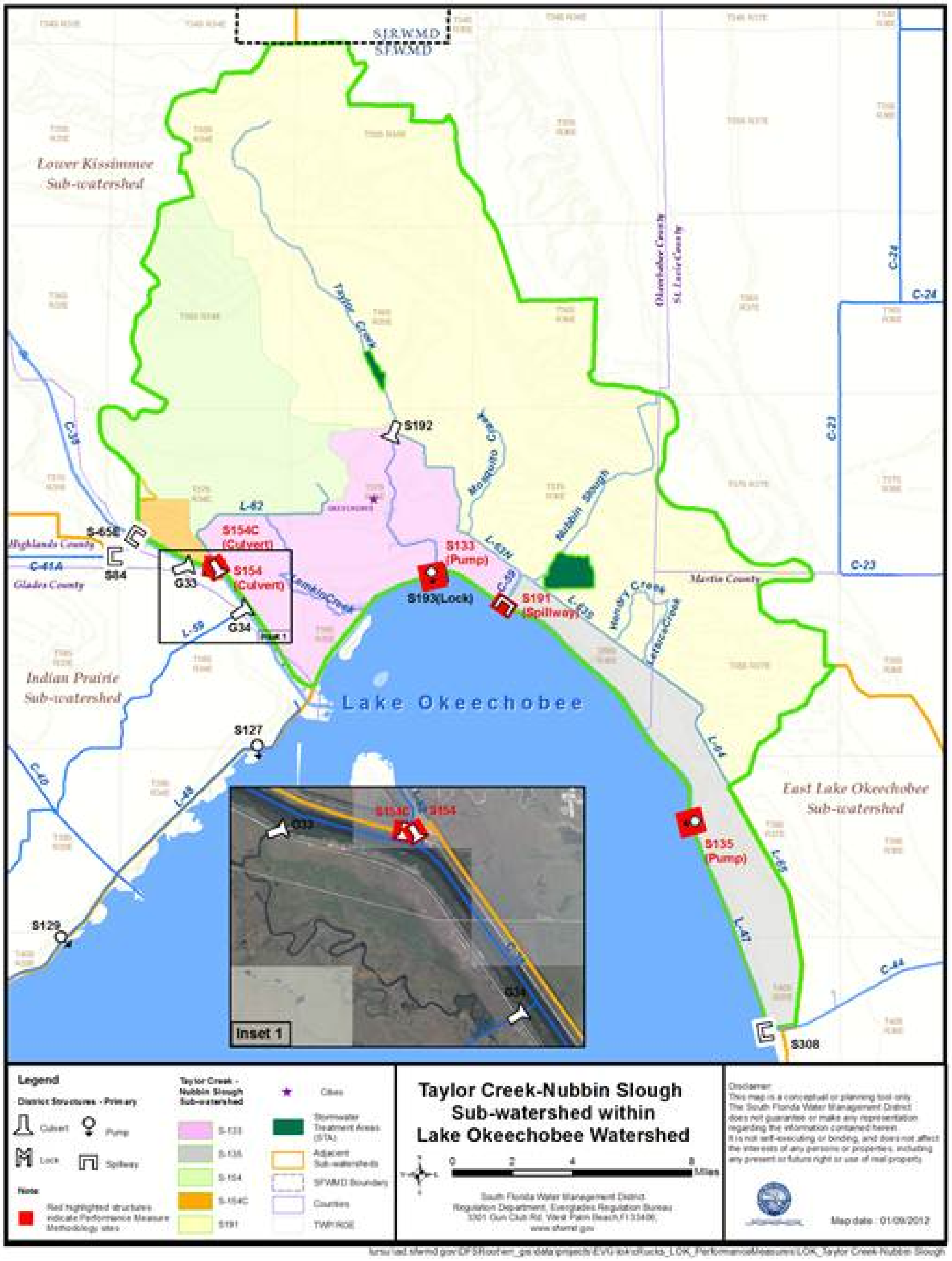
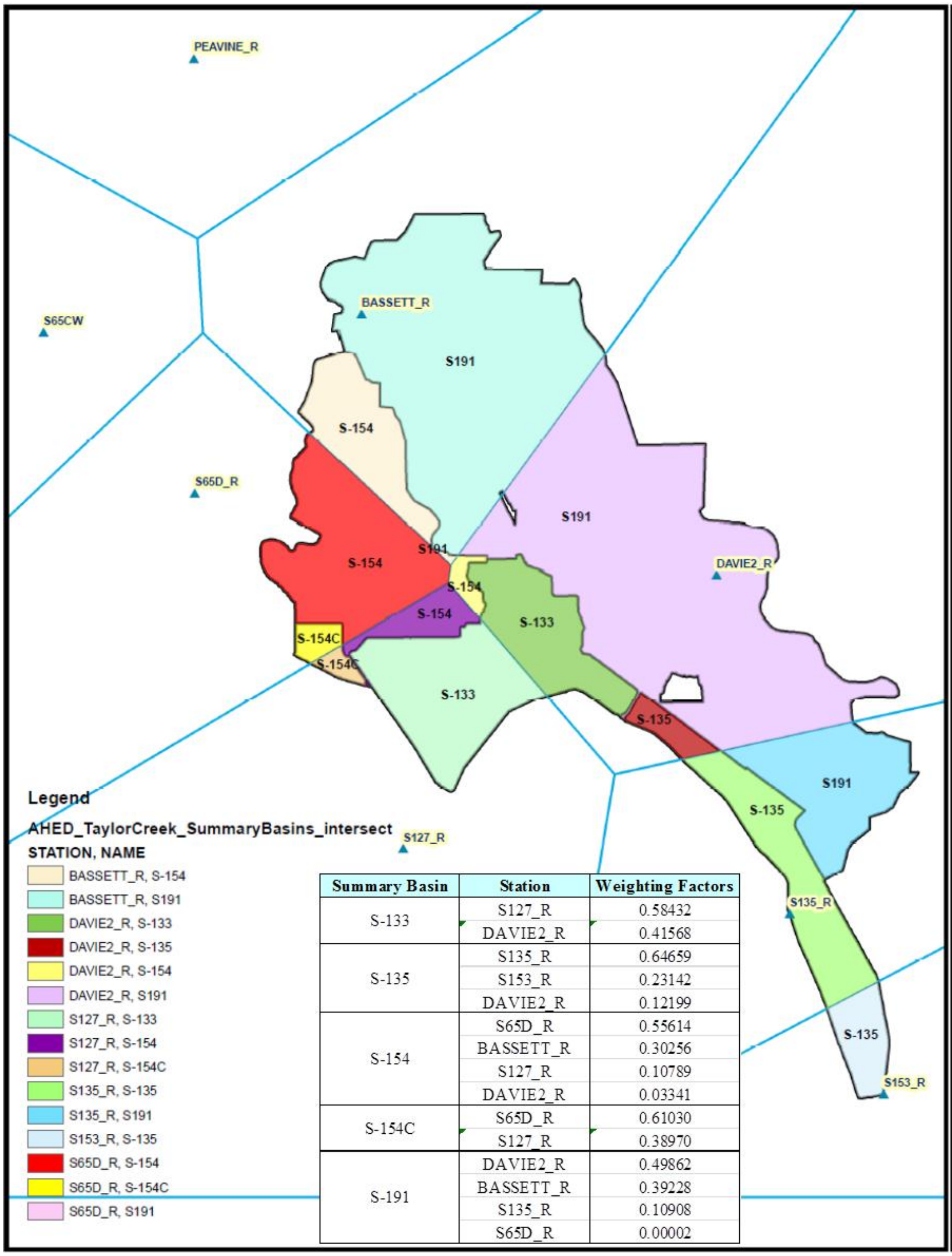


Figure 3-2. Schematic of Taylor Creek-Nubbin Slough Sub-watershed, summary basins and selected rainfall stations.



Summary Basin	Station	Weighting Factors
S-133	S127_R	0.58432
	DAVIE2_R	0.41568
S-135	S135_R	0.64659
	S153_R	0.23142
	DAVIE2_R	0.12199
S-154	S65D_R	0.55614
	BASSETT_R	0.30256
	S127_R	0.10789
	DAVIE2_R	0.03341
S-154C	S65D_R	0.61030
	S127_R	0.38970
S-191	DAVIE2_R	0.49862
	BASSETT_R	0.39228
	S135_R	0.10908
	S65D_R	0.00002

3.1.1 S-133 Summary Basin

The following sections present a description of the S-133 Summary Basin, a summary of historical flow and TP levels, the selection of a Base Period, an estimated range of load reductions attributable to collective source controls, and the derivation of the resulting performance measure.

3.1.1.1 Background

The 25,626-acre S-133 Summary Basin discharges into Lake Okeechobee through pump station S-133. Annual flow and TP data for discharges from the S-133 Summary Basin into Lake Okeechobee are summarized in **Table 3-2.** For the development of the performance measure methodology, a Base Period of WY1977-1986 was selected for the following reasons.

- it represents a period with minimal implementation of source controls. With the selection of the Base Period to precede significant source control implementation, no additional calculation is necessary in the performance measure methodology to account for source control implementation.
- basin water management operations were similar to current operating conditions affecting nutrient loading,
- it represents a period of relatively constant land use practices,
- reliable water quality and hydrologic data are available which captures a representative range of hydrologic variability, and
- a strong correlation exists between annual TP loads and rainfall, allowing for a performance measure methodology that explicitly incorporates hydrologic variability.

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-3**. This comparison is provided to identify the differences between the Base Period annual rainfall, flows and TP 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 TP when compared against both the period of record and recent ten-year period.

Table 3-2. Summary of historical data for S-133.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics: Kurtosis K	Coef. Of Var. CV	Skewness S
1977	5,705	2.427	345	41.00	2.67	0.21	5.984	0.980	2.142
1978	7,333	3.088	341	46.56	3.43	0.27	-1.416	0.648	0.470
1979	22,227	9.306	339	47.05	10.41	0.80	1.854	0.778	1.314
1980	46,858	22.864	396	53.41	21.94	1.97	3.211	0.929	1.629
1981	12,579	5.426	350	34.60	5.89	0.47	-0.972	0.690	0.330
1982	0	0.000		48.32	0.00	0.00	-1.646	0.759	0.424
1983	59,383	23.346	319	63.58	27.81	2.01	-0.546	0.609	0.623
1984	40,512	16.948	339	46.52	18.97	1.46	-0.692	0.520	0.470
1985	26,981	18.829	566	37.24	12.63	1.62	1.276	0.831	0.931
1986	4,931	1.401	230	33.01	2.31	0.12	1.166	0.853	1.073
1987	15,864	4.766	244	51.29	7.43	0.41	0.417	0.782	0.838
1988	18,567	6.694	292	40.62	8.69	0.58	-0.183	0.636	0.786
1989	17,486	6.584	305	47.14	8.19	0.57	-0.457	0.835	0.662
1990	0	0.000		40.33	0.00	0.00	-0.425	0.668	0.216
1991	282	0.123	354	52.50	0.13	0.01	1.151	0.805	1.101
1992	27,334	8.363	248	44.59	12.80	0.72	-0.499	0.775	0.893
1993	53,151	19.526	298	52.87	24.89	1.68	3.446	1.028	1.726
1994	9,571	2.874	243	42.53	4.48	0.25	0.349	0.455	0.463
1995	42,218	9.083	174	55.72	19.77	0.78	0.312	0.430	0.410
1996	46,936	11.927	206	60.01	21.98	1.03	-1.344	0.851	0.400
1997	10,441	1.694	132	44.53	4.89	0.15	-0.560	0.777	0.663
1998	33,968	6.474	155	53.54	15.91	0.56	0.553	0.429	-1.065
1999	13,403	2.350	142	42.93	6.28	0.20	2.970	0.992	1.601
2000	27,491	7.506	221	48.73	12.87	0.65	2.278	0.960	1.306
2001	0	0.000		22.76	0.00	0.00	-1.175	1.006	0.636
2002	13,891	5.878	343	38.50	6.50	0.51	4.800	1.028	1.943
2003	14,013	5.853	339	44.91	6.56	0.50	4.150	0.922	1.786
2004	21,984	5.423	200	38.89	10.29	0.47	-0.543	0.739	0.793
2005	39,731	21.068	430	42.10	18.60	1.81	0.299	1.080	1.200
2006	46,255	17.829	312	48.00	21.66	1.53	1.148	0.859	0.973
2007	0	0.000		28.27	0.00	0.00	0.201	1.065	1.165
2008	0	0.000		39.70	0.00	0.00	-0.682	0.690	0.399
2009	16,128	10.728	539	34.04	7.55	0.92	3.756	1.414	1.946
2010	3,459	1.045	245	46.88	1.62	0.09	-0.790	0.717	0.532
Minimum	***0***	***0.000***	***132***	***22.76***	***0.00***	***0.00***	***-1.646***	***0.429***	***-1.065***
Average	***20,549***	***7.630***	***301***	***44.49***	***9.62***	***0.66***	***0.806***	***0.810***	***0.905***
Maximum	***59,383***	***23.346***	***566***	***63.58***	***27.81***	***2.01***	***5.984***	***1.414***	***2.142***
Std. Dev.	***17,502***	***7.264***	***104***	***8.56***	***8.20***	***0.62***	***1.956***	***0.207***	***0.637***
Skewness	***0.632***	***0.923***	***0.713***	***-0.206***	***0.632***	***0.92***	***1.024***	***0.353***	***-0.344***
Median	***15,996***	***5.866***	***305***	***44.75***	***7.49***	***0.50***	***0.306***	***0.794***	***0.816***

Table 3-3. Comparison of Base Period with period of record and WY2001-2010 data for S-133.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1977-2010					
Annual Minimum	0	0.000	132	22.76	0.00
Annual Average	20,549	7.630	301	44.49	0.66
Annual Median	15,996	5.866	305	44.75	0.50
Annual Maximum	59,383	23.346	566	63.58	2.01
Base Period WY1977-1986					
Annual Minimum	0	0.000	230	33.01	0.00
Annual Average	22,651	10.364	371	45.13	0.89
Annual Median	17,403	7.366	341	46.54	0.63
Annual Maximum	59,383	23.346	566	63.58	2.01
Difference between Period of Record and Base Period					
Annual Minimum	0	0.000	-98	-10.25	0.00
Annual Average	-2,101	-2.733	-70	-0.64	-0.24
Annual Median	-1,407	-1.501	-36	-1.79	-0.13
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	N/A	N/A	-43%	-31%	N/A
Annual Average	-9%	-26%	-19%	-1%	-26%
Annual Median	-8%	-20%	-11%	-4%	-20%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	0	0.000	200	22.76	0.00
Annual Average	15,546	6.782	354	38.41	0.58
Annual Median	13,952	5.638	339	39.30	0.49
Annual Maximum	46,255	21.068	539	48.00	1.81
Difference between WY2001-2010 and Base Period					
Annual Minimum	0	0.000	-30	-10.25	0.00
Annual Average	-7,105	-3.581	-17	-6.72	-0.31
Annual Median	-3,451	-1.728	-2	-7.25	-0.15
Annual Maximum	-13,128	-2.278	-27	-15.58	-0.20
Annual Minimum	N/A	N/A	-13%	-31%	N/A
Annual Average	-31%	-35%	-5%	-15%	-35%
Annual Median	-20%	-23%	-1%	-16%	-23%
Annual Maximum	-22%	-10%	-5%	-25%	-10%

3.1.1.2 Performance Measure 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 25 percent was determined to be reasonable and appropriate. Details are provided in Appendix D and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 25 percent load reduction. The Annual Load Target and Annual Load Limit will be calculated according to the following equations and explanation:

$$\text{Target} = -200.98003 + 19.638\ X + 29.41568\ P + 30.52657\ C$$

Explained Variance = 79.1%, Standard Error of Regression = 3.885 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:

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

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

$$X = \ln (12\ m_1)$$

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

$$\text{Limit} = \text{Target} + 1.43976\ SE$$

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

$$SE = 3.88541\ [\ 1 + 1/10 + 3.01635\ (X-X_m)^2 + 4.00198\ (P-P_m)^2 + 10.51972\ (C-C_m)^2 + 0.38068\ (X-X_m)\ (P-P_m) + 2.9188\ (X-X_m)\ (C-C_m) + 8.67534\ (P-P_m)\ (C-C_m)\ ]^{0.5}$$

Where:

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

P = the natural logarithm of the rainfall for the previous water year (ln[inches])

C = coefficient of variation calculated from 12 monthly rainfall totals

X_m = average value of the predictor in base period = 3.79116

P_m = average value of the predictor in base period = 3.77727

C_m = average value of the predictor in base period = 0.75970

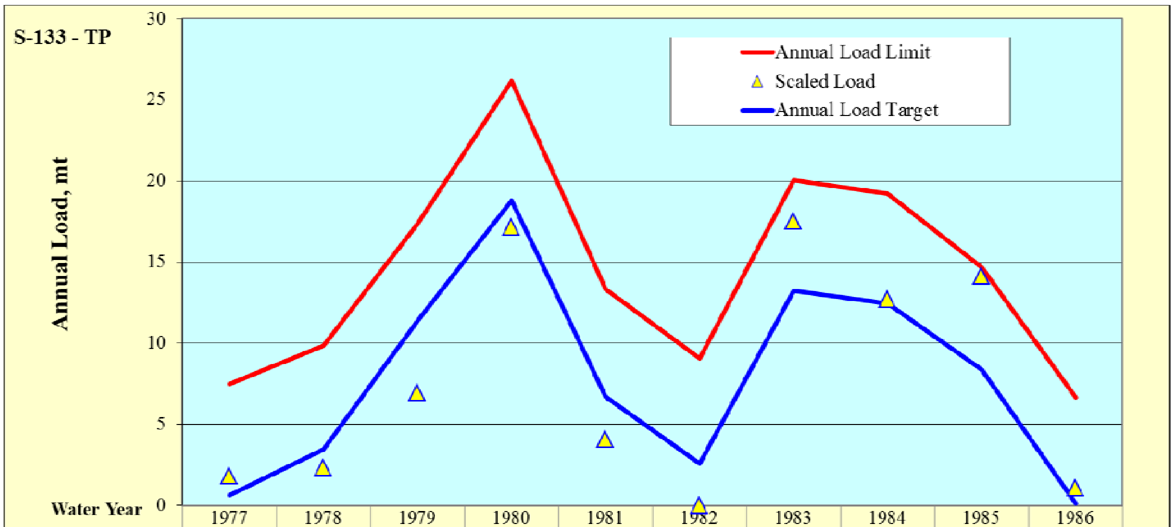
In general, the use of the previous year's rainfall as a predictor variable was avoided due to concerns of collinearity between rainfall and the previous year's rainfall[8]. Consistent with the guidance of Section 2.6, collinearity was checked for the Target equation above, and determined to be not a problem, in that there was no statistically significant correlation between annual rainfall and prior year's rainfall.

The first and second predictors (X and P) indicate that load increases with total annual rainfall and total annual previous year's rainfall. The third 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 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 scaled loads, i.e., the observed Base Period loads reduced by the recommended 25 percent load reduction, at S-133 and the resulting Targets and Limits for the Base Period are presented in **Figure 3-3.** Annual TP loads at S-133, adjusted to account for regional projects (if applicable), will be evaluated against the performance measure described above.

[8] In the case of the S-133 Summary Basin, the highest adjusted R^2 for a regression equation that did not contain prior year as a predictor variable was only 23 percent.

Figure 3-3. Comparison of scaled annual loads to the Annual Load Targets and Limits for the S-133 Summary Basin.



Water Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Annual Load Limit	7.476	9.840	17.365	26.153	13.329	9.050	20.066	19.221	14.655	6.670
Scaled Load	1.820	2.316	6.980	17.147	4.070	0.000	17.510	12.711	14.123	1.051
Annual Load Target	0.639	3.463	11.378	18.785	6.693	2.588	13.223	12.444	8.378	0.137

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), at S-133 exceeds the Annual Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (30.03 – 77.63 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 P and C to their mean values for the calibration period.

$$\text{Adjusted Rainfall} = \exp\left[X + 1.49790\,(P - 3.77727) + 1.55446\,(C - 0.75970)\right]$$

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the WY1977-2010 period of record are summarized in

Table 3-4. The annual performance determination process will account for regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

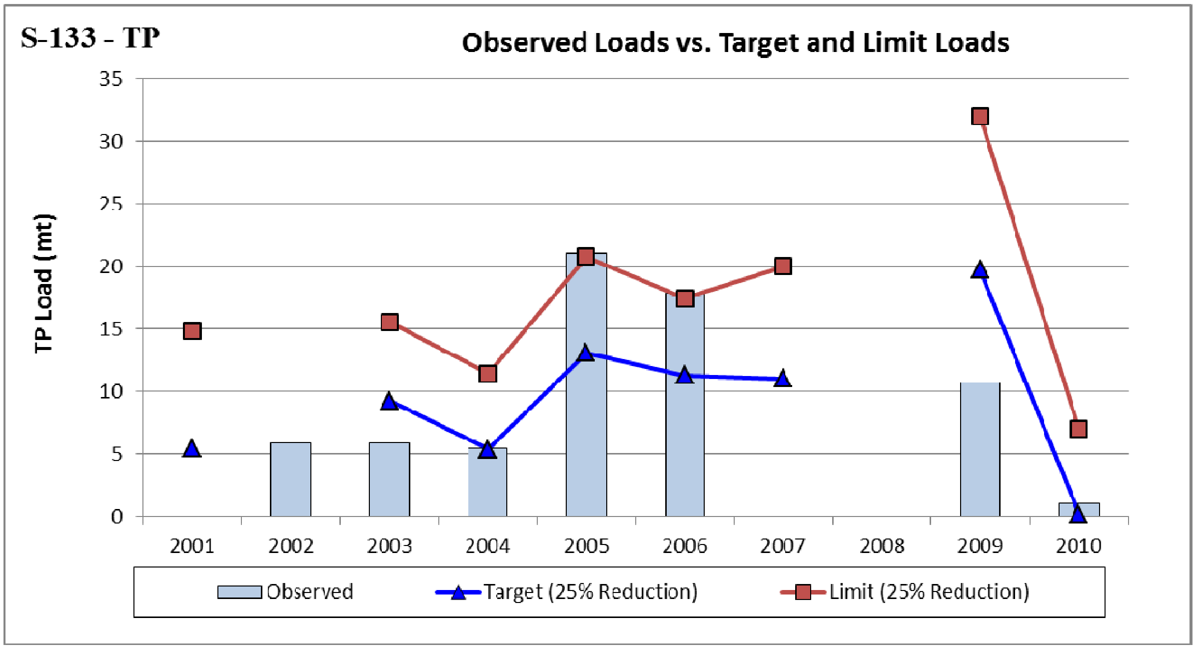
Table 3-4. Estimates of Annual Load Targets and Limits for the historical period of record for the S-133 Summary Basin (Base Period: WY1977-1986).

Water Year	Observed Load, mt	Observed Rain, in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1977	2.427	41.00	0.980	0.639	7.476	30.81
1978	3.088	46.56	0.648	3.463	9.839	35.58
1979	9.306	47.05	0.778	11.378	17.364	53.24
1980	22.864	53.41	0.929	18.785	26.153	77.63
1981	5.426	34.60	0.690	6.693	13.328	41.94
1982	0.000	48.32	0.759	2.588	9.049	34.03
1983	23.346	63.58	0.609	13.223	20.066	58.48
1984	16.948	46.52	0.520	12.444	19.221	56.21
1985	18.829	37.24	0.831	8.378	14.654	45.70
1986	1.401	33.01	0.853	0.137	6.670	30.03
1987	4.766	51.29	0.782	3.077	9.753	34.89
1988	6.694	40.62	0.636	7.003	13.234	42.61
1989	6.584	47.14	0.835	9.141	15.157	47.50
1990	0.000	40.33	0.668	5.357	11.486	39.18
1991	0.123	52.50	0.805	10.129	16.307	49.96
1992	8.363	44.59	0.775	13.764	20.049	60.11
1993	19.526	52.87	1.028	20.028	28.211	82.70
1994	2.874	42.53	0.455	3.273	10.687	35.23
1995	9.083	55.72	0.430	1.413	9.821	32.05
1996	11.927	60.01	0.851	23.667	31.584	99.54
1997	1.694	44.53	0.777	17.731	24.706	73.57
1998	6.474	53.54	0.429	1.950	10.104	32.94
1999	2.350	42.93	0.992	20.220	28.557	83.51
2000	7.506	48.73	0.960	15.235	22.255	64.79
2001	0.000	22.76	1.006	5.417	14.862	39.30
2002	5.878	38.50	1.028	-5.983	1.980	21.99
2003	5.853	44.91	0.922	9.268	15.570	47.81
2004	5.423	38.89	0.739	5.385	11.411	39.24
2005	21.068	42.10	1.080	13.119	20.773	58.17
2006	17.829	48.00	0.859	11.281	17.456	52.97
2007	0.000	28.27	1.065	11.031	19.977	52.30
2008	0.000	39.70	0.690	-9.321	-0.929	18.55
2009	10.728	34.04	1.414	19.748	32.019	81.53
2010	1.045	46.88	0.717	0.231	6.987	30.18

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.

Comparison to WY2001-2010. A comparison of the loads observed during WY2001-2010 to the Annual Load Targets and Limits is presented in **Figure 3-4**.

Figure 3-4. Comparison of WY2001-2010 observed loads to the Annual Load Targets and Limits for the S-133 Summary Basin.



Note: The performance determination for WY2002 and WY2008) would have been suspended due to the adjusted rainfall being below the minimum value during the Base Period coupled with the observed load being greater than the Load Target.

Exceedance Frequency Analysis. As shown in **Figure 3-3,** although the scaled observed loads fall above the Annual Load Target roughly half the time (five out of nine years, or 55 percent), three of these exceedances occur in successive years. In accordance with the proposed performance determination process discussed in Section 2.6, three successive years when the observed load exceeds the Annual Load Target would prevent the basin from meeting its performance measure. In the case of the scaled Base Period data, this is an example of a Type I error[9], or "false positive" - when the performance method suggests a

[9] The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the

lack of compliance when the basin's load actually achieves the long-term reduction goals. While this occurrence is not common, it is statistically possible. The use of a three-year cycle for the Annual Load Target is consistent with the District's Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of 12.5 percent. Using the approach described in 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 3-5**). 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 3-5. Exceedance frequencies for the proposed determination methodology for the S-133 Summary Basin.

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%	12.1%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	8.8%
Step 4. Load > Annual Load Limit?	<10%	1.8%
Cumulative Exceedance Frequency	**<17.5%**	**10.1%**

null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.

3.1.2 S-135 Summary Basin

The following sections present a description of the S-135 Summary Basin and a summary of historical flow and TP levels.

3.1.2.1 Background

The 17,756-acre S-135 Summary Basin discharges into Lake Okeechobee through pump station S-135. Annual flow and TP data for discharges from the S-135 Summary Basin into Lake Okeechobee are summarized in **Table 3-6.**

3.1.2.2 Performance Measure Methodology

Since this summary basin has historically contributed a small percentage of the annual Lake Okeechobee total phosphorus load (approximately one percent), no performance metric will be assigned to this area. However, the water quality from this basin will be assessed annually to determine if there is an increasing trend.

Table 3-6. Summary of historical data for S-135 for the WY 1977-2010 period of record.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics: Kurtosis K	Rainfall Characteristics: Coef. Of Var. CV	Rainfall Characteristics: Skewness S
1977	7,666	0.681	72	48.49	5.18	0.08	1.288	0.872	1.135
1978	7,323	0.650	72	46.37	4.95	0.08	1.159	0.640	1.225
1979	27,191	2.415	72	43.08	18.38	0.30	-0.209	0.641	0.218
1980	59,966	15.862	214	53.70	40.53	1.97	4.326	1.076	1.985
1981	10,816	0.950	71	38.82	7.31	0.12	-0.143	0.859	0.994
1982	0	0.000		43.77	0.00	0.00	-0.241	0.931	0.904
1983	36,351	3.459	77	54.85	24.57	0.43	1.946	0.635	1.228
1984	38,937	4.393	91	51.04	26.31	0.55	-0.624	0.547	0.425
1985	16,550	1.720	84	40.38	11.18	0.21	0.619	0.810	0.749
1986	5,629	0.843	121	38.65	3.80	0.10	1.245	0.973	1.286
1987	21,669	1.931	72	53.44	14.64	0.24	0.236	0.800	0.904
1988	17,891	2.036	92	47.04	12.09	0.25	-1.065	0.569	-0.003
1989	15,725	1.667	86	38.87	10.63	0.21	-0.215	0.786	0.633
1990	0	0.000		45.84	0.00	0.00	0.356	0.911	0.959
1991	180	0.024	108	49.11	0.12	0.00	-1.409	0.619	-0.047
1992	15,133	1.729	93	47.89	10.23	0.21	2.449	0.792	1.606
1993	43,194	6.146	115	61.04	29.19	0.76	4.584	0.930	1.783
1994	18,096	1.432	64	42.35	12.23	0.18	0.070	0.533	0.154
1995	39,209	4.781	99	49.10	26.50	0.59	-0.636	0.498	0.165
1996	47,512	8.553	146	56.97	32.11	1.06	-1.142	0.828	0.304
1997	11,155	1.095	80	40.51	7.54	0.14	-0.804	0.605	0.404
1998	26,941	2.671	80	40.62	18.21	0.33	-0.714	0.523	-0.195
1999	17,151	1.769	84	30.93	11.59	0.22	-1.166	0.772	0.578
2000	26,669	4.489	136	37.00	18.02	0.56	-1.261	0.778	0.300
2001	0	0.000		25.21	0.00	0.00	-1.048	0.953	0.639
2002	5,781	0.577	81	31.33	3.91	0.07	-1.252	0.869	0.702
2003	20,373	2.254	90	38.01	13.77	0.28	-0.795	0.663	0.645
2004	32,078	2.699	68	37.32	21.68	0.34	1.274	0.879	1.324
2005	30,473	10.087	268	42.28	20.59	1.25	0.696	0.990	1.168
2006	42,394	8.745	167	46.42	28.65	1.09	4.259	1.065	1.784
2007	0	0.000		26.47	0.00	0.00	0.020	0.927	0.971
2008	0	0.000		35.12	0.00	0.00	0.406	0.642	0.760
2009	10,511	3.321	256	31.19	7.10	0.41	3.015	1.104	1.600
2010	10,613	0.595	45	50.13	7.17	0.07	-1.352	0.686	0.269
Minimum	***0***	***0.000***	***45***	***25.21***	***0.00***	***0.00***	***-1.409***	***0.498***	***-0.195***
Average	***19,505***	***2.870***	***119***	***43.04***	***13.18***	***0.36***	***0.408***	***0.785***	***0.810***
Maximum	***59,966***	***15.862***	***268***	***61.04***	***40.53***	***1.97***	***4.584***	***1.104***	***1.985***
Std. Dev.	***15,867***	***3.471***	***55***	***8.56***	***10.72***	***0.43***	***1.680***	***0.171***	***0.566***
Skewness	***0.660***	***2.146***	***1.905***	***-0.118***	***0.660***	***2.15***	***1.220***	***0.029***	***0.252***
Median	***16,851***	***1.749***	***86***	***42.72***	***11.39***	***0.22***	***-0.062***	***0.796***	***0.755***

3.1.3 S-154 Summary Basin

The following sections present a description of the S-154 Summary Basin, a summary of historical flow and TP levels, the selection of a Base Period, an estimated range of load reductions attributable to collective source controls, and the derivation of the resulting performance measure.

3.1.3.1 Background

The 31,815-acre S-154 Summary Basin discharges into Lake Okeechobee through S-154. Annual flow and TP data for discharges from the S-154 Summary Basin into Lake Okeechobee are summarized in **Table 3-7.** For the development of the performance measure methodology, a Base Period of WY1977-1984 was selected for the following reasons:

- it represents a period with minimal implementation of source controls. With the selection of the Base Period to precede significant source control implementation, no additional calculation is necessary in the performance measure methodology to account for prior source control implementation.
- basin water management operations were similar to current operating conditions affecting nutrient loading,
- it represents a period of relatively constant land use practices,
- it traversed a wide range of hydrologic conditions (wet and dry years),
    - Monthly and annual flow for Water Year 1983 (May 1982 – April 1983) were higher than during the other years, however, no individual month was identified as a potential outlier. Similarly, the TP concentrations for WY1983 were relatively high, yet no outliers were detected. The combination of high flows and high concentrations resulted in relatively high monthly loads for this period as well.

Table 3-7. Summary of historical data for S-154.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1977	6,185	1.093	143	37.82	2.33	0.08	1.024	0.935	1.173
1978	10,946	6.453	478	39.21	4.13	0.45	-1.299	0.599	0.194
1979	47,160	25.106	432	46.19	17.79	1.74	2.016	0.774	1.323
1980	44,896	37.800	683	52.55	16.93	2.62	3.975	0.956	1.871
1981	4,659	2.977	518	30.06	1.76	0.21	0.955	0.890	1.091
1982	5,605	6.663	964	42.01	2.11	0.46	-0.949	0.812	0.426
1983	116,218	149.667	1,044	56.20	43.84	10.37	-0.872	0.572	0.422
1984	8,521	9.880	940	42.03	3.21	0.68	-0.290	0.574	0.519
1985	19,319	23.612	991	36.13	7.29	1.64	4.210	0.954	1.618
1986	14,142	12.701	728	32.18	5.33	0.88	-1.141	0.660	0.455
1987	39,927	53.714	1,091	45.90	15.06	3.72	-1.080	0.659	0.185
1988	30,730	42.574	1,123	48.99	11.59	2.95	0.950	0.609	0.534
1989	7,786	7.786	811	42.13	2.94	0.54	-0.482	0.631	0.231
1990	19,243	23.787	1,002	42.20	7.26	1.65	-0.345	0.809	0.603
1991	10,958	14.526	1,075	52.89	4.13	1.01	-0.735	0.670	0.385
1992	23,280	24.308	847	46.11	8.78	1.68	0.018	0.873	0.925
1993	26,185	25.192	780	48.63	9.88	1.75	2.736	0.967	1.421
1994	4,301	2.089	394	41.23	1.62	0.14	-0.961	0.403	-0.571
1995	36,619	23.949	530	56.25	13.81	1.66	-0.536	0.524	0.851
1996	19,328	26.028	1,092	52.38	7.29	1.80	-1.451	0.782	0.343
1997	437	0.351	651	37.01	0.16	0.02	-1.068	0.599	0.023
1998	48,869	43.391	720	55.98	18.43	3.01	0.106	0.420	-0.873
1999	7,917	7.621	780	32.78	2.99	0.53	0.271	0.741	0.712
2000	79,204	82.860	848	55.01	29.87	5.74	7.101	1.147	2.337
2001	173	0.116	544	27.22	0.07	0.01	0.050	1.129	0.912
2002	22,411	24.815	898	42.46	8.45	1.72	-1.373	0.851	0.562
2003	13,165	8.244	508	41.92	4.97	0.57	1.287	0.589	1.200
2004	27,033	17.816	534	40.91	10.20	1.23	0.630	0.737	0.933
2005	56,536	65.602	941	49.61	21.32	4.55	0.233	1.014	1.024
2006	49,216	36.142	595	47.72	18.56	2.50	2.634	1.016	1.477
2007	547	0.323	479	21.59	0.21	0.02	-0.892	0.988	0.822
2008	91	0.025	223	34.74	0.03	0.00	-0.397	0.675	0.371
2009	37,837	40.845	875	42.72	14.27	2.83	2.638	1.192	1.635
2010	13,119	10.123	626	54.80	4.95	0.70	-1.047	0.665	0.028
Minimum	***91***	***0.025***	***143***	***21.59***	***0.03***	***0.00***	***-1.451***	***0.403***	***-0.873***
Average	***25,075***	***25.241***	***816***	***43.40***	***9.46***	***1.75***	***0.468***	***0.777***	***0.740***
Maximum	***116,218***	***149.667***	***1,123***	***56.25***	***43.84***	***10.37***	***7.101***	***1.192***	***2.337***
Std. Dev.	***25,002***	***29.601***	***257***	***8.77***	***9.43***	***2.05***	***1.924***	***0.204***	***0.663***
Skewness	***1.817***	***2.588***	***-0.341***	***-0.424***	***1.817***	***2.59***	***1.690***	***0.241***	***0.019***
Median	***19,281***	***20.714***	***754***	***42.33***	***7.27***	***1.44***	***-0.136***	***0.758***	***0.658***

- reliable water quality and hydrologic data are available, and

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

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-8.**

Table 3-8. Comparison of Base Period with period of record data for S-154.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1977-2010					
Annual Minimum	91	0.025	143	21.59	0.00
Annual Average	25,075	25.241	816	43.40	1.75
Annual Median	19,281	20.714	754	42.33	1.44
Annual Maximum	116,218	149.667	1,123	56.25	10.37
Base Period WY1977-1984					
Annual Minimum	4,659	1.093	143	30.06	0.08
Annual Average	30,524	29.955	796	43.26	2.08
Annual Median	9,734	8.272	601	42.02	0.57
Annual Maximum	116,218	149.667	1,044	56.20	10.37
Difference between Period of Record and Base Period					
Annual Minimum	-4,568	-1.068	0	-8.47	-0.07
Annual Average	-5,448	-4.714	20	0.14	-0.33
Annual Median	9,548	12.443	154	0.31	0.86
Annual Maximum	0	0.000	79	0.05	0.00
Annual Minimum	-98%	-98%	0%	-28%	-98%
Annual Average	-18%	-16%	3%	0%	-16%
Annual Median	98%	150%	26%	1%	150%
Annual Maximum	0%	0%	8%	0%	0%
WY2001-2010					
Annual Minimum	91	0.025	223	21.59	0.00
Annual Average	22,013	20.405	751	40.37	1.41
Annual Median	17,788	13.970	570	42.19	0.97
Annual Maximum	56,536	65.602	941	54.80	4.55
Difference between WY2001-2010 and Base Period					
Annual Minimum	-4,568	-1.068	80	-8.47	-0.07
Annual Average	-8,511	-9.550	-44	-2.89	-0.66
Annual Median	8,055	5.698	-31	0.17	0.39
Annual Maximum	-59,682	-84.065	-103	-1.40	-5.83
Annual Minimum	-98%	-98%	56%	-28%	-98%
Annual Average	-28%	-32%	-6%	-7%	-32%
Annual Median	83%	69%	-5%	0%	69%
Annual Maximum	-51%	-56%	-10%	-2%	-56%

3.1.3.2 Performance Measure 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 D 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. The Annual Load Target and Annual Load Limit will be calculated according to the following equations and explanation:

$\text{Target} = \exp(-5.20573 + 0.16556\,X)$

Explained Variance = 80.1%, Standard Error of Regression[10] = 0.74134

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:

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

$X = 12\,m_1$

$\text{Limit} = \text{Target} * \exp(1.43976\,SE)$

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

$SE = 0.74134\,[\,1 + 1/8 + (X-X_m)^2 / 485.64409\,]^{0.5}$

Where:

X = the 12-month total rainfall (inches)

X_m = average value of the predictor in base period = 43.2588 inches

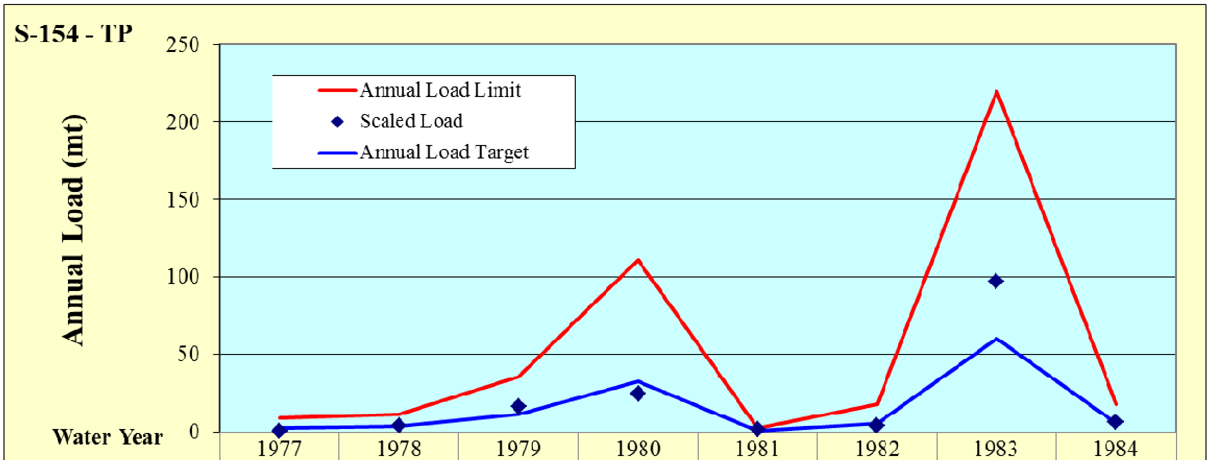
[10] The standard error of the regression equation is expressed in the same units as the transformed load, i.e., ln(metric tons).

The predictor X indicates that the load increases exponentially with total annual rainfall. A comparison of the scaled loads and the resulting Targets and Limits for the Base Period are presented in **Figure 3-5.** Annual TP loads at S-154, adjusted to account for regional projects (if applicable), will be evaluated against the performance measure described above.

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), at S-154 exceeds the Annual Load Target and the rainfall falls outside the range of rainfall values for the Base Period (30.06 – 56.20 inches). The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the WY1977-2010 period of record are summarized in **Table 3-9**.

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

Figure 3-5. Comparison of scaled annual loads with the Annual Load Targets and Limits for the S-154 Summary Basin.



	1977	1978	1979	1980	1981	1982	1983	1984
Annual Load Limit	9.189	11.412	35.956	111.333	2.918	17.868	219.770	17.926
Scaled Load	0.710	4.194	16.319	24.570	1.935	4.331	97.284	6.422
Annual Load Target	2.874	3.617	11.488	32.926	0.795	5.751	60.253	5.770

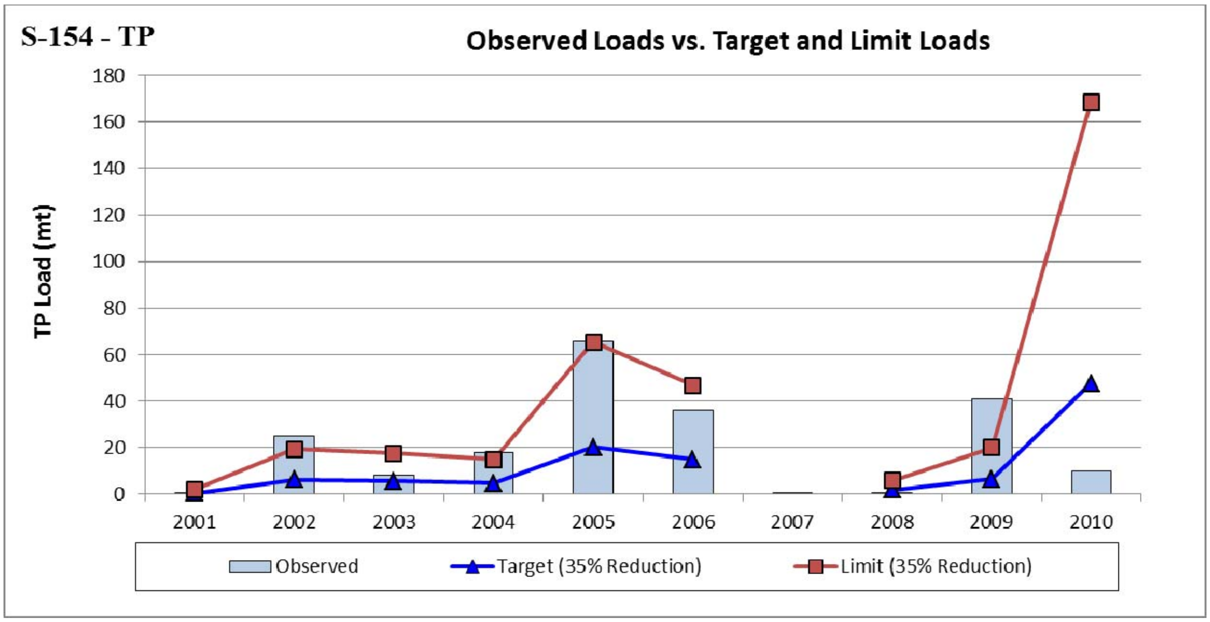
Table 3-9. Estimates of Annual Load Targets and Limits for the historical period of record for the S-154 Summary Basin (Base Period: WY1977-1984).

Water Year	Observed Load, mt	Rain in	Target Load, mt	Limit Load, mt
1977	1.093	37.82	2.874	9.189
1978	6.453	39.21	3.617	11.412
1979	25.106	46.19	11.488	35.956
1980	37.800	52.55	32.926	111.332
1981	2.977	30.06	0.795	2.918
1982	6.663	42.01	5.751	17.868
1983	149.667	56.20	60.252	219.768
1984	9.880	42.03	5.770	17.926
1985	23.612	36.13	2.172	7.095
1986	12.701	32.18	1.130	3.954
1987	53.714	45.90	10.950	34.213
1988	42.574	48.99	18.263	58.587
1989	7.786	42.13	5.866	18.221
1990	23.787	42.20	5.934	18.431
1991	14.526	52.89	34.832	118.509
1992	24.308	46.11	11.337	35.466
1993	25.192	48.63	17.206	54.975
1994	2.089	41.23	5.054	15.745
1995	23.949	56.25	60.753	221.856
1996	26.028	52.38	32.012	107.917
1997	0.351	37.01	2.513	8.112
1998	43.391	55.98	58.097	210.824
1999	7.621	32.78	1.248	4.314
2000	82.860	55.01	49.478	175.677
2001	0.116	27.22	0.497	1.961
2002	24.815	42.46	6.195	19.232
2003	8.244	41.92	5.665	17.608
2004	17.816	40.91	4.793	14.954
2005	65.602	49.61	20.237	65.410
2006	36.142	47.72	14.800	46.860
2007	0.323	21.59	0.196	0.916
2008	0.025	34.74	1.726	5.758
2009	40.845	42.72	6.468	20.070
2010	10.123	54.80	47.787	168.906

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.

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

Figure 3-6. Comparison of WY2001-2010 observed loads to the Annual Load Targets and Limits for the S-154 Summary Basin.



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.

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 3-10**). 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 determination methodology for the S-154 Summary 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%	5.6%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.0%
Step 4. Load > Annual Load Limit?	<10%	4.0%
Cumulative Exceedance Frequency	**<17.5%**	**13.9%**

3.1.4 S-154C Summary Basin

The following sections present a description of the S-154C Summary Basin and a summary of historical flow and TP levels.

3.1.4.1 Background

The S-154C Summary Basin consists of 2,134 acres of predominantly improved pasture. A single discharge structure (S-154C) located in the southeast corner of the basin conveys stormwater runoff from the basin into Lake Okeechobee approximately 3 miles downstream of S-65E and approximately 5 miles upstream of the State Road 78 bridge over the Kissimmee River. Flow and TP data collection began at S-154C in July 2008. Monthly summaries are provided in **Table 3-11** for a portion WY2009 and WY2010.

3.1.4.2 Performance Measure Methodology

Since this summary basin has historically contributed a small percentage of the annual Lake Okeechobee total phosphorus load (less than one percent), no performance metric will be assigned to this area. However, the water quality from the basin will be assessed annually to determine if there is an increasing trend.

Table 3-11. Summary of historical flow and TP data for S-154C.

Month	Flow AF	TP Load kg	TP Conc µg/L
200807	277	200	585
200808	1,588	2,546	1,300
200809	697	563	655
200810	385	156	328
200811	123	57	376
200812	119	51	347
200901	44	18	332
200902	0	0	
200903	0	0	
200904	0	0	
200905	0	0	
200906	274	88	260
200907	446	230	418
200908	115	75	529
200909	91	59	526
200910	81	37	370
200911	65	24	299
200912	1	0	
201001	20	13	527
201002	110	81	597
201003	872	754	701
201004	317	295	754
Average	*256*	*239*	*524*
Flow-weighted mean TP Conc.			*756*
Geometric mean TP Conc.			*481*
Median	*113*	*58*	*526*
Std Dev	*378*	*550*	*250*

3.1.5 S-191 Summary Basin

The following sections present a description of the S-191 Summary Basin, a summary of historical flow and TP levels, the selection of a Base Period, an estimated range of load reductions attributable to collective source controls, and the derivation of the resulting performance measure.

3.1.5.1 Background

The 119,402-acre S-191 Summary Basin discharges into Lake Okeechobee through S-191. Annual flow and TP data observed at S-191 are summarized in **Table 3-12.** For the development of the performance measure methodology, a Base Period of WY1977-1988 was selected for the following reasons:

- it represents a period with minimal implementation of source controls. With the selection of the Base Period to precede significant source control implementation, no additional calculation is necessary in the performance measure methodology to account for prior source control implementation.
- basin water management operations were similar to current operating conditions affecting nutrient loading, with the exception of recent regional projects. The proposed performance measure methodology accounts for the influence of these regional projects on basin loads.
- it represents a period of relatively constant land use practices,
- it traversed a wide range of hydrologic conditions (wet and dry years),
    - Monthly and annual flow for Water Year 1980 (May 1979 – April 1979) were relatively higher than during the other years due to tropical storm activity. The TP concentrations for WY1980 were also relatively high, yet no outliers were detected. The combination of high flows and high concentrations resulted in relatively high monthly loads for this period as well.

- reliable water quality and hydrologic data are available, and
- a very strong correlation exists between annual TP loads and rainfall, allowing for a performance measure methodology that explicitly incorporates hydrologic variability.

Table 3-12. Summary of historical data for S-191.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics: Kurtosis K	Coef. Of Var. CV	Skewness S
1977	157,712	185.092	951	44.62	15.85	3.42	-0.399	0.836	0.736
1978	123,421	156.780	1,030	48.24	12.40	2.89	-0.487	0.557	0.561
1979	147,602	176.433	969	51.94	14.83	3.26	0.161	0.628	0.772
1980	195,007	239.196	994	54.82	19.60	4.42	5.312	1.038	2.104
1981	44,844	51.039	923	35.01	4.51	0.94	3.245	0.817	1.379
1982	107,623	183.556	1,383	45.02	10.82	3.39	-0.318	0.853	0.668
1983	206,721	204.033	800	63.58	20.78	3.77	-0.464	0.536	0.544
1984	77,818	78.301	816	44.54	7.82	1.45	-1.004	0.555	0.135
1985	51,376	66.775	1,054	36.55	5.16	1.23	2.362	0.850	1.178
1986	78,395	85.978	889	35.74	7.88	1.59	0.665	0.757	0.938
1987	139,706	142.242	825	44.10	14.04	2.63	-0.375	0.795	0.794
1988	61,889	57.785	757	41.09	6.22	1.07	-0.340	0.592	0.145
1989	47,010	42.844	739	40.23	4.72	0.79	-1.151	0.686	0.298
1990	61,061	63.274	840	46.43	6.14	1.17	0.482	0.893	0.916
1991	121,462	100.327	670	48.43	12.21	1.85	-1.668	0.640	-0.140
1992	76,465	52.372	555	48.97	7.68	0.97	-1.308	0.784	0.513
1993	158,297	127.422	653	59.51	15.91	2.35	3.033	0.944	1.529
1994	38,590	20.648	434	45.01	3.88	0.38	-0.771	0.415	-0.165
1995	173,986	120.673	562	56.64	17.49	2.23	-0.332	0.520	0.425
1996	169,688	144.982	693	60.78	17.05	2.68	-1.499	0.838	0.314
1997	34,195	20.554	487	42.78	3.44	0.38	-1.145	0.678	0.451
1998	126,309	85.797	551	53.69	12.69	1.58	-0.804	0.490	-0.393
1999	61,962	48.313	632	31.08	6.23	0.89	-0.532	0.706	0.711
2000	150,747	143.699	773	55.00	15.15	2.65	5.709	1.173	2.158
2001	13,557	11.290	675	25.52	1.36	0.21	-0.694	1.096	0.850
2002	87,642	77.970	721	47.49	8.81	1.44	7.429	1.178	2.424
2003	85,497	74.273	704	47.65	8.59	1.37	0.767	0.748	1.109
2004	89,666	71.207	644	37.94	9.01	1.31	1.022	0.816	1.185
2005	167,369	148.557	720	48.22	16.82	2.74	1.499	1.047	1.390
2006	187,800	143.248	618	51.80	18.87	2.64	1.510	1.008	1.228
2007	17,850	13.564	616	30.26	1.79	0.25	0.637	1.031	1.161
2008	23,960	15.683	531	37.56	2.41	0.29	-0.689	0.690	0.358
2009	98,634	77.643	638	33.55	9.91	1.43	5.621	1.214	2.106
2010	52,899	30.585	469	48.36	5.32	0.56	-1.358	0.680	0.022
Minimum	***13,557***	***11.290***	***434***	***25.52***	***1.36***	***0.21***	***-1.668***	***0.415***	***-0.393***
Average	***101,081***	***95.945***	***770***	***45.36***	***10.16***	***1.77***	***0.709***	***0.797***	***0.835***
Maximum	***206,721***	***239.196***	***1,383***	***63.58***	***20.78***	***4.42***	***7.429***	***1.214***	***2.424***
Std. Dev.	***55,813***	***60.831***	***198***	***9.05***	***5.61***	***1.12***	***2.328***	***0.211***	***0.690***
Skewness	***0.240***	***0.507***	***1.038***	***-0.111***	***0.240***	***0.51***	***1.521***	***0.306***	***0.557***
Median	***88,654***	***78.136***	***712***	***45.73***	***8.91***	***1.44***	***-0.336***	***0.790***	***0.754***

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-13.** The median WY2001-2010 annual load was approximately 51 percent lower than the Base Period, reflecting the effectiveness of source controls already implemented in this basin.

Table 3-13. Comparison of Base Period with period of record data for S-191.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1977-2010					
Annual Minimum	13,557	11.290	434	25.52	0.21
Annual Average	101,081	95.945	770	45.36	1.77
Annual Median	88,654	78.136	712	45.73	1.44
Annual Maximum	206,721	239.196	1,383	63.58	4.42
Base Period WY1977-1988					
Annual Minimum	44,844	51.039	757	35.01	0.94
Annual Average	116,010	135.601	948	45.44	2.50
Annual Median	115,522	149.511	937	44.58	2.76
Annual Maximum	206,721	239.196	1,383	63.58	4.42
Difference between Period of Record and Base Period					
Annual Minimum	-31,287	-39.749	-323	-9.49	-0.73
Annual Average	-14,928	-39.656	-178	-0.08	-0.73
Annual Median	-26,868	-71.376	-225	1.15	-1.32
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	-70%	-78%	-43%	-27%	-78%
Annual Average	-13%	-29%	-19%	0%	-29%
Annual Median	-23%	-48%	-24%	3%	-48%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	13,557	11.290	469	25.52	0.21
Annual Average	82,487	66.402	653	40.84	1.23
Annual Median	86,570	72.740	641	42.72	1.34
Annual Maximum	187,800	148.557	721	51.80	2.74
Difference between WY2001-2010 and Base Period					
Annual Minimum	-31,287	-39.749	-288	-9.49	-0.73
Annual Average	-33,522	-69.199	-295	-4.60	-1.28
Annual Median	-28,953	-76.771	-296	-1.86	-1.42
Annual Maximum	-18,921	-90.639	-662	-11.78	-1.67
Annual Minimum	-70%	-78%	-38%	-27%	-78%
Annual Average	-29%	-51%	-31%	-10%	-51%
Annual Median	-25%	-51%	-32%	-4%	-51%
Annual Maximum	-9%	-38%	-48%	-19%	-38%

3.1.5.2 Performance Measure 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 40 percent was determined to be reasonable and appropriate. Details are provided in Appendix D and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 40 percent load reduction. The Annual Load Target and Annual Load Limit will be calculated according to the following equations and explanation:

$$\text{Target} = -692.35612 + 210.9038\ X + 84.89757\ C$$

Explained Variance = 89.4%, Standard Error of Regression = 13.995 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:

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

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

$$X = \ln\ (12\ m_1)$$

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

$$\text{Limit} = \text{Target} + 1.38303\ \text{SE}$$

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

$$\text{SE} = 13.99487\ [\ 1 + 1/12 + 3.1233\ (X-X_m)^2 + 2.11893\ (C-C_m)^2\ + 1.54068\ (X-X_m)\ (C-C_m)\ ]^{0.5}$$

Where:

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

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

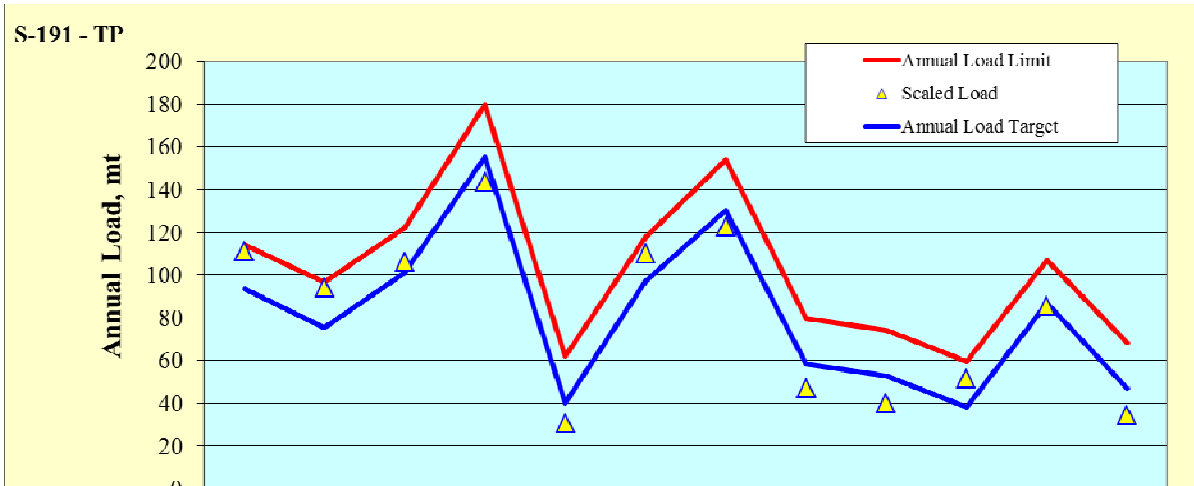
X_m = average value of the predictor in base period = 3.80143

C_m = average value of the predictor in base period = -0.33003

The first predictor (X) indicates that load increases with 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 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 scaled loads and the resulting Targets and Limits for the Base Period is presented in **Figure 3-7.** Annual TP loads at S-191, adjusted to account for regional projects, will be evaluated against the performance measure described above.

Figure 3-7. Comparison of scaled annual loads with the Annual Load Targets and Limits for the S-191 Summary Basin.



Water Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Annual Load Limit	114.070	96.751	122.084	179.858	62.092	117.807	154.076	79.773	74.190	59.719	107.076	68.111
Scaled Load	111.055	94.068	105.860	143.518	30.623	110.134	122.420	46.981	40.065	51.587	85.345	34.671
Annual Load Target	93.487	75.466	101.237	155.282	40.380	97.079	130.436	58.330	52.822	38.258	86.746	46.804

Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load, adjusted for regional projects, at S-191 exceeds the Annual Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (36.49 – 63.56 inches), as derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall amount which reflects the cumulative effect of the predictor variables that make up the Annual Load Target equation. The adjusted rainfall is the rainfall that would produce the equivalent annual load using the Annual Load Target equation by setting the value of C to its mean value for the calibration period.

$$\text{Adjusted Rainfall} = \exp\left[\, X + 0.40254\,(C + 0.33003)\,\right]$$

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1977-2010 period of record are summarized in **Table 3-14**. The annual performance determination process will account for regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

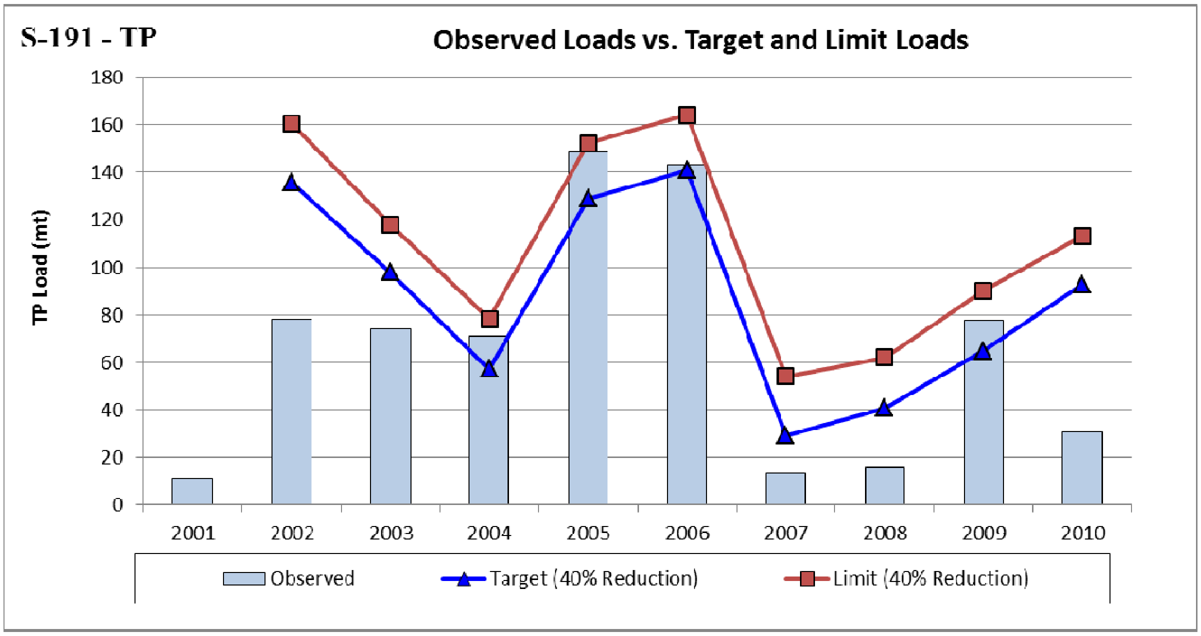
Table 3-14. Estimates of annual Load Targets and Limits for the historical period of record for the S-191 Summary Basin (Base Period: WY1977-1988).

Water Year	Observed Load, mt	Observed Rain, in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1977	185.092	44.62	0.836	93.487	114.070	47.41
1978	156.780	48.24	0.557	75.466	96.751	43.53
1979	176.433	51.94	0.628	101.237	122.084	49.19
1980	239.196	54.82	1.038	155.281	179.857	63.56
1981	51.039	35.01	0.817	40.381	62.092	36.86
1982	183.556	45.02	0.853	97.079	117.807	48.23
1983	204.033	63.58	0.536	130.436	154.076	56.49
1984	78.301	44.54	0.555	58.330	79.772	40.13
1985	66.775	36.55	0.850	52.822	74.191	39.10
1986	85.978	35.74	0.757	38.258	59.719	36.49
1987	142.242	44.10	0.795	86.746	107.075	45.92
1988	57.785	41.09	0.592	46.805	68.112	38.00
1989	42.844	40.23	0.686	54.856	75.443	39.48
1990	63.274	46.43	0.893	107.473	128.670	50.67
1991	100.327	48.43	0.640	88.087	108.545	46.22
1992	52.372	48.97	0.784	107.655	128.288	50.71
1993	127.422	59.51	0.944	164.535	189.119	66.41
1994	20.648	45.01	0.415	35.865	61.238	36.08
1995	120.673	56.64	0.520	103.486	126.067	49.72
1996	144.982	60.78	0.838	158.876	182.561	64.65
1997	20.554	42.78	0.678	66.822	87.132	41.78
1998	85.797	53.69	0.490	87.160	109.984	46.01
1999	48.313	31.08	0.706	2.872	26.656	30.85
2000	143.699	55.00	1.173	166.352	192.883	66.98
2001	11.290	25.52	1.096	-1.359	26.565	30.24
2002	77.970	47.49	1.178	135.750	160.657	57.93
2003	74.273	47.65	0.748	97.901	118.226	48.42
2004	71.207	37.94	0.816	57.228	78.169	39.93
2005	148.557	48.22	1.047	128.959	152.211	56.10
2006	143.248	51.80	1.008	140.840	164.291	59.35
2007	13.564	30.26	1.031	29.381	54.018	34.99
2008	15.683	37.56	0.690	40.866	62.017	36.94
2009	77.643	33.55	1.214	65.020	90.197	41.43
2010	30.585	48.36	0.680	92.929	113.247	47.29

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.

Comparison to WY2001-2010. A comparison of the loads observed during WY2001-2010 to the Annual Load Targets and Limits is presented in **Figure 3-8**.

Figure 3-8. Comparison of WY2001-2010 observed loads to the Annual Load Targets and Limits for the S-191 Summary Basin.



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

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 3-15**). 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 3-15. Exceedance frequencies for the proposed determination methodology for the S-191 Summary Basin.

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%	8.0%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.2%
Step 4. Load > Annual Load Limit?	<10%	4.2%
Cumulative Exceedance Frequency	**<17.5%**	**13.4%**

3.2 Lower Kissimmee Sub-watershed

The following sections present a description of the Lower Kissimmee Sub-watershed, a summary of historical flow and TP levels, the selection of a Base Period, an estimated range of load reductions attributable to collective source controls, and the derivation of the resulting performance measure.

3.2.1.1 Background

The Upper and Lower Kissimmee Sub-watersheds comprise the Kissimmee River Basin, which includes most of the area that drains into Lake Okeechobee from the north and northwest through the Kissimmee River (C-38 canal). The 429,188-acre Lower Kissimmee Sub-watershed includes the tributary watersheds of the Kissimmee River that lie between the outlet from Lake Kissimmee and the inlet to Lake Okeechobee. The S-65 sub-basins (S-65A, S-65BC, S-65D, and S-65E) are located along the length of the C-38 canal and form four pools (**Figure 3-9**). Structure S-65B was removed as a part of the first phase of Kissimmee River Restoration Project and reduced the number of pools from five to four. Water levels in each of the pools are regulated according to interim regulation schedules. Monitoring stations are located at each S-65 structure (at the downstream boundary of each sub-basin) and at station S-65, which is at the outlet from Lake Kissimmee to the Kissimmee River. The S-65 structures are gated spillways and locks that are operated to enhance the natural resources of the river floodplain and to provide flood protection within their respective sub-basins and the Upper Kissimmee River Basin. Discharge monitoring locations are shown in **Figure 3-9** and listed in **Tables C-1** and **C-2**.

District staff identified the rainfall stations considered to be representative of the Lower Kissimmee Sub-watershed for the period WY1976-2010. Rainfall stations are shown in **Figure 3-10** with their associated Theissen polygons and weighting factors. In order to separate discharges originating in the upstream Upper Kissimmee Sub-watershed, pass-through loads are estimated by comparing daily discharges from S-65 to the flows at the outlet structure S-65E (Appendix A).

Figure 3-9. Lower Kissimmee Sub-watershed boundary and discharge monitoring locations.

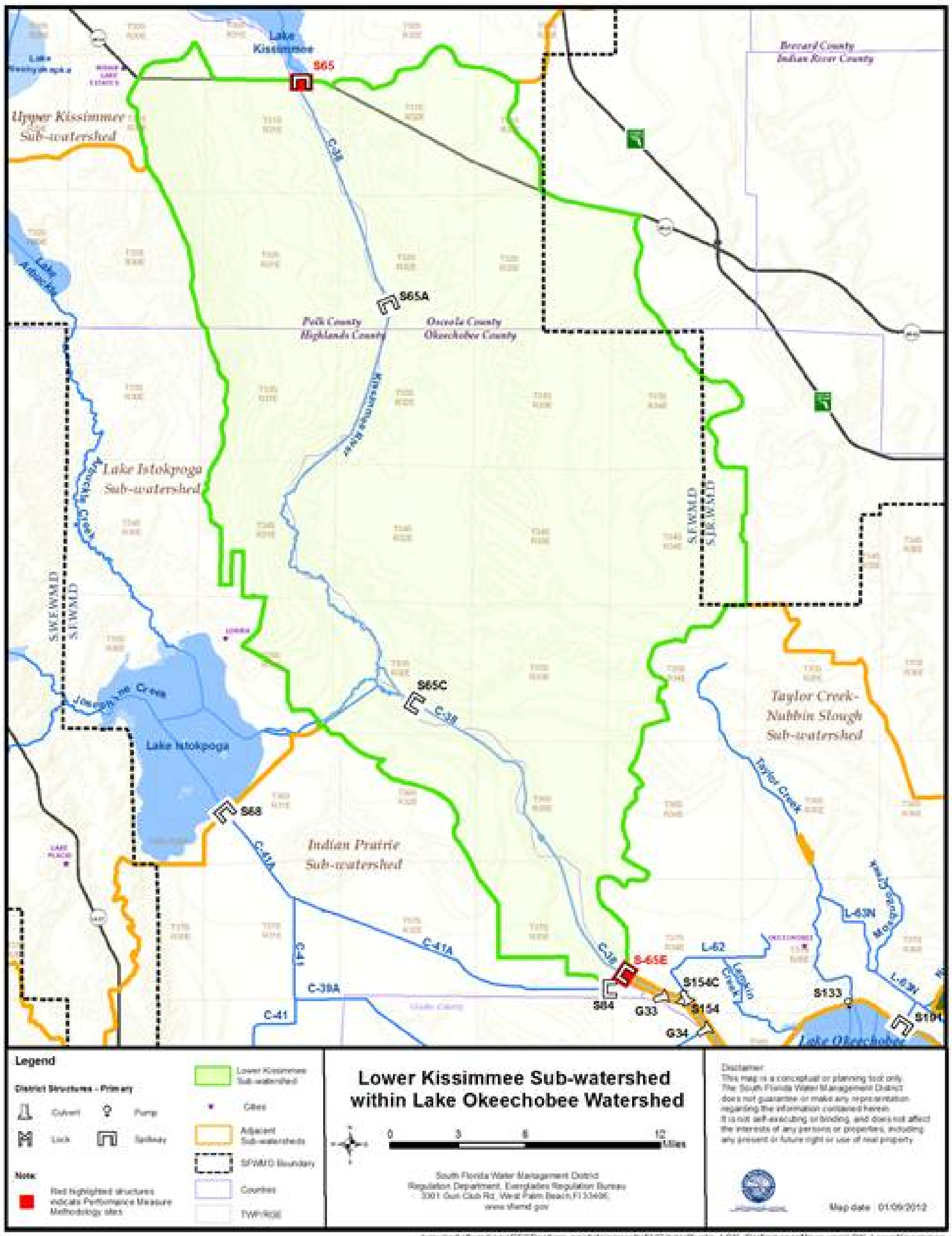
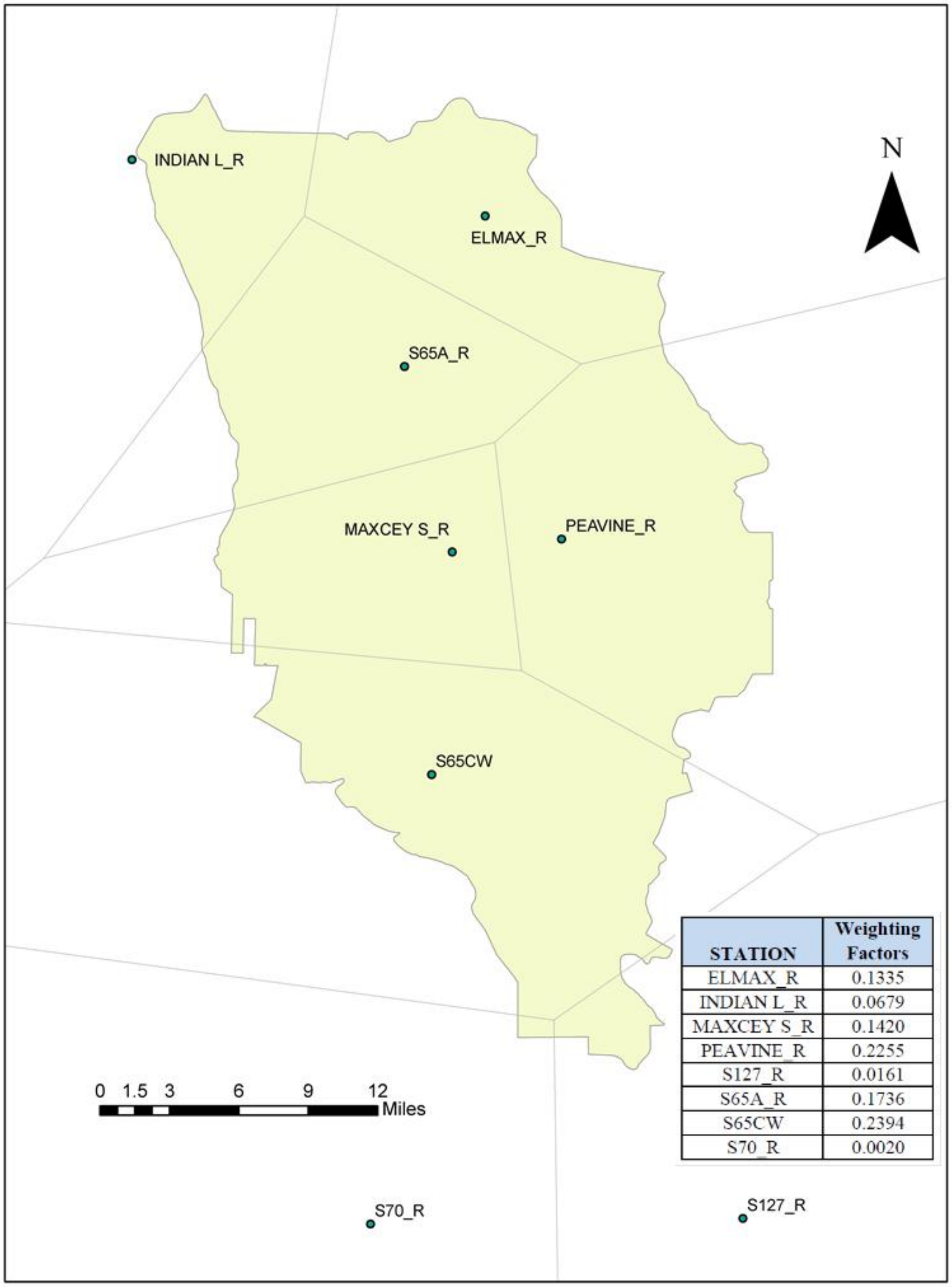


Figure 3-10. Schematic of Lower Kissimmee Sub-watershed and the selected rainfall stations.



STATION	Weighting Factors
ELMAX_R	0.1335
INDIAN L_R	0.0679
MAXCEY S_R	0.1420
PEAVINE_R	0.2255
S127_R	0.0161
S65A_R	0.1736
S65CW	0.2394
S70_R	0.0020

Annual flow and TP data for discharges from the Lower Kissimmee Sub-watershed into Lake Okeechobee are summarized in **Table 3-16.** For the development of the performance measure methodology, a Base Period of WY1977-1990 was selected for the following reasons:

- it represents a period with minimal implementation of source controls. With the selection of the Base Period to precede significant source control implementation, no additional calculation is necessary in the performance measure methodology to account for prior source control implementation.
- it represents a period of relatively constant land use practices,
- it traversed a wide range of hydrologic conditions (wet and dry years),
  - Monthly and annual flow and TP levels for Water Year 1980 (May 1979 – April 1979) were relatively higher than during the other years due to tropical storm activity.
- reliable water quality and hydrologic data are available, and
- a strong correlation exists between annual TP loads and rainfall, allowing for a performance measure methodology that explicitly incorporates hydrologic variability.

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-17.**

Table 3-16. Summary of historical data for the Lower Kissimmee Sub-watershed.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1977	413,364	60.731	119	51.72	11.56	0.31	-1.733	0.884	0.476
1978	242,506	29.763	99	47.79	6.78	0.15	-0.497	0.553	-0.033
1979	679,833	146.321	174	59.10	19.01	0.75	0.847	0.737	1.071
1980	631,914	157.288	202	55.96	17.67	0.81	1.053	0.807	1.307
1981	91,591	19.994	177	39.33	2.56	0.10	-0.276	0.707	0.336
1982	99,717	31.589	257	45.05	2.79	0.16	-1.290	0.675	0.261
1983	851,549	197.316	188	61.84	23.81	1.01	-1.535	0.526	-0.038
1984	80,459	37.387	377	43.25	2.25	0.19	-0.057	0.565	0.572
1985	211,885	79.258	303	41.71	5.92	0.41	-0.999	0.747	0.405
1986	136,112	43.588	260	43.05	3.81	0.22	-0.594	0.794	0.910
1987	244,506	100.068	332	47.04	6.84	0.51	2.710	0.748	1.275
1988	372,249	129.497	282	55.94	10.41	0.67	0.243	0.649	0.512
1989	100,602	34.449	278	43.14	2.81	0.18	0.232	0.577	0.809
1990	122,723	51.390	339	47.96	3.43	0.26	-0.944	0.648	0.238
1991	257,169	73.414	231	51.37	7.19	0.38	-0.201	0.616	0.297
1992	341,430	118.047	280	52.11	9.55	0.61	1.545	0.831	1.171
1993	353,751	87.536	201	62.62	9.89	0.45	1.678	0.825	1.365
1994	110,516	15.485	114	49.07	3.09	0.08	-0.777	0.469	0.192
1995	555,041	138.797	203	67.55	15.52	0.71	-1.149	0.481	0.581
1996	470,881	71.604	123	56.39	13.17	0.37	-0.235	0.806	0.719
1997	160,921	8.174	41	47.24	4.50	0.04	-0.542	0.735	0.824
1998	683,024	178.028	211	82.31	19.10	0.91	-0.764	0.377	-0.438
1999	223,967	44.198	160	47.91	6.26	0.23	0.543	0.918	1.174
2000	425,118	148.916	284	60.11	11.89	0.76	-1.359	0.788	0.425
2001	54,838	10.543	156	39.14	1.53	0.05	-0.288	1.109	0.884
2002	419,512	68.369	132	47.01	11.73	0.35	-1.355	0.762	0.476
2003	593,953	116.200	159	63.32	16.61	0.60	0.262	0.745	0.873
2004	608,979	104.848	140	50.31	17.03	0.54	0.282	0.838	1.053
2005	526,704	47.038	72	59.74	14.73	0.24	2.161	0.913	1.430
2006	651,415	26.793	33	61.15	18.21	0.14	-1.427	0.770	0.156
2007	86,663	24.679	231	32.72	2.42	0.13	-0.551	0.906	0.961
2008	75,414	16.480	177	44.16	2.11	0.08	2.482	0.712	1.140
2009	434,150	120.876	226	44.53	12.14	0.62	0.631	1.274	1.404
2010	243,614	43.948	146	54.00	6.81	0.23	-1.842	0.630	-0.117
Minimum	***54,838***	***8.174***	***33***	***32.72***	***1.53***	***0.04***	***-1.842***	***0.377***	***-0.438***
Average	***339,884***	***75.959***	***181***	***51.64***	***9.50***	***0.39***	***-0.110***	***0.739***	***0.667***
Maximum	***851,549***	***197.316***	***377***	***82.31***	***23.81***	***1.01***	***2.710***	***1.274***	***1.430***
Std. Dev.	***222,855***	***52.862***	***84***	***9.77***	***6.23***	***0.27***	***1.203***	***0.177***	***0.488***
Skewness	***0.478***	***0.630***	***0.096***	***0.852***	***0.478***	***0.63***	***0.771***	***0.648***	***-0.227***
Median	***299,300***	***64.550***	***195***	***49.69***	***8.37***	***0.33***	***-0.282***	***0.746***	***0.650***

Table 3-17. Comparison of Base Period with period of record data for Lower Kissimmee Sub-watershed.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1977-2010					
Annual Minimum	54,838	8.174	33	32.72	0.04
Annual Average	339,884	75.959	181	51.64	0.39
Annual Median	299,300	64.550	195	49.69	0.33
Annual Maximum	851,549	197.316	377	82.31	1.01
Base Period WY1977-1990					
Annual Minimum	80,459	19.994	99	39.33	0.10
Annual Average	305,644	79.903	212	48.78	0.41
Annual Median	227,196	56.061	259	47.42	0.29
Annual Maximum	851,549	197.316	377	61.84	1.01
Difference between Period of Record and Base Period					
Annual Minimum	-25,621	-11.820	-66	-6.61	-0.06
Annual Average	34,241	-3.944	-31	2.86	-0.02
Annual Median	72,104	8.489	-64	2.28	0.04
Annual Maximum	0	0.000	0	20.47	0.00
Annual Minimum	-32%	-59%	-67%	-17%	-59%
Annual Average	11%	-5%	-15%	6%	-5%
Annual Median	32%	15%	-25%	5%	15%
Annual Maximum	0%	0%	0%	33%	0%
WY2001-2010					
Annual Minimum	54,838	10.543	33	32.72	0.05
Annual Average	369,524	57.977	127	49.61	0.30
Annual Median	426,831	45.493	151	48.66	0.23
Annual Maximum	651,415	120.876	231	63.32	0.62
Difference between WY2001-2010 and Base Period					
Annual Minimum	-25,621	-9.451	-66	-6.61	-0.05
Annual Average	63,881	-21.925	-85	0.83	-0.11
Annual Median	199,636	-10.568	-108	1.25	-0.05
Annual Maximum	-200,134	-76.440	-146	1.48	-0.39
Annual Minimum	-32%	-47%	-67%	-17%	-47%
Annual Average	21%	-27%	-40%	2%	-27%
Annual Median	88%	-19%	-42%	3%	-19%
Annual Maximum	-24%	-39%	-39%	2%	-39%

3.2.1.2 Performance Measure 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 30 percent was determined to be reasonable and appropriate. Details are provided in Appendix D 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 for the Lower Kissimmee Sub-watershed will be calculated according to the following equations and explanation:

Target = $[-8.42963 + 0.31747\ X\ ]^2$

Explained Variance = 75.1%, Standard Error of Regression[11] = 1.33557

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:

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

$X = 12\ m_1$

Limit = $[\ \text{sqrt(Target)} + (1.35622\ \text{SE})\ ]^2$

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

$SE = 1.33557\ [\ 1 + 1/14 + (X-X_m)^2\ /\ 641.63129\ ]^{0.5}$

Where:

X = the 12-month total rainfall (inches)

X_m = average value of the predictor in base period = 48.7771 inches

[11] The standard error of the regression equation is expressed in the same units as the transformed load, i.e., sqrt(metric tons).

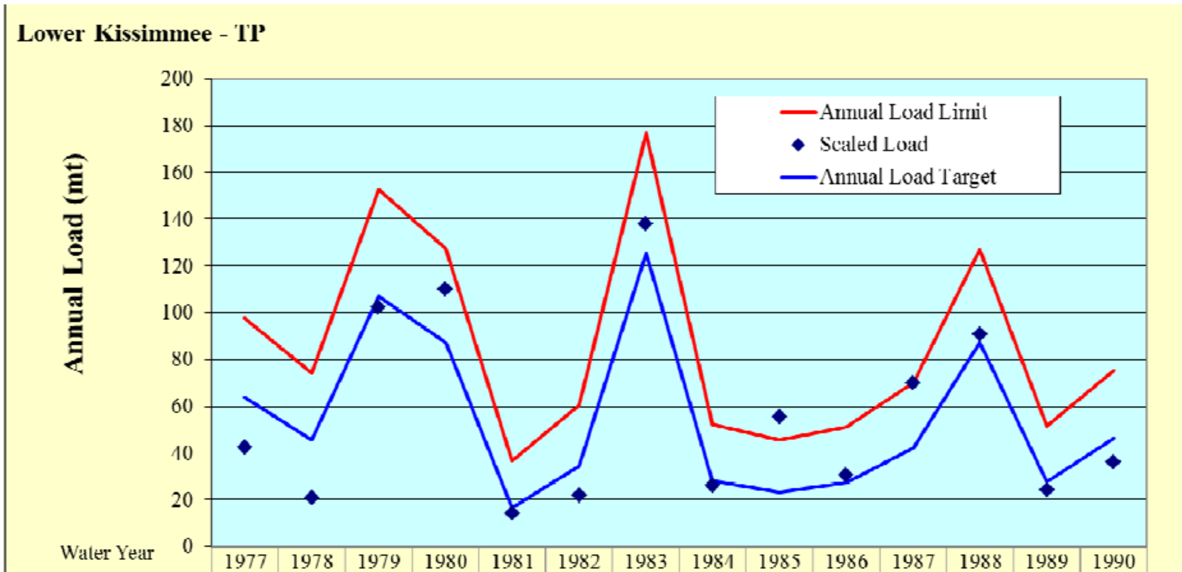
The predictor X indicates that load increases with total annual rainfall.

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 S-65E, adjusted to account for pass-through loads as described in Appendix A and regional projects (if applicable), will be evaluated against the performance measure described above.

Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load for the sub-watershed, adjusted for regional projects (if present), exceeds the Annual Load Target and the rainfall falls outside the range of observed rainfall values for the Base Period (39.33 – 61.84 inches). The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the WY1977-2010 period of record are summarized in **Table 3-18**.

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**.

Figure 3-11. Comparison of scaled annual loads with the Annual Load Targets and Limits for the Lower Kissimmee Sub-watershed.



	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Annual Load Limit	97.550	74.281	152.473	127.241	36.596	60.315	176.826	52.088	45.616	51.218	70.280	127.090	51.608	75.207
Scaled Load	42.512	20.834	102.425	110.102	13.996	22.112	138.121	26.171	55.481	30.512	70.048	90.648	24.114	35.973
Annual Load Target	63.841	45.460	106.771	87.164	16.456	34.486	125.505	28.101	23.157	27.432	42.306	87.045	27.732	46.191

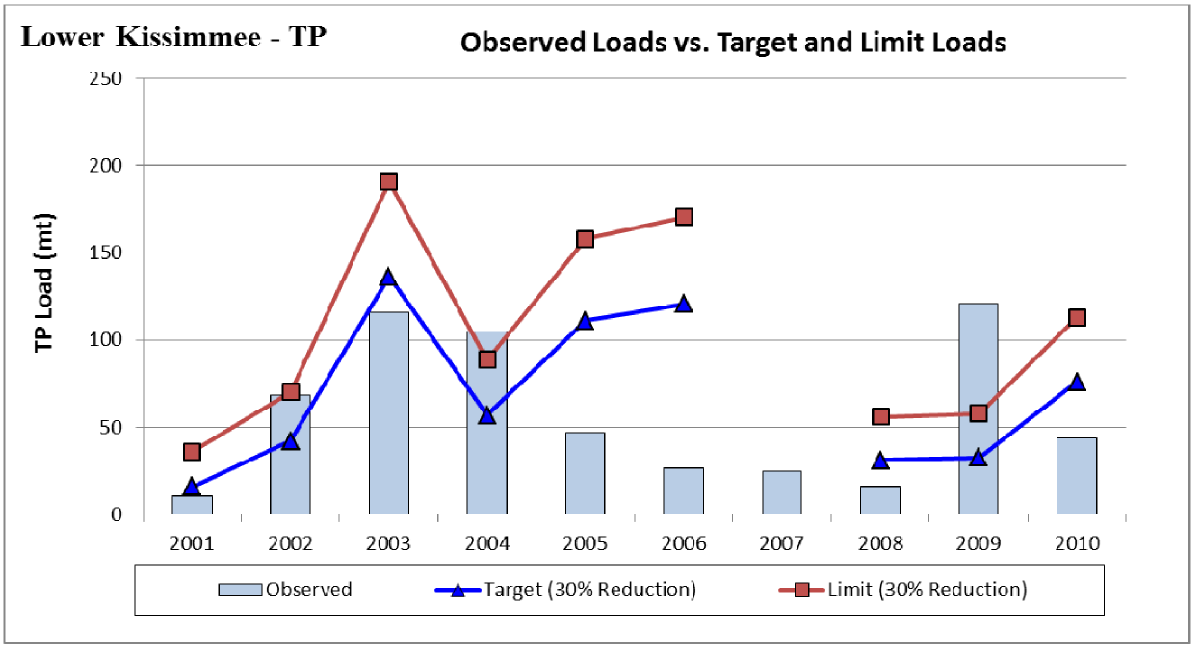
Table 3-18. Estimates of annual Load Targets and Limits for the historical period of record for the Lower Kissimmee Sub-watershed (Base Period: WY1977-1984).

Water Year	Observed Load, mt	Rain inches	Target Load, mt	Limit Load, mt
1977	60.731	51.72	63.841	97.550
1978	29.763	47.79	45.460	74.281
1979	146.321	59.10	106.771	152.473
1980	157.288	55.96	87.164	127.241
1981	19.994	39.33	16.456	36.596
1982	31.589	45.05	34.486	60.315
1983	197.316	61.84	125.505	176.826
1984	37.387	43.25	28.101	52.088
1985	79.258	41.71	23.157	45.616
1986	43.588	43.05	27.432	51.218
1987	100.068	47.04	42.306	70.280
1988	129.497	55.94	87.045	127.090
1989	34.449	43.14	27.732	51.608
1990	51.390	47.96	46.191	75.207
1991	73.414	51.37	62.078	95.316
1992	118.047	52.11	65.835	100.077
1993	87.536	62.62	131.114	184.163
1994	15.485	49.07	51.105	81.429
1995	138.797	67.55	169.407	234.751
1996	71.604	56.39	89.731	130.530
1997	8.174	47.24	43.136	71.333
1998	178.028	82.31	313.345	430.371
1999	44.198	47.91	45.975	74.934
2000	148.916	60.11	113.500	161.193
2001	10.543	39.14	15.970	35.926
2002	68.369	47.01	42.182	70.123
2003	116.200	63.32	136.253	190.902
2004	104.848	50.31	56.888	88.746
2005	47.038	59.74	111.011	157.964
2006	26.793	61.15	120.644	170.485
2007	24.679	32.72	3.834	17.278
2008	16.480	44.16	31.248	56.156
2009	120.876	44.53	32.575	57.863
2010	43.948	54.00	75.932	112.904

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.

Comparison to WY2001-2010. A comparison of the loads observed during WY2001-2010 to the Annual Load Targets and Limits is presented in **Figure 3-12**.

Figure 3-12. Comparison of WY2001-2010 observed loads to the Annual Load Targets and Limits for the Lower Kissimmee 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.

Exceedance Frequency Analysis. As shown in **Figure 3-11**, although the scaled observed loads fall above the Annual Load Targets exactly half the time (seven out of fourteen years), the scaled observed load for WY1985 exceeded the calculated Annual Load Limit. In accordance with the proposed performance determination process discussed in Section 2.6, having the observed load exceed the Annual Load Limit would prevent the basin from meeting its performance measure for that year. In the case of the scaled Base Period data, this is an example of a Type I error[12], or "false positive" - when the performance method suggests a lack of compliance when the basin's load actually achieves the long-term reduction goals. While this occurrence is not common, it is statistically possible. The use of the upper 90 percent confidence limit for the Annual Load Limit is consistent with the District's Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of approximately ten percent. Using the approach described in Section 2.6, 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 3-19**). 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 3-19. Exceedance frequencies for the proposed determination methodology for the Lower Kissimmee Sub-watershed.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain is outside the range and Load > Annual Load Target	<20%	5.9%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.1%
Step 4. Load > Annual Load Limit?	<10%	6.3%
Cumulative Exceedance Frequency	**<17.5%**	**15.6%**

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

3.3 East Lake Okeechobee Sub-watershed

The C-44 Hydrologic Unit and the L-8 Summary Basin, collectively referred to as the East Lake Okeechobee Sub-watershed, drain into Lake Okeechobee from the east. The C-44 Canal discharges into Lake Okeechobee through the navigation lock S-308, and also discharges to the St Lucie Canal and estuary to the east through spillway S-80. The L-8 Canal discharges into Lake Okeechobee through gated Culvert 10A, and also discharges to the southeast through numerous water control structures. In total, the East Lake Okeechobee Sub-watershed comprises 239,013 acres located east of Lake Okeechobee (**Figure 3-13**).

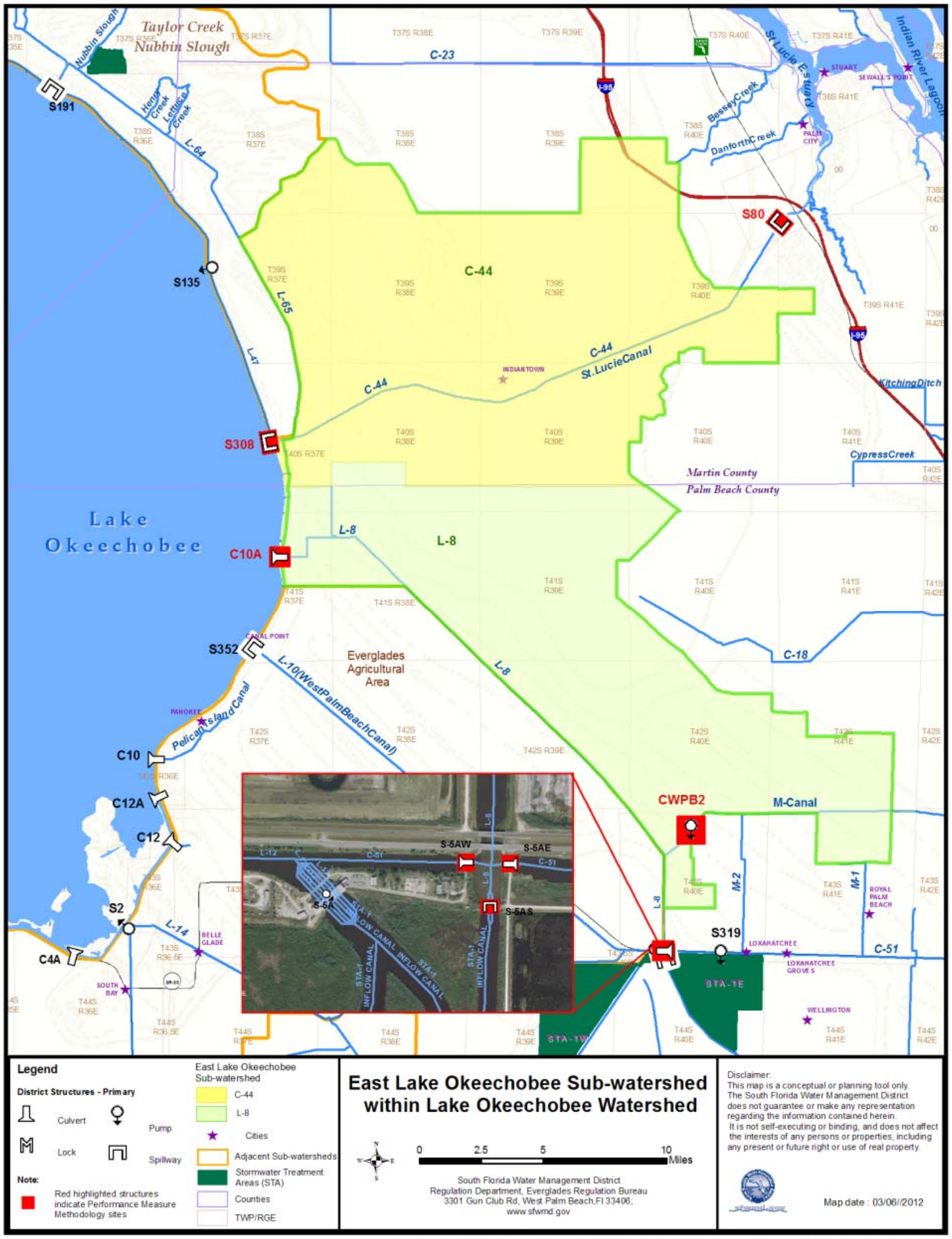
The following sections describe the derivation of the performance measure methodologies for the basins within the East Lake Okeechobee Sub-watershed.

3.3.1 C-44 Hydrologic Unit

The C-44 Hydrologic Unit is composed of 132,572 acres located in Martin County. Inflows enter the basin from Lake Okeechobee via S-308. Outflows from the C-44 Hydrologic Unit are discharged in two directions: to Lake Okeechobee at S-308 (when lake stages are at, or below 14.5 feet, NGVD), and to the St Lucie Estuary at S-80. Flow and TP monitoring sites are identified in **Tables C-1** and **C-2**. The performance measure methodology for the C-44 Hydrologic Unit was developed by HDR Engineering, Inc. (HDR 2011c) and is summarized herein. It is based on flows and TP loads resulting from rainfall and runoff from the C-44 Hydrologic Unit and accounts for pass-through flows and loads from Lake Okeechobee. The performance measure methodology is based on the total discharges from the basin to Lake Okeechobee and the St. Lucie Estuary. A few refinements were made to the performance measure methodology developed by HDR, including

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

Figure 3-13. East Lake Okeechobee Sub-watershed boundary and discharge monitoring locations.



2. 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.
3. The rainfall data were revised for the C-44 Hydrologic Unit.
4. A minor refinement was made to the C-44 Hydrologic Unit boundary to add approximately 2,850 acres of contributing area from Basin 8.

As a result of these refinements, the performance measure was slightly revised from that found in the HDR final report (HDR 2011c).

3.3.1.1 Background

Basin flows and loads from the C-44 Hydrologic Unit, adjusted for pass-through flows and loads discharged from Lake Okeechobee, were calculated using algorithms provided in Appendix A. **Table 3-20** provides a summary of the historical flow, load, and rainfall data for the C-44 Hydrologic Unit for the period of record WY1982-2010. The pass-through calculations for WY1998 yielded negative TP load and concentration, reflecting a decrease in TP concentrations as the pass-through flows transited the basin. District staff identified four rainfall stations considered to be representative of the C-44 Hydrologic Unit. Weighting factors, based on the Thiessen polygon areas for each rainfall station, were used to calculate daily basin rainfall values. **Figure 3-14** presents a schematic of the Thiessen polygon areas represented by each of the rainfall stations. For the development of the performance measure methodology, a base period of WY2000-2010 was selected for the following reasons (HDR 2011c).

- Basin water management operations during the Base Period (WY2000-2010) were similar to current operating conditions (represented by WY2001-2010).
- It provides a strong relationship between rainfall and nutrient load,

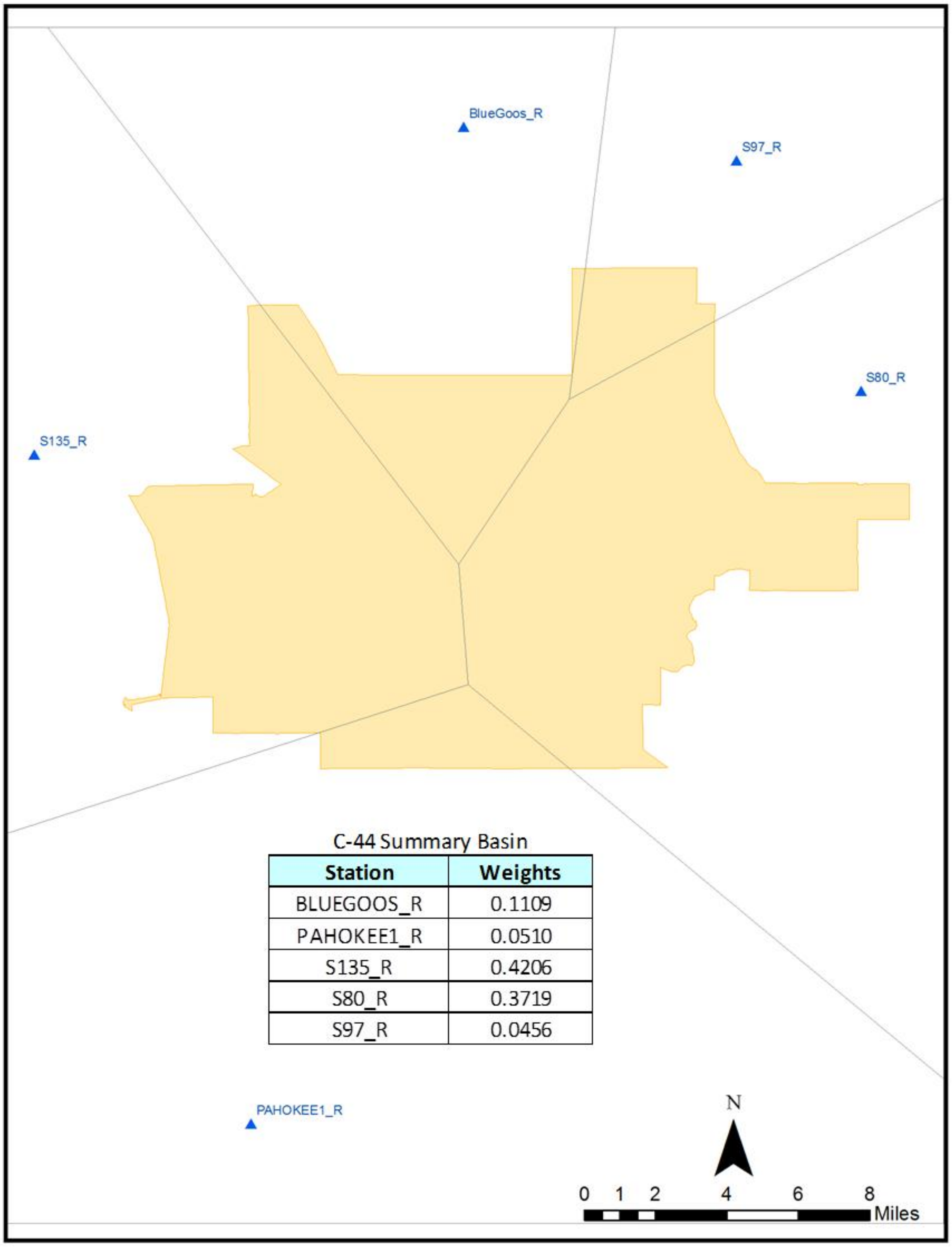
- Some level of source control implementation occurred, but no affects were observed in the basin's nutrient load levels.
- Flow and nutrient concentration data are available and monitoring is ongoing,
- No significant trends were identified for the monthly or annual data, and
- Rainfall patterns during this period are reasonably representative of long-term conditions.

Table 3-20. Summary of historical data for the C-44 Hydrologic Unit.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1981				37.17			0.326	0.708	0.830
1982	33,047	5.929	145	51.15	2.99	0.10	1.913	0.917	1.413
1983	200,611	37.047	150	70.12	18.16	0.62	-0.839	0.491	0.138
1984	216,426	28.397	106	58.90	19.59	0.47	-0.732	0.630	0.360
1985	192,015	51.046	216	47.82	17.38	0.85	-0.771	0.704	-0.004
1986	231,135	54.573	191	46.55	20.92	0.91	0.826	0.797	0.933
1987	157,737	41.639	214	50.89	14.28	0.69	3.789	0.859	1.622
1988	283,537	51.434	147	48.34	25.66	0.86	-0.706	0.580	0.143
1989	280,212	52.858	153	40.56	25.36	0.88	-0.944	0.724	0.310
1990	245,572	43.126	142	45.17	22.23	0.72	-0.369	0.774	0.808
1991	148,999	27.331	149	54.32	13.49	0.45	-0.722	0.626	0.265
1992	209,544	38.721	150	41.83	18.97	0.64	-0.819	0.601	0.359
1993	359,996	72.273	163	68.22	32.59	1.20	0.742	0.792	0.962
1994	177,180	29.672	136	57.09	16.04	0.49	-0.100	0.470	0.086
1995	439,087	83.710	155	67.89	39.74	1.39	-1.129	0.472	0.209
1996	307,569	71.564	189	70.58	27.84	1.19	-0.165	0.993	0.891
1997	129,269	19.529	122	47.22	11.70	0.32	-1.053	0.497	0.311
1998	157,244	-20.791	-107	57.74	14.23	-0.35	-0.642	0.463	-0.241
1999	148,623	27.924	152	45.45	13.45	0.46	0.431	0.844	1.129
2000	218,672	54.759	203	50.95	19.79	0.91	-0.418	0.795	0.727
2001	106,872	18.805	143	33.53	9.67	0.31	-1.050	0.913	0.619
2002	140,276	52.861	306	52.48	12.70	0.88	-0.608	0.795	0.738
2003	131,019	35.645	221	46.68	11.86	0.59	0.161	0.722	0.991
2004	200,497	69.692	282	40.07	18.15	1.16	0.910	0.865	1.247
2005	207,987	83.848	327	54.20	18.83	1.39	3.895	1.160	1.834
2006	370,613	121.520	266	59.63	33.55	2.02	1.091	0.921	1.096
2007	58,545	14.779	205	30.41	5.30	0.25	-0.764	0.825	0.728
2008	189,664	74.924	320	57.53	17.17	1.25	-1.420	0.535	0.176
2009	118,819	52.596	359	44.41	10.76	0.87	2.324	1.034	1.441
2010	136,617	37.478	222	44.84	12.37	0.62	-0.691	0.545	0.085
Minimum	***33,047***	***5.929***	***106***	***30.41***	***2.99***	***0.10***	***-1.420***	***0.470***	***-0.004***
Average	***201,434***	***48.346***	***195***	***50.96***	***18.23***	***0.80***	***0.099***	***0.746***	***0.701***
Maximum	***439,087***	***121.520***	***359***	***70.58***	***39.74***	***2.02***	***3.895***	***1.160***	***1.834***
Std. Dev.	***92,060***	***25.167***	***68***	***10.24***	***8.33***	***0.42***	***1.407***	***0.182***	***0.517***
Skewness	***0.710***	***0.836***	***0.963***	***0.299***	***0.710***	***0.84***	***1.558***	***0.187***	***0.480***
Median	***196,256***	***47.086***	***176***	***49.62***	***17.76***	***0.78***	***-0.513***	***0.783***	***0.728***

Notes: 1. Summary statistics exclude WY1998 due to negative TP levels.
2. Slight differences in values presented in HDR (2011c) are due to different protocol for significant digits, revised rainfall data, and a different estimate of basin area.

Figure 3-14. Schematic of the C-44 Hydrologic Unit and the selected rainfall stations.



C-44 Summary Basin

Station	Weights
BLUEGOOS_R	0.1109
PAHOKEE1_R	0.0510
S135_R	0.4206
S80_R	0.3719
S97_R	0.0456

Table 3-21 compares rainfall, flow, and TP data for the WY 2000-2010 base period with the WY1982-2010 period of record and the recent WY2001-2010 period.

Table 3-21. Comparison of base period with period of record data for the C-44 Hydrologic Unit.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	33,047	5.929	106	30.41	0.10
Annual Average	201,434	48.346	195	50.96	0.80
Annual Median	196,256	47.086	176	49.62	0.78
Annual Maximum	439,087	121.520	359	70.58	2.02
Base Period WY2000-2010					
Annual Minimum	58,545	14.779	143	30.41	0.25
Annual Average	170,871	56.082	266	46.79	0.93
Annual Median	140,276	52.861	266	46.68	0.88
Annual Maximum	370,613	121.520	359	59.63	2.02
Difference between Period of Record and Base Period					
Annual Minimum	-25,498	-8.850	-37	0.00	-0.15
Annual Average	30,563	-7.737	-72	4.16	-0.13
Annual Median	55,980	-5.775	-90	2.94	-0.10
Annual Maximum	68,474	0.000	0	10.95	0.00
Annual Minimum	-44%	-60%	-26%	0%	-60%
Annual Average	18%	-14%	-27%	9%	-14%
Annual Median	40%	-11%	-34%	6%	-11%
Annual Maximum	18%	0%	0%	18%	0%
WY2001-2010					
Annual Minimum	58,545	14.779	143	30.41	0.25
Annual Average	166,091	56.215	274	46.38	0.93
Annual Median	138,447	52.729	274	45.76	0.88
Annual Maximum	370,613	121.520	359	59.63	2.02
Difference between WY2001-2010 and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-4,780	0.132	8	-0.42	0.00
Annual Median	-1,830	-0.133	8	-0.92	0.00
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-3%	0%	3%	-1%	0%
Annual Median	-1%	0%	3%	-2%	0%
Annual Maximum	0%	0%	0%	0%	0%

3.3.1.2 Performance Measure 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 D and in the *Data Analysis and Performance Measure Development for the St. Lucie River Watershed Source Control Program* (HDR 2011c).

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 and adjusted rainfall for the C-44 Hydrologic Unit will be calculated according to the following equations and explanation.

Target = exp [-6.33102 + 2.47876 X + 0.32418 S]

Explained Variance = 83.9%, Standard Error of Regression[13] = 0.28227

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:

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

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

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

$X = \ln (12\, m_1)$

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

[13] The standard error of the regression equation is expressed in the same units as the transformed load, i.e., ln(metric tons).

Limit = Target * exp (1.39682 SE)

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

$$SE = 0.28227 [1 + 1/11 + 2.17743 (X-X_m)^2 + 0.37715 (S-S_m)^2 - 0.19128 (X-X_m) (S-S_m)]^{0.5}$$

Where:

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

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

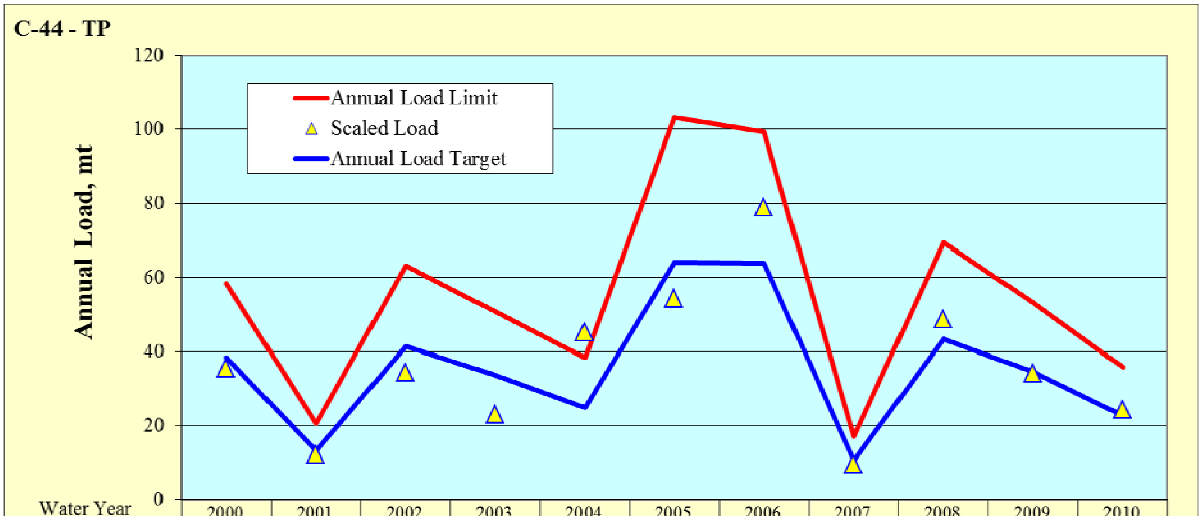
S = is the skewness of the annual rainfall calculated from 12 monthly rainfall totals

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 scaled loads and the resulting Targets and Limits for the Base Period are presented in **Figure 3-15.** The combined annual TP loads at S-308 and S-80, adjusted to account for pass-through loads as described in Appendix A and regional projects (if applicable), will be evaluated against the performance measure described above.

Figure 3-15. Comparison of scaled annual TP loads with the Annual Load Targets and Limits for the C-44 Hydrologic Unit.



Water Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Annual Load Limit	58.371	20.660	63.210	50.889	38.539	103.288	99.310	17.202	69.451	53.188	35.791
Scaled Load	35.593	12.223	34.360	23.169	45.300	54.501	78.988	9.606	48.701	34.187	24.361
Annual Load Target	38.408	13.146	41.478	33.680	25.063	64.098	63.933	10.691	43.412	34.439	22.726

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 61.40 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)

$$Rain_{adj} = \exp[\ \ln(Rain) + 0.13078\ (S - 0.88018)\ ]$$

Table 3-22 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**.

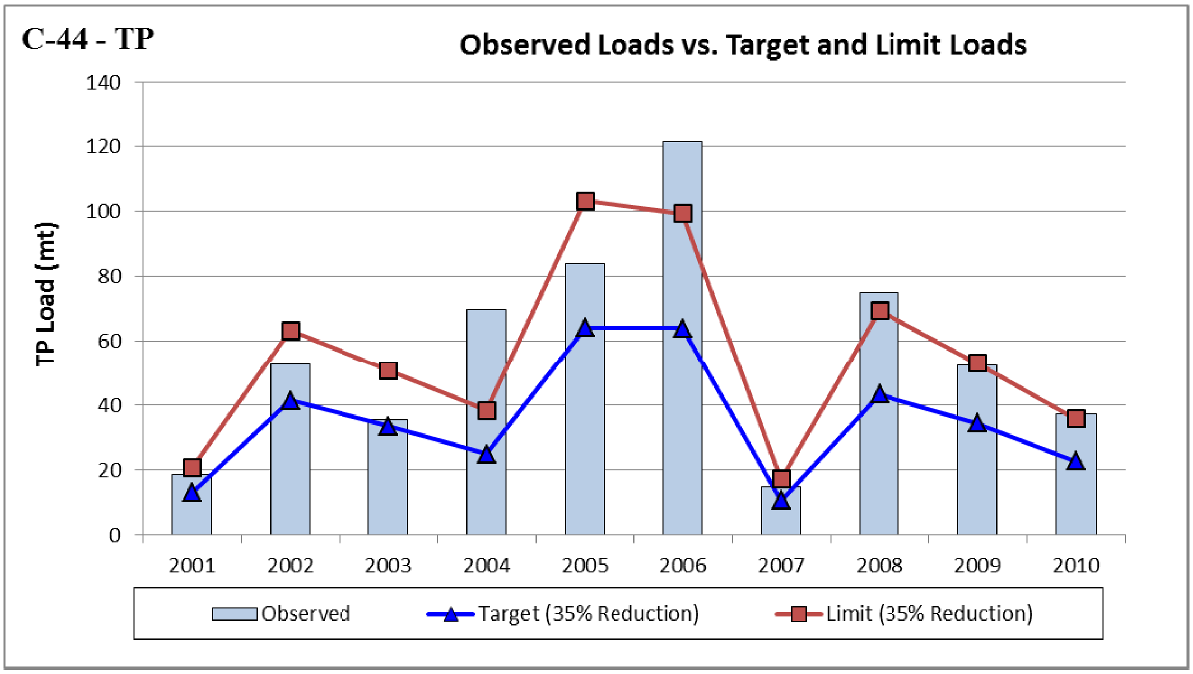
Comparison to WY2001-2010. A comparison of the loads observed during WY2001-2010 to the Annual Load Targets and Limits is presented in **Figure 3-16**.

Table 3-22. Annual adjusted rainfall for the period of record for the C-44 Hydrologic Unit (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	48.442	74.781	54.84
1983	37.047	70.12	0.138	70.032	118.007	63.63
1984	28.397	58.90	0.360	48.848	77.286	55.03
1985	51.046	47.82	-0.004	25.897	41.268	42.60
1986	54.573	46.55	0.933	32.825	49.563	46.87
1987	41.639	50.89	1.622	51.188	80.342	56.07
1988	51.434	48.34	0.143	27.899	43.805	43.90
1989	52.858	40.56	0.310	19.063	29.535	37.65
1990	43.126	45.17	0.808	29.255	44.181	44.75
1991	27.331	54.32	0.265	38.755	60.919	50.12
1992	38.721	41.83	0.359	20.907	32.216	39.07
1993	72.273	68.22	0.962	85.455	136.943	68.95
1994	29.672	57.09	0.086	41.368	66.685	51.46
1995	83.710	67.89	0.209	66.146	109.698	62.18
1996	71.564	70.58	0.891	90.856	147.130	70.68
1997	19.529	47.22	0.311	27.798	42.954	43.83
1998	-20.791	57.74	-0.241	38.266	64.273	49.86
1999	27.924	45.45	1.129	32.965	49.986	46.95
2000	54.759	50.95	0.727	38.408	58.371	49.94
2001	18.805	33.53	0.619	13.146	20.660	32.40
2002	52.861	52.48	0.738	41.478	63.210	51.51
2003	35.645	46.68	0.991	33.680	50.889	47.36
2004	69.692	40.07	1.247	25.063	38.539	42.04
2005	83.848	54.20	1.834	64.098	103.288	61.40
2006	121.520	59.63	1.096	63.933	99.310	61.34
2007	14.779	30.41	0.728	10.691	17.202	29.81
2008	74.924	57.53	0.176	43.412	69.451	52.47
2009	52.596	44.41	1.441	34.439	53.188	47.79
2010	37.478	44.84	0.085	22.726	35.791	40.41

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 3-16. Comparison of WY2001-2010 observed loads to the Annual Load Targets and Limits for the C-44 Hydrologic Unit.



Note: The Base Period extended from WY2000-2010.

Exceedance Frequency Analysis. As shown in **Figure 3-15**, although the scaled observed loads fall above the Annual Load Targets less than half the time (three out of eleven years, or 33 percent), the scaled observed load for WY2004 exceeded the calculated Annual Load Limit. In accordance with the proposed performance determination process discussed in Section 2.6, having the observed load exceed the Annual Load Limit would prevent the basin from meeting its performance measure for that year. In the case of the scaled Base Period data, this is an example of a Type I error[14], or "false positive" - when the performance method suggests a lack of compliance when the basin's load actually achieves the long-term reduction goals. While this occurrence is not common, it is statistically possible. The use of

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

the upper 90 percent confidence limit for the Annual Load Limit is consistent with the District's Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of approximately ten percent. Using the approach described in Section 2.6, 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 3-23**). 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 were determined to be reasonable and defensible since the cumulative exceedance frequency is less than the theoretical value of approximately 17.5 percent.

Table 3-23. Exceedance frequencies for the proposed performance measure methodology for the C-44 Hydrologic Unit.

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%**

3.3.2 L-8 Summary Basin

The following sections present a description of the L-8 Summary Basin, a summary of historical flow and TP levels, the selection of a Base Period, an estimated range of load reductions attributable to collective source controls, and the derivation of the resulting performance measure.

3.3.2.1 Background

The L-8 Summary Basin is located within the East Lake Okeechobee Sub-watershed and comprises 106,440 acres located east of Lake Okeechobee (**Figure 3-13**). A summary of the L-8 Summary Basin water control structures is presented in **Table 3-24 and Figure 3-17**; their locations are provided in **Figure 3-13**. The L-8 Summary Basin discharges stormwater runoff and other flows to multiple receiving waters:

- To Lake Okeechobee at Lake Culvert 10A (C-10A)

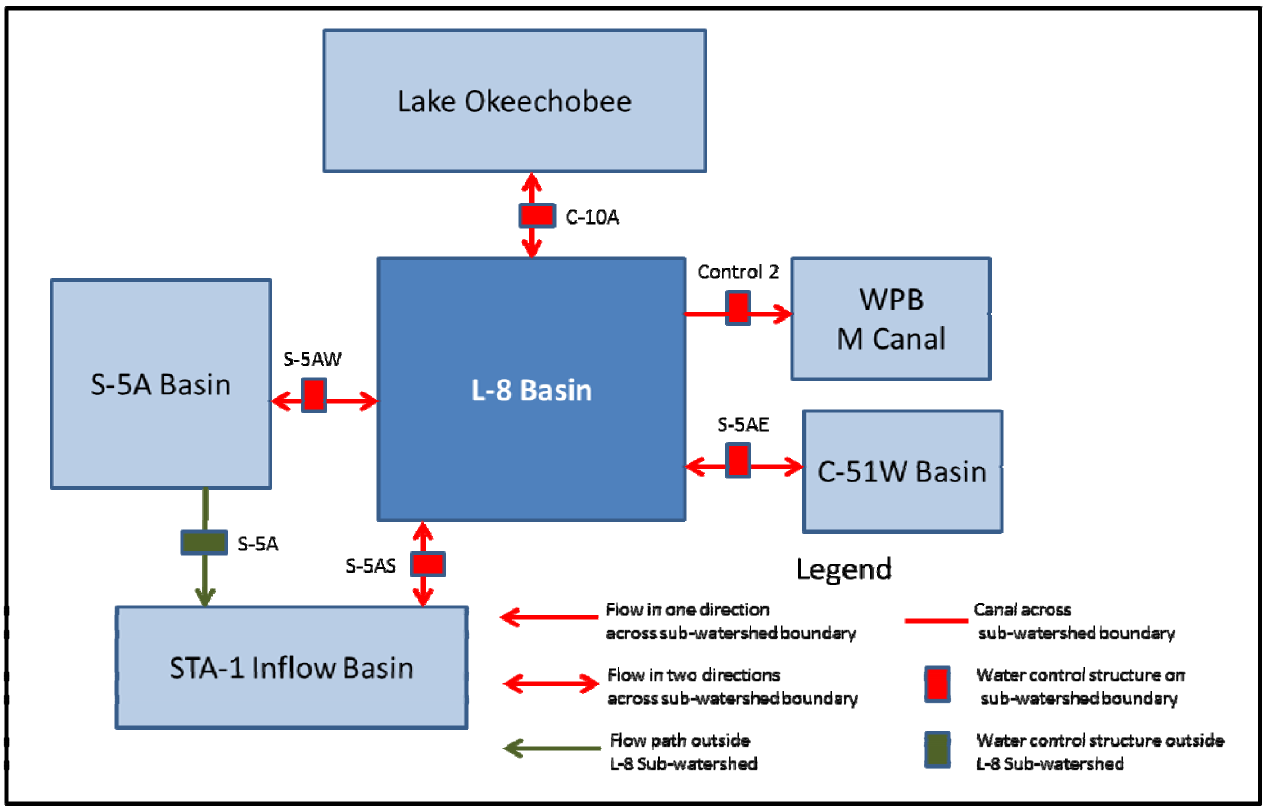
  The purpose of this structure is to provide irrigation releases from Lake Okeechobee to the agricultural lands along the L-8 Canal and to afford gravity drainage of that canal into Lake Okeechobee during flood periods, when the lake is lower than the canal (reference: SFWMD structure manual). During periods of water supply deliveries and regulatory releases from Lake Okeechobee, the flap gates at C-10A are raised and water flows into the L-8 Canal.

- To the City of West Palm Beach's Water Catchment Area through their Control Pump Station No. 2.
  - Flow data for this station is only available beginning May 1994, hence the historical data analysis for the L-8 Summary Basin began at this point in time.

Table 3-24. L-8 Summary Basin inflow and outflow structures.

Structure	Inflow/Outflow	Discharges From	Discharges To
C-10A	Both	L-8 to Lake	Lake to L-8
S-5AS	Both	Prior to June 1999: L-8 to WCA-1; After June 1999: L-8 to STA-1 Inflow Basin	Prior to June 1999: WCA-1 to L-8; After June 1999: STA-1 Inflow Basin to L-8
S-5AE	Both	L-8 to C-51 W Canal	C-51 W Canal to L-8
S-5AW	Both	L-8 to West Palm Beach Canal in EAA	WPB Canal to L-8
Control 2	Out	L-8 Canal	M-1 Canal

Figure 3-17. Flow diagram for the L-8 Summary Basin



- To Water Conservation Area 1 (WCA1) through S-5AS,
- To the West Palm Beach Canal Basin (also known as the S-5A Basin), part of the Everglades Agricultural Area (EAA) through S-5AW, and
- To C-51 West Basin through S-5AE.

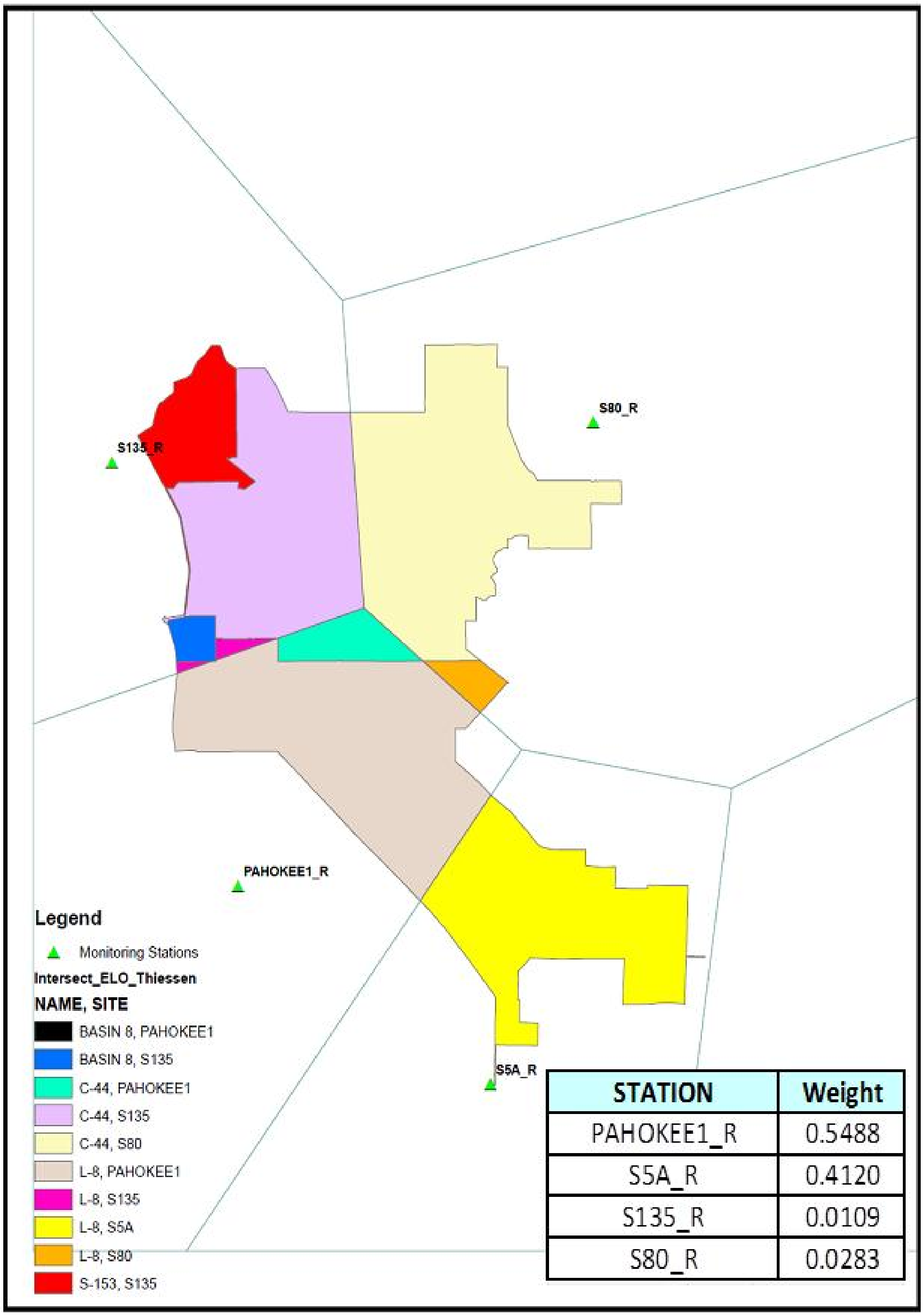
The L-8 Summary Basin receives inflows from multiple sources:

- from Lake Okeechobee at C-10A;
- from WCA-1 at S-5AS;
- from the C-51 West Basin at S-5AE, and
- from the West Palm Beach Canal Basin in the EAA at S-5AW.

Basin flows and loads from the L-8 Summary Basin, adjusted for pass-through flows and loads, were calculated using algorithms provided in Appendix A.

District staff identified four rainfall stations considered to be representative of the L-8 Summary Basin. Weighting factors, based on the Thiessen polygon areas for each rainfall station, were used to calculate daily basin rainfall values. **Figure 3-18** presents a schematic of the Thiessen polygon areas represented by each of the rainfall stations.

Figure 3-18. Schematic of L-8 Summary Basin and the selected rainfall stations.



STATION	Weight
PAHOKEE1_R	0.5488
S5A_R	0.4120
S135_R	0.0109
S80_R	0.0283

Annual flow and TP data for discharges from the L-8 Summary Basin are summarized in **Table 3-25.** For the development of the performance measure methodology, a Base Period of WY1995-2003 was selected for the following reasons.

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

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-26.**

Table 3-25. Summary of historical data for the L-8 Summary Basin.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics: Kurtosis K	Coef. Of Var. CV	Skewness S
1995	346,189	34.383	81	73.63	106,440	39.03	0.71	-1.834	0.545	-0.162
1996	231,284	20.855	73	54.83	106,440	26.07	0.43	-0.205	0.895	0.886
1997	116,731	8.544	59	53.36	106,440	13.16	0.18	-0.811	0.575	0.276
1998	219,254	19.086	71	62.11	106,440	24.72	0.40	-0.704	0.517	0.020
1999	147,738	13.232	73	42.28	106,440	16.66	0.27	0.466	0.856	1.207
2000	174,897	13.195	61	60.17	106,440	19.72	0.27	1.795	0.789	1.251
2001	102,466	17.134	136	37.65	106,440	11.55	0.35	-1.452	0.933	0.451
2002	181,863	17.979	80	54.39	106,440	20.50	0.37	-1.735	0.715	0.345
2003	104,544	5.220	40	50.27	106,440	11.79	0.11	0.104	0.653	0.737
2004	136,930	2.587	15	49.95	106,440	15.44	0.05	1.061	0.825	1.058
2005	139,143	9.533	56	56.45	106,440	15.69	0.20	2.534	1.014	1.532
2006	99,927	3.319	27	43.33	106,440	11.27	0.07	-1.595	0.698	-0.096
2007	64,844	6.907	86	36.98	106,440	7.31	0.14	-0.684	1.030	0.823
2008	164,628	14.918	73	44.39	106,440	18.56	0.31	-1.266	0.605	0.340
2009	151,572	8.705	47	46.48	106,440	17.09	0.18	1.865	1.107	1.367
2010	97,433	11.686	97	63.89	106,440	10.98	0.24	-1.462	0.578	0.082
Minimum	***64,844***	***2.587***	***15***	***36.98***	***106,440***	***7.31***	***0.05***	***-1.834***	***0.517***	***-0.162***
Average	***154,965***	***12.955***	***68***	***51.89***	***106,440***	***17.47***	***0.27***	***-0.245***	***0.771***	***0.632***
Maximum	***346,189***	***34.383***	***136***	***73.63***	***106,440***	***39.03***	***0.71***	***2.534***	***1.107***	***1.532***
Std. Dev.	***68,117***	***7.973***	***28***	***10.03***	***0***	***7.68***	***0.17***	***1.413***	***0.188***	***0.549***
Skewness	***1.519***	***1.183***	***0.418***	***0.414***		***1.519***	***1.18***	***0.735***	***0.311***	***0.124***
Median	***143,441***	***12.441***	***72***	***51.82***	***106,440***	***16.17***	***0.26***	***-0.694***	***0.752***	***0.594***

Table 3-26. Comparison of Base Period with period of record data and WY2001-2010 for the L-8 Summary Basin.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1995-2010					
Annual Minimum	64,844	2.587	15	36.98	0.05
Annual Average	154,965	12.955	68	51.89	0.27
Annual Median	143,441	12.441	72	51.82	0.26
Annual Maximum	346,189	34.383	136	73.63	0.71
Base Period WY1995-2003					
Annual Minimum	102,466	5.220	40	37.65	0.11
Annual Average	180,552	16.625	75	54.30	0.34
Annual Median	174,897	17.134	73	54.39	0.35
Annual Maximum	346,189	34.383	136	73.63	0.71
Difference between Period of Record and Base Period					
Annual Minimum	-37,622	-2.633	-25	-0.67	-0.05
Annual Average	-25,587	-3.670	-7	-2.41	-0.08
Annual Median	-31,457	-4.694	-1	-2.58	-0.10
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	-37%	-50%	-63%	-2%	-50%
Annual Average	-14%	-22%	-9%	-4%	-22%
Annual Median	-18%	-27%	-1%	-5%	-27%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	64,844	2.587	15	36.98	0.05
Annual Average	124,335	9.799	64	48.38	0.20
Annual Median	120,737	9.119	65	48.22	0.19
Annual Maximum	181,863	17.979	136	63.89	0.37
Difference between WY2001-2010 and Base Period					
Annual Minimum	-37,622	-2.633	-25	-0.67	-0.05
Annual Average	-56,217	-6.827	-11	-5.92	-0.14
Annual Median	-54,160	-8.015	-9	-6.18	-0.17
Annual Maximum	-164,326	-16.404	0	-9.74	-0.34
Annual Minimum	-37%	-50%	-63%	-2%	-50%
Annual Average	-31%	-41%	-14%	-11%	-41%
Annual Median	-31%	-47%	-12%	-11%	-47%
Annual Maximum	-47%	-48%	0%	-13%	-48%

3.3.2.2 Performance Measure 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 20 percent was determined to be reasonable and appropriate. Details are provided in Appendix D and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 20 percent load reduction. The Annual Load Target and Annual Load Limit for the L-8 Summary Basin will be calculated according to the following equations and explanation.

$$\text{Target} = (-5.06793 + 0.08241\ X - 1.54007\ S + 6.93876\ C)^2$$

Explained Variance = 84.1%, Standard Error of Regression[15] = 0.46154

Predictors (X, C, 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:

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

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

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

$$X = (12\ m_1)$$

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

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

[15] The standard error of the regression equation is expressed in the same units as the transformed load, i.e., sqrt(metric tons).

Limit = $[\text{sqrt(Target)} + (1.47588\ \text{SE})]^2$

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

$$SE = 0.46154\ [\ 1 + 1/9 + 0.00211\ (X\text{-}X_m)^2 + 0.98133\ (S\text{–}S_m)^2 + 14.63127\ (C\text{-}C_m)^2 - 0.0005\ (X\text{-}X_m)\ (S\text{–}S_m) + 0.19976\ (X\text{-}X_m)\ (C\text{-}C_m) - 4.37464\ (S\text{-}S_m)\ (C\text{-}C_m)\ ]^{0.5}$$

Where:

X = the 12-month total rainfall (inches)

C = coefficient of variation calculated from 12 monthly rainfall totals

S = skewness coefficient calculated from 12 monthly rainfall totals

X_m = average value of the predictor in calibration period = 54.2989

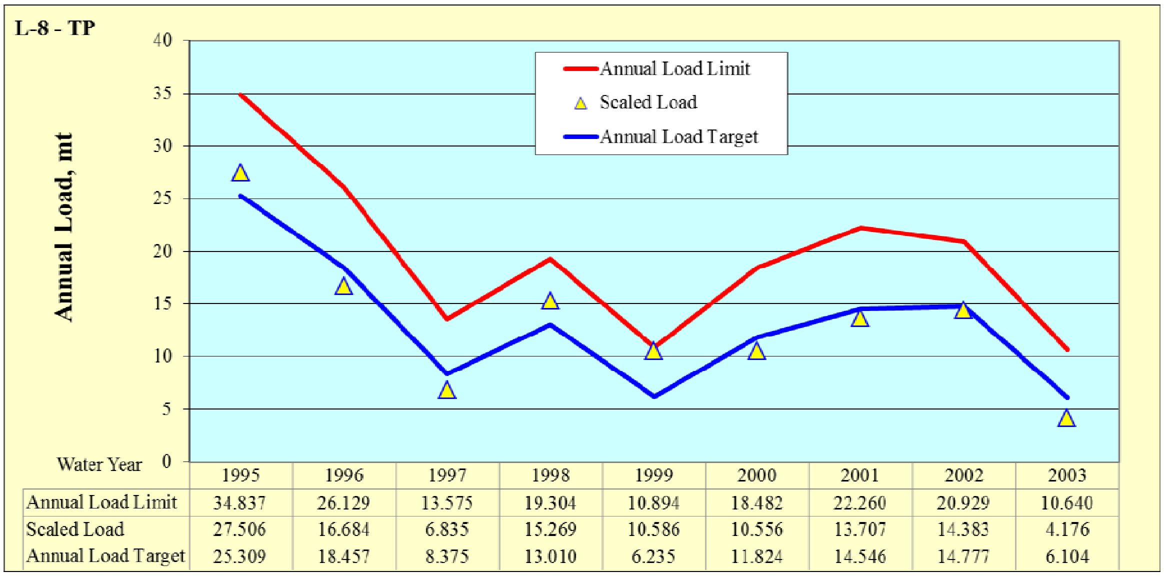
C_m = average value of the predictor in calibration period = 0.71978

S_m = average value of the predictor in calibration period = 0.55678

The first predictor (X) indicates that load increases with 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 or lower 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 scaled loads and the resulting Targets and Limits for the Base Period are presented in **Figure 3-19.** Annual TP loads at S-5AE, S-5AS, S-5AW, WPB2 and C-10A, adjusted to account for pass-through loads as described in Appendix A and regional projects (if applicable), will be evaluated against the performance measure described above.

Figure 3-19. Comparison of scaled observed loads with the Annual Load Targets and Limits for the L-8 Summary Basin.



Water Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
Annual Load Limit	34.837	26.129	13.575	19.304	10.894	18.482	22.260	20.929	10.640
Scaled Load	27.506	16.684	6.835	15.269	10.586	10.556	13.707	14.383	4.176
Annual Load Target	25.309	18.457	8.375	13.010	6.235	11.824	14.546	14.777	6.104

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 (41.28 to 72.35 inches), as derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall amount which reflects the cumulative effect of the predictor variables that make up 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 its mean value for the calibration period.

Adjusted Rainfall = equivalent rainfall for mean C and S variables (inches)

Adjusted Rainfall = X - 18.68862 (S - 0.55678) + 84.20099 (C – 0.71978)

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1995-2010 period of record are summarized in **Table 3-27**.

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 WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-20**.

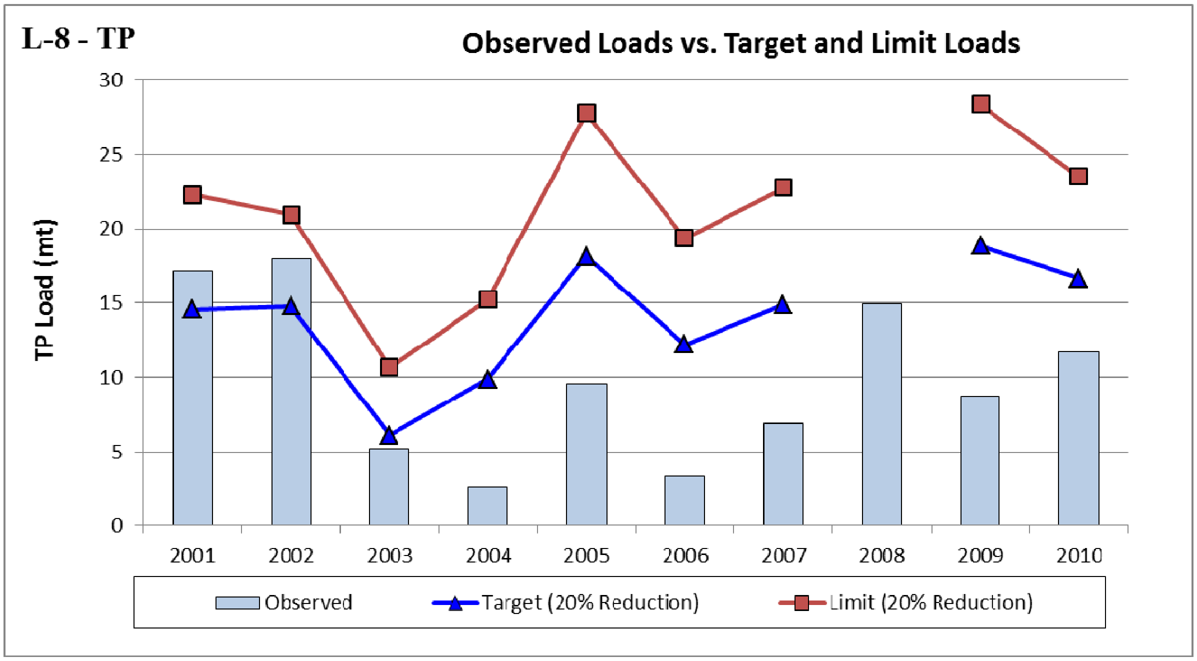
Exceedance Frequency Analysis. Using the approach described in Section 2.6, an approximation of the cumulative exceedance frequency for the determination methodology was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP loads of the Base Period (**Table 3-28**). Because 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 3-27. Annual adjusted rainfall for the historical period of record for the L-8 Summary Basin (Base Period: WY1995-2003).

Water Year	Observed Load, mt	Observed Rain, in	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1995	34.383	73.63	25.309	34.837	72.35
1996	20.855	54.83	18.457	26.129	63.43
1997	8.544	53.36	8.375	13.575	46.42
1998	19.086	62.11	13.010	19.304	55.07
1999	13.232	42.28	6.235	10.894	41.60
2000	13.195	60.17	11.824	18.482	53.02
2001	17.134	37.65	14.546	22.260	57.58
2002	17.979	54.39	14.777	20.929	57.95
2003	5.220	50.27	6.104	10.640	41.28
2004	2.587	49.95	9.881	15.221	49.44
2005	9.533	56.45	18.151	27.759	63.00
2006	3.319	43.33	12.207	19.366	53.70
2007	6.907	36.98	14.891	22.756	58.13
2008	14.918	44.39	5.128	9.897	38.78
2009	8.705	46.48	18.821	28.370	63.94
2010	11.686	63.89	16.658	23.475	60.82

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 Annual Load Target.

Figure 3-20. Comparison of WY2001-2010 observed loads to the Annual Load Targets and Limits for the L-8 Summary Basin.



Notes: 1. The performance determination for WY2008 would have been suspended due to rainfall below the minimum value during the Base Period coupled with the observed load being greater than the Load Target.
2. The Base Period extended from WY1995-2003.

Table 3-28. Exceedance frequencies for the proposed determination methodology for the L-8 Summary Basin.

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%	16.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	7.1%
Step 4. Load > Annual Load Limit?	<10%	1.2%
Cumulative Exceedance Frequency	**<17.5%**	**8.0%**

3.4 Indian Prairie Sub-watershed

The following sections present a description of the sub-watershed, a summary of historical flow and TP levels, the selection of a Base Period, an estimated range of load reductions attributable to collective source controls, and the derivation of the resulting performance measure.

3.4.1.1 Background

The Indian Prairie Sub-watershed occupies 276,577 acres lying between Lakes Istokpoga and Okeechobee (**Figure 3-21**). It is bordered on the west by the Fisheating Creek and Lake Istokpoga Sub-watersheds and on the east by the Lower Kissimmee and Taylor Creek-Nubbin Slough Sub-watersheds. Three primary canals convey water through the sub-watershed, C-41 (Harney Pond Canal), C-40 (Indian Prairie Canal), and C-41A. Discharges are made from Lake Istokpoga through S-68 into C-41A and are then conveyed through one of three routes:

- C-41A discharges at S-84 into C-38 downstream of S-65E,
- C-40 discharges at S-72 into Lake Okeechobee, and
- C-41 discharges at S-71 into Lake Okeechobee.

Table 3-29 and **Figure 3-22** identifies the inflow and outflow structures that move water across the sub-watershed borders. Four minor structures (HP-7, Inflow-1, Inflow-2 and Inflow-3) are located along the east and west banks of the C-41 Canal downstream of S-71, although flow and water quality are not monitored at these structures. Flow and water quality monitoring was initiated downstream of these structures in the C-41 Canal at a location known as C41H78, but the first year of reported TP load data was not available until WY2010. Because insufficient data were available, these minor structures were excluded from the derivation of the performance measure for the Indian Prairie Sub-watershed.

Figure 3-21. Indian Prairie Sub-watershed boundary and discharge monitoring locations.

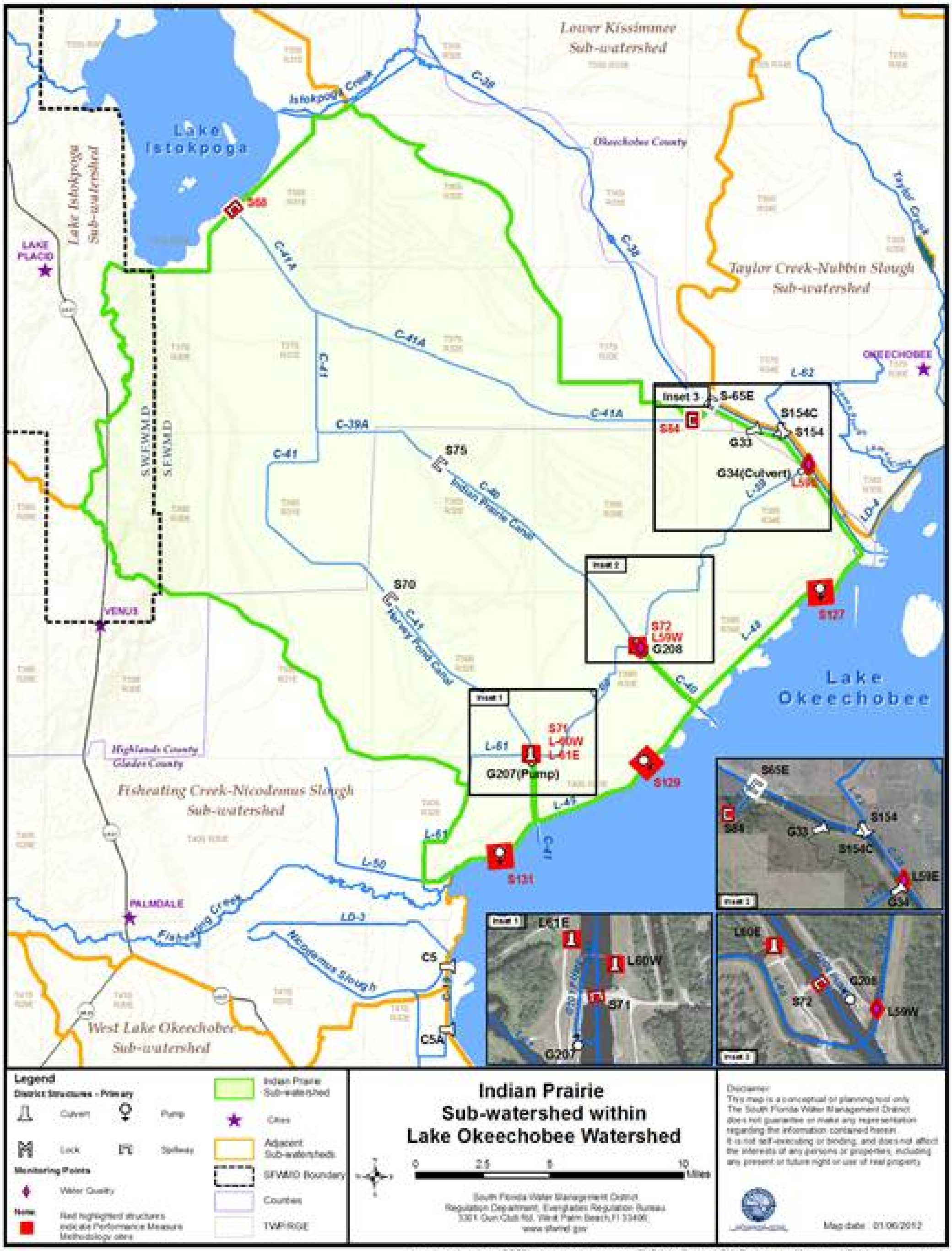


Table 3-29. Indian Prairie Sub-watershed inflow and outflow structures.

Station	Inflow/Outflow	Discharges From	Discharges To
G-33	Out	Paradise Run	Lake Okeechobee via C-38
G-34/L-59E	Out	L-59	Lake Okeechobee via C-38
G-207	In	Lake Okeechobee	C-41
G-208	In	Lake Okeechobee	C-40
L-59W	Out	C-59	Lake Okeechobee via C-40
L-60E	Out	L-60	Lake Okeechobee via C-40
L-60W	Out	L-60	Lake Okeechobee via C-41
L-61 E	Out	L-61	Lake Okeechobee via C-41
S-68	In	Lake Istokpoga	C-41A
S-71	Out	C-41	Lake Okeechobee via C-41
S-72	Out	C-40	Lake Okeechobee via C-40
S-84	Out	C-41A	Lake Okeechobee via C-38
S-127	Out	S-127 Basin	Lake Okeechobee
S-129	Out	S-129 Basin	Lake Okeechobee
S-131	Out	S-131 Basin	Lake Okeechobee

Note: flow and TP monitoring sites are identified in **Tables C-1** and **C-2**.

There are no structures downstream of the L-61, L-60, and L-59 outlets; so their discharges flow directly to Lake Okeechobee. Water quality data at G-207, G-208 and G-33 are not collected. Therefore, flows and loads at these structures are not used in the performance measure methodology. It is not anticipated that this omission will significantly affect the annual performance determination. G-207 and G-208 only pump supplemental water supply into the sub-watershed during drought conditions and the volume and quality of stormwater runoff should not be significantly affected. After a review of the S-129 spillway data, it was determined that the negative flows were questionable, and therefore, they were omitted from the analyses.

District staff identified rainfall stations considered to be representative of the Indian Prairie Sub-watershed for the period WY1989-2010. A schematic of the sub-watershed with the various rain stations is presented in **Figure 3-23.** Monthly rainfall data and weighting factors for the rainfall stations for each basin were developed and provided by the District. Weighting factors are shown in **Figure 3-23**. Missing daily data were filled in with values of an adjacent station.

Figure 3-22. Flow diagram for Indian Prairie Sub-watershed.

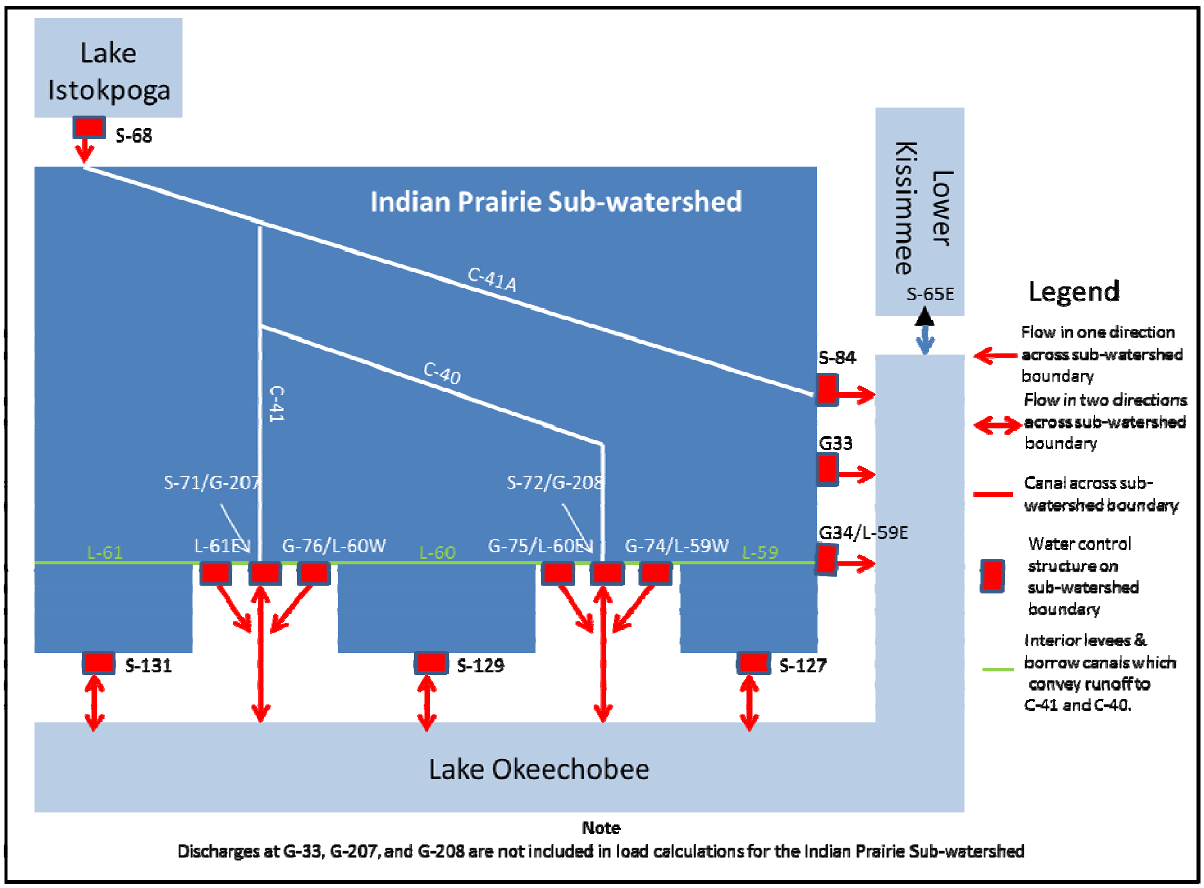
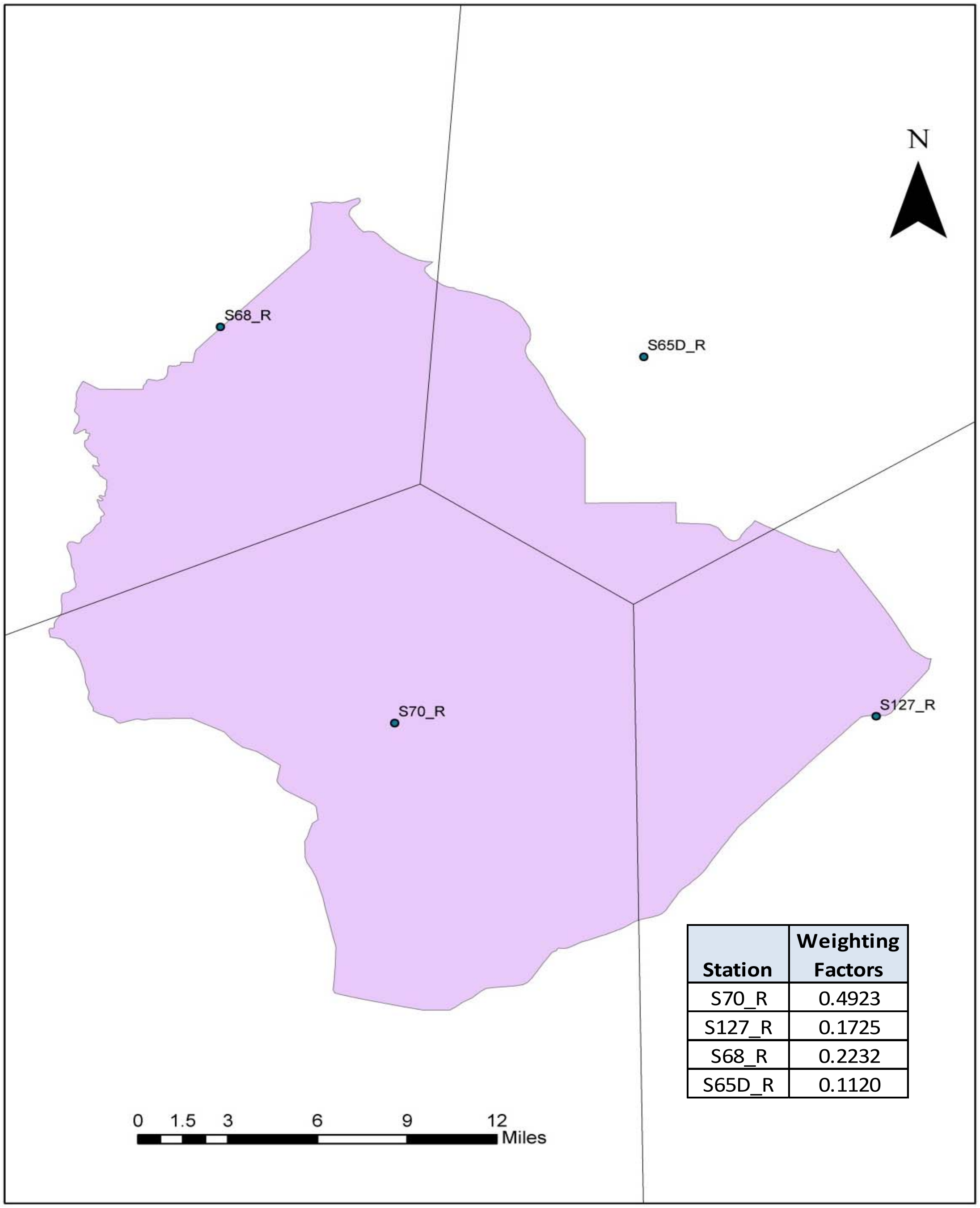


Figure 3-23. Schematic of Indian Prairie Sub-watershed and the selected rainfall stations.



Station	Weighting Factors
S70_R	0.4923
S127_R	0.1725
S68_R	0.2232
S65D_R	0.1120

The performance measure methodology is based on flows and TP loads resulting from rainfall and runoff from the Indian Prairie 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. Annual flow and TP data for discharges from the Indian Prairie Sub-watershed into Lake Okeechobee are summarized in **Table 3-30.**

Table 3-30. Summary of historical data for the Indian Prairie Sub-watershed.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1989	107,966	27.851	209	40.18	4.68	0.22	-1.686	0.705	0.252
1990	202,940	55.363	221	40.56	8.81	0.44	0.385	0.816	0.985
1991	174,913	71.071	329	49.86	7.59	0.57	0.069	0.746	0.772
1992	214,626	67.635	255	46.49	9.31	0.54	0.512	0.749	0.756
1993	187,848	90.336	390	47.18	8.15	0.72	3.195	0.888	1.604
1994	74,500	23.478	255	37.70	3.23	0.19	-1.133	0.540	0.443
1995	312,342	76.579	199	49.45	13.55	0.61	-0.500	0.524	0.980
1996	350,771	119.585	276	47.60	15.22	0.95	-1.044	0.802	0.478
1997	100,752	29.220	235	37.40	4.37	0.23	0.445	0.846	0.929
1998	363,576	86.631	193	54.87	15.77	0.69	0.190	0.471	-0.985
1999	180,128	65.140	293	42.68	7.82	0.52	-0.418	0.908	0.963
2000	283,700	68.956	197	37.09	12.31	0.55	7.950	1.171	2.528
2001	59,726	14.763	200	26.90	2.59	0.12	-0.943	1.078	0.791
2002	215,063	114.458	431	30.24	9.33	0.91	-0.801	1.001	0.678
2003	341,652	155.802	370	43.78	14.82	1.24	3.817	0.686	1.550
2004	256,333	95.566	302	36.24	11.12	0.76	-1.418	0.691	0.165
2005	389,025	178.081	371	37.99	16.88	1.42	0.169	0.964	1.016
2006	373,094	69.216	150	38.07	16.19	0.55	2.241	0.906	1.254
2007	112,267	52.797	381	28.31	4.87	0.42	0.516	1.127	1.216
2008	58,630	20.593	285	38.01	2.54	0.16	2.393	0.771	1.232
2009	280,338	166.168	481	40.21	12.16	1.32	0.096	1.211	1.174
2010	269,223	107.779	325	52.95	11.68	0.86	-1.029	0.704	0.317
Minimum	***58,630***	***14.763***	***150***	***26.90***	***2.54***	***0.12***	***-1.686***	***0.471***	***-0.985***
Average	***223,155***	***79.867***	***290***	***41.08***	***9.68***	***0.64***	***0.591***	***0.832***	***0.868***
Maximum	***389,025***	***178.081***	***481***	***54.87***	***16.88***	***1.42***	***7.950***	***1.211***	***2.528***
Std. Dev.	***107,026***	***46.310***	***88***	***7.47***	***4.64***	***0.37***	***2.206***	***0.204***	***0.666***
Skewness	***-0.059***	***0.623***	***0.491***	***-0.040***	***-0.059***	***0.62***	***2.035***	***0.182***	***-0.316***
Median	***214,845***	***70.144***	***281***	***40.20***	***9.32***	***0.56***	***0.133***	***0.809***	***0.946***

A Base Period of WY1989-2001 was selected for the development of the performance measure methodology. This period was selected for the following reasons:

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

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-31.**

Table 3-31. Comparison of Base Period with period of record and WY2001-2010 data for the Indian Prairie Sub-watershed.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1989-2010					
Annual Minimum	58,630	14.763	150	26.90	0.12
Annual Average	223,155	79.867	290	41.08	0.64
Annual Median	214,845	70.144	281	40.20	0.56
Annual Maximum	389,025	178.081	481	54.87	1.42
Base Period WY1989-2001					
Annual Minimum	59,726	14.763	193	26.90	0.12
Annual Average	201,061	61.278	247	42.92	0.49
Annual Median	187,848	67.635	235	42.68	0.54
Annual Maximum	363,576	119.585	390	54.87	0.95
Difference between Period of Record and Base Period					
Annual Minimum	-1,096	0.000	-43	0.00	0.00
Annual Average	22,095	18.589	43	-1.84	0.15
Annual Median	26,997	2.508	46	-2.49	0.02
Annual Maximum	25,449	58.496	91	0.00	0.47
Annual Minimum	-2%	0%	-22%	0%	0%
Annual Average	11%	30%	17%	-4%	30%
Annual Median	14%	4%	19%	-6%	4%
Annual Maximum	7%	49%	23%	0%	49%
WY2001-2010					
Annual Minimum	58,630	14.763	150	26.90	0.12
Annual Average	235,535	97.522	336	37.27	0.78
Annual Median	262,778	101.673	348	38.00	0.81
Annual Maximum	389,025	178.081	481	52.95	1.42
Difference between WY2001-2010 and Base Period					
Annual Minimum	-1,096	0.000	-43	0.00	0.00
Annual Average	34,474	36.245	89	-5.65	0.29
Annual Median	74,930	34.038	113	-4.68	0.27
Annual Maximum	25,449	58.496	91	-1.92	0.47
Annual Minimum	-2%	0%	-22%	0%	0%
Annual Average	17%	59%	36%	-13%	59%
Annual Median	40%	50%	48%	-11%	50%
Annual Maximum	7%	49%	23%	-3%	49%

3.4.2 Performance Measure 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 30 percent was determined to be reasonable and appropriate. Details are provided in Appendix D 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 for the Indian Prairie Sub-watershed will be calculated according to the following equations and explanation:

$$\text{Target} = \exp(-12.83843 + 4.02124\,X + 1.76267\,C)$$

Explained Variance = 91.1%, Standard Error of Regression[16] = 0.20346

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:

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

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

$$X = \ln(12\, m_1)$$

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

$$\text{Limit} = \text{Target} * \exp(1.37218\ \text{SE})$$

16 The standard error of the regression equation is expressed in the same units as the transformed load, i.e., ln(metric tons).

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

$$SE = 0.20346 \left[1 + 1/13 + 3.91995 (X-X_m)^2 + 3.19741 (C-C_m)^2 + 4.34342 (X-X_m)(C-C_m) \right]^{0.5}$$

Where:

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

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

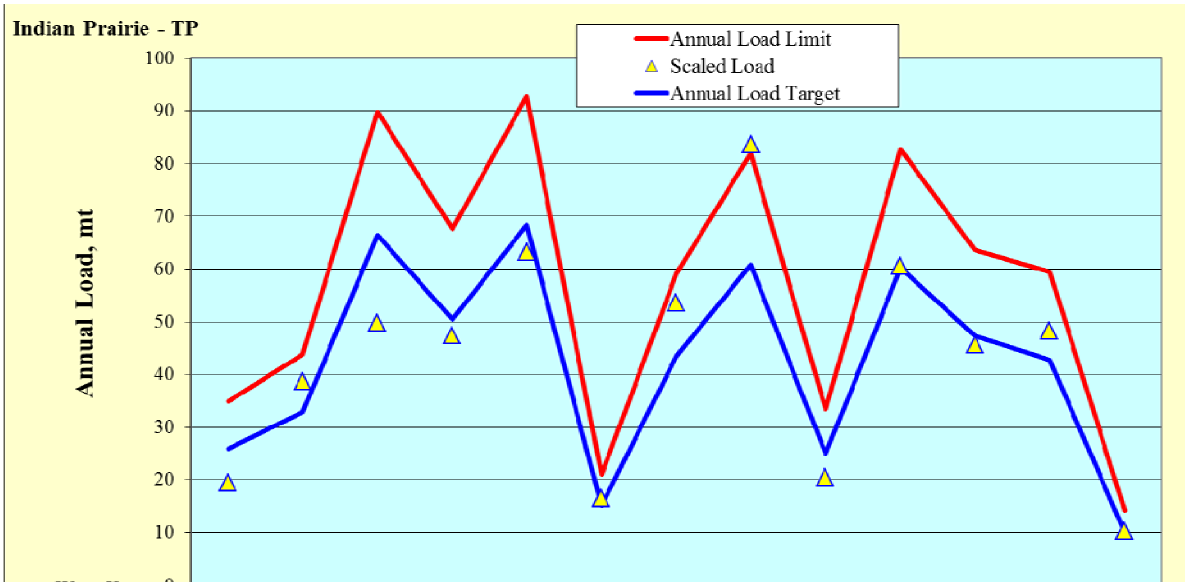
X_m = average value of the predictor in base period = 3.74445

C_m = average value of the predictor in base period = 0.78800

The first predictor (X) indicates that load increases with 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 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 scaled loads and the resulting Targets and Limits for the Base Period is presented in **Figure 3-24.** Annual TP loads at the sub-watershed outlet structures, adjusted to account for pass-through loads as described in Appendix A, will be evaluated against the performance measure described above.

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



Water Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Annual Load Limit	34.905	43.814	89.744	67.575	92.834	21.014	59.133	81.992	33.491	82.741	63.640	59.475	14.166
Scaled Load	19.496	38.754	49.750	47.345	63.235	16.435	53.605	83.710	20.454	60.642	45.598	48.269	10.334
Annual Load Target	25.950	32.775	66.448	50.416	68.343	15.016	43.462	60.860	24.938	60.143	47.309	42.768	9.976

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 sub-watershed exceeds the Annual Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (30.55 – 49.29 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 Rainfall = exp [X + 0.43834 (C – 0.788)]

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1989-2010 period of record are summarized in **Table 3-32**.

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**.

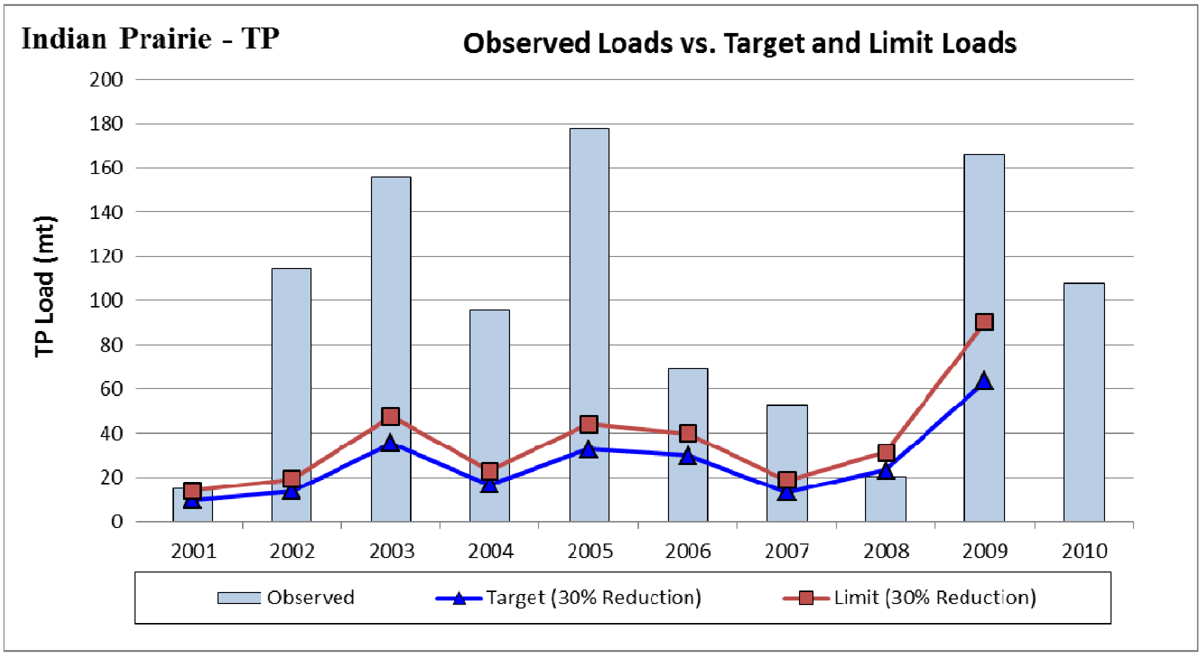
Table 3-32. Annual adjusted rainfall, Annual Load Targets and Limits for the period of record for the Indian Prairie Sub-watershed (Base Period: WY1989-2001).

Water Year	Observed Load, mt	Observed Rain, in	Ln(Rain)	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1989	27.851	40.18	3.69337	0.705	25.950	34.905	38.74
1990	55.363	40.56	3.70278	0.816	32.775	43.814	41.06
1991	71.071	49.86	3.90922	0.746	66.448	89.745	48.95
1992	67.635	46.49	3.83924	0.749	50.415	67.574	45.70
1993	90.336	47.18	3.85397	0.888	68.343	92.834	49.29
1994	23.478	37.70	3.62966	0.54	15.016	21.013	33.82
1995	76.579	49.45	3.90096	0.524	43.463	59.134	44.05
1996	119.585	47.60	3.86283	0.802	60.861	81.993	47.89
1997	29.220	37.40	3.62167	0.846	24.938	33.492	38.36
1998	86.631	54.87	4.00497	0.471	60.142	82.740	47.75
1999	65.140	42.68	3.75373	0.908	47.309	63.639	44.99
2000	68.956	37.09	3.61335	1.171	42.767	59.473	43.87
2001	14.763	26.90	3.29213	1.078	9.976	14.167	30.55
2002	114.458	30.24	3.40917	1.001	13.944	19.293	33.20
2003	155.802	43.78	3.77918	0.686	35.436	47.488	41.87
2004	95.566	36.24	3.59016	0.691	16.718	22.886	34.73
2005	178.081	37.99	3.63732	0.964	32.698	44.048	41.04
2006	69.216	38.07	3.63943	0.906	29.771	39.956	40.09
2007	52.797	28.31	3.34322	1.127	13.356	18.768	32.85
2008	20.593	38.01	3.63785	0.771	23.318	31.376	37.73
2009	166.168	40.21	3.69412	1.211	63.502	90.062	48.40
2010	107.779	52.95	3.96935	0.704	78.585	106.912	51.04

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 Annual Load Target.

Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-25**.

Figure 3-25. Comparison of WY2001-2010 observed loads with the Annual Load Targets and Limits for the Indian Prairie Sub-watershed.



Notes: 1. The performance determination for WY2010 would have been suspended due to adjusted rainfall above the maximum value during the Base Period coupled with the observed load being greater than the Load Target.
2. The Base Period extended from WY1989-2001.

Exceedance Frequency Analysis. As shown in **Figure 3-24**, although the scaled observed loads fall above the Annual Load Targets less than half the time (five out of thirteen years, or 38 percent), the scaled observed load for WY1996 exceeded the calculated Annual Load Limit. In accordance with the proposed performance determination process discussed in Section 2.6, having the observed load exceed the Annual Load Limit would prevent the basin from meeting its performance measure for that year. In the case of the scaled Base Period data, this is an example of a Type I error[17], or "false positive" - when the performance method suggests a lack of compliance when the basin's load actually achieves the long-term

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

reduction goals. While this occurrence is not common, it is statistically possible. The use of the upper 90 percent confidence limit for the Annual Load Limit is consistent with the District's Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of approximately ten percent. Using the approach described in Section 2.6, 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 3-33**). 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 3-33. Exceedance frequencies for the proposed determination methodology for the Indian Prairie 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 Adj. Rain is outside the range and Load > Annual Load Target	<20%	10.5%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.3%
Step 4. Load > Annual Load Limit?	<10%	4.4%
Cumulative Exceedance Frequency	**<17.5%**	**12.5%**

3.5 Fisheating Creek-Nicodemus Slough Sub-watershed

The Fisheating Creek-Nicodemus Slough Sub-watershed comprises 318,042 acres located directly west of Lake Okeechobee (**Figure 3-26**). The sub-watershed contains two summary basins that discharge to the lake in close proximity: the Fisheating Creek (FECR) Summary Basin and the Nicodemus Slough Summary Basin. Flow and TP monitoring sites are identified in **Tables C-1** and **C-2**.

District staff identified the rainfall stations considered to be representative of the Fisheating Creek-Nicodemus Slough Sub-watershed and summary basins for the period WY1976-2010. A schematic of the sub-watershed with the various rain stations is presented in **Figure 3-27.** Monthly rainfall data and weighting factors for the rainfall stations for each summary basin were developed and provided by the District. Weighting factors are shown in **Figure 3-27**. Missing daily data were filled in with values of an adjacent station.

The following sections describe the derivation of the performance measure methodologies for the summary basins within the Fisheating Creek-Nicodemus Slough Sub-watershed.

Figure 3-26. Fisheating Creek-Nicodemus Slough Sub-watershed boundary and discharge monitoring locations.

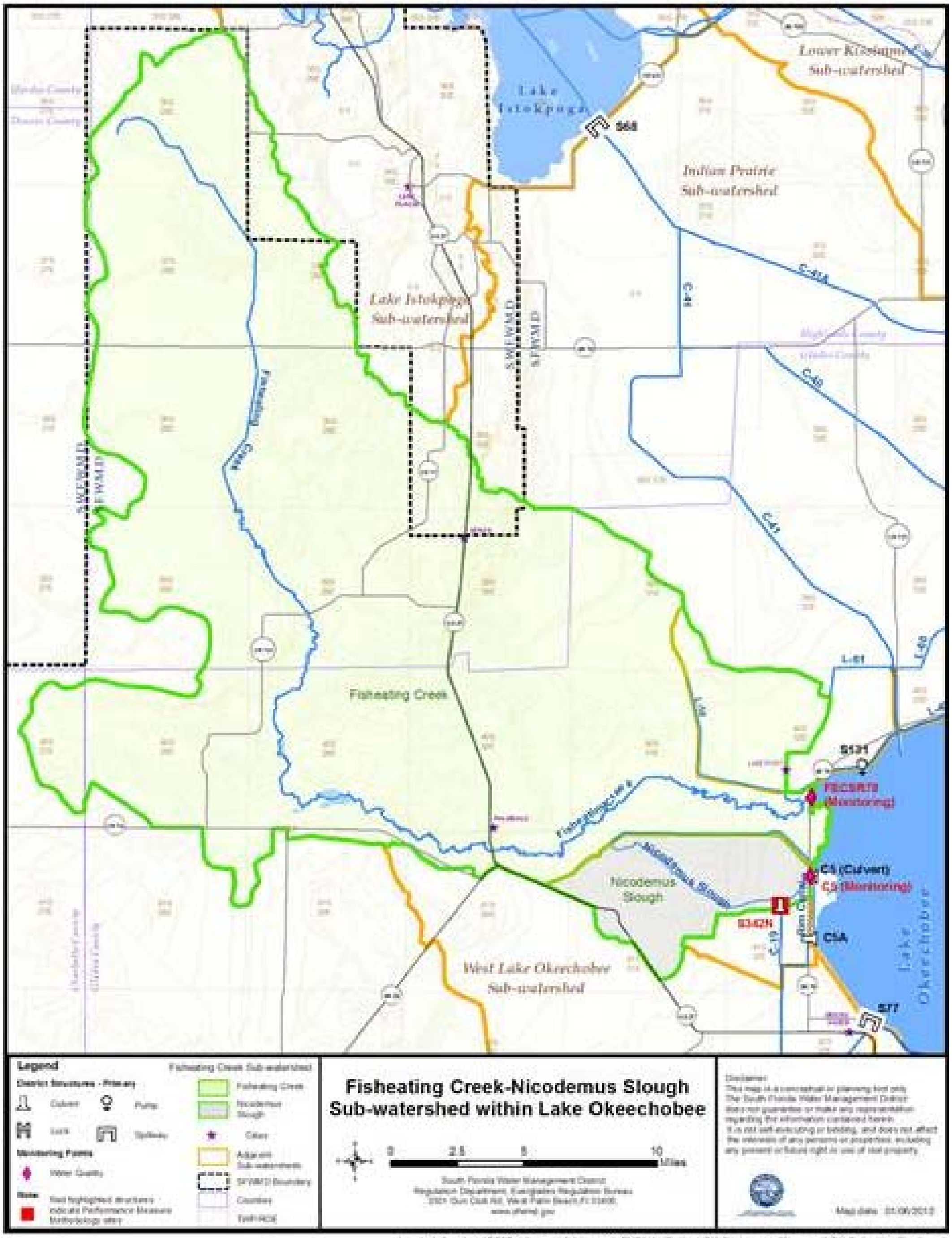
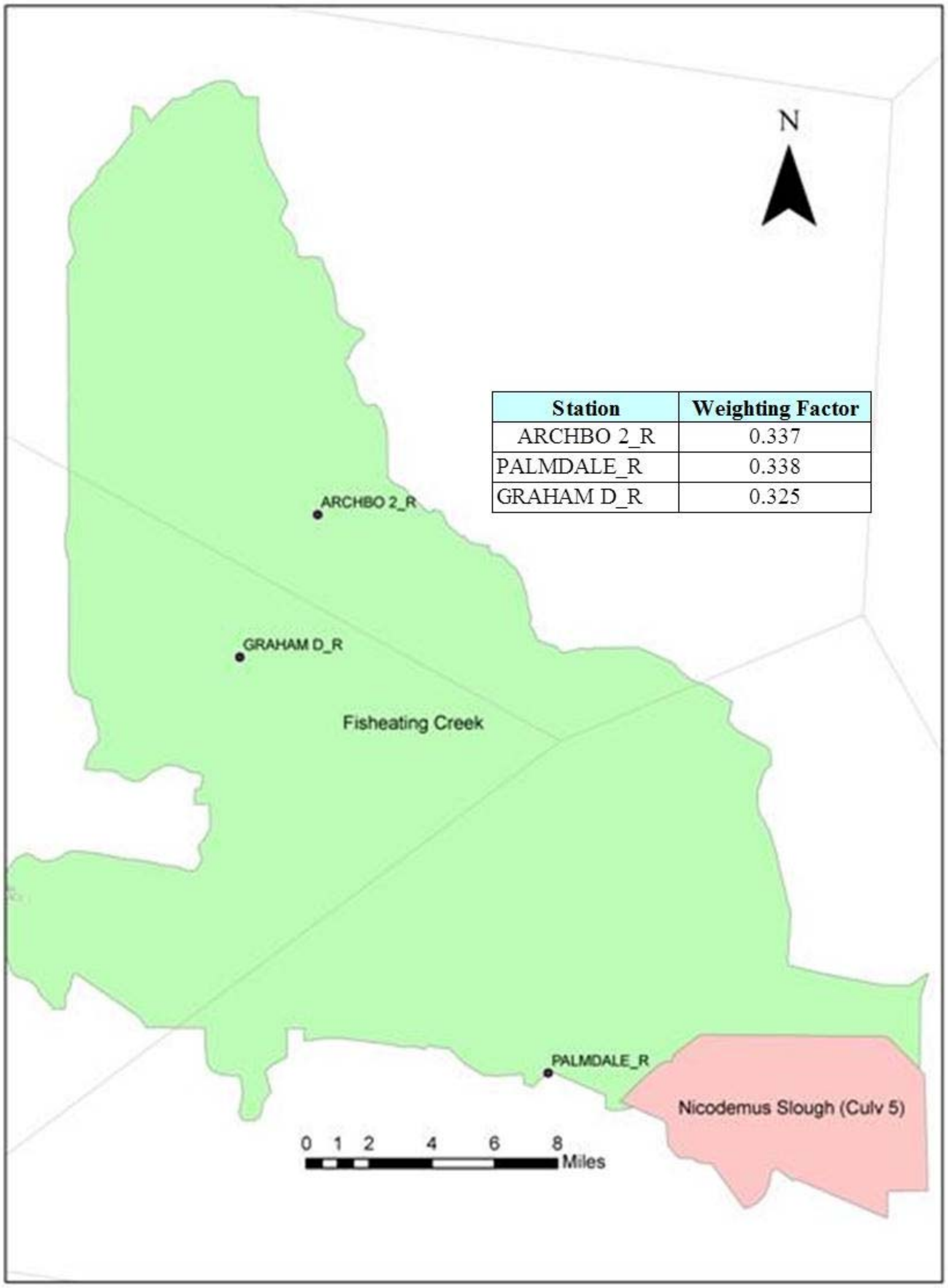


Figure 3-27. Schematic of Fisheating Creek-Nicodemus Slough Sub-watershed and the selected rainfall stations.



3.5.1 Fisheating Creek Summary Basin

The Fisheating Creek Summary Basin comprises 298,713 acres and is the only basin in the Lake Okeechobee Watershed with an uncontrolled "natural" discharge, i.e., Fisheating Creek (SFWMD 2008). Fisheating Creek originates in western Highlands County and flows south through Cypress Swamp and into Glades County with an average gradient of 0.5 foot per mile (SFWMD 2011a). From central Glades County, water leaves the creek channel and flows east through Cowbone Marsh into Lake Okeechobee. Levees have been constructed roughly parallel to Fisheating Creek near its outlet to the lake.

3.5.1.1 Background

Annual flow and TP data for discharges from the Fisheating Creek Summary Basin, as monitored at the SR 78 bridge near Lakeport, are summarized in **Table 3-34.** For the development of the performance measure methodology, a Base Period of WY1998-2008 was selected for the following reasons.

- it represents a period with minimal implementation of source controls. With the selection of the Base Period to precede significant source control implementation, no additional calculation is necessary in the performance measure methodology to account for prior source control implementation.
- basin water management operations were similar to current operating conditions affecting nutrient loading, in that the basin has remained unregulated (e.g., no water control structures exist to regulate flows) from the selected base period to present,
- it represents a period of relatively constant land use practices,
- it traversed a wide range of hydrologic conditions (wet and dry years),
- reliable water quality and hydrologic data are available, and
- a strong correlation exists between annual TP loads and rainfall, allowing for a performance measure methodology that explicitly incorporates hydrologic variability.

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-35.**

Table 3-34. Summary of historical data for the Fisheating Creek Summary Basin.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics: Kurtosis K	Rainfall Characteristics: Coef. Of Var. CV	Rainfall Characteristics: Skewness S
1998	535,316	129.919	197	67.22	21.50	0.96	0.270	0.527	-0.132
1999	183,933	45.813	202	44.68	7.39	0.34	-0.685	0.789	0.648
2000	237,576	49.094	168	62.08	9.54	0.36	-0.131	0.958	0.991
2001	13,727	2.719	161	33.31	0.55	0.02	0.597	0.980	0.959
2002	329,509	135.612	334	54.36	13.24	1.00	-0.290	0.946	0.914
2003	409,394	103.714	205	78.23	16.45	0.77	0.345	0.744	0.851
2004	359,710	67.618	152	53.67	14.45	0.50	-0.804	0.818	0.598
2005	391,353	137.727	285	60.14	15.72	1.02	1.116	0.934	1.233
2006	385,019	77.389	163	47.89	15.47	0.57	0.067	1.053	0.993
2007	163,419	64.542	320	43.14	6.56	0.48	7.454	1.489	2.491
2008	41,528	11.236	219	42.21	1.67	0.08	0.142	0.746	0.935
2009	222,597	77.283	281	40.01	8.94	0.57	-0.181	1.161	1.158
2010	197,349	77.137	317	52.29	7.93	0.57	-1.111	0.691	0.307
Minimum	***13,727***	***2.719***	***152***	***33.31***	***0.55***	***0.02***	***-1.111***	***0.527***	***-0.132***
Average	***266,956***	***75.369***	***229***	***52.25***	***10.72***	***0.56***	***0.522***	***0.910***	***0.919***
Maximum	***535,316***	***137.727***	***334***	***78.23***	***21.50***	***1.02***	***7.454***	***1.489***	***2.491***
Std. Dev.	***151,236***	***43.244***	***67***	***12.36***	***6.08***	***0.32***	***2.166***	***0.242***	***0.599***
Skewness	***-0.085***	***-0.057***	***0.399***	***0.597***	***-0.085***	***-0.06***	***3.133***	***0.938***	***1.142***
Median	***237,576***	***77.137***	***205***	***52.29***	***9.54***	***0.57***	***0.067***	***0.934***	***0.935***

Table 3-35. Comparison of Base Period with period of record and WY2001-2010 data for the Fisheating Creek Summary Basin.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1998-2010					
Annual Minimum	13,727	2.719	152	33.31	0.02
Annual Average	266,956	75.369	229	52.25	0.56
Annual Median	237,576	77.137	205	52.29	0.57
Annual Maximum	535,316	137.727	334	78.23	1.02
Base Period WY1998-2008					
Annual Minimum	13,727	2.719	152	33.31	0.02
Annual Average	277,317	75.035	219	53.36	0.55
Annual Median	329,509	67.618	202	53.67	0.50
Annual Maximum	535,316	137.727	334	78.23	1.02
Difference between Period of Record and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-10,361	0.335	10	-1.11	0.00
Annual Median	-91,933	9.519	3	-1.38	0.07
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-4%	0%	4%	-2%	0%
Annual Median	-28%	14%	1%	-3%	14%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	13,727	2.719	152	33.31	0.02
Annual Average	251,361	75.498	243	50.53	0.56
Annual Median	276,053	77.210	250	50.09	0.57
Annual Maximum	409,394	137.727	334	78.23	1.02
Difference between WY2001-2010 and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-25,956	0.463	24	-2.83	0.00
Annual Median	-53,456	9.592	48	-3.58	0.07
Annual Maximum	-125,922	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-9%	1%	11%	-5%	1%
Annual Median	-16%	14%	24%	-7%	14%
Annual Maximum	-24%	0%	0%	0%	0%

3.5.1.2 Performance Measure 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 30 percent was determined to be reasonable and appropriate. Details are provided in Appendix D 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 for the Fisheating Creek Summary Basin will be calculated according to the following equations and explanation:

Target = -340.304899 + 99.44445 X

Explained Variance = 53.5%, Standard Error of Regression = 23.828 mt

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:

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

$X = \ln(12\,m_1)$

Limit = Target + 1.38303 SE

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

$SE = 23.82794\,[\,1 + 1/11 + (X-X_m)^2 / 0.59477\,]^{0.5}$

Where:

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

X_m = average value of the predictor in base period = 3.95024

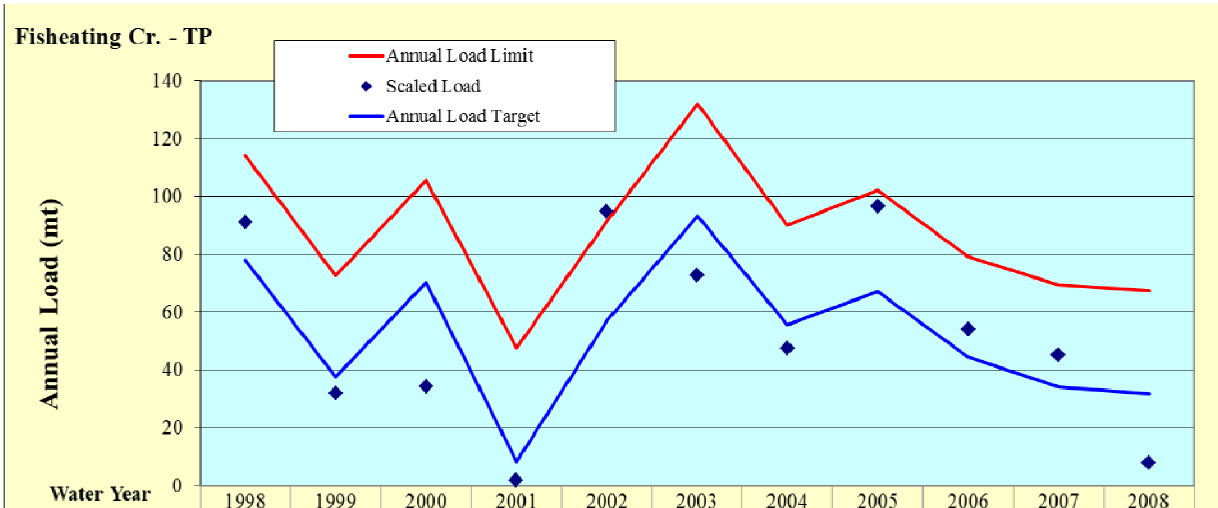
The predictor X indicates that load increases with total annual rainfall.

A comparison of the scaled loads and the resulting Targets and Limits for the Base Period are presented in **Figure 3-28.** Annual TP loads monitored at the SR 78 bridge near Lakeport will be evaluated against the performance measure described above.

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 (33.31 – 78.23 inches). The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the period of record are summarized in **Table 3-36**.

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

Figure 3-28. Comparison of scaled loads with the Annual Load Targets and Limits for the Fisheating Creek Summary Basin.



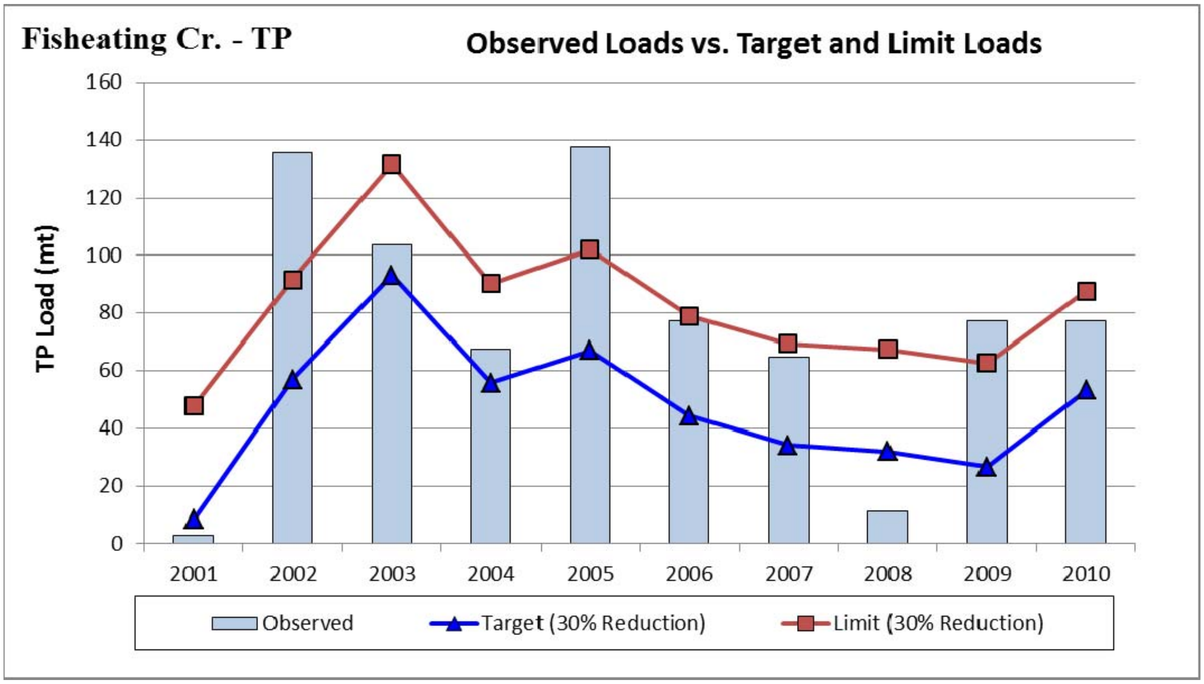
Water Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Annual Load Limit	114.293	72.555	105.496	47.644	91.513	131.849	90.216	102.072	79.032	69.373	67.427
Scaled Load	90.943	32.069	34.366	1.903	94.928	72.600	47.333	96.409	54.172	45.179	7.865
Annual Load Target	78.154	37.537	70.244	8.333	57.038	93.238	55.767	67.087	44.437	34.049	31.882

Table 3-36. Estimates of annual Load Targets and Limits for the historical period of record for the Lower Kissimmee Sub-watershed (Base Period: WY1998-2008).

Water Year	Observed Load, mt	ln(Rain) ln(inches)	Target Load, mt	Limit Load, mt
1998	129.919	4.20797	78.154	114.293
1999	45.813	3.79953	37.537	72.555
2000	49.094	4.12842	70.244	105.496
2001	2.719	3.50586	8.333	47.644
2002	135.612	3.99563	57.038	91.513
2003	103.714	4.35965	93.238	131.849
2004	67.618	3.98285	55.767	90.216
2005	137.727	4.09668	67.087	102.072
2006	77.389	3.86891	44.437	79.032
2007	64.542	3.76445	34.049	69.373
2008	11.236	3.74266	31.882	67.427
2009	77.283	3.68913	26.559	62.742
2010	77.137	3.95681	53.178	87.599

Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-29**.

Figure 3-29. Comparison of WY2001-2010 observed loads to the Annual Load Targets and Limits for the Fisheating Creek Summary Basin.



Note: The Base Period extended from WY1998-2008.

Exceedance Frequency Analysis. As shown in **Figure 3-28**, although the scaled observed loads fall above the Annual Load Targets less than half the time (five out of eleven years, or 45 percent), the scaled observed load for WY2002 exceeded the calculated Annual Load Limit. In accordance with the proposed performance determination process discussed in Section 2.6, having the observed load exceed the Annual Load Limit would prevent the basin from meeting its performance measure for that year. In the case of the scaled Base Period data, this is an example of a Type I error[18], or "false positive" - when the performance

[18] The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the

method suggests a lack of compliance when the basin's load actually achieves the long-term reduction goals. While this occurrence is not common, it is statistically possible. The use of the upper 90 percent confidence limit for the Annual Load Limit is consistent with the District's Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of approximately ten percent. Using the approach described in Section 2.6, 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 3-37**). 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 3-37. Exceedance frequencies for the proposed determination methodology for the Fisheating Creek Summary Basin.

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain is outside the range and Load > Annual Load Target	<20%	4.0%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.6%
Step 4. Load > Annual Load Limit?	<10%	5.7%
Cumulative Exceedance Frequency	**<17.5%**	**15.7%**

null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.

3.5.2 Nicodemus Slough Summary Basin

The following sections present a description of the Nicodemus Slough Summary Basin and a summary of historical flow and TP levels.

3.5.2.1 Background

The Nicodemus Slough Summary Basin comprises 19,329 acres located west of Lake Okeechobee and south of the Fisheating Creek Summary Basin. The connection to Lake Okeechobee is through control structure Culvert 5, located at the crossing of SR 78 and the levee LD-3. The purpose of Culvert 5 is to provide releases from Lake Okeechobee to the lower reaches of Nicodemus Slough and to afford gravity drainage of that slough into Lake Okeechobee during flood periods when the lake is lower than the slough. Reliable flow data for the Nicodemus Slough Summary Basin at Culvert 5 are available only from March 2008 to the present. In that time, only four TP samples were collected on days with flow, hence there is insufficient flow and TP data available to adequately analyze alternative Base Periods for the basin. Another structure, S-342N, is located on the southern boundary of the basin, and minimal flow and TP data are available. Due to the lack of a long-term data set of sufficient quality, insufficient data were available for a complete historical data analysis. Monthly summaries are provided in **Table 3-38** for WY2009 and WY2010.

Table 3-38. Monthly summary of flow and TP data for the Nicodemus Slough Summary Basin.

Date	Flow AF	TP load kg	TP Conc µg/L	Rainfall inches
200805	0	0		0.520
200806	0	0		10.690
200807	1236	139	91	6.640
200808	10555	1199	92	12.730
200809	17	2	95	4.230
200810	0	0		3.530
200811	3	1	270	0.400
200812	0	0		1.540
200901	1	0	0	1.060
200902	0	0		0.190
200903	0	0		0.900
200904	7	2	232	0.990
200905	0	0		7.410
200906	269	109	328	10.270
200907	2006	176	71	10.930
200908	95	9	77	7.790
200909	63	6	77	3.350
200910	3	0	0	0.060
200911	0	0		0.810
200912	0	0		6.220
201001	3	0	0	1.950
201002	0	0		1.850
201003	301	46	124	8.030
201004	390	62	129	6.780

3.5.2.2 Performance Measure Methodology

Since this summary basin has historically contributed a small percentage of the annual Lake Okeechobee total phosphorus load (less than one percent), no performance metric will be assigned to this area. However, the water quality from the basin will be assessed annually to determine if there is an increasing trend.

3.6 Lake Istokpoga Sub-watershed

The following sections present a description of the Lake Istokpoga Sub-watershed, a summary of historical flow and TP levels, the selection of Reference Periods, and the derivation of the resulting performance indicators for tributaries within the sub-watershed.

3.6.1 Background

The Lake Istokpoga Sub-watershed comprises 394,203 acres located northeast of Lake Okeechobee (**Figure 3-30**). The Lake Istokpoga sub-watershed is located to the west and north (upstream) of Lake Istokpoga. Lake Istokpoga receives direct runoff from adjacent land areas and inflows from Josephine Creek and Arbuckle Creek. The primary outlet from Lake Istokpoga is through the S-68 structure[19], which releases water through a series of canals southeastward to both Lake Okeechobee and the Kissimmee River. The location of S-68 is shown in **Figure 3-30**.

District staff identified the rainfall stations considered to be representative of the Lake Istokpoga Sub-watershed for the period WY1976-2010. A schematic of the sub-watershed with the various rain stations is presented in **Figure 3-31.** Monthly rainfall data and weighting factors for the rainfall stations were developed and provided by the District. Because of the nutrient attenuation effect of Lake Istokpoga, the nutrient loads discharged at S-68 may not be representative of stormwater runoff from within the sub-watershed, and thus the criteria for the establishment of a performance measure at S-68 were not met. Therefore, tributaries upstream of Lake Istokpoga were evaluated to see if there were sufficient data to develop performance measure methodologies in the individual tributaries.

[19] A secondary structure, G-85, is located along the Istokpoga Canal and historically has discharged minimal flow. This structure is operated very infrequently by manipulation of the flashboards; normally, all flashboards are in place (SFWMD Structure Books).

Figure 3-30. Lake Istokpoga Sub-watershed boundary and discharge monitoring locations (from SFWMD).

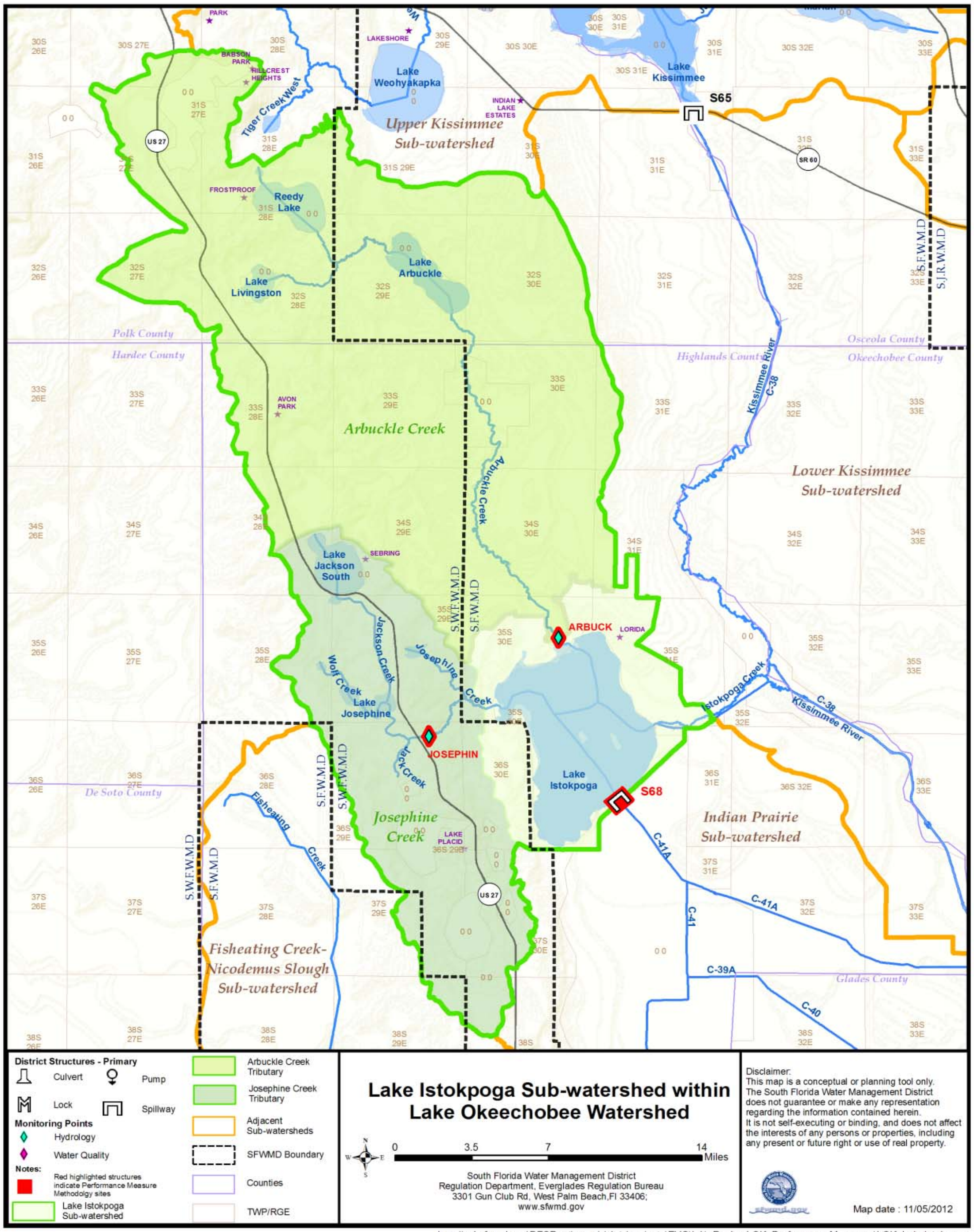
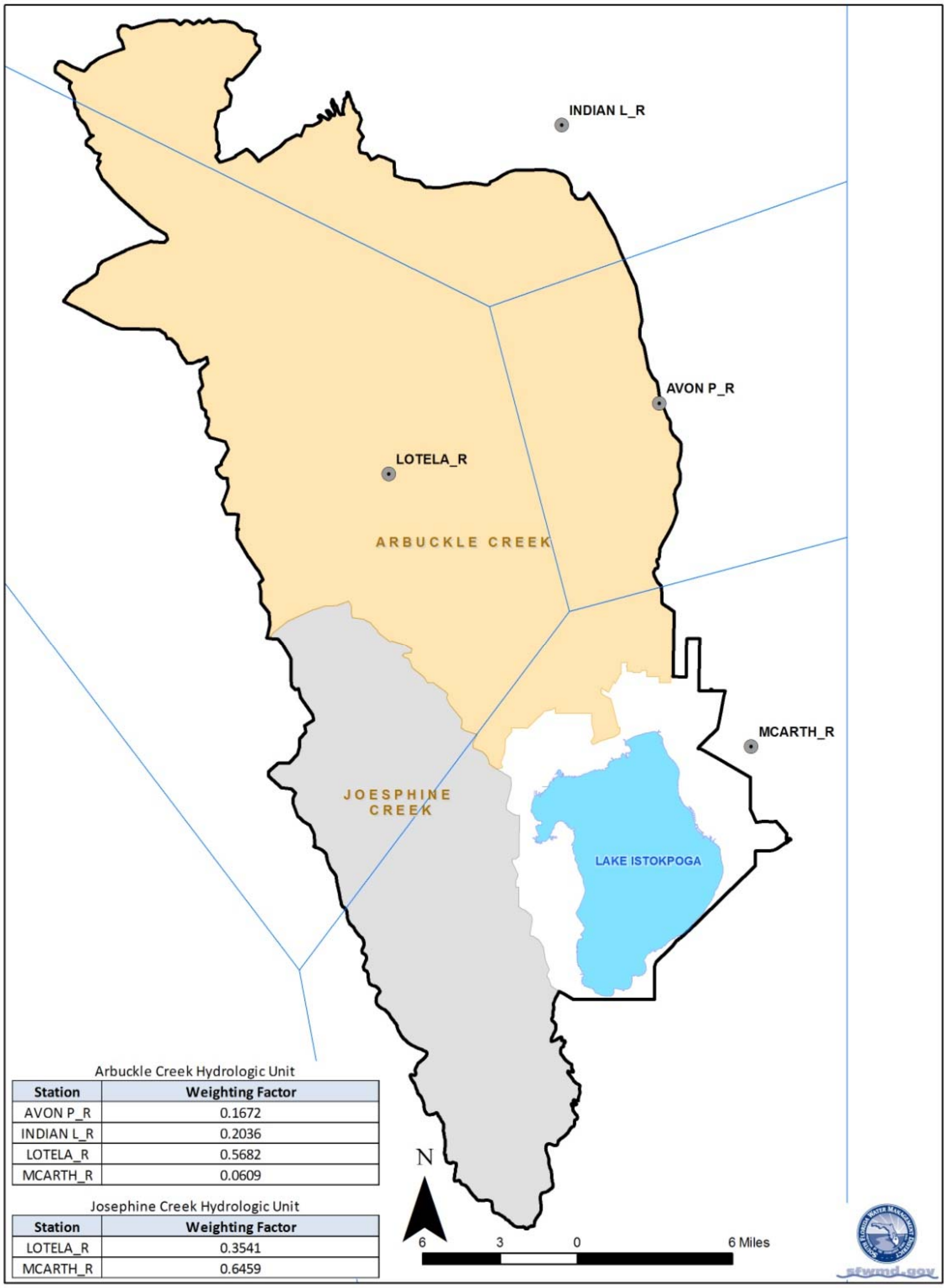


Figure 3-31. Schematic of Lake Istokpoga Sub-watershed (from SFWMD).



Arbuckle Creek Hydrologic Unit

Station	Weighting Factor
AVON P_R	0.1672
INDIAN L_R	0.2036
LOTELA_R	0.5682
MCARTH_R	0.0609

Josephine Creek Hydrologic Unit

Station	Weighting Factor
LOTELA_R	0.3541
MCARTH_R	0.6459

Stormwater runoff from roughly eighty-six percent of the sub-watershed of the sub-watershed flows into Lake Istokpoga via Arbuckle Creek and Josephine Creek. The remaining portion of the sub-watershed is Lake Istokpoga itself and the surrounding land area that discharges into Lake Istokpoga via sheet flow and is not monitored. A review of available data identified monitoring sites located on two major tributaries upstream of Lake Istokpoga. These discharge monitoring locations are shown in **Figure 3-31** and are further described below:

1. One site is located on Arbuckle Creek (ARBUCK), which flows into Lake Istokpoga from the north. Arbuckle Creek has a tributary area of approximately 246,264 acres, or roughly sixty-three percent of the Lake Istokpoga Sub-watershed area. Flow data are recorded at a nearby USGS gauge (Arbuckle Creek near De Soto City, FL: ID no. 02270500).
2. One site is located on Josephine Creek (JOSEPHIN) (LI02362923), which flows into Lake Istokpoga. Shingle Creek has a tributary area of approximately 90,607 acres, or roughly twenty-three percent of the Lake Istokpoga Sub-watershed area. Flow data are recorded at a nearby USGS gauge (Josephine Creek near De Soto City, FL: ID no. 02271500).

Both water quality and flow data were available for the tributaries in the Lake Istokpoga Sub-watershed. However, performance measures were not developed for these tributaries because the boundaries were not well defined. Instead, prediction equations for <u>performance indicators</u> are recommended for the upstream tributaries at Arbuckle Creek and Josephine Creek. The following section summarizes the performance indicators for Arbuckle Creek and Josephine Creek.

3.6.1.1 Performance Measure Methodology

Site 1: Arbuckle Creek

Annual flow and TP data for discharges from the Arbuckle Creek Tributary are summarized in **Table 3-39**. For the development of the performance indicator, a Reference Period of WY1997-2007 was selected for the following reasons:

- it represents a period with minimal implementation of source controls. With the selection of the Reference Period to precede significant source control implementation, no additional calculation is necessary in the performance indicator to account for prior source control implementation,
- it represents a period of relatively constant land use practices,
- reliable water quality and hydrologic data are available, and
- a strong correlation exists between annual TP loads and rainfall, allowing for a performance indicator that explicitly incorporates hydrologic variability

The Reference Period is compared to the historical period of record and WY2001-2010 in **Table 3-40**.

Table 3-39. Summary of historical data for ARBUCK, the outlet structure for the Arbuckle Creek Tributary for the WY 1992-2010 period of record.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics Kurtosis K	Coef. Of Var. CV	Skewness S
1992	190,774	21.775	93	53.87	246,266	9.30	0.19	-0.193	0.852	0.829
1993	213,813	25.570	97	59.28	246,266	10.42	0.23	1.399	0.914	1.448
1994	73,471	9.051	100	43.87	246,266	3.58	0.08	-1.138	0.734	0.593
1995	255,078	25.216	80	60.60	246,266	12.43	0.23	3.421	0.765	1.822
1996	234,590	37.065	128	55.91	246,266	11.43	0.33	-0.762	0.765	0.556
1997	98,572	9.748	80	42.95	246,266	4.80	0.09	-1.440	0.644	-0.011
1998	515,250	87.642	138	77.45	246,266	25.11	0.78	0.053	0.436	-0.393
1999	165,150	30.417	149	45.41	246,266	8.05	0.27	0.749	0.954	1.261
2000	198,903	26.846	109	43.95	246,266	9.69	0.24	0.447	0.856	0.978
2001	35,771	4.264	97	40.71	246,266	1.74	0.04	-0.498	1.097	0.922
2002	292,832	38.802	107	53.88	246,266	14.27	0.35	-1.289	0.712	0.256
2003	293,748	58.961	163	58.37	246,266	14.31	0.53	-0.536	0.724	0.594
2004	261,554	90.876	282	52.55	246,266	12.74	0.81	-0.899	0.804	0.656
2005	257,547	69.319	218	53.04	246,266	12.55	0.62	0.991	0.871	1.134
2006	341,771	48.603	115	50.00	246,266	16.65	0.44	-0.269	0.882	0.682
2007	87,730	12.087	112	33.74	246,266	4.27	0.11	-0.901	0.784	0.825
2008	63,589	4.741	60	40.42	246,266	3.10	0.04	1.918	0.749	1.060
2009	161,959	38.276	192	39.80	246,266	7.89	0.34	2.784	1.057	1.599
2010	110,761	24.379	178	47.15	246,266	5.40	0.22	-1.805	0.664	-0.002
Minimum	***35,771***	***4.264***	***60***	***33.74***	***246,266***	***1.74***	***0.04***	***-1.805***	***0.436***	***-0.393***
Average	***202,782***	***34.928***	***140***	***50.16***	***246,266***	***9.88***	***0.31***	***0.107***	***0.803***	***0.779***
Maximum	***515,250***	***90.876***	***282***	***77.45***	***246,266***	***25.11***	***0.81***	***3.421***	***1.097***	***1.822***
Std. Dev.	***116,298***	***25.944***	***55***	***10.01***	***0***	***5.67***	***0.23***	***1.448***	***0.150***	***0.564***
Skewness	***0.874***	***0.965***	***1.337***	***0.919***	***0.000***	***0.874***	***0.97***	***0.942***	***-0.196***	***-0.201***
Median	***198,903***	***26.846***	***112***	***50.00***	***246,266***	***9.69***	***0.24***	***-0.269***	***0.784***	***0.825***

Table 3-40. Comparison of the Reference Period with the period of record data for Arbuckle Creek.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Load lbs/ac
Period of Record - WY1992-2010					
Annual Minimum	35,771	4.264	60	33.74	0.04
Annual Average	202,782	34.928	140	50.16	0.31
Annual Median	198,903	26.846	112	50.00	0.24
Annual Maximum	515,250	90.876	282	77.45	0.81
Reference Period WY1997-2007					
Annual Minimum	35,771	4.264	80	33.74	0.04
Annual Average	231,712	43.415	152	50.19	0.39
Annual Median	257,547	38.802	115	50.00	0.35
Annual Maximum	515,250	90.876	282	77.45	0.81
Difference between Period of Record and Reference Period					
Annual Minimum	0	0.000	-20	0.00	0.000
Annual Average	-28,929	-8.487	-12	-0.03	-0.076
Annual Median	-58,644	-11.956	-3	0.00	-0.107
Annual Maximum	0	0.000	0	0.00	0.000
Annual Minimum	0%	0%	-25%	0%	0%
Annual Average	-12%	-20%	-8%	0%	-20%
Annual Median	-23%	-31%	-3%	0%	-31%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	35,771	4.264	60	33.74	0.04
Annual Average	190,726	39.031	166	46.97	0.35
Annual Median	209,753	38.539	139	48.58	0.35
Annual Maximum	341,771	90.876	282	58.37	0.81
Difference between WY2001-2010 and Reference Period					
Annual Minimum	0	0.000	-20	0.00	0.00
Annual Average	-40,985	-4.384	14	-3.22	-0.04
Annual Median	-47,794	-0.263	24	-1.43	0.00
Annual Maximum	-173,479	0.000	0	-19.08	0.00
Annual Minimum	0%	0%	-25%	0%	0%
Annual Average	-18%	-10%	9%	-6%	-10%
Annual Median	-19%	-1%	21%	-3%	-1%
Annual Maximum	-34%	0%	0%	-25%	0%

Based on the fact that the annual median total phosphorus concentration for the period of record (112 μg/l) is below the Numeric Nutrient Criteria (120 μg/l) (Chapter 62-302, F.A.C.) it is recommended that no reduction goal be applied to tributary. An Annual Load Target and an Annual Load Limit for the Arbuckle Creek Tributary will be calculated according to the following equations and explanation:

Target = -406.10066 + 115.44341 X

Explained Variance = 67.5 percent, Standard Error of Regression Equation = 18.275

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

m_1 = Sum [r_i] / 12

X = ln (12 m_1)

Limit = Target + 1.38303 SE

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

$SE = 18.27506 [1 + 1/11 + (X-X_m)^2 / 0.46933]^{0.5}$

Where:

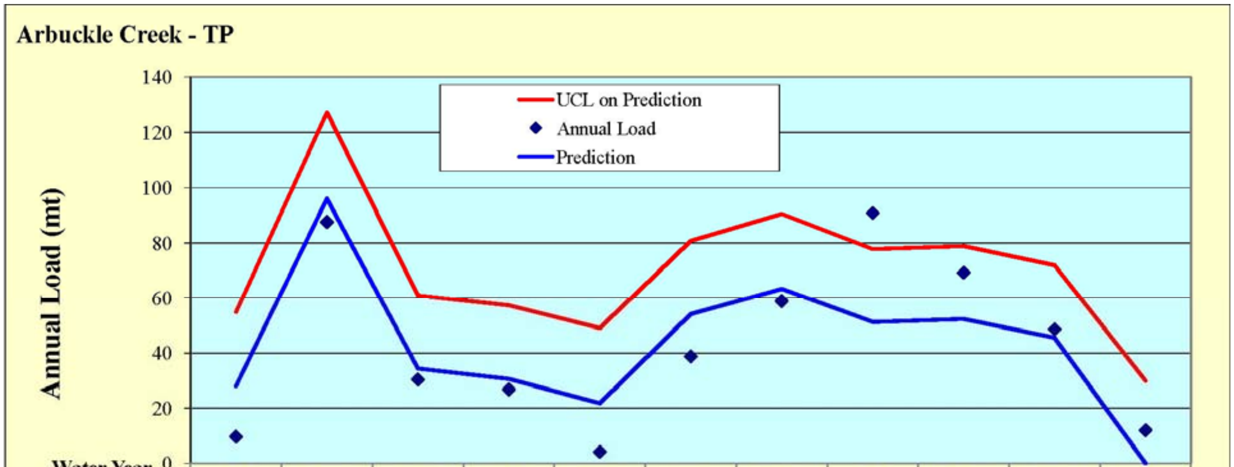
X = the natural logarithm of the 12-month total rainfall (ln(inches))

X_m = average value of the predictor in Reference Period = 3.89382

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

A comparison of the observed loads and the resulting Targets and Limits for the Reference Period are presented in **Figure 3-32.** Annual TP loads at the tributary outlet monitoring location will be evaluated against the performance measure described above.

Figure 3-32. Comparison of observed annual loads with the Annual Load Targets and Limits for the Arbuckle Creek Tributary.



Water Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
UCL on Prediction	54.827	127.336	60.956	57.341	49.076	80.765	90.544	77.777	78.883	71.924	29.915
Annual Load	9.748	87.642	30.417	26.846	4.264	38.802	58.961	90.876	69.319	48.603	12.087
Prediction	27.971	96.035	34.400	30.628	21.787	54.145	63.385	51.260	52.331	45.516	0.108

Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load from the basin, adjusted for regional projects (if present), exceeds the Annual Load Target and the rainfall falls outside the range of rainfall values for the Reference Period (33.74 – 77.45 inches). The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the period of record are summarized in **Table 3-41**.

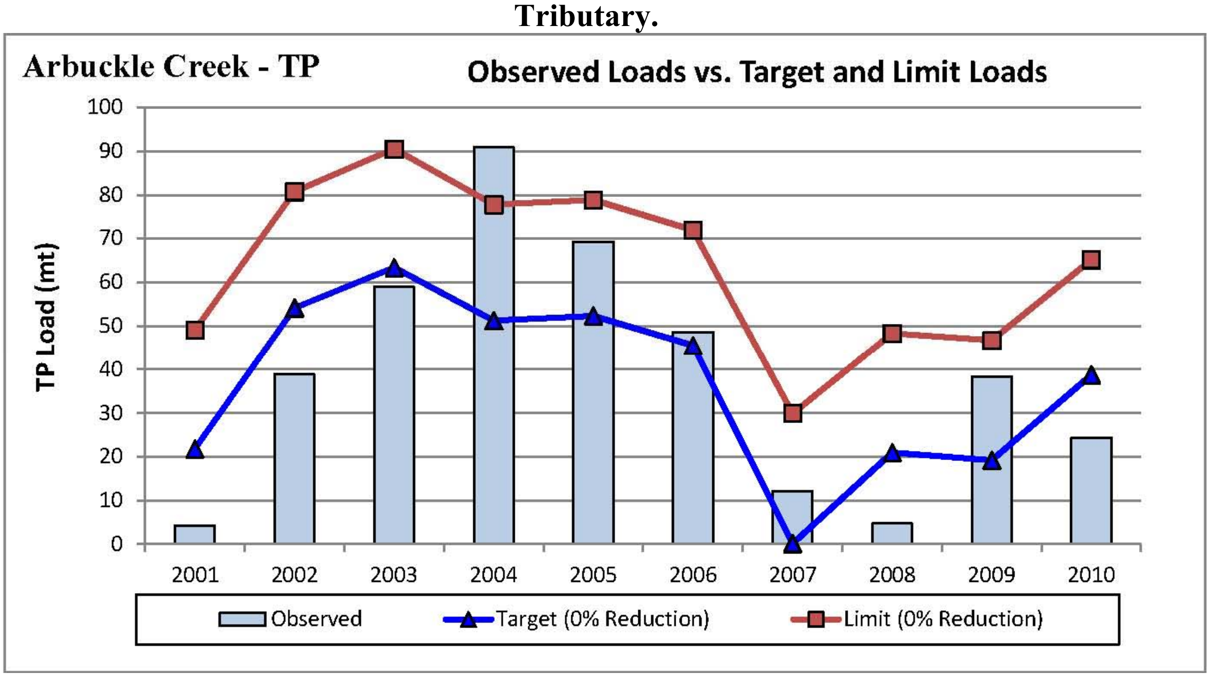
The annual performance determination process will account for regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-33**.

Table 3-41. Annual adjusted rainfall for the historical period of record for the Arbuckle Creek Tributary (Reference Period: WY1997-2007).

Water Year	Observed Load, mt	ln(Rain) ln(inches)	Target Load, mt	SE Load, mt	Limit Load, mt
1997	9.748	3.76004	27.971	19.418	54.827
1998	87.642	4.34963	96.035	22.632	127.336
1999	30.417	3.81573	34.400	19.201	60.956
2000	26.846	3.78305	30.628	19.315	57.341
2001	4.264	3.70647	21.787	19.731	49.076
2002	38.802	3.98676	54.145	19.248	80.765
2003	58.961	4.06680	63.385	19.638	90.544
2004	90.876	3.96177	51.260	19.174	77.777
2005	69.319	3.97105	52.331	19.199	78.883
2006	48.603	3.91202	45.516	19.094	71.924
2007	12.087	3.51868	0.108	21.552	29.915
2008	4.741	3.69932	20.961	19.780	48.318
2009	38.276	3.68387	19.178	19.892	46.690
2010	24.379	3.85333	38.741	19.118	65.182

Figure 3-33. Comparison of WY2001-2010 loads with Reference Period loads and Annual Load Targets, adjusted for hydrologic variability, for the Boggy Creek Tributary.



Note: The Reference Period extended from WY1997-2007.

Exceedance Frequency Analysis. As shown in **Figure 3-32,** although the scaled observed loads fall above the Annual Load Target less than half the time (four out of eleven years, or 36 percent), these exceedances occur in successive years. 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 3-42**). 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 3-42. Exceedance frequencies for the proposed determination methodology for the Arbuckle 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 Rain is outside the range and Load > Annual Load Target	<20%	2.8%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	12.1%
Step 4. Load > Annual Load Limit?	<10%	5.7%
Cumulative Exceedance Frequency	**<17.5%**	**16.1%**

Site 2: Josephine Creek

Annual flow and TP data for discharges from the Josephine Creek Tributary are summarized in **Table 3-43**. For the development of the performance indicator, a Reference Period of WY1997-2004 was selected for the following reasons:

- it represents a period with minimal implementation of source controls. With the selection of the Reference Period to precede significant source control implementation, no additional calculation is necessary in the performance indicator to account for prior source control implementation,
- it represents a period of relatively constant land use practices,
- reliable water quality and hydrologic data are available, and
- a strong correlation exists between annual TP loads and rainfall, allowing for a performance indicator that explicitly incorporates hydrologic variability

The Reference Period is compared to the historical period of record and WY2001-2010 in **Table 3-44**.

Table 3-43. Summary of historical data for JOSEPHIN, the outlet structure for the Josephine Creek Tributary for the WY 1997-2010 period of record.

Water Year	Flow AF	Load mt	FWM Conc, µg/L	Rainfall inches	Unit Area Runoff, inches	Unit Area Load, lbs/ac	Rainfall Characteristics		
							Kurtosis	Coef. Of Var.	Skewness
1997	18,073	0.887	40	41.67	2.39	0.02	-1.595	0.660	0.030
1998	84,407	7.435	71	77.63	11.18	0.18	0.506	0.376	-0.519
1999	36,978	2.349	51	42.72	4.90	0.06	-0.583	1.009	1.038
2000	40,666	2.869	57	54.65	5.39	0.07	-0.927	0.904	0.722
2001	6,852	0.360	43	36.85	0.91	0.01	-1.084	1.143	0.818
2002	47,295	3.139	54	51.20	6.26	0.08	-1.453	0.771	0.309
2003	79,216	5.525	57	62.30	10.49	0.13	-1.497	0.633	0.322
2004	67,107	4.453	54	52.75	8.89	0.11	-0.215	0.721	0.519
2005	83,943	6.323	61	53.51	11.12	0.15	2.431	0.913	1.474
2006	102,465	5.271	42	45.88	13.57	0.13	0.748	0.854	0.840
2007	21,561	1.374	52	29.68	2.86	0.03	-0.284	0.753	0.869
2008	20,122	1.272	51	42.77	2.66	0.03	-0.360	0.630	0.270
2009	71,127	4.639	53	40.19	9.42	0.11	2.746	1.193	1.692
2010	38,864	2.477	52	49.22	5.15	0.06	-1.349	0.690	0.396
Minimum	***6,852***	***0.360***	***40***	***29.68***	***0.91***	***0.01***	***-1.595***	***0.376***	***-0.519***
Average	***51,334***	***3.455***	***53***	***48.64***	***6.80***	***0.08***	***-0.208***	***0.804***	***0.627***
Maximum	***102,465***	***7.435***	***71***	***77.63***	***13.57***	***0.18***	***2.746***	***1.193***	***1.692***
Std. Dev.	***29,906***	***2.183***	***8***	***11.79***	***3.96***	***0.05***	***1.387***	***0.218***	***0.570***
Median	***43,981***	***3.004***	***53***	***47.55***	***5.82***	***0.07***	***-0.472***	***0.762***	***0.621***
Skewness	***0.168***	***0.307***	***0.471***	***0.958***	***0.168***	***0.307***	***1.214***	***0.136***	***0.037***

Table 3-44. Comparison of the Reference Period with the period of record data for Josephine Creek.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Load lbs/ac
Period of Record - WY1997-2010					
Annual Minimum	6,852	0.360	40	36.85	0.01
Annual Average	51,334	3.455	55	52.66	0.08
Annual Median	43,981	3.004	53	53.13	0.07
Annual Maximum	102,465	7.435	71	77.63	0.18
Preliminary Reference Period WY1997-2004					
Annual Minimum	6,852	0.360	40	41.67	0.01
Annual Average	47,574	3.377	58	53.24	0.08
Annual Median	43,981	3.004	54	52.58	0.07
Annual Maximum	84,407	7.435	71	77.63	0.18
Difference between Period of Record and Reference Period					
Annual Minimum	0	0.000	0	-4.82	0.000
Annual Average	3,760	0.078	-3	-0.59	0.002
Annual Median	0	0.000	-2	0.55	0.000
Annual Maximum	18,058	0.000	0	0.00	0.000
Annual Minimum	0%	0%	0%	-12%	0%
Annual Average	8%	2%	-5%	-1%	2%
Annual Median	0%	0%	-3%	1%	0%
Annual Maximum	21%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	6,852	0.360	42	36.85	0.01
Annual Average	53,855	3.483	52	52.97	0.08
Annual Median	57,201	3.796	53	53.13	0.09
Annual Maximum	102,465	6.323	61	77.63	0.15
Difference between WY2001-2010 and Reference Period					
Annual Minimum	0	0.000	2	-4.82	0.00
Annual Average	6,281	0.106	-5	-0.28	0.00
Annual Median	13,221	0.792	-2	0.55	0.02
Annual Maximum	18,058	-1.112	-10	0.00	-0.03
Annual Minimum	0%	0%	5%	-12%	0%
Annual Average	13%	3%	-9%	-1%	3%
Annual Median	30%	26%	-3%	1%	26%
Annual Maximum	21%	-15%	-14%	0%	-15%

Based on the fact that the annual median total phosphorus concentration for the period of record (53 µg/l) is below the Numeric Nutrient Criteria (120 µg/l) (Chapter 62-302, F.A.C.), it is recommended that no reduction goal be applied to tributary. An Annual Load Target and an Annual Load Limit for the Josephine Creek Tributary will be calculated according to the following equations and explanation:

Target = -33.98677 + 9.49604 X

Explained Variance = 92.7 percent, Standard Error of Regression Equation = 0.686

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

m_1 = Sum [r_i] / 12

X = ln (12 m_1)

Limit = Target + 1.43976 SE

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

$SE = 0.68581\,[1 + 1/8 + (X-X_m)^2 / 0.40023]^{0.5}$

Where:

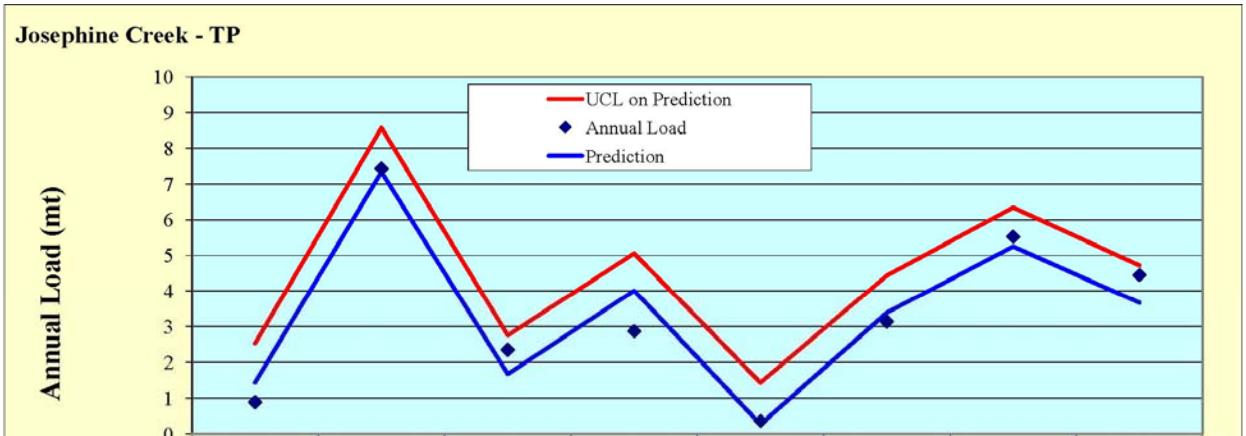
X = the natural logarithm of the 12-month total rainfall (ln(inches))

X_m = average value of the predictor in Reference Period = 3.93468

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

A comparison of the observed loads and the resulting Targets and Limits for the Reference Period are presented in **Figure 3-34.** Annual TP loads at the tributary outlet monitoring location, will be evaluated against the performance measure described above.

Figure 3-34. Comparison of observed annual loads with the Annual Load Targets and Limits for the Josephine Creek Tributary.



Water Year	1997	1998	1999	2000	2001	2002	2003	2004
UCL on Prediction	2.526	8.573	2.752	5.059	1.430	4.434	6.342	4.719
Annual Load	0.887	7.435	2.349	2.869	0.360	3.139	5.525	4.453
Prediction	1.431	7.340	1.668	4.006	0.264	3.387	5.250	3.670

Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load from the basin, adjusted for regional projects (if present), exceeds the Annual Load Target and the rainfall falls outside the range of rainfall values for the Reference Period (36.85 – 77.63 inches). The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the period of record are summarized in **Table 3-45**.

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

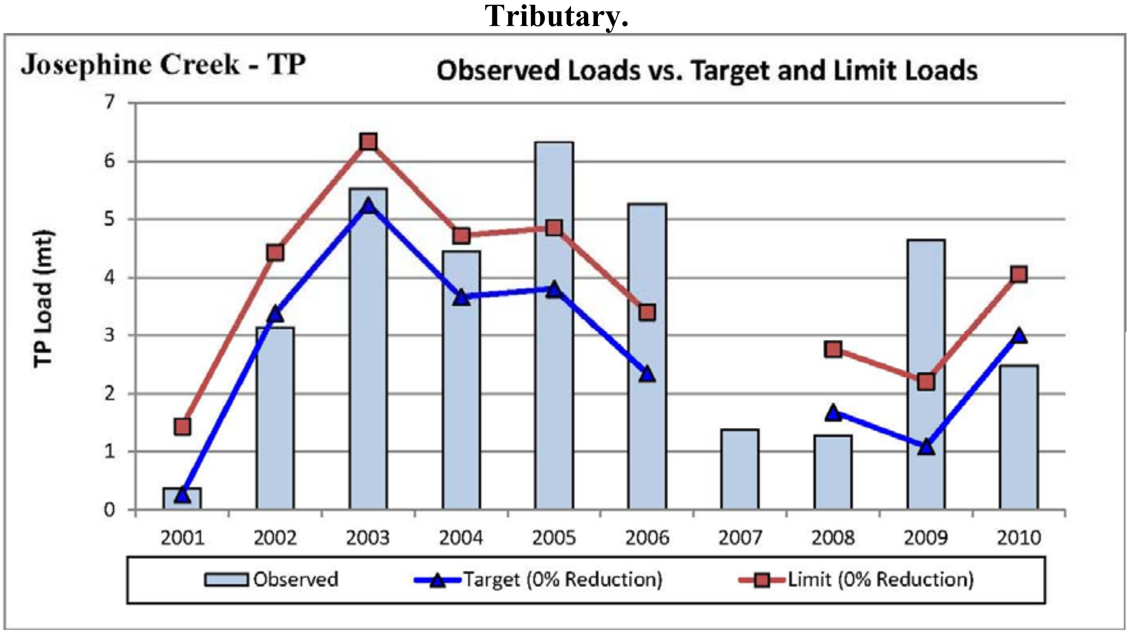
Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-35**.

Table 3-45. Annual adjusted rainfall for the historical period of record for the Josephine Creek Tributary (Reference Period: WY1997-2004).

Water Year	Observed Load, mt	ln(Rain) ln(inches)	Target Load, mt	SE Load, mt	Limit Load, mt
1997	0.887	3.72978	1.431	0.761	2.526
1998	7.435	4.35195	7.340	0.857	8.573
1999	2.349	3.75467	1.668	0.753	2.752
2000	2.869	4.00095	4.006	0.731	5.059
2001	0.360	3.60686	0.264	0.810	1.430
2002	3.139	3.93574	3.387	0.727	4.434
2003	5.525	4.13196	5.250	0.758	6.342
2004	4.453	3.96556	3.670	0.728	4.719
2005	6.323	3.97987	3.806	0.729	4.856
2006	5.271	3.82603	2.345	0.737	3.406
2007	1.374	3.39047	-1.791	0.937	-0.442
2008	1.272	3.75584	1.679	0.753	2.763
2009	4.639	3.69362	1.088	0.773	2.201
2010	2.477	3.89630	3.013	0.729	4.062

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 3-35. Comparison of WY2001-2010 loads with Reference Period loads and Annual Load Targets, adjusted for hydrologic variability, for the Josephine Creek Tributary.



Note: The Reference Period extended from WY1997-2004. The performance determination for WY2007 would have been suspended due to rainfall below the minimum value during the Reference Period coupled with the observed load being greater than the Load Target.

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 3-46**). 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 3-46. Exceedance frequencies for the proposed determination methodology for the Josephine 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 Rain is outside the range and Load > Annual Load Target	<20%	6.0%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.9%
Step 4. Load > Annual Load Limit?	<10%	4.0%
Cumulative Exceedance Frequency	**<17.5%**	**13.8%**

3.7 West Lake Okeechobee Sub-watershed

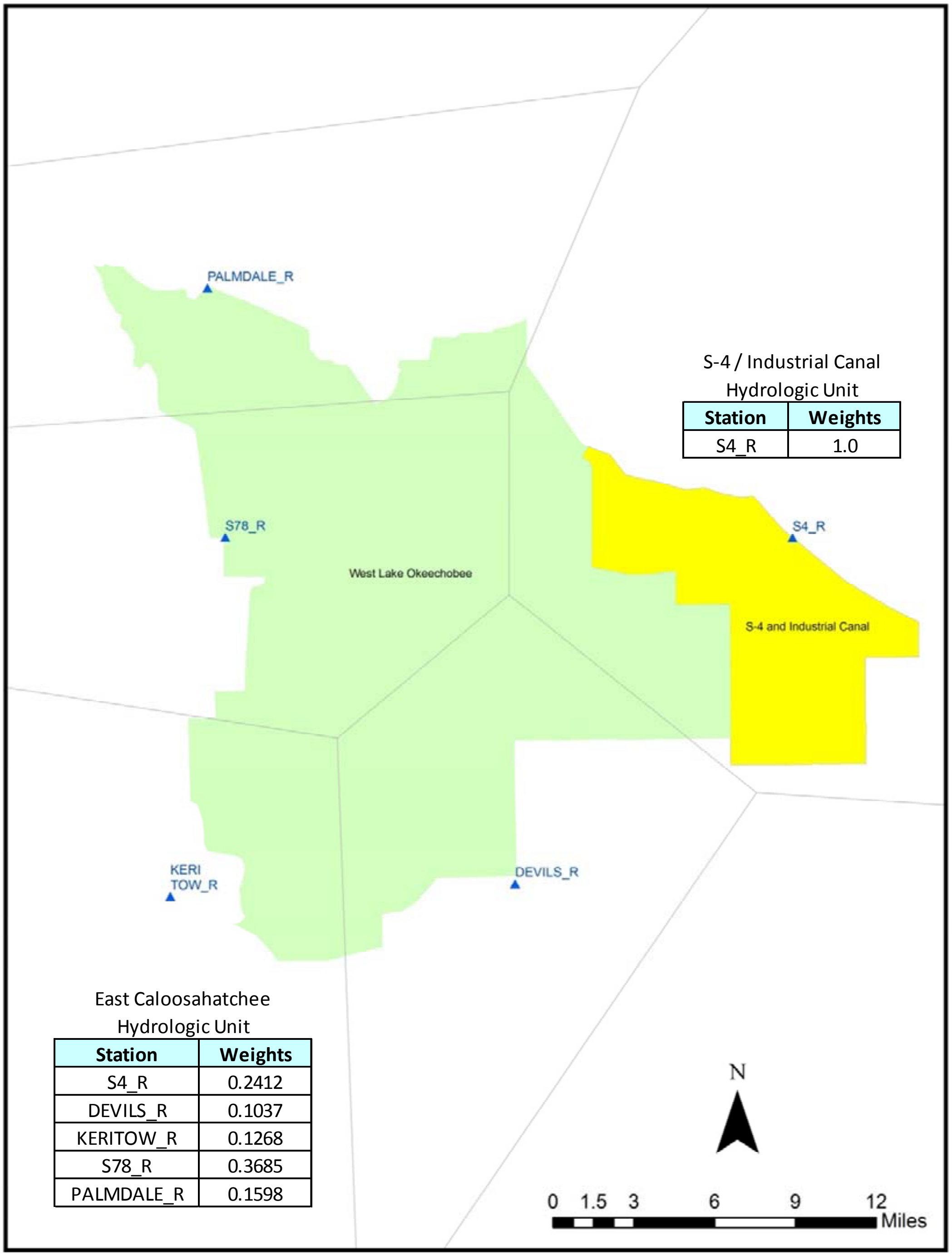
The West Lake Okeechobee Sub-watershed is composed of 246,240 acres located along the west shore of Lake Okeechobee, south of Fisheating Creek and northeast of the South Lake Okeechobee Sub-watershed **(Figure 3-36)**. The sub-watershed consists of two smaller hydrologic units, East Caloosahatchee and S-4/Industrial Canal. These two hydrologic units are referred to as summary basins in reference to the Lake Okeechobee Watershed, while they are referred to as sub-watersheds in the Caloosahatchee River Watershed. For the purposes of this report, both areas will simply be referred to as hydrologic units or basins. Flow and TP monitoring sites are identified in **Tables C-1** and **C-2**.

District staff identified five rainfall stations considered to be representative of the West Lake Okeechobee Sub-watershed. Monthly rainfall data and weighting factors for the rainfall stations for each basin were developed and provided by the District. All selected rainfall stations had periods of record that began no later than May 1976. The Thiessen Polygons and associated weighting factors used to calculate basin rainfall values are shown in **Figure 3-37**.

The following sections describe the derivation of the performance measure methodologies for TP for the basins within the West Lake Okeechobee Sub-watershed. Performance measure(s) for nitrogen species will be addressed in a future document for the Caloosahatchee River Watershed.

Figure 3-36. West Lake Okeechobee Sub-watershed boundary and discharge monitoring locations.

3688 **Figure 3-37. Schematic of West Lake Okeechobee Sub-watershed, hydrologic units and**
3689 **selected rainfall stations.**



S-4 / Industrial Canal Hydrologic Unit

Station	Weights
S4_R	1.0

East Caloosahatchee Hydrologic Unit

Station	Weights
S4_R	0.2412
DEVILS_R	0.1037
KERITOW_R	0.1268
S78_R	0.3685
PALMDALE_R	0.1598

3690

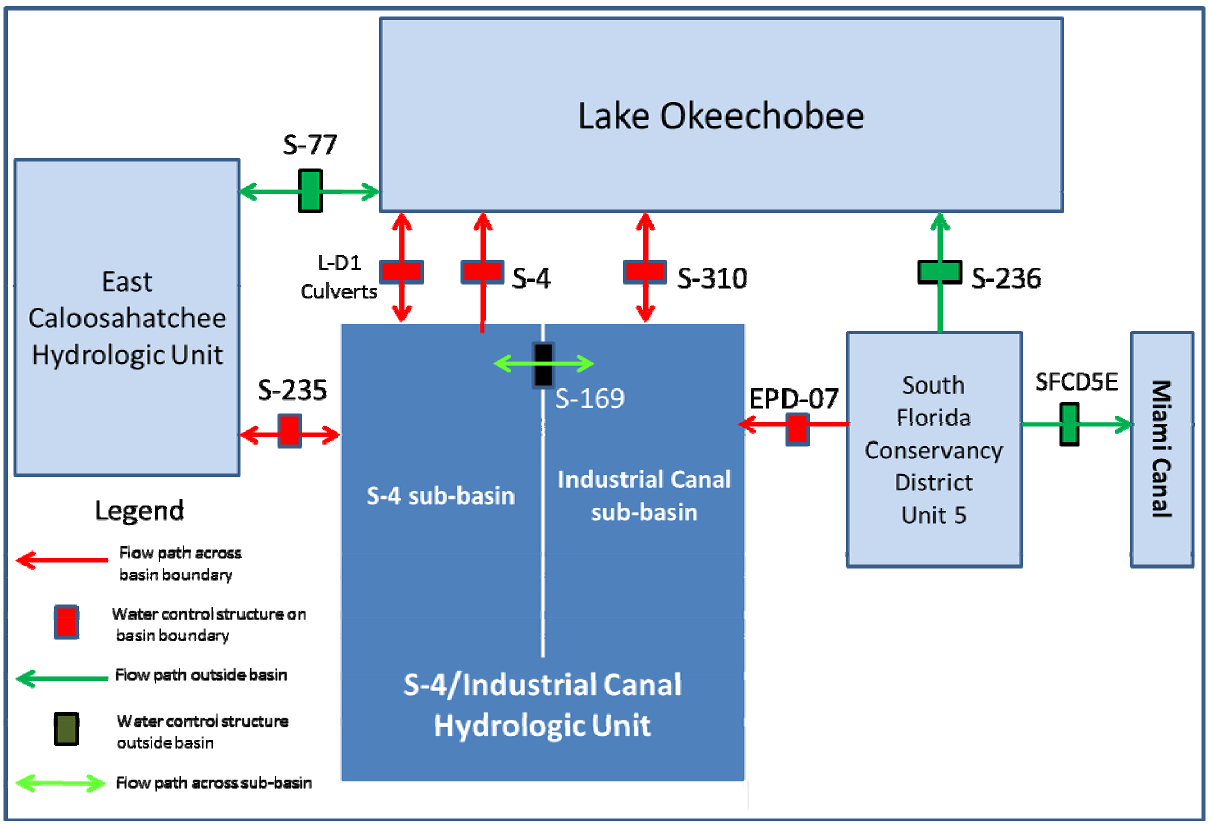
3.7.1 S-4/Industrial Canal Hydrologic Unit

The S-4/Industrial Canal Hydrologic Unit is composed of 42,145 acres located along the west shore of Lake Okeechobee between the East Caloosahatchee Hydrologic Unit and the South Lake Okeechobee Sub-watershed. The S-4/Industrial Canal Hydrologic Unit contains two interconnected sub-basins: S-4 and Industrial Canal. The S-4/Industrial Canal Hydrologic Unit is also referred to as the S-4 Sub-watershed, e.g., in the Caloosahatchee River Watershed. S-169 is a culvert structure that discharges in both directions between the Industrial Canal Sub-basin and the S-4 Sub-basin. The S-4/Industrial Canal Hydrologic Unit has four primary structures on its borders with Lake Okeechobee, the East Caloosahatchee Hydrologic Unit, and the South Florida Conservancy District (SFCD) Unit 5 which is within the South Lake Okeechobee Sub-watershed (east of structure EPD-07) (**Figure 3-38**):

- S-235 is a culvert that discharges in both directions between S-4/Industrial Canal Hydrologic Unit and the East Caloosahatchee Hydrologic Unit;
- S-4 is a pump station that discharges from the S-4/Industrial Canal Hydrologic Unit to Lake Okeechobee;
- S-310 is a boat lock that passes water in both directions between the S-4/Industrial Canal Hydrologic Unit and Lake Okeechobee when lake stages are below 15.5 feet, NGVD (the gate is closed when the lake stage is above 15.5 ft NGVD, from SFWMD Structure Books); and
- EPD-07 is a pump station that discharges excess water from the SFCD Unit 5 in the South Lake Okeechobee Sub-watershed to Industrial Canal. In August 2005, new facilities became operational that enabled the diversion of a long-term average annual 80 percent of the SFCD Unit 5 drainage away from Lake Okeechobee as required by the Everglades Forever Act (Burns & McDonnell, 2008).

Other structures that discharge to and from the S-4/Industrial Canal Hydrologic Unit are the LD-1 culverts (C-1, C-1A, and C-2 – discharge to/from Lake Okeechobee) and the Disston Island Conservancy District Pump Station No. 3 (DICD#3 - discharges to/from the East Caloosahatchee Hydrologic Unit). No discharge records are available for these structures and it is assumed that the nutrient loads discharged from these structures are not significant. Hence, these structures are not addressed in this performance measure.

Figure 3-38. S-4/Industrial Canal Hydrologic Unit Flow Schematic.



3.7.1.1 Background

The performance measure methodology is based on flows and TP loads resulting from rainfall and runoff from the S-4/Industrial Canal Hydrologic Unit. Basin flows and loads, adjusted for pass-through flows and loads discharged from external sources, were calculated using algorithms provided in Appendix A. Annual basin flow and TP data for discharges from the S-4/Industrial Canal Hydrologic Unit for the WY1993-2010 period of record are summarized in **Table 3-47**.

Table 3-47. Summary of historical data for the S-4/Industrial Canal Hydrologic Unit.

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

For the development of the performance measure methodology, a Base Period of WY1993-2001 was selected for the following reasons.

- It represents a period with minimal implementation of source controls. With the selection of the Base Period to precede significant source control implementation, no additional calculation is necessary in the performance measure methodology to account for prior source control implementation.
- Beginning in WY2006, discharges into the basin from the adjacent Ch. 298 District have decreased by more than 80 percent, a result of the mandated diversion project. However, there has been no noticeable effect on the basin flows and TP loads, likely due to the pass-through algorithm used to account for these external inflows.
- It represents a period of relatively constant land use practices.
- It contained a reasonably wide range of hydrologic conditions.
- Reliable water quality and flow data are available
- A strong correlation exists between annual TP loads and rainfall, allowing for a performance measure methodology that explicitly incorporates hydrologic variability.

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-48.**

Table 3-48. Comparison of Base Period with period of record and WY2001-2010 data for the S-4/Industrial Canal Hydrologic Unit.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1993-2010					
Annual Minimum	15,712	4.519	84	24.83	0.24
Annual Average	84,095	16.913	163	42.91	0.88
Annual Median	91,861	16.901	171	41.72	0.88
Annual Maximum	131,064	30.280	272	58.34	1.58
Base Period WY1993-2001					
Annual Minimum	36,636	6.888	84	33.83	0.36
Annual Average	95,552	17.192	146	45.70	0.90
Annual Median	101,775	17.622	147	46.54	0.92
Annual Maximum	131,064	28.655	212	58.34	1.50
Difference between Period of Record and Base Period					
Annual Minimum	-20,924	-2.369	0	-9.00	-0.12
Annual Average	-11,457	-0.279	17	-2.80	-0.01
Annual Median	-9,915	-0.721	24	-4.83	-0.04
Annual Maximum	0	1.625	60	0.00	0.09
Annual Minimum	-57%	-34%	0%	-27%	-34%
Annual Average	-12%	-2%	12%	-6%	-2%
Annual Median	-10%	-4%	16%	-10%	-4%
Annual Maximum	0%	6%	28%	0%	6%
WY2001-2010					
Annual Minimum	15,712	4.519	143	24.83	0.24
Annual Average	69,038	15.660	184	39.53	0.82
Annual Median	68,490	15.926	186	38.73	0.83
Annual Maximum	113,392	30.280	272	56.29	1.58
Difference between WY2001-2010 and Base Period					
Annual Minimum	-20,924	-2.369	59	-9.00	-0.12
Annual Average	-26,515	-1.532	38	-6.17	-0.08
Annual Median	-33,285	-1.696	39	-7.82	-0.09
Annual Maximum	-17,672	1.625	60	-2.05	0.09
Annual Minimum	-57%	-34%	70%	-27%	-34%
Annual Average	-28%	-9%	26%	-14%	-9%
Annual Median	-33%	-10%	27%	-17%	-10%
Annual Maximum	-13%	6%	28%	-4%	6%

3.7.1.2 Performance Measure 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 30 percent was determined to be reasonable and appropriate. Details are provided in Appendix D 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:

Target = -14.62787 + 0.41452 X + 8.44621 C

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

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

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

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

$X = 12\, m_1$

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

Limit = Target + 1.43976 SE

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

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

Where:

X = the 12-month total rainfall (inches)

C = coefficient of variation calculated from 12 monthly rainfall totals

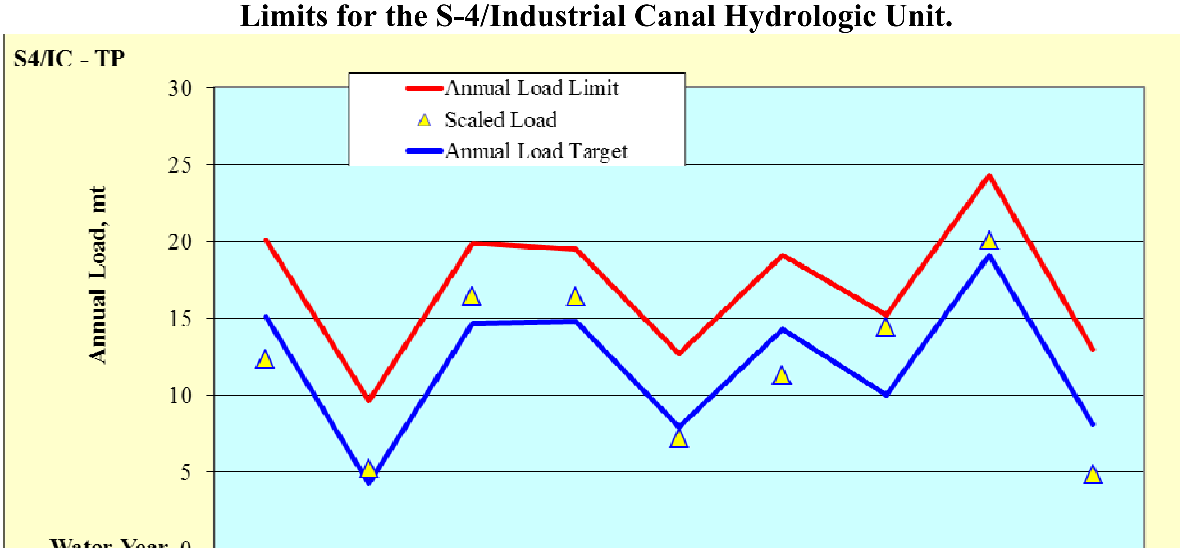
X_m = average value of the predictor in base period = 45.704 inches

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

The first predictor (X) indicates that load increases with 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 occurs when rainfall is evenly distributed across months and the highest load occurs when all of the rain falls 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 3-39.** Annual TP loads at the sub-watershed outlet structures, adjusted to account for regional projects (as applicable) and pass-through loads as described in Appendix A, will be evaluated against the performance measure described above.

Figure 3-39. Comparison of scaled annual loads with the Annual Load Targets and Limits for the S-4/Industrial Canal Hydrologic Unit.



Water Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
Annual Load Limit	20.109	9.662	19.906	19.527	12.733	19.118	15.201	24.303	12.987
Scaled Load	12.335	5.240	16.472	16.408	7.195	11.325	14.454	20.059	4.822
Annual Load Target	15.095	4.260	14.701	14.797	7.943	14.292	10.011	19.125	8.087

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

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

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1993-2010 period of record are summarized in **Table 3-49**.

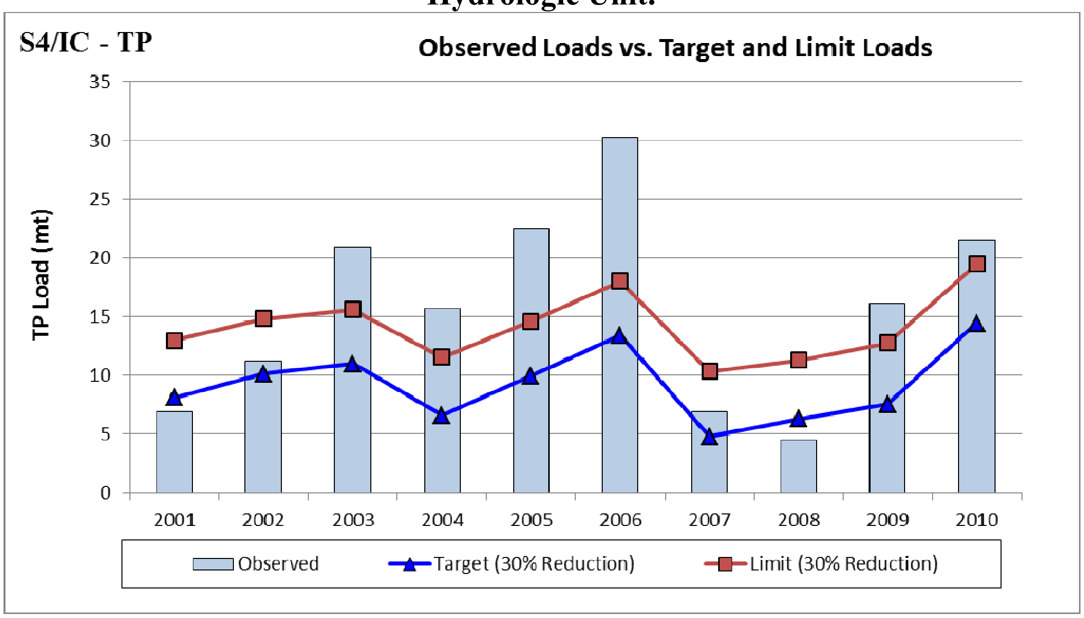
The annual performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-40**.

Table 3-49. Annual adjusted rainfall for the historical period of record for the S-4/Industrial Canal Hydrologic Unit (Base Period: WY1993-2001).

Water Year	Observed Load, mt	Rain in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1993	17.622	46.54	1.235	15.095	20.110	53.09
1994	7.485	33.83	0.576	4.260	9.661	26.95
1995	23.532	58.12	0.620	14.701	19.906	52.14
1996	23.440	53.38	0.864	14.797	19.527	52.37
1997	10.278	38.13	0.801	7.943	12.733	35.83
1998	16.179	54.22	0.763	14.292	19.119	51.15
1999	20.649	34.48	1.225	10.011	15.201	40.82
2000	28.655	58.34	1.133	19.125	24.303	62.81
2001	6.888	34.30	1.006	8.087	12.987	36.18
2002	11.258	43.78	0.783	10.133	14.810	41.12
2003	20.933	42.96	0.923	10.976	15.586	43.15
2004	15.699	36.98	0.696	6.580	11.566	32.54
2005	22.510	40.47	0.927	9.977	14.632	40.74
2006	30.280	48.63	0.930	13.385	17.999	48.96
2007	6.906	24.83	1.079	4.778	10.331	28.20
2008	4.519	36.52	0.683	6.279	11.309	31.82
2009	16.153	30.54	1.128	7.559	12.776	34.91
2010	21.455	56.29	0.679	14.440	19.459	51.51

Figure 3-40. Comparison of WY2001-2010 loads with Base Period loads and Annual Load Targets, adjusted for hydrologic variability, for the S-4/Industrial Canal Hydrologic Unit.



Note: The Base Period extended from WY1993-2001.

Exceedance Frequency Analysis. As shown in **Figure 3-39,** although the scaled observed loads fall above the Annual Load Target roughly half the time (five out of nine years, or 55 percent), three of these exceedances occur in successive years. In accordance with the proposed performance determination process discussed in Section 2.6, three successive years when the observed load exceeds the Annual Load Target would prevent the basin from meeting its performance measure. In the case of the scaled Base Period data, this is an example of a Type I error[20], or "false positive" - when the performance method suggests a lack of compliance when the basin's load actually achieves the long-term reduction goals. The use of a three-year cycle for the Annual Load Target is consistent with the District's Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of 12.5 percent. Using the approach described in 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 3-50**). 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.

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

Table 3-50. Exceedance frequencies for the proposed determination methodology for the S-4/Industrial Canal Hydrologic Unit.

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

3.7.2 East Caloosahatchee Hydrologic Unit

The East Caloosahatchee Hydrologic Unit consists of 204,094 acres located adjacent to the west shoreline of Lake Okeechobee. It includes the area that drains to C-43 Canal between S-77 and S-78. Flows are discharged to and from Lake Okeechobee at S-77. Flows are also discharged to and from the S-4/Industrial Canal Hydrologic Unit at S-235. The East Caloosahatchee Hydrologic Unit is also referred to as the East Caloosahatchee Sub-watershed of the Caloosahatchee River Watershed[21]. The historical data analysis for the East Caloosahatchee Hydrologic Unit was prepared under a separate contract by HDR Engineering, Inc. (2011b) and is summarized herein.

There are five additional locations where flows cross the boundaries of the East Caloosahatchee Hydrologic Unit (**Figure 3-417**), as described below:

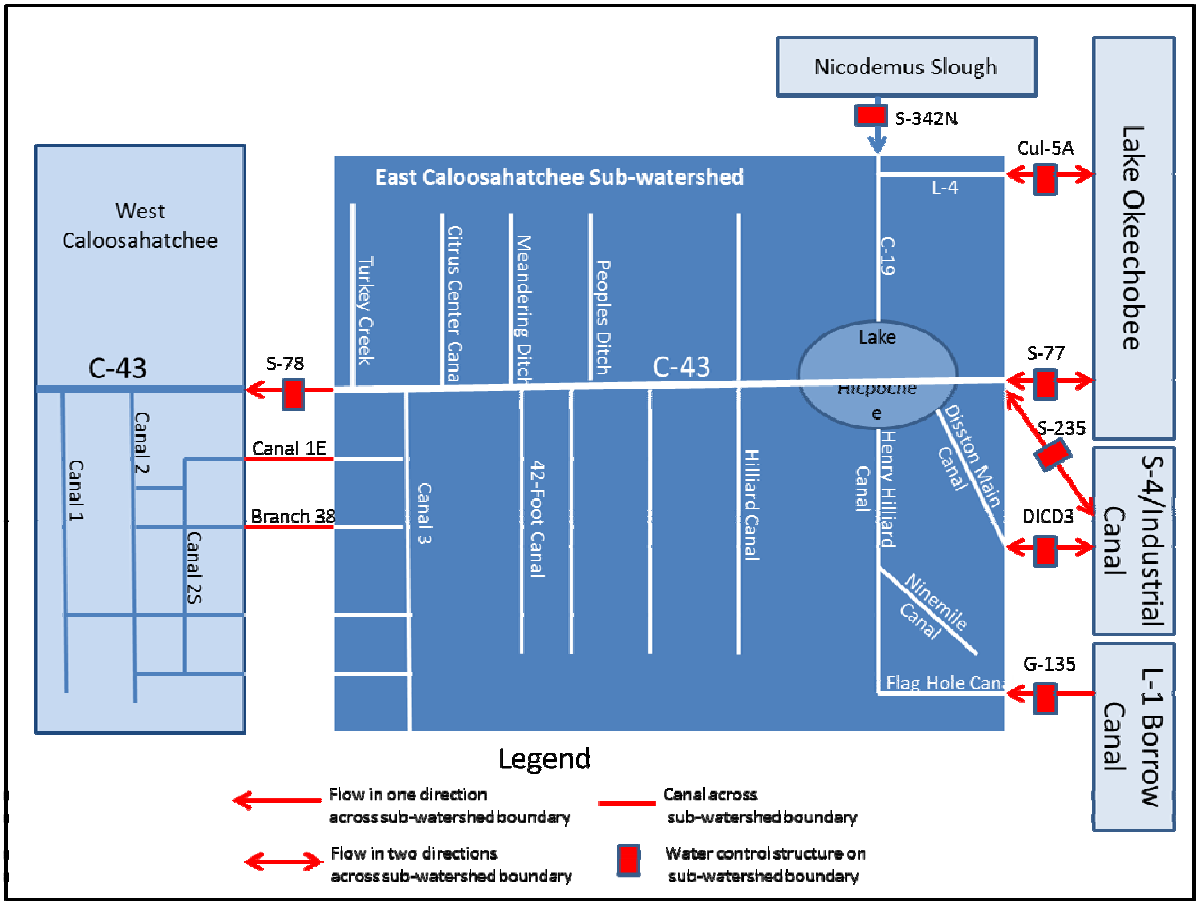
- Disston Island Conservancy District Pump No. 3 (DICD3) discharges in both directions to and from the S-4/Industrial Canal Hydrologic Unit,
- S-342N discharges from Nicodemus Slough,
- G-135 discharges from the L-1 Borrow Canal (Flaghole Drainage District) to C-43, and
- Canals 1, 2, and 3, with other tertiary canals, provide a connection with the West Caloosahatchee Sub-watershed (the area that drains to C-43 between S-78 and S-79).
- Culvert 5A discharges both directions to and from Lake Okeechobee.

The discharges at these locations are small and there are little or no flow or water quality data (HDR 2011b for DICD3, S-342N G-135, and Canals 1, 2, and 3. Culvert 5A data was evaluated by District staff and was assumed that the nutrient loads discharge from this

[1] Performance measure(s) for nitrogen species will be addressed in a future document for the Caloosahatchee River Watershed

structure was not significant). Hence, these flows and loads were not considered in this performance measure methodology.

Figure 3-41. Flow diagram for East Caloosahatchee basin.



3.7.2.1 *Background*

The performance measure methodology is based on flows and TP loads resulting from rainfall and runoff from the East Caloosahatchee Hydrologic Unit. Basin flows and loads, adjusted for pass through flows and loads discharged from external sources, were calculated using algorithms provided in Appendix A. Annual flow and TP data for discharges from the East Caloosahatchee Hydrologic Units are summarized in **Table 3-51**.

Table 3-51. Summary of historical data for the East Caloosahatchee Hydrologic Unit.

							Rainfall Characteristics		
Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Kurtosis K	Coef. Of Var. CV	Skewness S
1981				32.31			2.043	0.887	1.348
1982	89,153	23.523	214	42.29	5.24	0.25	3.411	0.840	1.538
1983	588,703	191.161	263	72.47	34.61	2.06	0.128	0.664	0.382
1984	211,215	23.371	90	52.22	12.42	0.25	1.338	0.620	0.673
1985	267,350	110.460	335	47.99	15.72	1.19	-0.694	0.890	0.584
1986	199,891	54.939	223	46.57	11.75	0.59	-1.014	0.724	0.556
1987	343,358	77.368	183	56.21	20.19	0.84	-0.388	0.772	0.687
1988	254,651	61.198	195	48.58	14.97	0.66	1.105	0.617	0.830
1989	145,877	28.798	160	46.03	8.58	0.31	1.480	0.912	1.319
1990	112,163	23.185	168	43.81	6.59	0.25	-1.113	0.787	0.650
1991	156,204	35.224	183	52.85	9.18	0.38	-0.175	0.791	0.718
1992	238,943	63.448	215	59.68	14.05	0.69	0.294	0.714	0.859
1993	275,410	68.616	202	52.67	16.19	0.74	3.817	1.009	1.823
1994	205,552	37.434	148	47.73	12.09	0.40	-1.252	0.520	0.013
1995	295,839	61.030	167	57.57	17.39	0.66	0.018	0.449	0.924
1996	317,530	64.927	166	57.42	18.67	0.70	-1.614	0.839	0.367
1997	139,355	21.435	125	47.75	8.19	0.23	-0.276	0.814	0.587
1998	237,053	57.387	196	62.17	13.94	0.62	-0.421	0.578	-0.031
1999	287,114	52.252	148	42.46	16.88	0.56	-0.573	0.823	0.686
2000	364,314	53.363	119	60.47	21.42	0.58	2.354	1.078	1.506
2001	120,427	-3.251	-22	34.44	7.08	-0.04	-0.851	0.915	0.590
2002	226,842	71.866	257	54.89	13.34	0.78	-1.389	0.893	0.602
2003	462,008	101.832	179	61.45	27.16	1.10	2.209	0.805	1.395
2004	349,932	92.878	215	54.29	20.57	1.00	-1.524	0.748	0.251
2005	300,291	7.725	21	52.49	17.66	0.08	1.054	0.893	1.137
2006	575,220	93.518	132	57.97	33.82	1.01	0.026	0.947	0.881
2007	243,725	54.034	180	37.94	14.33	0.58	0.720	1.151	1.225
2008	108,808	18.112	135	51.49	6.40	0.20	2.054	0.766	1.267
2009	248,322	89.044	291	46.30	14.60	0.96	1.268	1.253	1.399
2010	334,902	66.063	160	63.32	19.69	0.71	-1.279	0.667	0.009
Minimum	***89,153***	***7.725***	***21***	***37.94***	***5.24***	***0.08***	***-1.614***	***0.449***	***-0.031***
Average	***270,704***	***60.864***	***182***	***52.75***	***15.92***	***0.66***	***0.342***	***0.806***	***0.816***
Maximum	***588,703***	***191.161***	***335***	***72.47***	***34.61***	***2.06***	***3.817***	***1.253***	***1.823***
Std. Dev.	***122,851***	***37.213***	***62***	***7.69***	***7.22***	***0.40***	***1.487***	***0.181***	***0.489***
Skewness	***1.045***	***1.538***	***0.097***	***0.360***	***1.045***	***1.54***	***0.710***	***0.432***	***0.129***
Median	***251,487***	***59.209***	***180***	***52.58***	***14.79***	***0.64***	***0.022***	***0.798***	***0.703***

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

For the development of the performance measure methodology, a Base Period of WY1982-1990 was selected for the following reasons.

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

The Base Period is compared to the historical period of record and WY2001-2010 in **Table 3-52**.

Table 3-52. Comparison of Base Period with period of record and WY2001-2010 data for the East Caloosahatchee Hydrologic Unit.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	89,153	7.725	21	37.94	0.08
Annual Average	270,704	60.864	182	52.75	0.66
Annual Median	251,487	59.209	180	52.58	0.64
Annual Maximum	588,703	191.161	335	72.47	2.06
Base Period WY1982-1990					
Annual Minimum	89,153	23.185	90	42.29	0.25
Annual Average	245,818	66.000	218	50.69	0.71
Annual Median	211,215	54.939	195	47.99	0.59
Annual Maximum	588,703	191.161	335	72.47	2.06
Difference between Period of Record and Base Period					
Annual Minimum	0	-15.460	-69	-4.35	-0.17
Annual Average	24,887	-5.136	-35	2.07	-0.06
Annual Median	40,272	4.270	-16	4.59	0.05
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	-67%	-77%	-10%	-67%
Annual Average	10%	-8%	-16%	4%	-8%
Annual Median	19%	8%	-8%	10%	8%
Annual Maximum	0%	0%	0%	0%	0%
WY2002-2010					
Annual Minimum	108,808	7.725	21	37.94	0.08
Annual Average	316,672	66.119	169	53.35	0.71
Annual Median	300,291	71.866	179	54.29	0.78
Annual Maximum	575,220	101.832	291	63.32	1.10
Difference between WY2002-2010 and Base Period					
Annual Minimum	19,655	-15.460	-69	-4.35	-0.17
Annual Average	70,854	0.119	-48	2.66	0.00
Annual Median	89,076	16.927	-16	6.30	0.18
Annual Maximum	-13,483	-89.329	-44	-9.15	-0.96
Annual Minimum	22%	-67%	-77%	-10%	-67%
Annual Average	29%	0%	-22%	5%	0%
Annual Median	42%	31%	-8%	13%	31%
Annual Maximum	-2%	-47%	-13%	-13%	-47%

Note: WY2001 was excluded due to negative TP Load, TP Concentration, and Unit Area Load.

3.7.2.2 Performance Measure 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 30 percent was determined to be reasonable and appropriate. Details are provided in Appendix D 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:

Target = -136.788 + 3.61027 Rain

Explained Variance = 72.6% , Standard Error of Regression = 21.79613 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:

$m_1 = \text{Sum}\ [\ r_1\ ]\ /\ 12$

$X = 12\ m_1$

Limit = Target + 1.41492 SE

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

$SE = 21.79613\ [\ 1 + 1/9 + (X-X_m)^2\ /\ 675.50602\ ]^{0.5}$

Where:

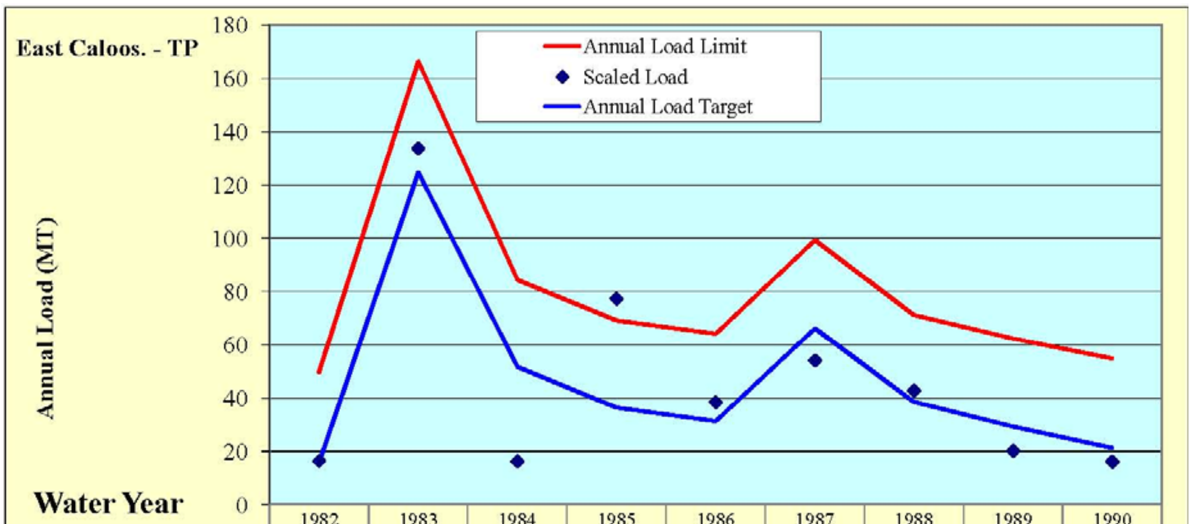
X = the 12-month total rainfall (inches)

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

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

A comparison of the scaled loads and the resulting Targets and Limits for the Base Period are presented in **Figure 3-42**. Annual TP loads at the hydrologic unit outlet structures, adjusted to account for regional projects (as applicable) and pass-through loads as described in Appendix A, will be evaluated against the performance measure described above.

Figure 3-42. Comparison of scaled annual loads with the Annual Load Targets and Limits for the East Caloosahatchee Hydrologic Unit.



Water Year	1982	1983	1984	1985	1986	1987	1988	1989	1990
Annual Load Limit	49.890	166.380	84.299	69.134	64.215	99.307	71.203	62.366	54.894
Scaled Load	16.466	133.813	16.360	77.322	38.457	54.158	42.839	20.159	16.230
Annual Load Target	15.890	124.848	51.740	36.469	31.342	66.145	38.599	29.392	21.378

Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load, adjusted for regional projects (if present), from the basin exceeds the Annual Load Target and the rainfall falls outside the range of rainfall values for the Base Period (42.29 – 72.47 inches). The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the WY1982-2010 period of record are summarized in **Table 3-53**. 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**.

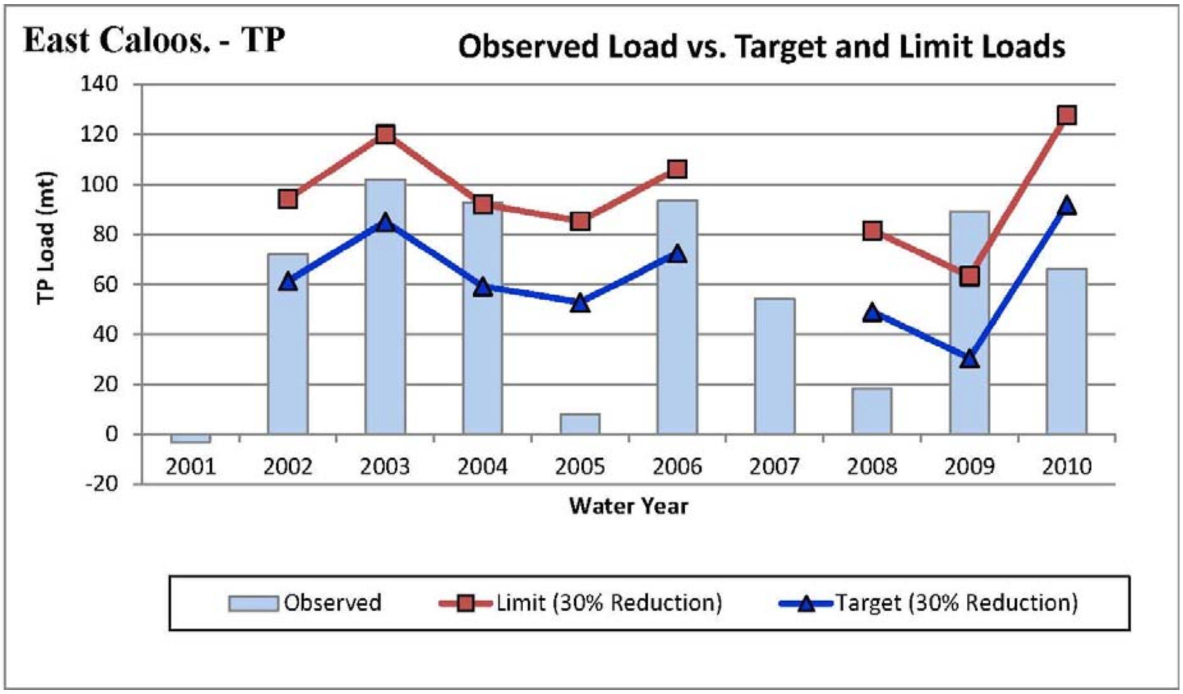
Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-43**.

Table 3-53. Annual adjusted rainfall for the historical period of record for the East Caloosahatchee Hydrologic Unit (Base Period: WY1982-1990).

Water Year	Observed Load, mt	Rain inches	Target Load, mt	Limit Load, mt
1982	23.523	42.29	15.890	49.890
1983	191.161	72.47	124.848	166.380
1984	23.371	52.22	51.740	84.299
1985	110.460	47.99	36.469	69.134
1986	54.939	46.57	31.342	64.215
1987	77.368	56.21	66.145	99.307
1988	61.198	48.58	38.599	71.203
1989	28.798	46.03	29.392	62.366
1990	23.185	43.81	21.378	54.894
1991	35.224	52.85	54.015	86.624
1992	63.448	59.68	78.673	112.888
1993	68.616	52.67	53.365	85.958
1994	37.434	47.73	35.530	68.227
1995	61.030	57.57	71.055	104.574
1996	64.927	57.42	70.513	103.989
1997	21.435	47.75	35.602	68.296
1998	57.387	62.17	87.662	122.911
1999	52.252	42.46	16.504	50.445
2000	53.363	60.47	81.525	116.044
2001	-3.251	34.44	-12.451	25.343
2002	71.866	54.89	61.379	94.268
2003	101.832	61.45	85.063	119.990
2004	92.878	54.29	59.213	92.001
2005	7.725	52.49	52.715	85.293
2006	93.518	57.97	72.499	106.137
2007	54.034	37.94	0.185	36.039
2008	18.112	51.49	49.105	81.627
2009	89.044	46.30	30.367	63.289
2010	66.063	63.32	91.814	127.612

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 3-43. Comparison of WY2001-2010 loads with Base Period loads and Annual Load Targets, adjusted for hydrologic variability, for the East Caloosahatchee Hydrologic Unit.



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

Exceedance Frequency Analysis. As shown in **Figure 3-42**, although the scaled observed loads fall above the Annual Load Target roughly half the time (five out of nine years, or 55 percent), only the scaled observed load for WY 1985 exceeded the calculated Annual Load Limit during the base period. In accordance with the proposed performance determination process discussed in Section 2.6, having the observed load exceed the Annual Load Limit would prevent the basin from meeting its performance measure for that year. In the case of the scaled Base Period data, this is an example of a Type I error[19], or "false positive" – when the performance method suggests a lack of compliance when the basin's load actually achieves the long-term reduction goals. While this occurrence is not common, it is statistically possible. The use of the upper 90 percent confidence limit for the Annual Load is consistent with the District's Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of approximately ten percent. Using the approach described in Section 2.6, 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 load of the Base Period (**Table 3-54**). 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 3-54. Exceedance frequencies for the proposed determination methodology for the East Caloosahatchee Hydrologic Unit.

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%	9.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.9%
Step 4. Load > Annual Load Limit?	<10%	4.3%
Cumulative Exceedance Frequency	**<17.5%**	**13.1%**

3.8 Upper Kissimmee Sub-watershed

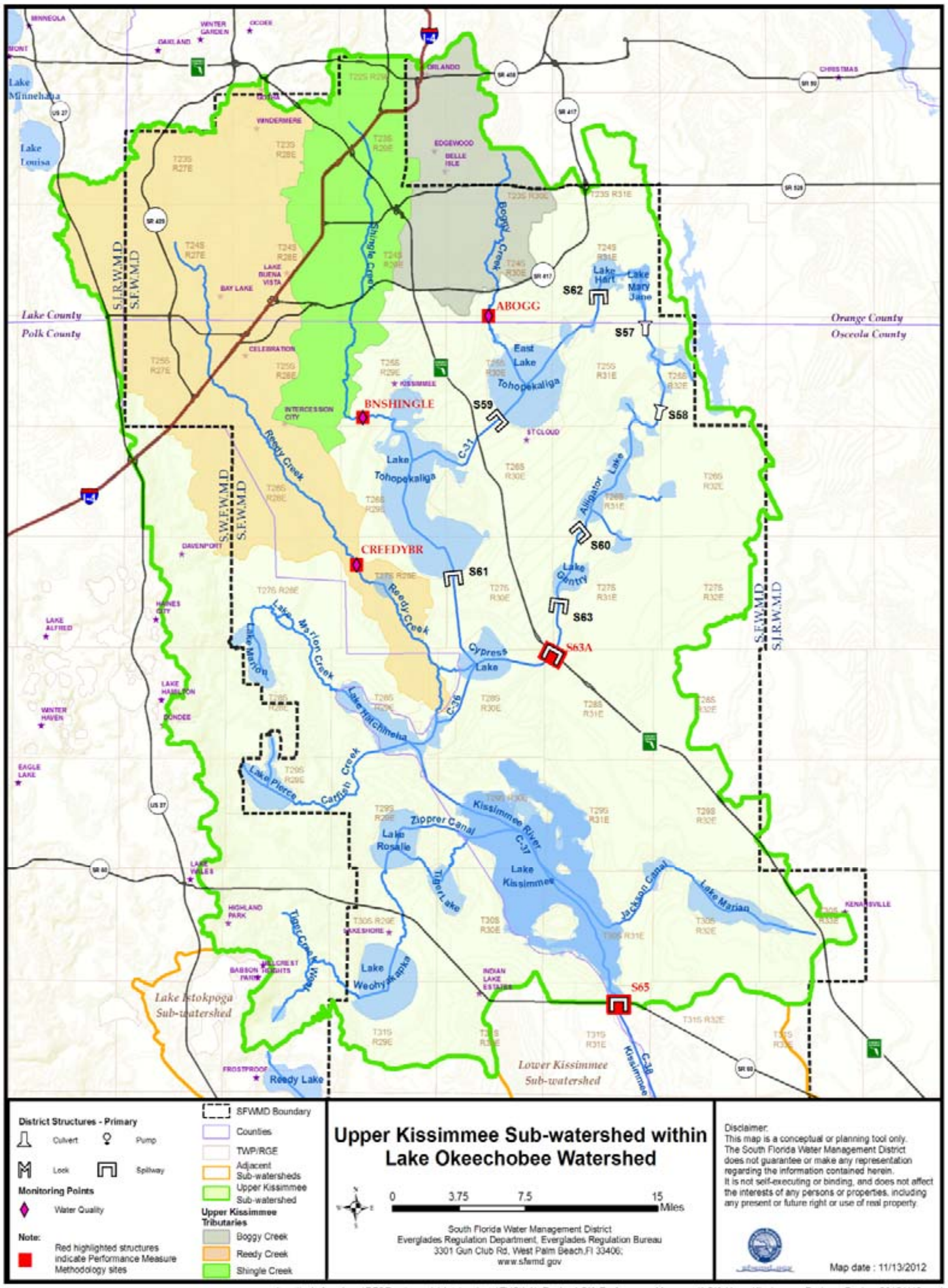
The following sections present a description of the Upper Kissimmee Sub-watershed, a summary of historical flow and TP levels, the selection of Reference Periods, and the derivation of the resulting performance indicators for tributaries within the sub-watershed.

3.8.1 Background

The Upper Kissimmee Sub-watershed is the headwaters of the Kissimmee-Okeechobee-Everglades hydrologic system, and consists of 1,028,421 acres occupying portions of Lake, Orange, Osceola, and Polk Counties (**Figure 3-44)**. The sub-watershed is composed of a large number of lakes connected by canals, creeks, and streams. Currently, canals connect all of the primary lakes to form the "Upper Kissimmee Chain of Lakes". Reedy Creek, Shingle Creek, and Boggy Creek are the largest tributaries in the sub-watershed. Lakes Kissimmee, Hatchineha, and Cypress are located at the downstream portion of the sub-watershed. Outflows from the Upper Kissimmee Sub-watershed are discharged to the Lower Kissimmee Sub-watershed via S-65.

District staff identified the rainfall stations considered to be representative of the Upper Kissimmee Sub-watershed for the period WY1976-2010. A schematic of the sub-watershed with the various rain stations is presented in **Figure 3-45** and **Figure 3-46B (Figure 3-45** is for WY 1976-2007 and **Figure 3-46** is for WY 2008 – Present). Monthly rainfall data and weighting factors for the rainfall stations were developed and provided by the District. Because of the nutrient attenuation effect of Lake Kissimmee, the nutrient loads discharged at S-65 may not be representative of stormwater runoff from within the sub-watershed, and thus the criteria for the establishment of a performance measure at S-65 were not met. Therefore, tributaries upstream of Lake Kissimmee were evaluated to see if there were sufficient data to develop performance measure methodologies in the individual tributaries.

Figure 3-44. Upper Kissimmee Sub-watershed boundary and discharge monitoring locations (from SFWMD).



\\sfwsd.sfwmd.gov\DFSRoot\err_gis\data\projects\EVG\lokRucks_LOK_PerformanceMeasures\LOK_UpperKissimmee_DrainageBasins_20121113.mxd

Figure 3-45. Schematic of Upper Kissimmee Sub-watershed (WY76-07) (from SFWMD).

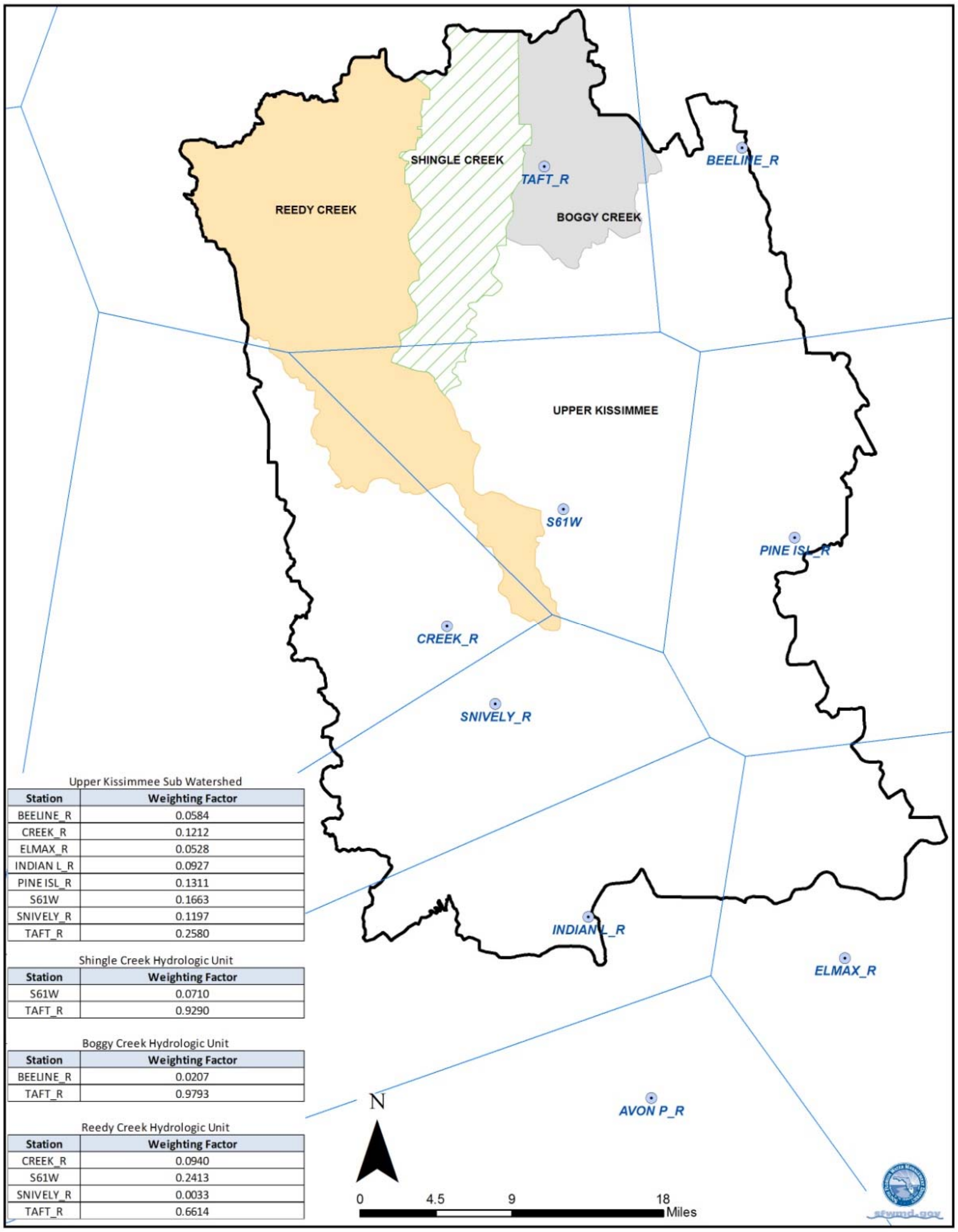
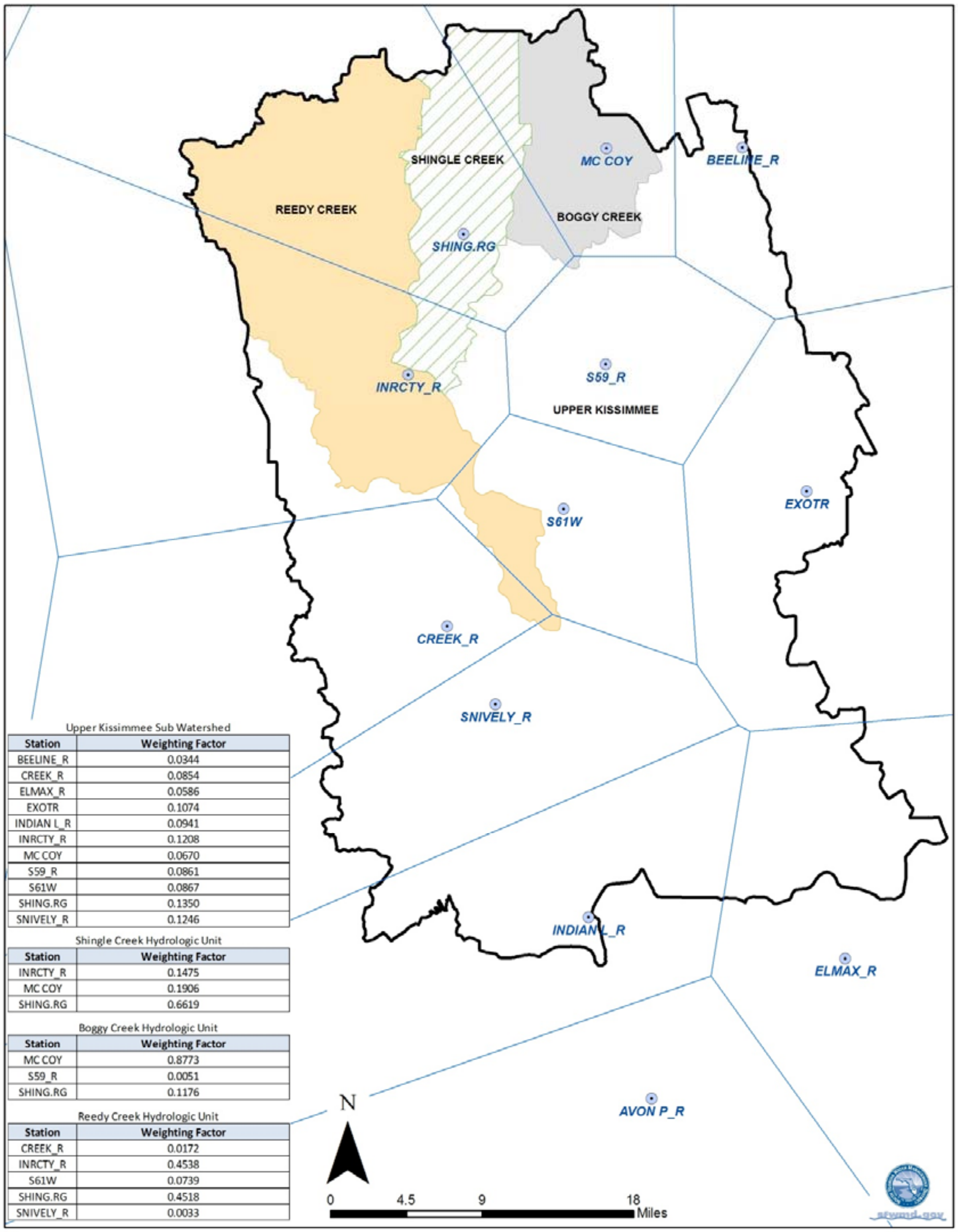


Figure 3-46. Schematic of Upper Kissimmee Sub-watershed (WY08-Present) (from SFWMD).



Upper Kissimmee Sub Watershed

Station	Weighting Factor
BEELINE_R	0.0344
CREEK_R	0.0854
ELMAX_R	0.0586
EXOTR	0.1074
INDIAN L_R	0.0941
INRCTY_R	0.1208
MC COY	0.0670
S59_R	0.0861
S61W	0.0867
SHING.RG	0.1350
SNIVELY_R	0.1246

Shingle Creek Hydrologic Unit

Station	Weighting Factor
INRCTY_R	0.1475
MC COY	0.1906
SHING.RG	0.6619

Boggy Creek Hydrologic Unit

Station	Weighting Factor
MC COY	0.8773
S59_R	0.0051
SHING.RG	0.1176

Reedy Creek Hydrologic Unit

Station	Weighting Factor
CREEK_R	0.0172
INRCTY_R	0.4538
S61W	0.0739
SHING.RG	0.4518
SNIVELY_R	0.0033

Stormwater runoff from much of the sub-watershed flows directly into multiple lakes within the sub-watershed (i.e., the Upper Chain of Lakes) and the majority of inflow locations are not monitored. Review of available data identified monitoring sites located on only three major tributaries upstream of the Upper Chain of Lakes. These discharge monitoring locations are shown in **Figure 3-44** and are further described below. In addition to the three major tributaries, there was another structure (S-63A) where both flow and water quality data are available (also shown in **Figure 3-44**). The S-63A structure is located on C-34, just upstream of Cypress Lake. These four areas are described below:

3. One site is located on Boggy Creek (ABOGG), which flows into East Lake Tohopekaliga. Monitoring has been conducted at that site for approximately 30 years. Boggy Creek has a tributary area of approximately 52,415 acres, or roughly five percent of the Upper Kissimmee Sub-watershed area. Flow data are recorded at a nearby USGS gauge (Boggy Creek near Taft, FL: ID no. 02262900).
4. One site is located on Shingle Creek (BNSHINGLE), which flows into Lake Tohopekaliga. Monitoring has been conducted at that site for approximately 30 years. Shingle Creek has a tributary area of approximately 68,153 acres, or roughly seven percent of the Upper Kissimmee Sub-watershed area. Flow data are recorded at a nearby USGS gauge (Shingle Creek at Campbell, FL: ID no. 02264495).
5. One site is located on Reedy Creek (CREEDYBR), which flows into Cypress Lake and Lake Hatchineha downstream of Lake Tohopekaliga. Reedy Creek has a tributary area of approximately 172,116 acres, or roughly seventeen percent of the Upper Kissimmee Sub-watershed area. Water quality monitoring has been conducted at that site for approximately 26 years; however, this site is not located at the discharge point from the tributary. Therefore, CREEDYBR does not represent the entire Reedy Creek Tributary. Also, there is not a nearby flow station. The nearest USGS station for flow monitoring is located approximately 10 river miles upstream and would not be adequate to estimate load with TP data collected at this water

quality monitoring site. However, it is recommended that monitoring be continued at this site so that in the future it can be determined if there is an increasing trend.

6. One site is located on C-34 (S-63A) just upstream of Cypress Lake. Water quality monitoring was initiated in WY2008, thus there is not sufficient water quality or flow data to provide a complete historical data analysis. It is recommended that monitoring be continued at this site so that in the future it can be determined if there is an increasing trend.

Both water quality and flow data are available for the Boggy Creek and Shingle Creek tributaries. However, performance measures were not developed for these tributaries because the boundaries were not well defined. Instead, prediction equations for performance indicators are recommended for the upstream tributaries at Boggy Creek and Shingle Creek. Available data were deemed not adequate to establish performance indicators for the Reedy Creek and S-63A basins. However, the water quality from these areas will be assessed annually to determine if there is an increasing trend. It is also recommended that in the remaining portion of the Upper Kissimmee Sub-watershed that bi-weekly grab monitoring for total phosphorus be conducted at key locations and assessed annually to determine if there is an increasing trend.

The following section summarizes the performance indicators for Boggy Creek and Shingle Creek.

3.8.1.1 Performance Measure Methodology

Site 1: Boggy Creek

Annual flow and TP data for discharges from the Boggy Creek Tributary are summarized in **Table 3-55**. For the development of the performance indicator, a Reference Period of WY2001-2008 was selected for the following reasons:

- it represents a period with minimal implementation of source controls. With the selection of the Reference Period to precede significant source control implementation, no additional calculation is necessary in the performance indicator to account for prior source control implementation,
- it represents a period of relatively constant land use practices,
- reliable water quality and hydrologic data are available, and
- a strong correlation exists between annual TP loads and rainfall, allowing for a performance indicator that explicitly incorporates hydrologic variability

The Reference Period is compared to the historical period of record and WY2001-2010 in **Table 3-56**.

Table 3-55. Summary of historical data for ABOGG, the outlet structure for the Boggy Creek Tributary for the WY 2001-2010 period of record.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
								Kurtosis K	Coef. Of Var. CV	Skewness S
2001	14,705	0.684	38	33.11	52,415	3.37	0.03	-0.987	0.890	0.696
2002	81,072	6.074	61	52.17	52,415	18.56	0.26	4.552	1.149	1.858
2003	114,393	9.034	64	78.11	52,415	26.19	0.38	-0.027	0.625	0.654
2004	70,089	3.961	46	54.94	52,415	16.05	0.17	2.017	0.919	1.359
2005	112,478	8.865	64	66.09	52,415	25.75	0.37	-1.434	0.849	0.655
2006	94,911	6.318	54	58.21	52,415	21.73	0.27	2.057	1.230	1.480
2007	22,714	0.832	30	37.94	52,415	5.20	0.03	-0.503	0.773	0.921
2008	37,085	1.507	33	45.58	52,415	8.49	0.06	3.993	0.762	1.492
2009	56,235	3.239	47	42.66	52,415	12.87	0.14	0.016	0.962	1.076
2010	88,570	3.760	34	69.45	52,415	20.28	0.16	3.080	0.604	1.370
Minimum	***14,705***	***0.684***	***30***	***33.11***	***52,415***	***3.37***	***0.03***	***-1.434***	***0.604***	***0.654***
Average	***69,225***	***4.427***	***52***	***53.83***	***52,415***	***15.85***	***0.19***	***1.276***	***0.876***	***1.156***
Maximum	***114,393***	***9.034***	***64***	***78.11***	***52,415***	***26.19***	***0.38***	***4.552***	***1.230***	***1.858***
Std. Dev.	***35,627***	***3.069***	***13***	***14.46***	***0***	***8.16***	***0.13***	***2.146***	***0.203***	***0.418***
Skewness	***-0.305***	***0.339***	***0.113***	***0.239***	***0.000***	***-0.305***	***0.34***	***0.289***	***0.441***	***0.138***
Median	***75,581***	***3.861***	***47***	***53.56***	***52,415***	***17.30***	***0.16***	***1.017***	***0.870***	***1.218***

Table 3-56. Comparison of the Reference Period with the period of record data for Boggy Creek.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	UAL lbs/ac
Period of Record - WY2001-2010					
Annual Minimum	14,705	0.684	30	33.11	0.03
Annual Average	69,225	4.427	52	53.83	0.19
Annual Median	75,581	3.861	47	53.56	0.16
Annual Maximum	114,393	9.034	64	78.11	0.38
Preliminary Reference Period WY2001-2008					
Annual Minimum	14,705	0.684	30	33.11	0.03
Annual Average	68,431	4.659	55	53.27	0.20
Annual Median	75,581	5.018	50	53.56	0.21
Annual Maximum	114,393	9.034	64	78.11	0.38
Difference between Period of Record and Reference Period					
Annual Minimum	0	0.000	0	0.00	0.000
Annual Average	794	-0.232	-3	0.56	-0.010
Annual Median	0	-1.157	-4	0.00	-0.049
Annual Maximum	0	0.000	0	0.00	0.000
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	1%	-5%	-6%	1%	-5%
Annual Median	0%	-23%	-7%	0%	-23%
Annual Maximum	0%	0%	0%	0%	0%
Preliminary Reference Period WY2001-2008					
Annual Minimum	14,705	0.684	30	33.11	0.03
Annual Average	68,431	4.659	55	53.27	0.20
Annual Median	75,581	5.018	50	53.56	0.21
Annual Maximum	114,393	9.034	64	78.11	0.38
WY2001-2010					
Annual Minimum	14,705	0.684	30	33.11	0.03
Annual Average	69,225	4.427	52	53.83	0.19
Annual Median	75,581	3.861	47	53.56	0.16
Annual Maximum	114,393	9.034	64	78.11	0.38
Difference between WY2001-2010 and Reference Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	794	-0.232	-3	0.56	-0.01
Annual Median	0	-1.157	-4	0.00	-0.05
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	1%	-5%	-6%	1%	-5%
Annual Median	0%	-23%	-7%	0%	-23%
Annual Maximum	0%	0%	0%	0%	0%

Based on the fact that the annual median total phosphorus concentration for the period of record (47 µg/l) is below the Numeric Nutrient Criteria (120 µg/l for TP) (Chapter 62-302, F.A.C.), it is recommended that no reduction goal be applied to tributary. An Annual Load Target and an Annual Load Limit for the Boggy Creek Tributary will be calculated according to the following equations and explanation:

$\text{Target} = (-2.39491 + 0.05939\ X + 1.35719\ C)^2$

Explained Variance = 98.0 percent, Standard Error of Regression Equation = 0.2072

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:

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

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

$X = 12\ m_1$

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

$\text{Limit} = [\ \text{sqrt}\ (\text{Target}) + (1.47588\ \text{SE})]^2$

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

$\text{SE} = 0.20722\ [1 + 1/8 + 0.0007\ (X-X_m)^2 + 3.58103\ (C–C_m)^2 + 0.0135\ (X-X_m)\ (C–C_m)]^{0.5}$

Where:

X = the 12-month total rainfall (inches)

C = coefficient of variation calculated from 12 monthly rainfall totals

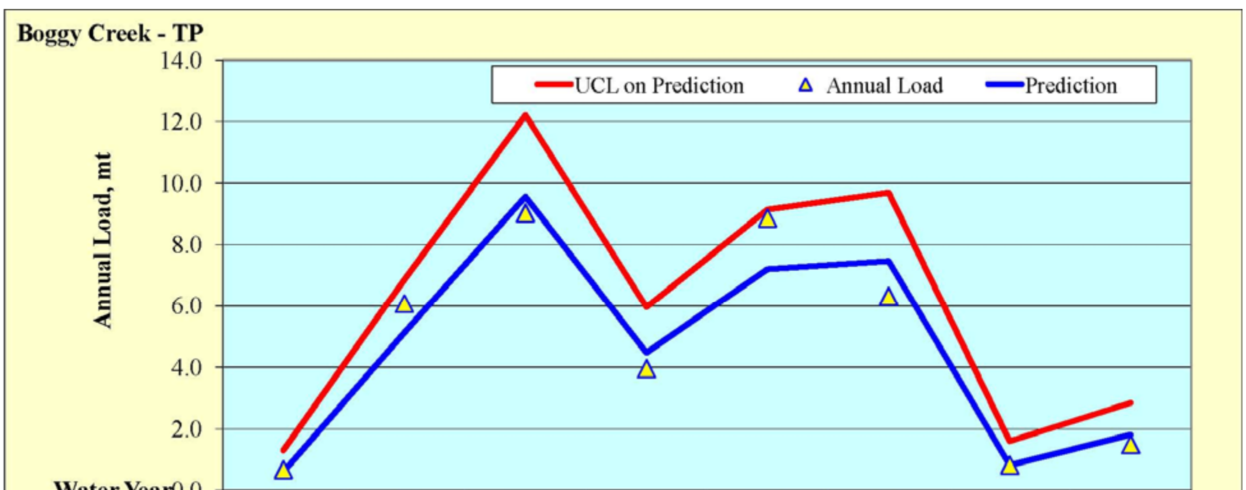
X_m = average value of the predictor in reference period = 53.269 inches

C_m = average value of the predictor in reference period = 0.89963

The first predictor (X) indicates that load increases with 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 occurs when rainfall is evenly distributed across months and the highest load occurs when all of the rain falls in one month. Real cases are likely to fall in between.

A comparison of the observed loads and the resulting Targets and Limits for the Reference Period are presented in **Figure 3-47.** Annual TP loads at the tributary outlet monitoring location, adjusted to account for regional projects (as applicable) and pass-through loads as described in Appendix A, will be evaluated against the performance measure described above.

Figure 3-47. Comparison of observed annual loads with the Annual Load Targets and Limits for the Boggy Creek Tributary.



Water Year	2001	2002	2003	2004	2005	2006	2007	2008
UCL on Prediction	1.306	6.852	12.216	5.955	9.139	9.691	1.602	2.850
Annual Load	0.684	6.074	9.034	3.961	8.865	6.318	0.832	1.507
Prediction	0.608	5.121	9.563	4.475	7.196	7.462	0.824	1.813

Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load from the basin, adjusted for regional projects (if present), exceeds the Annual Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Reference Period (32.89 – 71.83 inches), as derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall amount which reflects the cumulative effect of the predictor variables of the Annual Load Target equation. The adjusted rainfall is the rainfall that would produce the equivalent annual load using the Annual Load Target equation by setting the value of C to its mean value for the calibration period.

$$\text{Adjusted Rain} = X + 22.85216\,(C - 0.89963)$$

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY2001-2010 period of record are summarized in **Table 3-57**.

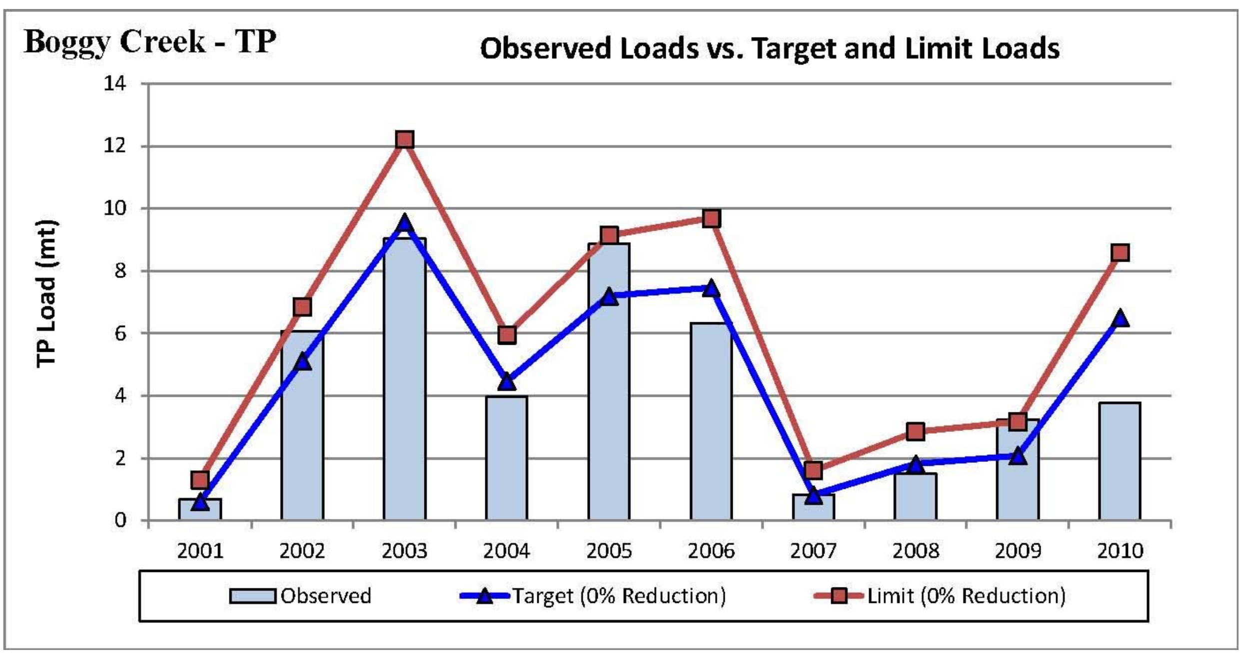
The annual performance determination process will account for pass-through loads and regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-48**.

Table 3-57. Annual adjusted rainfall for the historical period of record for the Boggy Creek Tributary (Reference Period: WY2001-2008).

Water Year	Observed Load, mt	Rain in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
2001	0.684	33.11	0.890	0.608	1.307	32.89
2002	6.074	52.17	1.149	5.121	6.852	57.87
2003	9.034	78.11	0.625	9.563	12.216	71.83
2004	3.961	54.94	0.919	4.475	5.955	55.38
2005	8.865	66.09	0.849	7.196	9.139	64.93
2006	6.318	58.21	1.230	7.462	9.691	65.76
2007	0.832	37.94	0.773	0.824	1.603	35.05
2008	1.507	45.58	0.762	1.813	2.850	42.43
2009	3.239	42.66	0.962	2.086	3.170	44.09
2010	3.760	69.45	0.604	6.500	8.591	62.69

Figure 3-48. Comparison of WY2001-2010 loads with Reference Period loads and Annual Load Targets, adjusted for hydrologic variability, for the Boggy Creek Tributary.



Note: The Reference Period extended from WY2001-2008.

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 3-58**). 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 3-58. Exceedance frequencies for the proposed determination methodology for the Boggy 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 $Rain_{adj}$ is outside the range and Load > Annual Load Target	<20%	9.9%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.7%
Step 4. Load > Annual Load Limit?	<10%	1.9%
Cumulative Exceedance Frequency	**<17.5%**	**10.9%**

Site 2: Shingle Creek

Annual flow and TP data for discharges from the Shingle Creek Tributary are summarized in **Table 3-59**. For the development of the performance indicator, a Reference Period of WY1999-2007 was selected for the following reasons:

- it represents a period with minimal implementation of source controls. With the selection of the Reference Period to precede significant source control implementation, no additional calculation is necessary in the performance indicator to account for prior source control implementation,
- it represents a period of relatively constant land use practices,
- reliable water quality and hydrologic data are available, and
- a strong correlation exists between annual TP loads and rainfall, allowing for a performance indicator that explicitly incorporates hydrologic variability

The Reference Period is compared to the historical period of record and WY2001-2010 in **Table 3-60**.

Table 3-59. Summary of historical data for BNSHINGLE, the outlet structure for the Shingle Creek Tributary for the WY 1999-2010 period of record.

Water Year	Flow AF	Load mt	FWM Conc, µg/L	Rainfall inches	Unit Area Runoff, inches	Unit Area Load, lbs/ac	Kurtosis K	Coef. Of Var. CV	Skewness S
1999	80,049	6.522	66	40.77	14.09	0.21	1.881	0.974	1.495
2000	95,791	8.870	75	49.97	16.87	0.29	4.365	1.057	1.875
2001	43,203	4.345	82	33.59	7.61	0.14	-0.960	0.897	0.696
2002	143,879	17.484	99	51.94	25.33	0.57	4.200	1.127	1.793
2003	300,377	39.935	108	76.98	52.89	1.29	-0.036	0.625	0.680
2004	214,290	21.736	82	53.90	37.73	0.70	1.913	0.907	1.324
2005	319,611	35.119	89	64.88	56.28	1.14	-1.344	0.851	0.685
2006	184,112	17.421	77	57.80	32.42	0.56	2.337	1.229	1.530
2007	87,421	7.388	69	37.45	15.39	0.24	-0.604	0.766	0.903
2008	132,363	10.956	67	43.71	23.31	0.35	5.591	0.754	1.888
2009	95,280	10.724	91	36.42	16.78	0.35	2.629	0.942	1.551
2010	231,653	18.445	65	75.82	40.79	0.60	0.617	0.641	0.817
Minimum	***43,203***	***4.345***	***65***	***33.59***	***7.61***	***0.14***	***-1.344***	***0.625***	***0.680***
Average	***160,669***	***16.579***	***84***	***51.94***	***28.29***	***0.54***	***1.716***	***0.898***	***1.270***
Maximum	***319,611***	***39.935***	***108***	***76.98***	***56.28***	***1.29***	***5.591***	***1.229***	***1.888***
Std. Dev.	***89,684***	***11.207***	***14***	***14.73***	***15.79***	***0.36***	***2.250***	***0.185***	***0.484***
Median	***138,121***	***14.189***	***80***	***50.96***	***24.32***	***0.46***	***1.897***	***0.902***	***1.410***
Skewness	***0.627***	***1.147***	***0.660***	***0.574***	***0.63***	***1.15***	***0.251***	***0.184***	***-0.080***

Table 3-60. Comparison of the Reference Period with the period of record data for Shingle Creek.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1999-2010					
Annual Minimum	43,203	4.345	65	33.59	0.14
Annual Average	160,669	16.579	84	51.94	0.54
Annual Median	138,121	14.189	80	50.96	0.46
Annual Maximum	319,611	39.935	108	76.98	1.29
Reference Period WY1999-2007					
Annual Minimum	43,203	4.345	66	33.59	0.14
Annual Average	163,193	17.647	88	51.92	0.57
Annual Median	143,879	17.421	82	51.94	0.56
Annual Maximum	319,611	39.935	108	76.98	1.29
Difference between Period of Record and Reference Period					
Annual Minimum	0	0.000	-1	0.00	0.00
Annual Average	-2,523	-1.068	-4	0.02	-0.03
Annual Median	-5,758	-3.233	-3	-0.98	-0.10
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	-2%	0%	0%
Annual Average	-2%	-6%	-5%	0%	-6%
Annual Median	-4%	-19%	-3%	-2%	-19%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	43,203	4.345	65	33.59	0.14
Annual Average	175,219	18.355	85	53.25	0.59
Annual Median	163,996	17.453	82	52.92	0.56
Annual Maximum	319,611	39.935	108	76.98	1.29
Difference between WY2001-2010 and Reference Period					
Annual Minimum	0	0.000	-1	0.00	0.00
Annual Average	12,026	0.709	-3	1.33	0.02
Annual Median	20,117	0.032	0	0.98	0.00
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	-2%	0%	0%
Annual Average	7%	4%	-3%	3%	4%
Annual Median	14%	0%	0%	2%	0%
Annual Maximum	0%	0%	0%	0%	0%

Based on the fact that the annual median total phosphorus concentration for the period of record (80 µg/l) is below the Numeric Nutrient Criteria (120 µg/l) (Chapter 62-302, F.A.C.), it is recommended that no reduction goal be applied to tributary. An Annual Load Target and an Annual Load Limit for the Shingle Creek Tributary will be calculated according to the following equations and explanation:

Target = -140.82331 + 43.29617 X + 9.1697 S

Explained Variance = 96.9 percent, Standard Error of Regression Equation = 2.5823

Predictors (X and S) are calculated from the first two 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 = 12 m_1

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

Limit = Target + 1.440 SE

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

$SE = 2.58225 [1 + 1/9 + 1.7741 (X-X_m)^2 + 0.52978 (S–S_m)^2 + 0.10178 (X-X_m) (S–S_m)]^{0.5}$

Where:

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

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

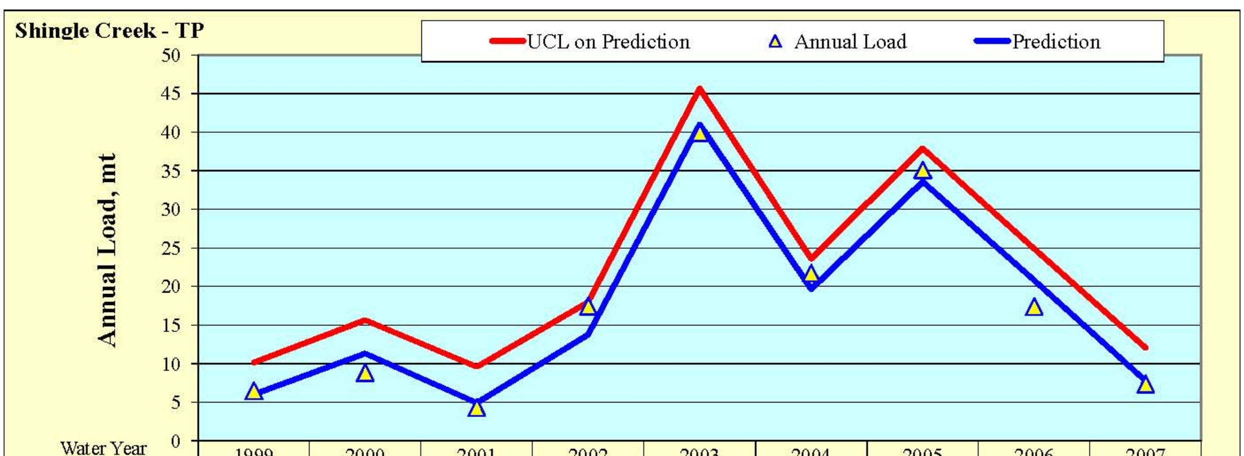
X_m = average value of the predictor in reference period = 3.919

S_m = average value of the predictor in reference period = 1.22011

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 observed loads and the resulting Targets and Limits for the Reference Period are presented in **Figure 3-49.** Annual TP loads at the tributary outlet monitoring location, adjusted to account for regional projects (as applicable) and pass-through loads as described in Appendix A, will be evaluated against the performance measure described above.

Figure 3-49. Comparison of observed annual loads with the Annual Load Targets and Limits for the Shingle Creek Tributary.



Water Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
UCL on Prediction	10.121	15.633	9.603	17.980	45.648	23.608	37.892	24.872	12.045
Annual Load	6.522	8.870	4.345	17.484	39.935	21.736	35.119	17.421	7.388
Prediction	6.008	11.333	4.947	13.759	41.000	19.663	33.550	20.799	7.759

Suspension of Performance Determination. The performance determination will be suspended due to rainfall conditions if the observed annual TP load from the basin, adjusted for regional projects (if present), exceeds the Annual Load Target and the adjusted rainfall falls outside the range of adjusted rainfall values for the Reference Period (37.53 – 86.31 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)

Adjusted Rain = exp[X – 0.21179 (S – 1.22011)

The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the WY1983-2010 period of record are summarized in **Table 3-61**.

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**.

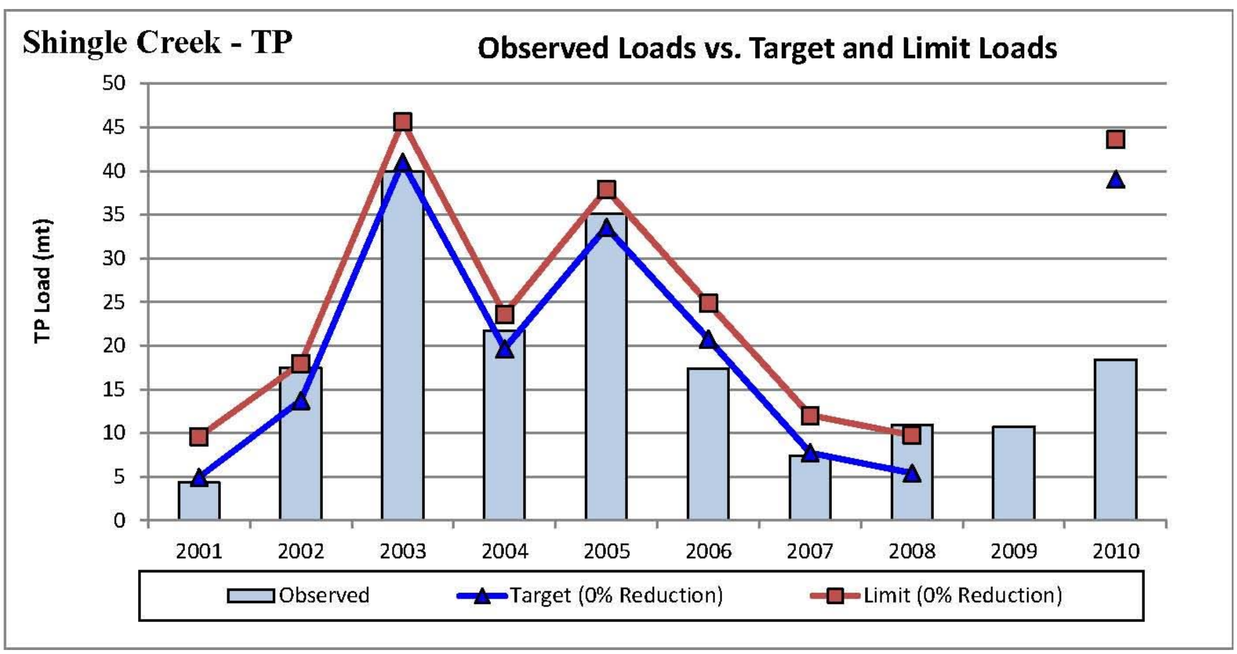
Comparison to WY2001-2010. A comparison of the WY2001-2010 observed loads to the Annual Load Targets and Limits is presented in **Figure 3-50**.

Table 3-61. Annual adjusted rainfall for the historical period of record for the Shingle Creek Tributary (Reference Period: WY2001-2008).

Water Year	Observed Load, mt	Ln(rain)	S	Target Load, mt	SE Load, mt	Limit Load, mt	Adjusted Rain, in
1999	6.522	3.70795	1.495	6.008	2.857	10.121	38.46
2000	8.870	3.91142	1.875	11.333	2.987	15.633	43.50
2001	4.345	3.51423	0.696	4.947	3.234	9.603	37.53
2002	17.484	3.95009	1.793	13.759	2.931	17.980	46.01
2003	39.935	4.34355	0.680	41.000	3.228	45.648	86.31
2004	21.736	3.98713	1.324	19.663	2.740	23.608	52.73
2005	35.119	4.17254	0.685	33.550	3.015	37.892	72.67
2006	17.421	4.05699	1.530	20.799	2.829	24.872	54.13
2007	7.388	3.62301	0.903	7.759	2.977	12.045	40.05
2008	10.956	3.77758	1.888	5.419	3.026	9.776	37.94
2009	10.724	3.59512	1.551	0.609	2.993	4.919	33.96
2010	18.445	4.32836	0.817	39.086	3.140	43.607	82.58

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 3-50. Comparison of WY2001-2010 loads with Reference Period loads and Annual Load Targets, adjusted for hydrologic variability, for the Shingle Creek Tributary.



Note: The Reference Period extended from WY2001-2007. The performance determination for WY2009 would have been suspended due to rainfall below the minimum value during the Reference Period coupled with the observed load being greater than the Load Target.

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 3-62**). 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.

Table 3-62. Exceedance frequencies for the proposed determination methodology for the Shingle 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%	6.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.8%
Step 4. Load > Annual Load Limit?	<10%	3.0%
Cumulative Exceedance Frequency	**<17.5%**	**13.0%**

3.9 South Lake Okeechobee Sub-watershed

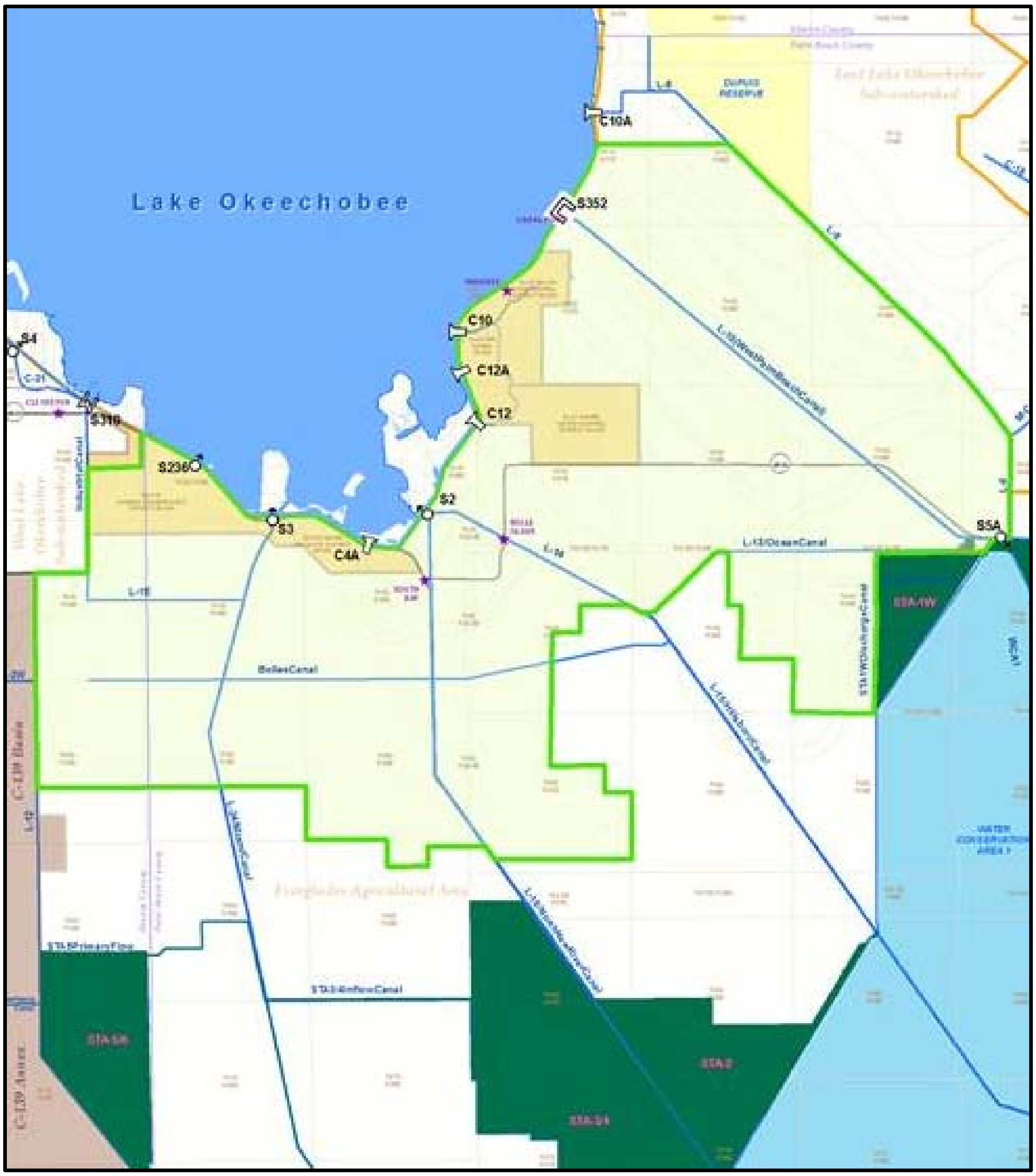
The South Lake Okeechobee Sub-watershed contains the northern Everglades Agricultural Area (EAA) including those portions of four special drainage districts established through Chapter 298 of the Florida Statutes historically discharging to Lake Okeechobee. In addition, Closter Farms, also known as 715 Farms and referenced as Agricultural Lease No. 3420 in the Everglades Forever Act (Chapter 473.4592, F.S.), is located within the South Lake Okeechobee Sub-watershed and historically discharged to the lake. These basins and structures discharging to Lake Okeechobee are presented in **Table 3-63** and **Figure 3-51**.

Table 3-63. South Lake Okeechobee Sub-Watershed basins and Lake discharge structures.

Basin Name	Structures discharging to Lake Okeechobee
Everglades Agricultural Area (EAA)	S2, S3, S352
East Beach Water Control District (EBWCD)	Culvert 10
East Shore Water Control District (ESWCD)	Culvert 12
South Shore Drainage District (SSDD)	Culvert 4A
South Florida Conservancy District (SFCD)	S-236
Closter Farms	Culvert 12A

Because of the critical importance of the Kissimmee-Lake Okeechobee-Everglades ecosystem, many programs work in concert to protect the water resources of the region as a whole. The performance measure methodologies summarized herein for the South Lake Okeechobee Sub-watershed complement the other regulatory programs designed to support achievement of the Lake Okeechobee TP TMDL of 140 metric tons per year (mt/yr), as defined in Chapter 62-304.700, F.A.C. Section 2.4 describes the relationship between the TMDL program and the performance measure methodologies developed for Chapters 40E-61 and 40E-63 F.A.C. The relationship between the 2011 LOPP planning level estimates and the performance measure methodologies summarized in this document is also described in Section 2.4.

Figure 3-51. South Lake Okeechobee Sub-watershed boundary and monitoring locations for structures that discharge into Lake Okeechobee.



The EAA Basin discharges to both Lake Okeechobee and, at times, to the Everglades Protection Area, although the primary receiving bodies for the southern discharges are the Everglades Stormwater Treatment Areas. The existing performance measure methodology for the collective source control programs within the EAA Basin is described in Chapter 40E-63 F.A.C. and encompasses cumulative basin runoff loads, regardless of the direction of discharge. The following sections summarize the historical annual flow, TP and rainfall data, a summary of the existing performance methodology for the EAA Basin and a summary of the proposed performance measure methodologies for the Chapter 298 Districts.

3.9.1 Summary of the Historic Data and Existing Performance Measure Methodology for the EAA Basin

The EAA Basin covers approximately 500,000 acres located south of Lake Okeechobee within eastern Hendry and western Palm Beach counties, an area of approximately 1,122 square miles of highly productive agricultural land comprised of rich organic peat or muck soils (SFWMD 2011b). The area is considered to be one of Florida's most important agricultural regions, with approximately 77 percent of the EAA devoted to agricultural production. The major crops in the EAA Basin include sugar cane, vegetables, and sod, with secondary crops in rice and citrus.

3.9.1.1 EAA Basin Background

The goal of the Everglades Regulatory Program in the EAA Basin under Chapter 40E-63 F.A.C. is to reduce the TP loads discharged from the basin by 25 percent. The EAA regulated area is defined by multiple hydrologic drainage sub-basins. EAA Basin runoff load is based upon the total discharge load less pass-through computed inflows from other areas. Although the boundaries of these sub-basins remain static, the acreage contributing flow and used in the rule-adopted compliance model for determining EAA Basin TP load varies from year to year as regional projects are constructed.

3.9.1.2 EAA Basin Historical Data

The District conducts EAA basin-level monitoring at all inflow and outflow structures to be used for assessing compliance with the source control program performance measure methodology. Annual observed runoff TP load from the EAA Basin for primary compliance includes both inflow and outflow structures from the EAA at which TP concentrations and flows are measured. EAA Basin runoff loads are estimated after first calculating pass-through loads from other sources. Specific details are provided in the Draft Technical Support Document for Chapter 40E-63, F.A.C. (SFWMD 1992).

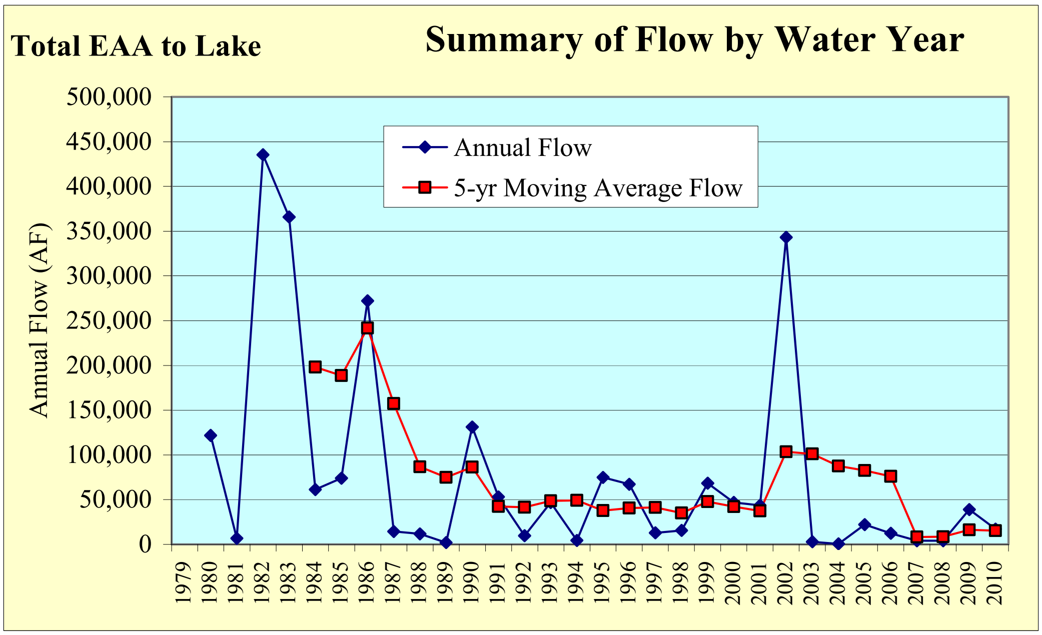
A summary of the annual rainfall, total flows (i.e., basin runoff plus pass-through), and total TP levels for the EAA is presented in **Table 3-64** and **Figure 3-52**. A downward trend in EAA flow volume and TP load in the direction of the lake is evident. This operational change has resulted in a greater percentage of the discharge being directed to the STAs for treatment and lowering the amount of discharge to the Lake Okeechobee, however, this diversion does not contribute to meeting the total runoff load reduction requirements.

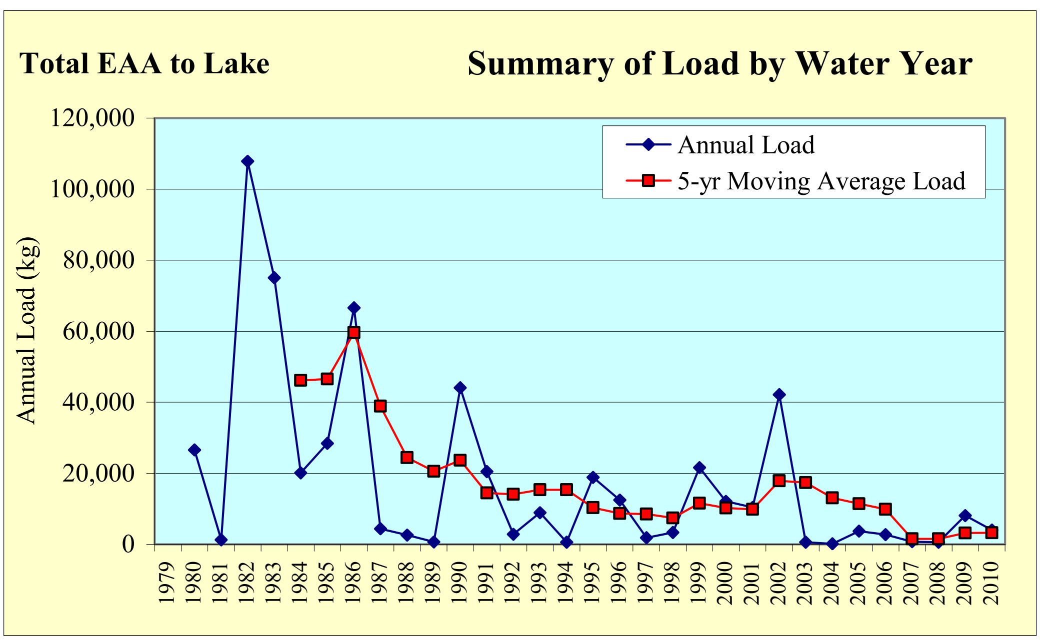
Table 3-64. Annual summary of total discharges from the EAA Basin.

Water Year	Rainfall inches	Total (1) Flow from EAA Basin: Total AF	To Lake AF	Percent to Lake	Total (1) TP Loads from EAA Basin: Total kg	To Lake kg	Percent to Lake	TP Concentrations: Total µg/L	To Lake µg/L
1980	53.50	1,217,485	121,763	10%	172,102	26,560	15%	115	177
1981	35.05	609,935	6,916	1%	90,503	1,250	1%	120	146
1982	46.65	830,700	435,530	52%	235,235	107,824	46%	230	201
1983	64.35	2,053,263	365,911	18%	520,894	74,996	14%	206	166
1984	49.83	1,258,721	61,174	5%	240,896	20,129	8%	155	267
1985	39.70	1,156,918	74,015	6%	260,503	28,426	11%	183	311
1986	51.15	1,174,455	272,057	23%	211,732	66,555	31%	146	198
1987	51.97	1,337,859	14,327	1%	279,160	4,356	2%	169	247
1988	43.43	914,909	11,790	1%	166,176	2,595	2%	147	178
1989	39.68	1,000,027	2,037	0%	218,289	682	0%	177	271
1990	40.14	966,874	131,261	14%	168,724	44,116	26%	141	272
1991	50.37	699,690	53,102	8%	172,568	20,485	12%	200	313
1992	47.61	1,123,912	9,703	1%	126,689	2,786	2%	91	233
1993	61.69	2,719,477	46,937	2%	411,485	8,918	2%	123	154
1994	50.45	1,057,001	4,546	0%	138,484	567	0%	106	101
1995	67.01	2,340,460	74,955	3%	340,763	18,820	6%	118	204
1996	56.86	1,824,342	67,336	4%	246,022	12,467	5%	109	150
1997	52.02	1,204,192	12,924	1%	147,757	1,866	1%	99	117
1998	56.12	1,465,369	15,615	1%	188,813	3,320	2%	104	172
1999	43.42	1,251,036	68,358	5%	182,610	21,566	12%	118	256
2000	57.51	1,623,541	46,785	3%	250,974	12,118	5%	125	210
2001	37.28	811,773	43,771	5%	109,043	10,392	10%	109	192
2002	49.14	1,306,561	343,221	26%	127,072	42,187	33%	79	100
2003	45.55	1,668,000	2,839	0%	209,482	617	0%	102	176
2004	46.76	1,280,414	465	0%	129,176	131	0%	82	228
2005	50.98	2,131,470	22,054	1%	278,050	3,691	1%	106	136
2006	50.08	1,292,920	12,323	1%	218,231	2,767	1%	137	182
2007	37.23	844,300	4,225	1%	175,601	744	0%	169	143
2008	46.95	655,894	4,108	1%	103,703	622	1%	128	123
2009	43.72	1,028,954	38,774	4%	165,371	8,093	5%	130	169
2010	61.88	1,290,235	17,082	1%	213,556	4,018	2%	134	191
POR Minimum	35.05	609,935	465	0%	90,503	131	0%	79	100
POR Average	49.29	1,294,861	76,965	6%	209,666	17,860	9%	131	188
POR Maximum	67.01	2,719,477	435,530	52%	520,894	107,824	46%	230	313
Base Period	**WY1980-1988**								
BP Minimum	35.05	609,935	6,916	1%	90,503	1,250	1%	115	146
BP Average	48.40	1,172,694	151,498	13%	241,911	36,966	15%	167	198
BP Maximum	64.35	2,053,263	435,530	52%	520,894	107,824	46%	230	311

Notes:
(1) Total includes flow-through from adjacent areas

Figure 3-52. Annual summary of total discharges from the EAA Basin to Lake Okeechobee.





3.9.1.3 EAA Basin Existing Performance Measure Summary

To evaluate compliance with the EAA basin-level TP load reduction requirements, the District annually evaluates BMP performance consistent with Chapter 40E-63 F.A.C. The EAA Basin must demonstrate a 25 percent reduction in load annually compared to the pre-BMP base period. Phosphorus load reduction calculations are conducted and reported annually. These calculations are made using an adjustment for the hydrologic variability associated with rainfall and surface water discharges over time. These adjusted equations, calibrated to the WY1980–WY1988 base period (May 1, 1979 through April 30, 1988), attempt to predict what the average annual TP load would have been for the EAA Basin if the current water year's rainfall amount and monthly distribution had occurred during the base period.

Compliance with EAA Basin performance goal is based on mathematical equations and methodology outlined in Chapter 40E-63, F.A.C. The target load is based upon a 25 percent reduction in loading as well as accounting for a reduction in the EAA Basin area by a factor equal to the current acreage divided by the baseline acreage. The performance determination is suspended if the adjusted rainfall for the Evaluation Year exceeds 63.76 inches and the basin load is above the target. Compliance is determined by comparing the observed runoff TP loads for the Evaluation Year, adjusted for pass-through loads, to the target loads from the base period.

The EAA Basin has been in compliance with the Everglades Regulatory Program of BMPs since the first compliance year, WY1996. Since the program's initiation, the EAA's average annual percentage load reduction is greater than 50 percent.

3.9.2 Summary of the Chapter 298 Districts Historic Data and Proposed Performance Measure Methodologies

The South Lake Okeechobee Sub-watershed contains four special drainage districts established through Chapter 298 of the Florida Statutes and Closter Farms, all located along the southern rim of Lake Okeechobee. In addition to discharging to the lake, the EBWCD, SSDD and SFCD also historically discharged stormwater into the surrounding canals of the EAA. Funded from agricultural privilege taxes and other sources, infrastructure improvements were completed between 2001 and 2005 to allow diversion of the lake discharges to the primary canal system of the EAA operated by the District:

- EBWCD: diversion works completed July 2001
- ESWCD: diversion works completed December 2001
- Closter Farms: diversion works completed December 2001
- SSDD: diversion works completed July 2004
- SFCD: diversion works completed June 2005

These basins are herein collectively referred to as the "Chapter 298 Districts". Performance measure methodologies for these basins will evaluate levels in each basin's combined discharge to Lake Okeechobee and the diversion works to the EAA. These methodologies are summarized herein and detailed within the *Draft – Performance Measure Methodology for the Chapter 298 Districts and Closter Farms* (Goforth et al. 2013)[22].

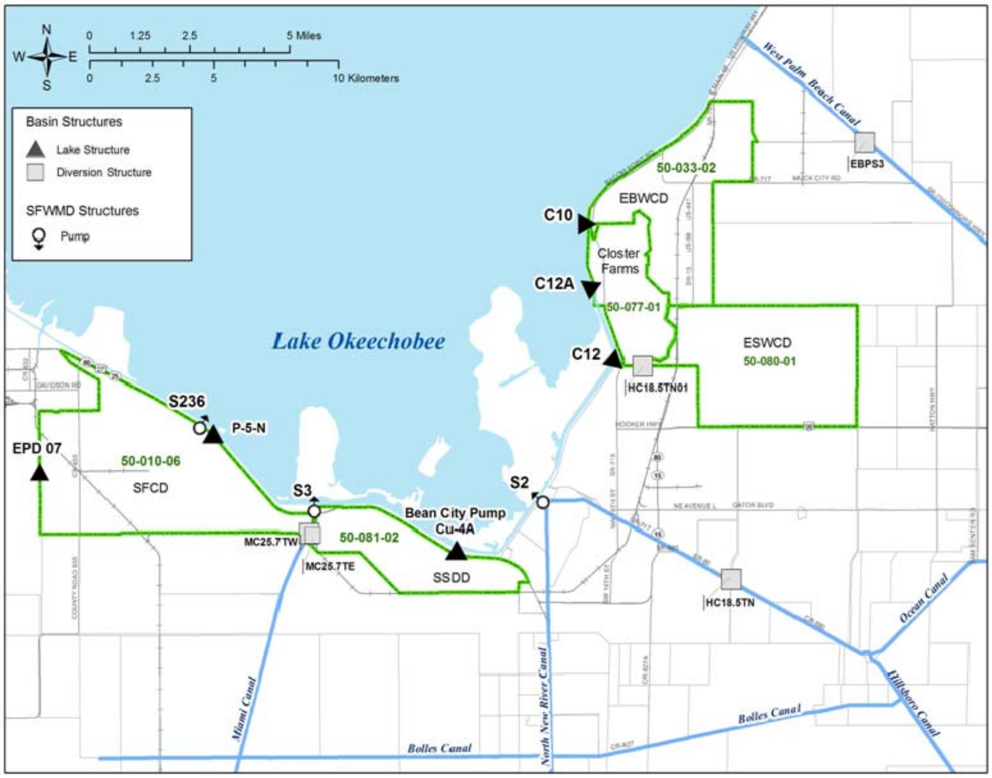
[22] The performance measure methodologies for the Ch. 298 Districts were developed under a different contract than the Lake Okeechobee Watershed performance measure methodologies, resulting in slight differences in data presentation, e.g., the period of record extended through WY2012 for the Ch. 298 Districts.

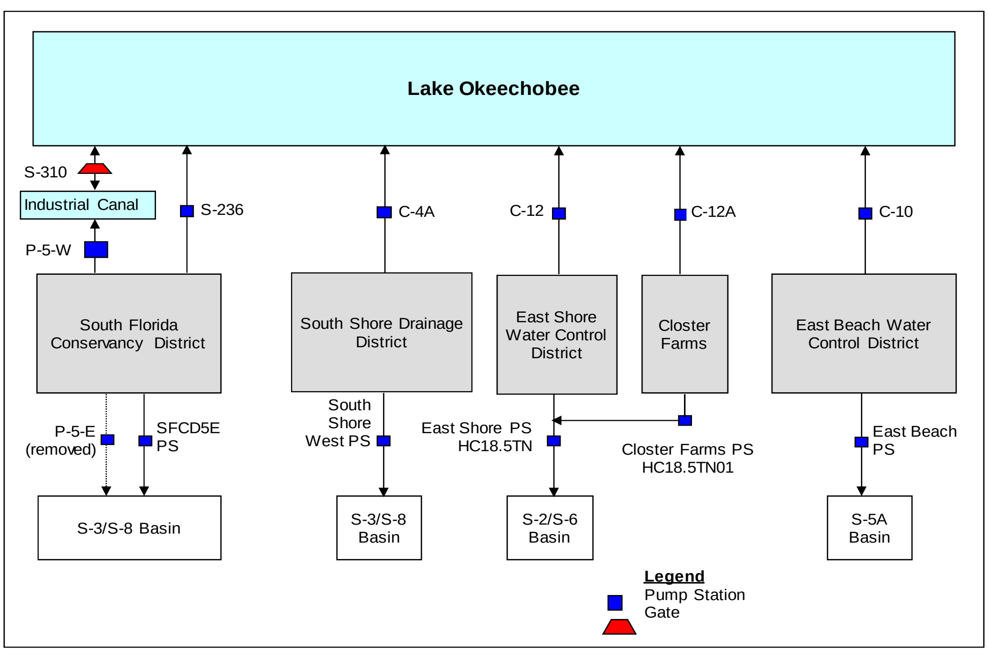
3.9.2.1 Background

Consistent with the Long-Term Plan for the Southern Everglades and the District's strategies for water quality restoration, the District administers a nutrient source control program within the Everglades Agricultural Area (EAA). The purpose of the nutrient source control program is to reduce nutrient loading from stormwater runoff to EAA canals, and ultimately to the District's stormwater treatment areas (STAs). Critical to meeting the nutrient reduction goals of the nutrient source control program, are best management practices (BMPs) which are implemented by stakeholders within the EAA, and are designed to reduce nutrient loading to stormwater runoff before its ultimate discharge to the District's STAs.

Performance measures quantify nutrient source control performance by establishing annual targets and limits for total phosphorus (TP) load. Performance measures have been developed for the EAA Chapter 298 Districts (East Beach Water Control District, East Shore Water Control District, South Florida Conservancy District, South Shore Water Control District, and the Closter Farms **(Figure 3-53))** areas which historically discharged to Lake Okeechobee and were therefore excluded from the EAA Basin performance measures under Chapter 40E-63, F.A.C. Since the Closter basin discharges to the East Shore Water Control District (ESWCD) basin through the Closter diversion structure, with limited monitoring at that structure, Closter and ESWCD have been combined into a single basin for the purpose of the performance measure development. The resulting four basins discharge to different EAA canals (West Palm Beach, Hillsboro, North New River, and Miami), and ultimately to different STAs, therefore in developing performance measures, historic (base period) water quality and hydrologic monitoring data has been analyzed separately for each of the four basins.

Figure 3-53. Ch. 298 District basins map and flow schematic.





The following is a description of the general approach used to develop performance measures for the EAA Chapter 298 Districts basins.

3.9.2.2 Historical Data Analysis

A summary of the annual rainfall, total flows, and total TP levels for the Chapter 298 Districts is presented in **Tables 3-66, 3-68, 3-70 and 3-72**.

Historical data analysis through Water Year 2012 (WY2012) was performed for each of the EAA Chapter 298 District basins. The analysis included the following.

- analysis of flows and TP loads resulting from rainfall and runoff from each basin; and
- identification of representative rainfall monitoring stations and use of the Thiessen polygon weighting method to estimate basin rainfall; and
- identification of an appropriate base period for each basin. The base period serves as the benchmark of historical observed data on which performance measures are based. Base periods should include sufficient concentration and flow data to adequately represent TP levels through a wide range of hydrologic conditions and be representative of current operating conditions affecting TP loadings. Base periods should also have reasonable correlation between rainfall and nutrient loads, should precede the full implementation of collective source control measures, and meet other statistical criteria.

Based on statistical analysis of base period water quality and hydrologic data, two equations, prediction (target) and upper confidence limit (limit) for annual TP load discharged, as a function of annual rainfall have been developed for each of the four basins. These equations provide TP load targets and TP load limits for discharges from each basin for a given year as a function of that given year's annual rainfall, as long as that given year's annual rainfall is within a statistically determined range based on base period data. The prediction and upper confidence limit equations provide predictions and limits for TP load based on a 25 percent reduction, and can be modified to predict an alternative TP load reduction goal. The equations so modified for a given load reduction, provide a metric for determining whether each individual basin is achieving that load reduction goal.

3.9.2.3 Performance Measure Methodologies

The general approach used to develop load based performance measures is described below with summaries of the proposed phosphorus source control performance measure methodologies. In order to quantify the performance of nutrient reduction source controls, the performance measures and performance indicators establish annual TP targets for the basins regardless of the receiving waterbody. Thus, loads are included for all structures that serve a basin although they may not discharge directly into the lake. Thus, the source control program participants with property in a basin that can discharge to multiple watersheds will have one goal to achieve rather than multiple goals. Requirements for the Chapter 298 District basins to divert 80% of historic flow and load discharges to Lake Okeechobee are currently specified in their respective Environmental Resource Permits and are not a topic of this document.

A total of over one hundred alternative regression equations were examined for each drainage basin.

- Fifty-four (54) regression equations correlating annual load with annual rainfall and monthly rainfall characteristics (coefficient of variation, skewness and kurtosis) were evaluated.
- Fifty-four (54) regression equations correlating annual concentration with annual rainfall and monthly rainfall characteristics (coefficient of variation, skewness and kurtosis) were evaluated.

- Multiple statistical selection factors were analyzed in selecting the recommended regression equation for each basin. These included strength of correlation, statistical significance of regression coefficients, standard error of the regression equation, variance of residuals, co-linearity of predictor variables, presence of outliers, presence of temporal trends during the base period, and presence of over-parameterization.
- In the case of the South Shore Drainage District, the base period is not characterized by a strong relationship between rainfall and TP load. An attempt to improve the correlation by using an independent variable to represent seepage from Lake Okeechobee successfully improved the predictive capability for flows, however, this did not improve the predictive capability for TP loads. For this basin, an alternative method of establishing annual predictions and UCL is recommended. The annual predicted value would be set equal to the base period average (arithmetic mean).

Annual Performance Determination

TP loads discharged at each of the EAA Chapter 298 District basins discharge structures will be assessed on an annual basis against the Annual Load Target and the Annual Load Limit **(Figure 1-2). Tables 3-65, 3-67, 3-69, and 3-71** present summaries of the equations for calculating the annual load targets, limits, and minimum and maximum rainfall values used to establish a rainfall range for TP load based performance measures for the EAA Chapter 298 District basins. **Figures 3-54 – 3-57** provide comparisons of the scaled load data with the proposed targets and limits for the base periods for each of the basins. **Tables 3-66, 3-68, 3-70, and 3-72** present summaries of historic discharges for the period of record for each of the basins.

Table 3-65. East Beach Water Control District TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance R^2	Recommended Source Control Reduction	Base Period Rainfall	
			Minimum inches	Maximum inches
4.757	89%	25%	45.71	68.05
Target = exp[-16.17942 + 4.30194 ln(Rain)]				
Limit = Target* exp(0.38288 sqrt[1.125 + (ln(Rain) - 4.02892)^2 / 0.17904])				

Figure 3-54. Comparison of the scaled Base Period annual TP loads with the Annual Targets and Limits for the EBWCD based on a 25% load reduction.

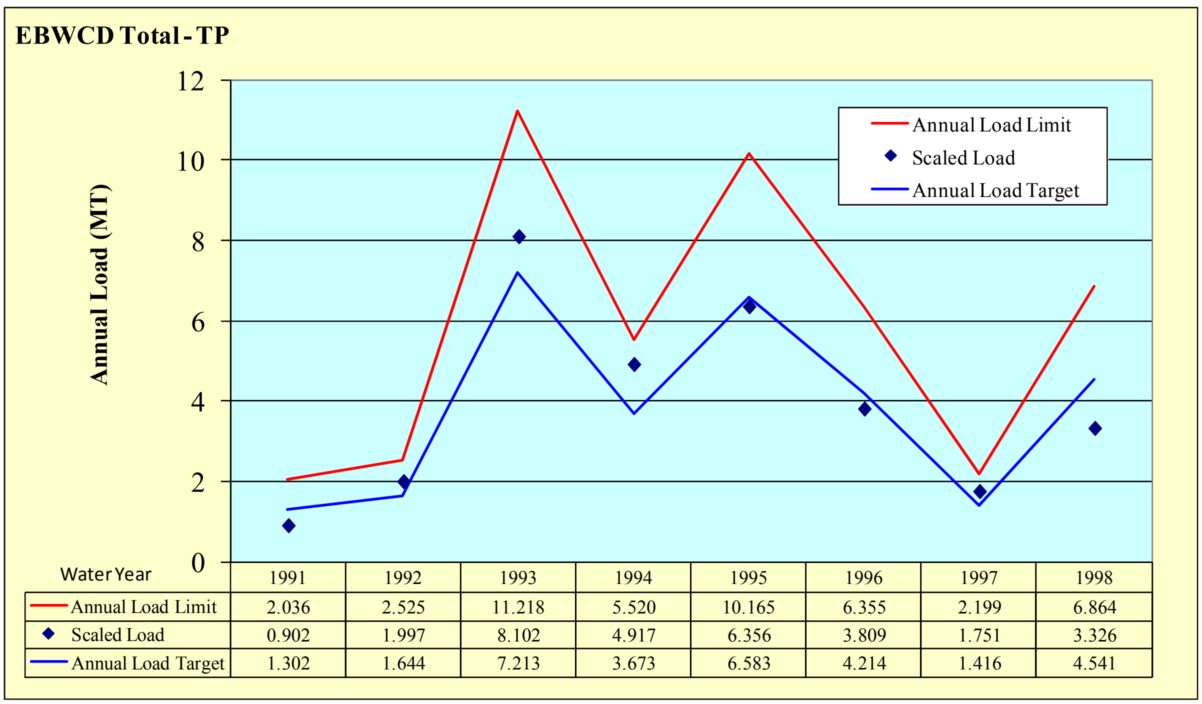


Table 3-66. Summary of historical discharges from EBWCD.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac
1990				34.81			
1991	4,357	1.203	224	45.71	6,542	7.99	0.41
1992	4,970	2.663	434	48.26	6,542	9.12	0.90
1993	15,558	10.804	563	68.05	6,542	28.54	3.64
1994	16,827	6.553	316	58.17	6,542	30.87	2.21
1995	19,909	8.475	345	66.62	6,542	36.52	2.86
1996	15,969	5.079	258	60.06	6,542	29.29	1.71
1997	8,226	2.335	230	46.61	6,542	15.09	0.79
1998	16,595	4.434	217	61.11	6,542	30.44	1.49
1999	20,284	10.587	423	40.58	6,542	37.21	3.57
2000	33,161	12.656	309	59.69	6,542	60.83	4.26
2001	6,074	1.318	176	35.74	6,542	11.14	0.44
2002	21,103	9.360	360	43.11	6,542	38.71	3.15
2003	20,419	8.022	318	52.51	6,542	37.45	2.70
2004	23,744	8.824	301	55.45	6,542	43.55	2.97
2005	28,216	15.033	432	65.31	6,542	51.76	5.07
2006	18,162	10.748	480	42.75	6,542	33.31	3.62
2007	12,438	5.588	364	42.39	6,542	22.82	1.88
2008	8,795	5.593	516	47.15	6,542	16.13	1.88
2009	16,046	12.811	647	48.96	6,542	29.43	4.32
2010	20,131	20.127	811	63.07	6,542	36.93	6.78
2011	10,640	5.717	436	41.61	6,542	19.52	1.93
2012	5,300	2.704	414	35.01	6,542	9.72	0.91
Minimum	***4,357***	***1.203***	***176***	***35.01***	***6,542***	***7.99***	***0.41***
Average	***15,769***	***7.756***	***399***	***51.27***	***6,542***	***28.93***	***2.61***
Maximum	***33,161***	***20.127***	***811***	***68.05***	***6,542***	***60.83***	***6.78***
Std. Dev.	***7,649***	***4.803***	***151***	***10.19***	***0***	***14.03***	***1.62***
Skewness	***0.288***	***0.734***	***1.094***	***0.147***		***0.288***	***0.73***
Median	***16,321***	***7.288***	***362***	***48.61***	***6,542***	***29.94***	***2.46***

Table 3-67. ESWCD and Closter TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance R^2	Recommended Source Control Reduction	Base Period Rainfall	
			Minimum inches	Maximum inches
4.369	86%	25%	48.10	67.62
Target = exp[-12.71472 + 3.41017 ln(Rain)]				
Limit = Target* exp(0.27273 sqrt[1.125 + (ln(Rain) - 4.05997)^2 / 0.11302])				

Figure 3-55. Comparison of the scaled Base Period annual TP loads with the Annual Targets and Limits for the ESWCD & Closter based on a 25% load reduction.

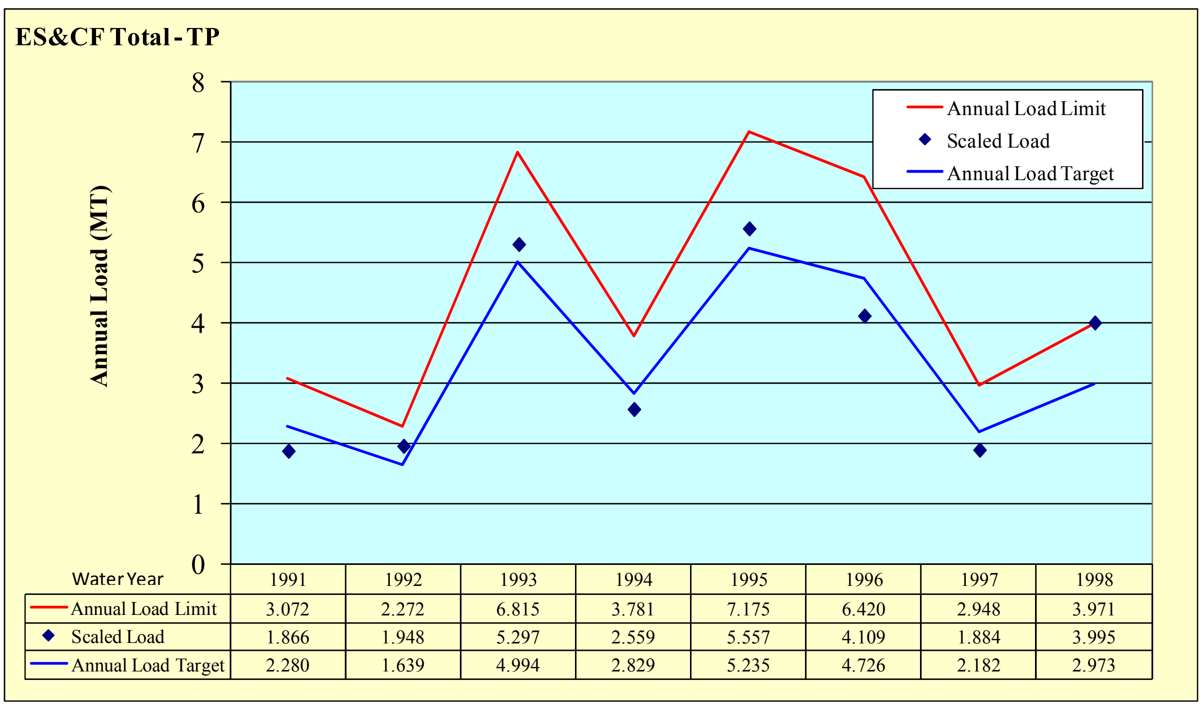


Table 3-68. Summary of historical discharges from ESWCD & Closter.

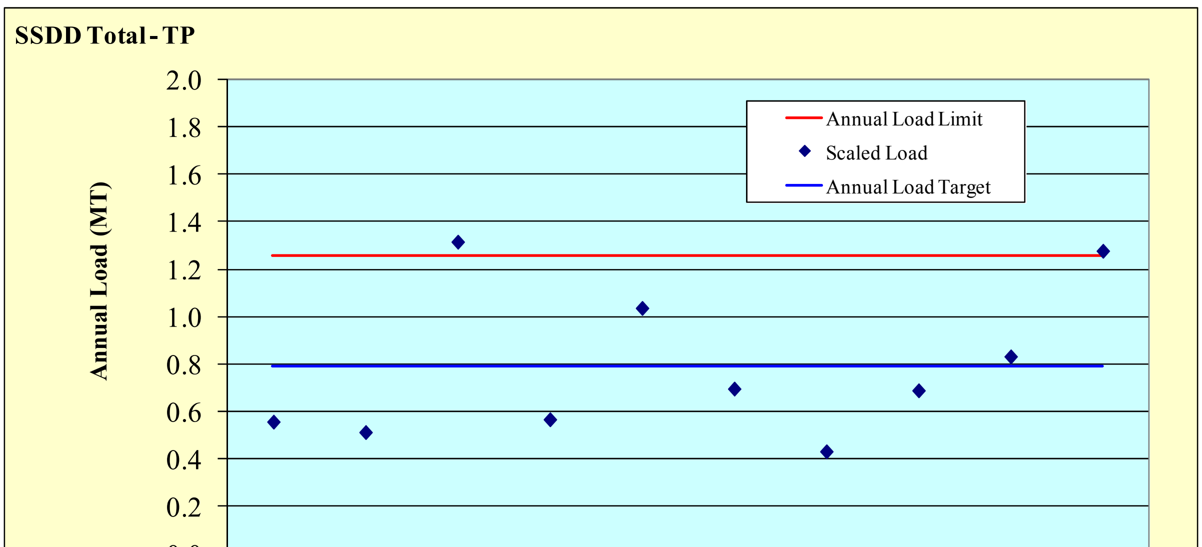
Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac
1990				38.28			
1991	11,337	2.488	178	52.99	11,534	11.80	0.48
1992	13,429	2.597	157	48.10	11,534	13.97	0.50
1993	32,569	7.062	176	66.69	11,534	33.88	1.35
1994	18,486	3.412	150	56.45	11,534	19.23	0.65
1995	34,326	7.409	175	67.62	11,534	35.71	1.42
1996	31,269	5.479	142	65.62	11,534	32.53	1.05
1997	19,790	2.512	103	52.31	11,534	20.59	0.48
1998	26,377	5.326	164	57.28	11,534	27.44	1.02
1999	25,059	2.999	97	39.83	11,534	26.07	0.57
2000	45,171	7.328	132	60.95	11,534	47.00	1.40
2001	12,677	2.422	155	40.30	11,534	13.19	0.46
2002	21,685	2.884	108	45.44	11,534	22.56	0.55
2003	32,692	3.621	90	54.93	11,534	34.01	0.69
2004	30,282	3.025	81	51.88	11,534	31.51	0.58
2005	41,209	7.752	153	67.14	11,534	42.87	1.48
2006	30,343	7.433	199	51.81	11,534	31.57	1.42
2007	21,011	4.202	162	40.82	11,534	21.86	0.80
2008	14,603	3.129	174	48.50	11,534	15.19	0.60
2009	22,304	3.912	142	46.36	11,534	23.21	0.75
2010	36,945	7.015	154	63.97	11,534	38.44	1.34
2011	18,327	2.534	112	42.89	11,534	19.07	0.48
2012	14,609	2.012	112	37.31	11,534	15.20	0.38
Minimum	***11,337***	***2.012***	***81***	***37.31***	***11,534***	***11.80***	***0.38***
Average	***25,205***	***4.389***	***141***	***52.69***	***11,534***	***26.22***	***0.84***
Maximum	***45,171***	***7.752***	***199***	***67.62***	***11,534***	***47.00***	***1.48***
Std. Dev.	***9,634***	***2.038***	***33***	***9.65***	***0***	***10.02***	***0.39***
Skewness	***0.361***	***0.618***	***-0.330***	***0.135***		***0.361***	***0.62***
Median	***23,682***	***3.517***	***152***	***52.10***	***11,534***	***24.64***	***0.67***

Table 3-69. SSDD TP Load Performance Measure.

Base Period Mean Annual Load mt	Explained Variance R^2	Recommended Source Control Reduction	Base Period Rainfall	
			Minimum inches	Maximum inches
1.054	NA*	25%	42.90	60.83
Target = 0.7905 mt				
Limit = 1.259 mt				

* An alternative method of establishing annual target predictions and limit is recommended. The annual target value to be equal to the scaled base period average (arithmetic mean).

Figure 3-56. Comparison of the scaled Base Period annual TP loads with the Annual Targets and Limits for the SSDD based on a 25% load reduction.



Water Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Annual Load Limit	1.259	1.259	1.259	1.259	1.259	1.259	1.259	1.259	1.259	1.259
Scaled Load	0.556	0.512	1.314	0.566	1.035	0.695	0.431	0.688	0.831	1.276
Annual Load Target	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791

Table 3-70. Summary of historical discharges from SSDD.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac
1990				39.07			
1991	4,005	0.741	150	49.88	4,230	11.36	0.39
1992	6,041	0.683	92	48.81	4,230	17.14	0.36
1993	9,606	1.752	148	54.64	4,230	27.25	0.91
1994	7,307	0.755	84	48.28	4,230	20.73	0.39
1995	11,331	1.380	99	60.83	4,230	32.14	0.72
1996	8,882	0.927	85	56.77	4,230	25.20	0.48
1997	7,471	0.575	62	50.37	4,230	21.19	0.30
1998	7,522	0.917	99	53.83	4,230	21.34	0.48
1999	7,196	1.108	125	42.90	4,230	20.41	0.58
2000	11,413	1.701	121	51.32	4,230	32.38	0.89
2001	2,968	0.605	165	37.02	4,230	8.42	0.32
2002	3,156	0.518	133	43.65	4,230	8.95	0.27
2003	6,695	0.987	120	36.17	4,230	18.99	0.51
2004	5,534	0.581	85	43.36	4,230	15.70	0.30
2005	10,985	1.842	136	51.51	4,230	31.16	0.96
2006	15,122	2.521	135	58.39	4,230	42.90	1.31
2007	6,175	0.972	128	30.10	4,230	17.52	0.51
2008	2,763	0.568	167	36.77	4,230	7.84	0.30
2009	7,780	1.639	171	39.62	4,230	22.07	0.85
2010	12,286	2.227	147	55.47	4,230	34.85	1.16
2011	10,431	1.816	141	45.04	4,230	29.59	0.95
2012	8,128	1.173	117	43.47	4,230	23.06	0.61
Minimum	***2,763***	***0.518***	***62***	***30.10***	***4,230***	***7.84***	***0.27***
Average	***7,854***	***1.181***	***122***	***47.19***	***4,230***	***22.28***	***0.62***
Maximum	***15,122***	***2.521***	***171***	***60.83***	***4,230***	***42.90***	***1.31***
Std. Dev.	***3,225***	***0.589***	***30***	***8.09***	***0***	***9.15***	***0.31***
Skewness	***0.277***	***0.776***	***-0.258***	***-0.285***		***0.277***	***0.78***
Median	***7,497***	***0.980***	***127***	***48.55***	***4,230***	***21.27***	***0.51***

Table 3-71. SFCD TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance R^2	Recommended Source Control Reduction	Base Period Rainfall	
			Minimum inches	Maximum inches
4.121	90%	25%	28.30	56.17
Target = exp (-10.37045 + 2.87238 ln(Rain) + 0.68204 S)] S = the skewness calculated from 12 monthly rainfall totals				
Limit = Target + 1.43976 (0.26292 [1 + 1/9 + 3.0389 (ln(Rain) - 3.85125)^2 + 0.92149 (S - 0.63211)^2 - 0.4311 (ln(Rain) - 3.85125) (S-0.63211)]$^{0.5}$				

Figure 3-57. Comparison of the scaled Base Period annual TP loads with the Annual Targets and Limits for the SFCD based on a 25% load reduction.

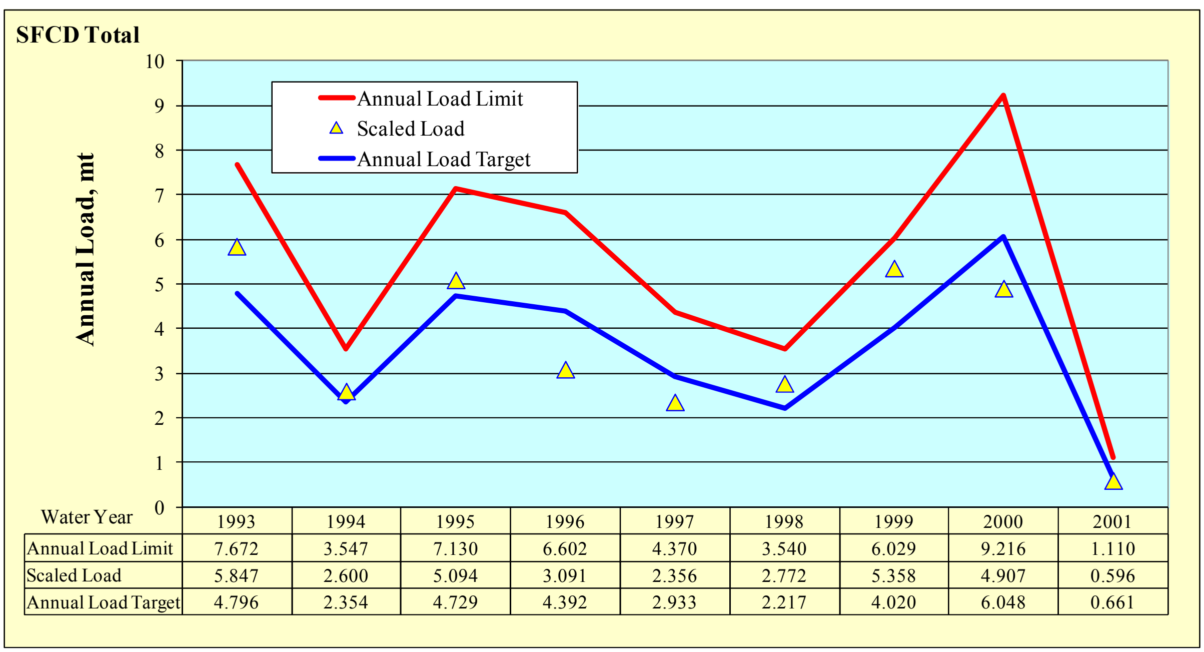


Table 3-72. Summary of historical discharges from SFCD.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac
1990				39.36			
1991	6,991	1.528	177	49.96	9,775	8.58	0.34
1992	4,360	0.893	166	48.65	9,775	5.35	0.20
1993	24,809	7.796	255	46.67	9,775	30.46	1.76
1994	24,578	3.466	114	45.75	9,775	30.17	0.78
1995	36,654	6.792	150	54.74	9,775	45.00	1.53
1996	32,576	4.121	103	53.62	9,775	39.99	0.93
1997	20,416	3.141	125	46.90	9,775	25.06	0.71
1998	26,795	3.696	112	49.16	9,775	32.89	0.83
1999	39,814	7.144	145	49.21	9,775	48.88	1.61
2000	49,990	6.543	106	56.17	9,775	61.37	1.48
2001	5,952	0.795	108	28.30	9,775	7.31	0.18
2002	19,473	2.734	114	49.37	9,775	23.91	0.62
2003	27,283	2.977	88	44.02	9,775	33.49	0.67
2004	27,611	3.498	103	47.01	9,775	33.90	0.79
2005	35,241	4.456	103	65.42	9,775	43.26	1.00
2006	43,760	6.751	125	66.06	9,775	53.72	1.52
2007	15,385	2.177	115	37.08	9,775	18.89	0.49
2008	7,191	0.784	88	38.11	9,775	8.83	0.18
2009	21,358	3.140	119	43.63	9,775	26.22	0.71
2010	27,130	3.902	117	53.94	9,775	33.31	0.88
2011	14,710	1.475	81	39.53	9,775	18.06	0.33
2012	18,201	2.613	116	49.19	9,775	22.34	0.59
Minimum	***4,360***	***0.784***	***81***	***28.30***	***9,775***	***5.35***	***0.18***
Average	***24,104***	***3.656***	***123***	***48.30***	***9,775***	***29.59***	***0.82***
Maximum	***49,990***	***7.796***	***255***	***66.06***	***9,775***	***61.37***	***1.76***
Std. Dev.	***12,414***	***2.144***	***38***	***8.56***	***0***	***15.24***	***0.48***
Skewness	***0.206***	***0.557***	***2.233***	***0.032***		***0.206***	***0.56***
Median	***24,694***	***3.304***	***115***	***48.91***	***9,775***	***30.31***	***0.75***

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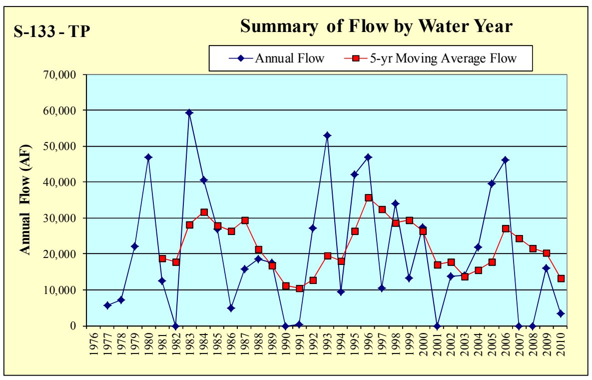
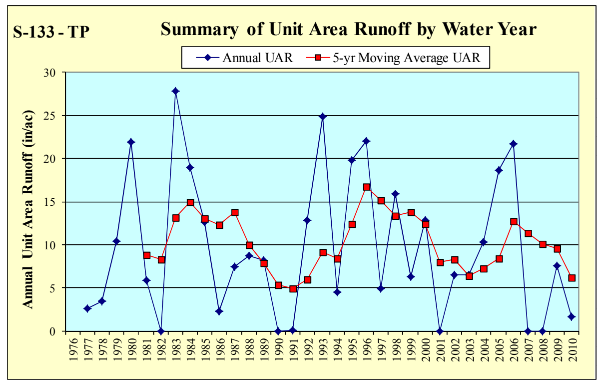
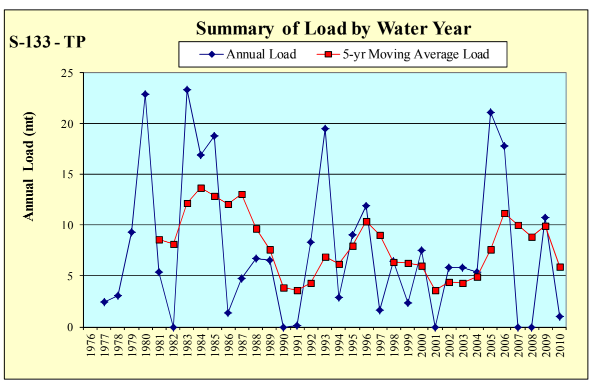
APPENDIX A - SUPPLEMENTAL INFORMATION FOR THE DERIVATION OF THE PERFORMANCE MEASURE METHODOLOGIES FOR THE LAKE OKEECHOBEE WATERSHED

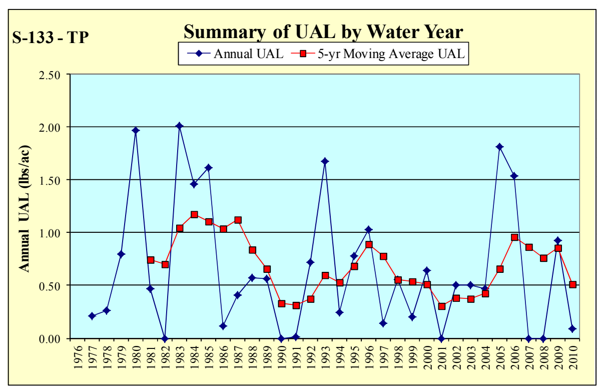
TAYLOR CREEK-NUBBIN SLOUGH SUB-WATERSHED

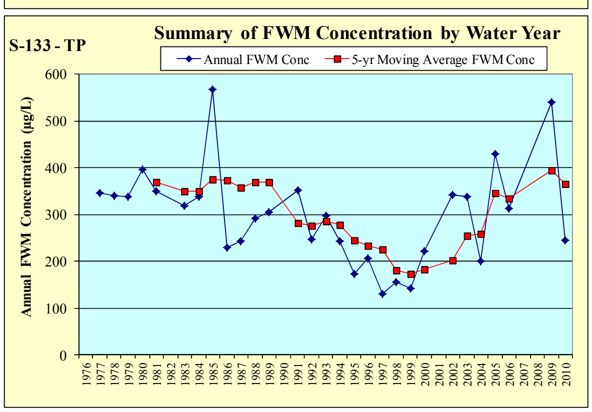
Summary of annual flow, TP and rainfall for S-133 Summary Basin

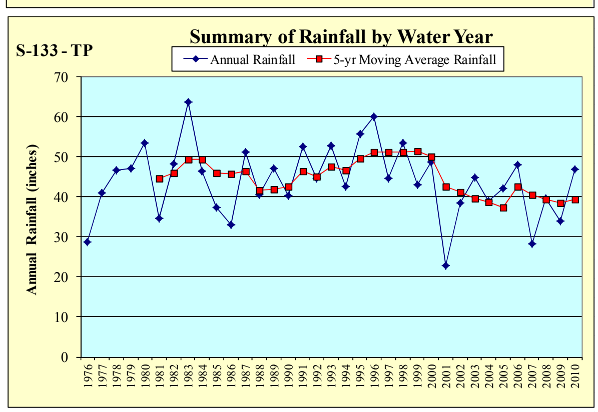




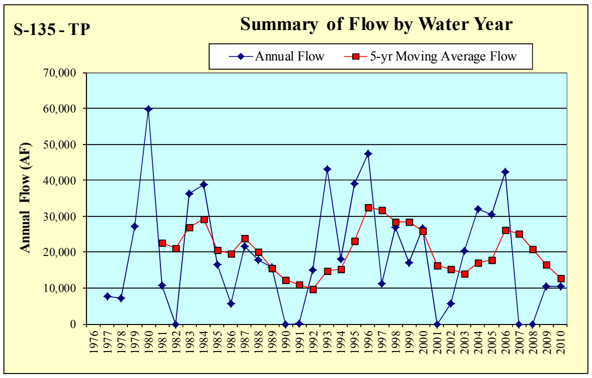


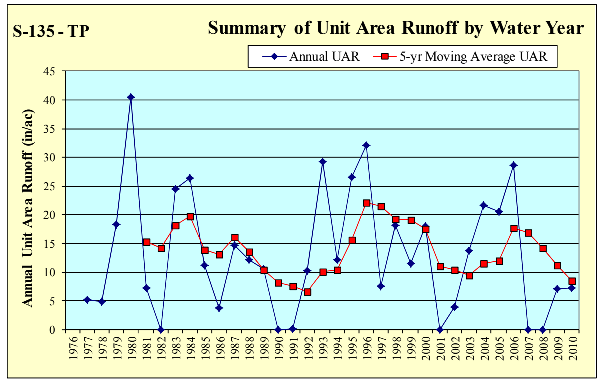


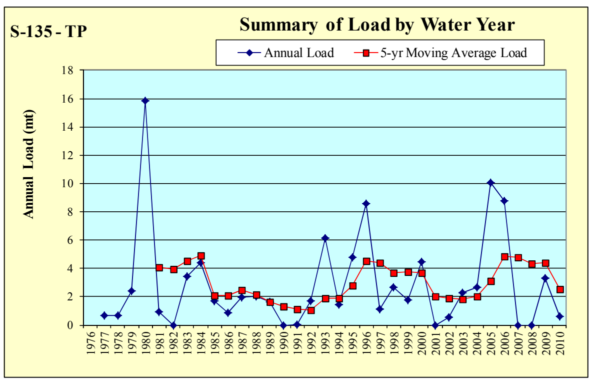


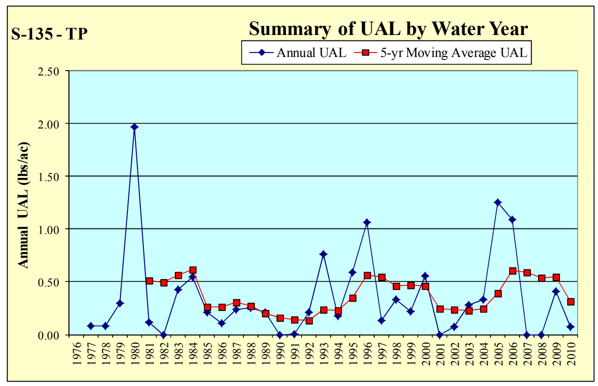


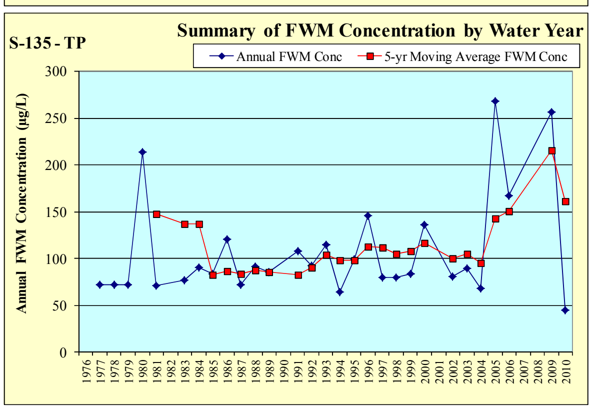
Summary of annual flow, TP and rainfall for S-135 Summary Basin

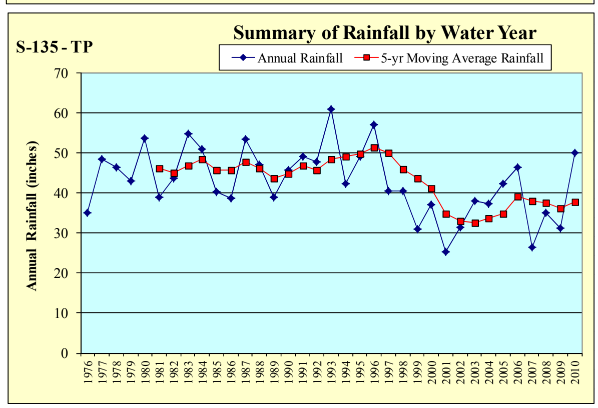




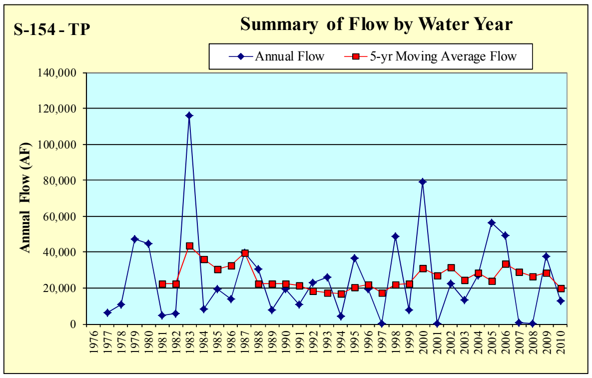


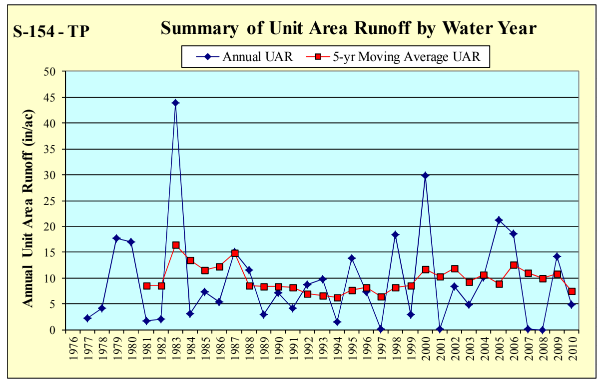


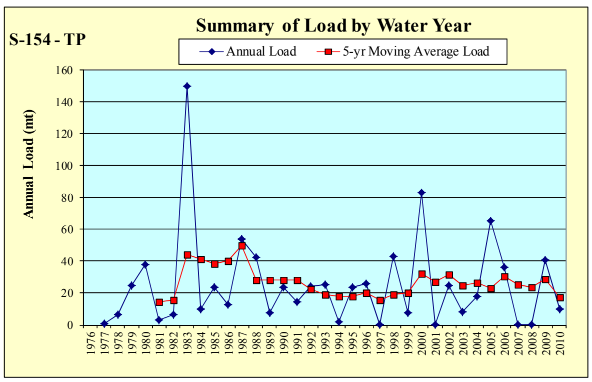


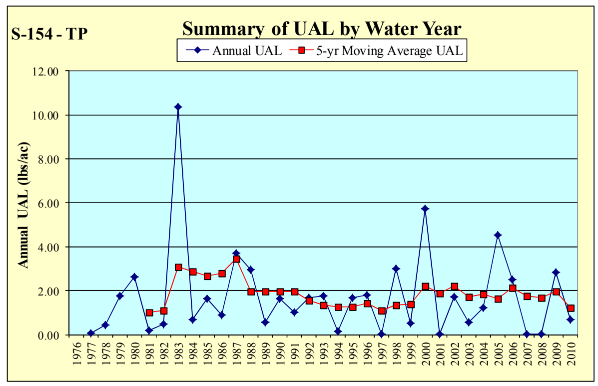


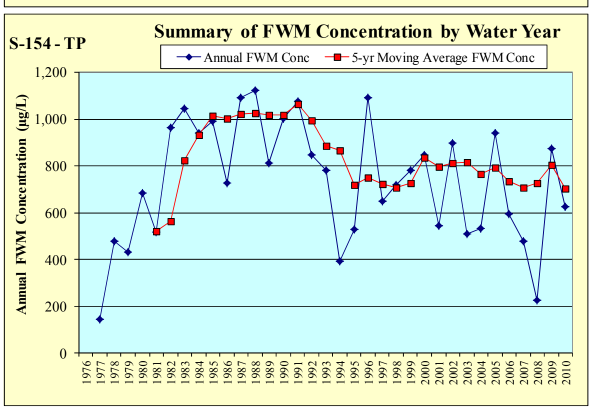
Summary of annual flow, TP and rainfall for S-154 Summary Basin

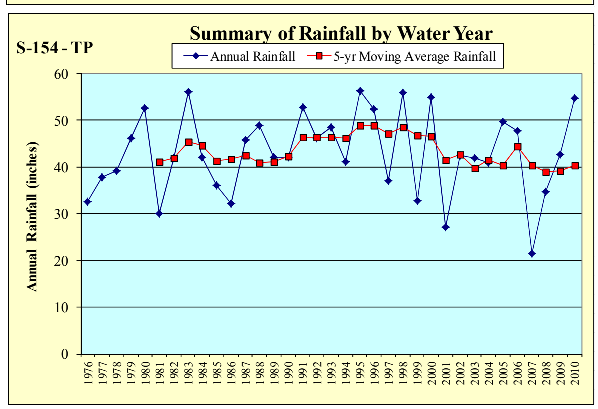




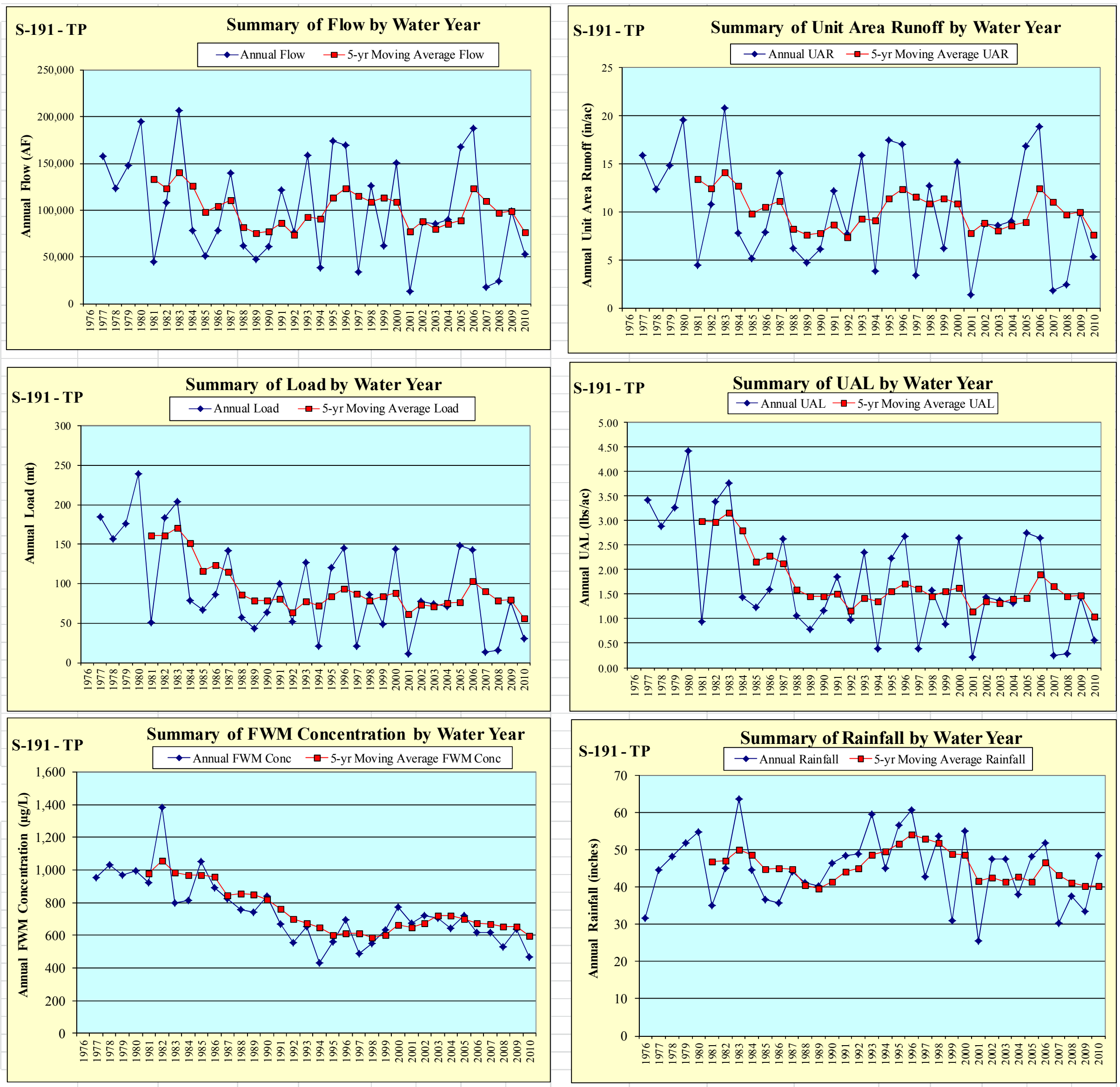




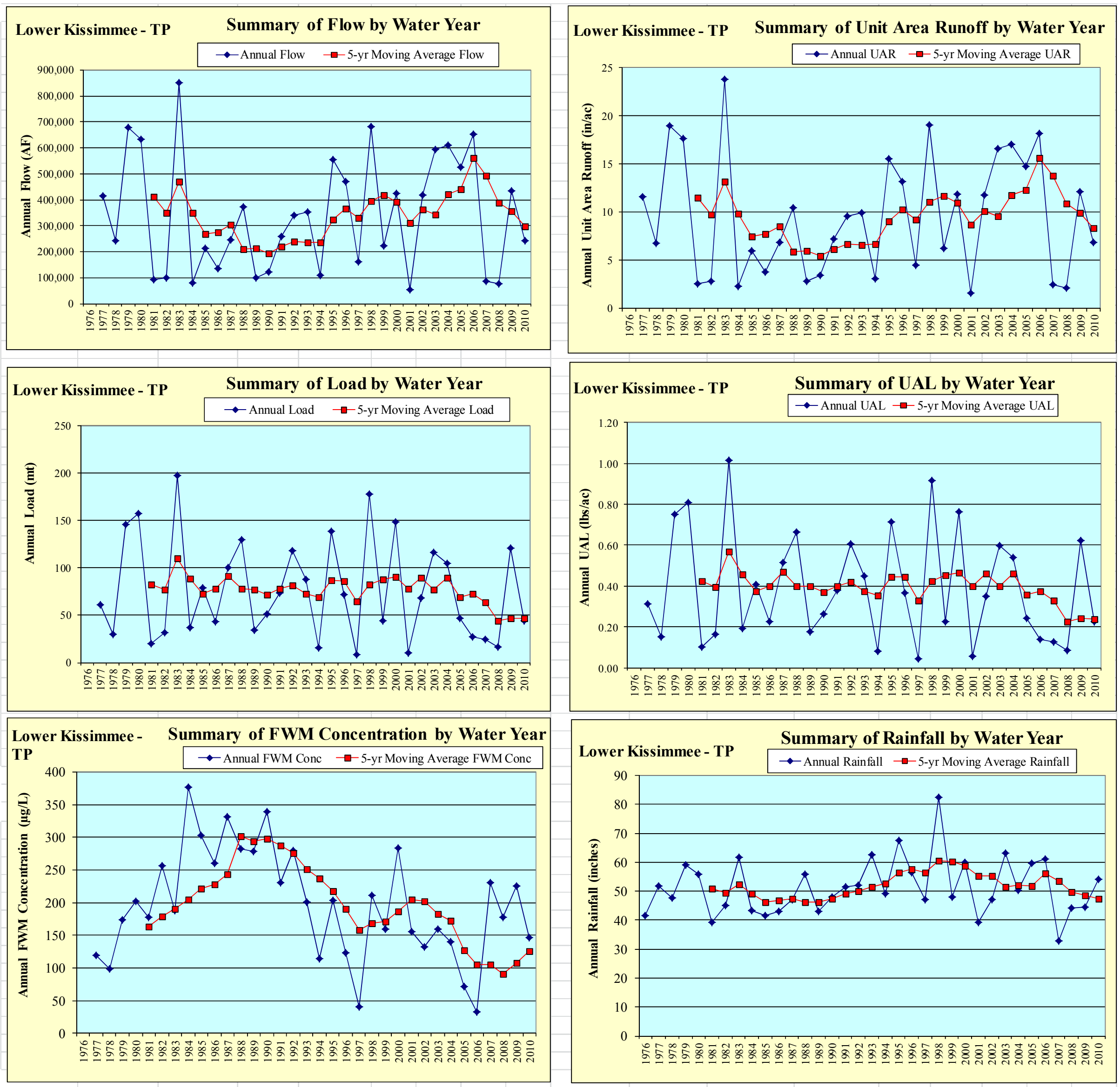




Summary of annual flow, TP and rainfall for S-191 Summary Basin



Summary of annual flow, TP and rainfall for the Lower Kissimmee Sub-watershed



Calculation of Net Basin TP Loads for the Lower Kissimmee Sub-watershed

The Lower Kissimmee Sub-watershed receives surface inflows from the Upper Kissimmee Sub-watershed at S-65 and discharges to Lake Okeechobee at S-65E. Some of the inflows from the Upper Kissimmee are retained in the Lower Kissimmee Sub-watershed as a result of evapotranspiration, water supply withdrawals, groundwater recharge, increased storage, etc. The portion of the total inflow from S-65 that is "passed through" the Lower Kissimmee and discharged to Lake Okeechobee is not considered in this evaluation. Only basin flows that are the result of local rainfall and runoff from the Lower Kissimmee Sub-watershed are evaluated in this analysis. (Note: Inflows from Lake Istokpoga via G-85 are limited to leakage through closed culvert stop logs and are considered insignificant.) Basin flows are calculated on a daily basis as follows:

I_{LK} = Total Inflow to the Lower Kissimmee Sub-watershed
= $Q_{S\text{-}65}$ = S-65 discharge
O_{LK} = Total Outflow from the Lower Kissimmee Sub-watershed
= $Q_{S\text{-}65E}$ = S-65E discharge
PT_{LK} = Pass-through flow
= the portion of S-65 inflow that is passed through the Lower Kissimmee Sub-watershed
= minimum (I_{LK} , O_{LK})
B_{LK} = net basin flow produced by local rainfall and runoff
= $O_{LK} - PT_{LK}$

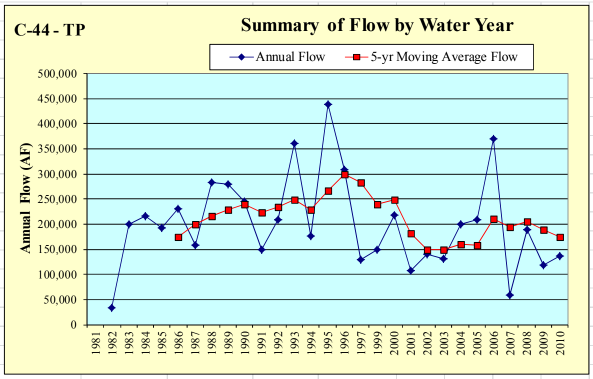
TP loading from the Lower Kissimmee Sub-watershed is the result of direct rainfall and runoff from within the sub-watershed and does not include external TP loading from the Upper Kissimmee Sub-watershed. Lower Kissimmee Sub-watershed basin loading is calculated using the following equations.

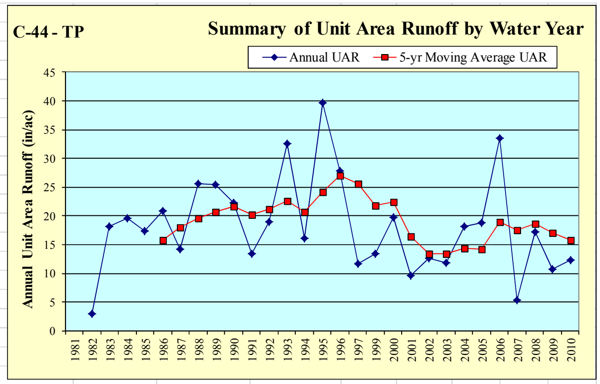
$C_{S\text{-}65}$ = S-65 TP concentration
PTL_{LK} = pass through TP load = the portion of S-65 TP load that is passed through the Lower Kissimmee Sub-watershed
= $PT_{LK} * C_{S\text{-}65}$
$C_{S\text{-}65E}$ = S-65E TP concentration
BL_{LK} = net basin TP loads produced by local rainfall and runoff
= $(Q_{S\text{-}65E} * C_{S\text{-}65E})$ - PTL_{LK}

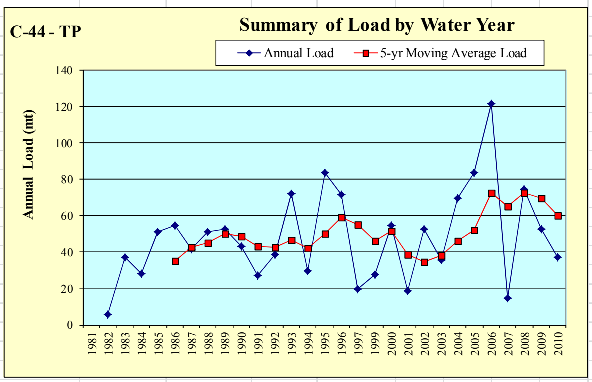
These calculations were performed on a daily time-step and the results were summed to monthly and annual totals.

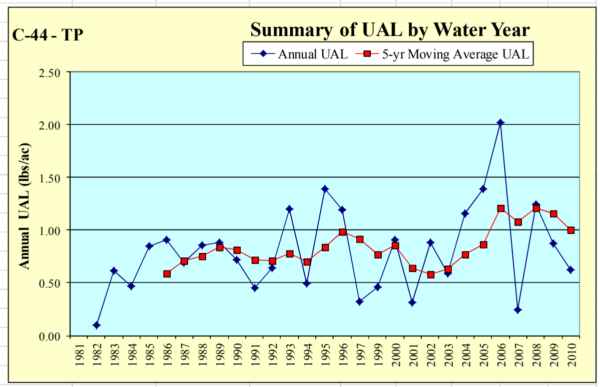
EAST LAKE OKEECHOBEE SUB-WATERSHED

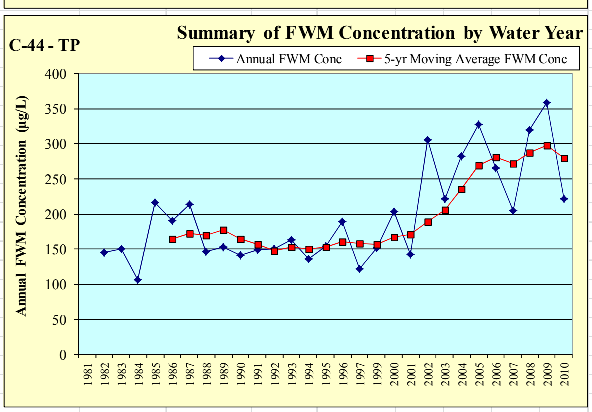
C-44 Hydrologic Unit

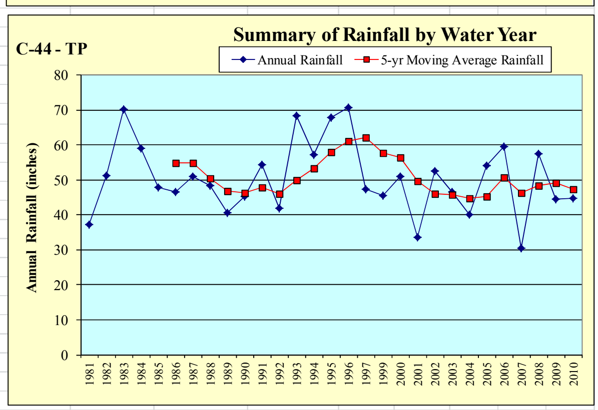












Calculation of Net Basin TP Loads for the C-44 Hydrologic Unit

C-44 Hydrologic 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
	$= \text{minimum}\ (I_{C\text{-}44}, O_{C\text{-}44})$
$B_{C\text{-}44}$	= net basin flow produced by local rainfall and runoff
	$= O_{C\text{-}44} - PT_{C\text{-}44}$

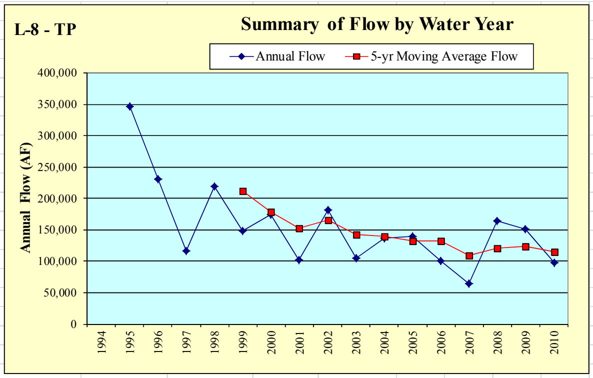
C-44 Hydrologic Unit Loads

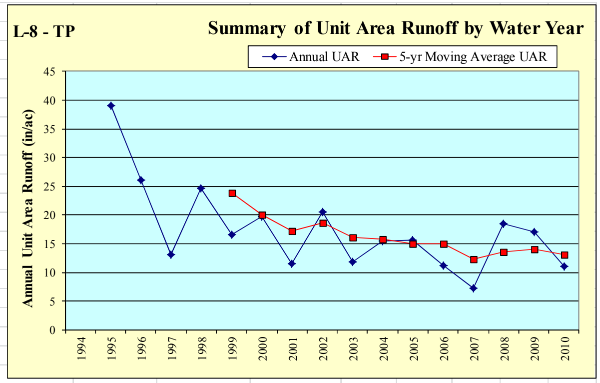
C_{In}	= total inflow concentration
	= total inflow load to C-44 / total inflow to C-44
	$= (Q_{S\text{-}308In} * C_{S\text{-}308In}) / I_{C\text{-}44}$
$PTL_{C\text{-}44}$	= pass-through load for C-44
	$= PT_{C\text{-}44} * C_{In}$
$C_{S\text{-}80}$	= S-80 concentration
$C_{S\text{-}308}$	= S-308 concentration
$OL_{C\text{-}44}$	= 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
	$= OL_{C\text{-}44} - PTL_{C\text{-}44}$

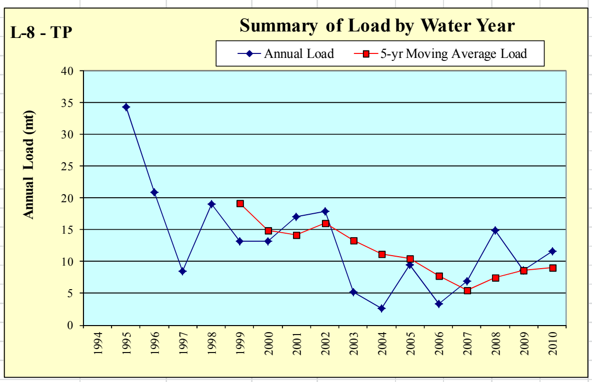
Comments:

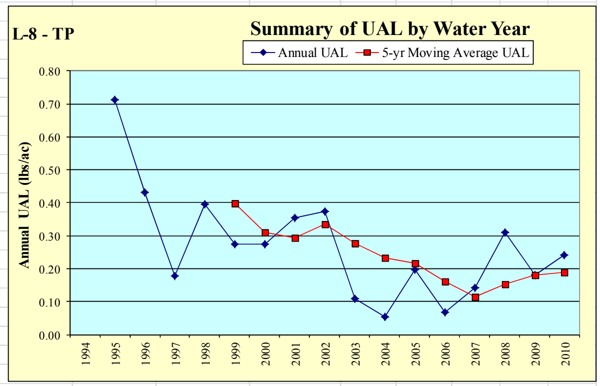
- The outflow concentration at S-308 to Lake Okeechobee ($C_{S\text{-}308}$) should be the grab concentrations at S-308C, as these reflect discharges from the C-44 into the lake.
- However, the inflow concentrations at S-308 from Lake Okeechobee into the C-44 are the autosampler concentrations at S308C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

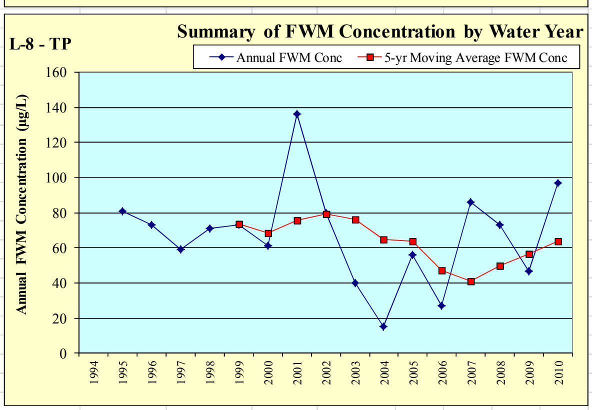
L-8 Summary Basin

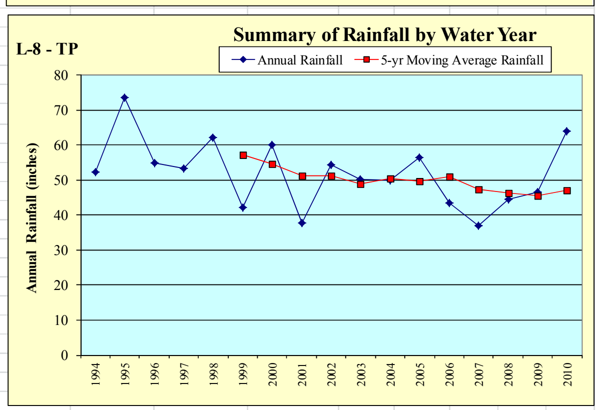












Calculation of Net Basin TP Loads for the L-8 Summary Basin

A combination of stormwater runoff and water supply deliveries are discharged from the L-8 Canal to multiple receiving waters: to Lake Okeechobee at C-10A, to the City of West Palm Beach's water catchment system at Control No. 2, to the EAA at S-5AW, to the WCA-1 at S-5AS, and to the C-51W Canal at S-5AE. The L-8 Summary Basin receives inflows from Lake Okeechobee at C-10A, from WCA-1 at S-5AS, from the C-51W Canal at S-5AE, and from the West Palm Beach Canal in the EAA at S-5AW. Some of the inflows are retained in the basin as a result of evapotranspiration, water supply withdrawals, groundwater recharge, increased storage, etc. The portion of the total inflow that is "passed through" the L-8 Summary Basin and discharged to adjacent waters is not considered basin flow in the evaluation of historical data analyses for the purpose of developing performance measures. Only basin flows that are the result of local rainfall and runoff from the L-8 Summary Basin are considered basin flow in the evaluation of historical data analyses. Following the standard District algorithm, L-8 Summary Basin flows were calculated on a daily basis by initially estimating the pass through volumes as follows:

$I_{L\text{-}8}$ = total inflow to the L-8 Summary Basin
= sum [$Q_{S\text{-}5AEIn} + Q_{S\text{-}5AWIn} + Q_{S\text{-}5ASIn} + Q_{C\text{-}10AIn}$]
$Q_{S\text{-}5AEIn}$ = flow at structure S-5AE into the L-8 Summary Basin
$Q_{S\text{-}5AWIn}$ = flow at structure S-5AW into the L-8 Summary Basin
$Q_{S\text{-}5ASIn}$ = flow at structure S-5AS into the L-8 Summary Basin
$Q_{C\text{-}10AIn}$ = flow at structure C-10A into the L-8 Summary Basin

$O_{L\text{-}8}$ = total outflow from the L-8 Summary Basin
= sum [$Q_{S\text{-}5AEOut} + Q_{S\text{-}5AWOut} + Q_{S\text{-}5ASOut} + Q_{C\text{-}10AOut} + Q_{WPB2}$]
$Q_{S\text{-}5AEOut}$ = flow at structure S-5AE out of the L-8 Summary Basin
$Q_{S\text{-}5AWOut}$ = flow at structure S-5AW out of the L-8 Summary Basin
$Q_{S\text{-}5ASOut}$ = flow at structure S-5AS out of the L-8 Summary Basin
$Q_{C\text{-}10AOut}$ = flow at structure C-10A out of the L-8 Summary Basin
Q_{WPB2} = flow at City of West Palm Beach pump No. 2

$PT_{L\text{-}8}$ = pass-through flow
= minimum [$I_{L\text{-}8}$, $O_{L\text{-}8}$]
$B_{L\text{-}8}$ = net basin flow produced by local rainfall and runoff
= $O_{L\text{-}8} - PT_{L\text{-}8}$

These calculations were performed on a daily basis and the results were summed to monthly and annual totals. Daily flow and TP data were provided by the District. Flow data for the City of West Palm Beach's Control No. 2 was only available beginning May 1994, hence the historical data analysis for the L-8 Summary Basin began at this point in time.

Net Basin TP loading from the L-8 Summary Basin is the result of direct rainfall and runoff from within the summary basin and does not include external TP loading from surrounding basins. Following the standard District algorithm for calculating pass-through loads, the L-8 Summary Basin loading was calculated on a daily basis for each boundary structure using the following algorithms.

$PTL_{L\text{-}8}$ = $PT_{L\text{-}8}$ * cumulative flow-weighted mean inflow concentration measured at S-5AE, S-5AW, S-5AS and C-10A

$C_{L\text{-}8In}$ = $[(Q_{S5ASIn} * C_{S5ASIn} + Q_{S5AEIn} * C_{S5AEIn} + Q_{S5AWIn} * C_{S5AWIn} + Q_{C10AIn} * C_{C10AIn}) / I_{L\text{-}8}]$

$PTL_{L\text{-}8}$ = $PT_{L\text{-}8} * C_{L\text{-}8In}$

C_{S5ASIn} = S-5AS TP inflow concentration

C_{S5AEIn} = S-5AE TP inflow concentration

C_{S5AWIn} = S-5AW TP inflow concentration

C_{C10AIn} = C-10A TP inflow concentration

$O_{L\text{-}8}$ = total outflow load from the L-8 Summary Basin
= $Q_{S5ASOut} * C_{S5ASOut} + Q_{S5AEOut} * C_{S5AEOut} + Q_{S5AWOut} * C_{S5AWOut} + Q_{C10AOut} * C_{C10AOut} + Q_{WPB2} * C_{WPB2}$

$C_{S5ASOut}$ = S-5AS TP outflow concentration

$C_{S5AEOut}$ = S-5AE TP outflow concentration

$C_{S5AWOut}$ = S-5AW TP outflow concentration

$C_{C10AIOut}$ = C-10A TP outflow concentration

C_{WPB2} = estimated concentration at City of West Palm Beach pump No. 2
= estimated as the cumulative flow-weighted mean inflow concentration measured at S-5AE, S-5AW, S-5AS and C-10A
= $C_{L\text{-}8In}$

$BL_{L\text{-}8}$ = net basin TP loads produced by local rainfall and runoff
= $OL_{L\text{-}8} - PT_{L\text{-}8}$

These calculations were performed on a daily time-step and the results were summed to monthly and annual total loads.

Algorithm for Estimating TP Loads Discharged from the Southern L-8 Canal Structures (S-5AW, S-5AS, S-5AE): Deriving a Common Daily Time Series of TP Concentrations

1. Using the District's LOAD Program for the period WY1995-2011, daily, monthly and annual flow weighted mean (FWM) TP concentrations for discharges through the S-5AW, S-5AS and S-5AE[23] exhibited considerable heterogeneity, with annual coefficients of variation (standard deviation / mean) ranging up to 1.02 (see **Table A-1** and **Figure A-1**).

2. For structures located as close together as these three, it was expected that there would be a closer range of FWM concentrations[24]. However, the LOAD Program looks only at the specific station in question in establishing an appropriate concentration to apply to the flow, and does not look at adjacent stations. As a result, TP concentrations from grab samples were applied to flow values up to 2,229 days (i.e., more than six years) distant from the date of flow in estimating load (see **Table A-2**).

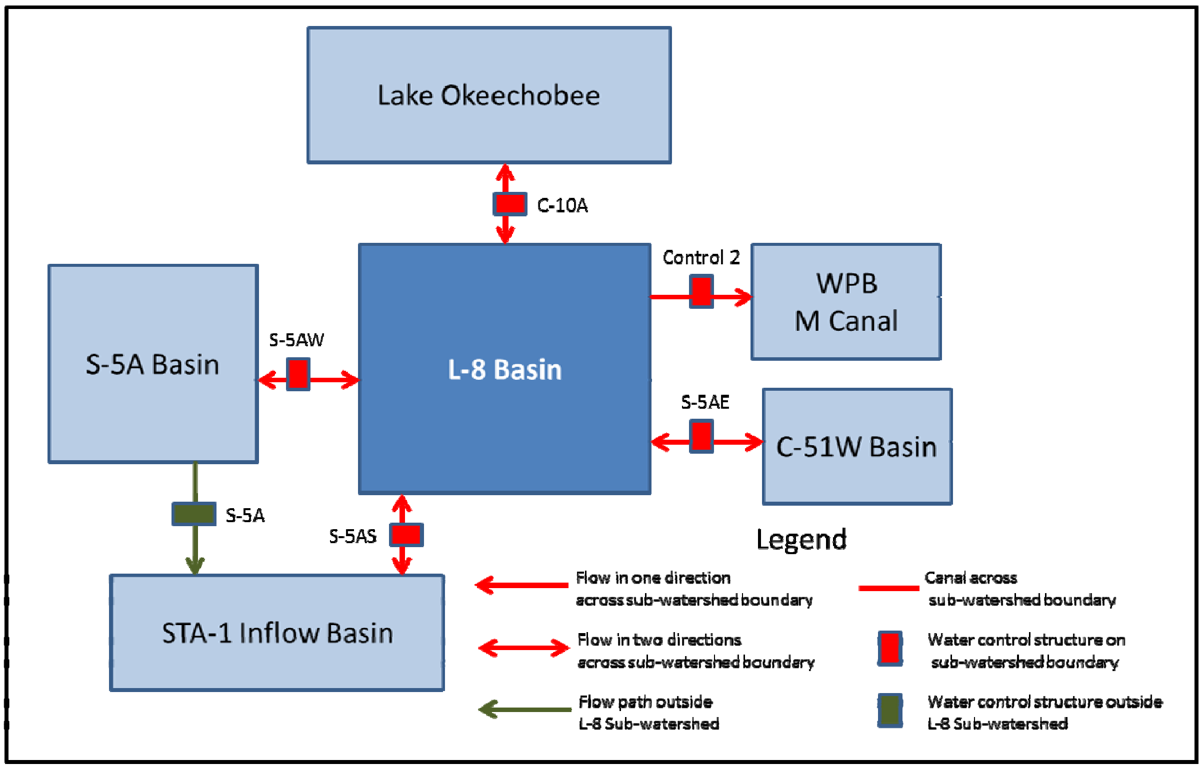
3. An alternative algorithm was investigated to reduce the heterogeneity between the concentrations at these structures, utilizing a common concentration time series for the southern terminus of the L-8 Canal. The time series was derived according to the following procedure.
    a. TP concentrations collected on days when flow occurred at each structure, with the following criteria
        i. S-5AW:
            1. Priority was given to grab samples collected at S-5AW on days with flow.
            2. If a grab sample was not collected at S-5AW on the day with flow, a concurrent grab sample at S-5A was used if the flow at S-5A was less than or equal to the flow from S-5AW, in order to minimize the influence of EAA water quality on the S-5A sample.

[23] Discharge through S-5AW from east to west (to the S-5A Basin); discharge through S-5AS from north to south (to the STA 1 Inflow and Distribution Works); discharge through S-5AE from west to east (to the C-51 West Basin).
[24] A recent decision by the District to eliminate sampling at S-5AS and S-5AW and use samples taken at S-5AE was based on analyses that bear out this expectation.

ii. S-5AE:

1. Within a 14-day window, priority was given to autosampler composite concentrations over grab sample concentration, consistent with the LOAD Program algorithm using the 14-day window option.

Figure A-1. Flow diagram for the L-8 Summary Basin



b. A single daily time series was compiled from the concentrations at the three structures.

i. If values were available at all three stations, an arithmetic average was calculated for that day (note: this concurrent sample collection never occurred).

ii. If values were available for only two structures, an arithmetic average was calculated for that day (note: this occurred 16 days during of the period of record)

iii. If only one value was available, that value was used for that day (note: this occurred 758 days during the period of record).

iv. Concentrations on days prior to the first value were set to the first value.
v. Concentrations on days after the last value were set to the last value.
vi. Concentrations for days with no value were estimated from linear interpolation.

c. The resulting time series was then applied to the daily flow for each structure to calculate a daily TP load.
d. The heterogeneity of daily, monthly and annual FWM TP concentrations was reduced in 13 of the 17 years of record (**Table A-3** and **Figure A-2**).
e. The net effect was to decrease the estimated total TP loads discharged out of the L-8 Canal (see **Table A-4**). Ninety-six (96) percent of the net change in TP loads occurred in WY1995, with most of that (97%) attributed to a revision in the TP loads estimated leaving through S-5AW.

i. S-5AW: a net reduction of 28.848 mt (1.697 mt/yr)
ii. S-5AS: a net reduction of 4.594 mt (0.270 mt/yr)
iii. S-5AE: a net *increase* of 3.593 mt (0.211 mt/yr)

4. The updated data sets for the L-8 Basin utilized this alternative algorithm for estimating TP loads from these three structures.

Calculations are contained in the spreadsheet:
"L-8 Southern Concentrations – 1 5 2012.xlsx" and
"L-8 Basin Flows and Loads – 1 5 2012.xlsx"

Table A-1. Annual FWM TP Concentrations at the Southern L-8 Canal Structures.

Water Year	S-5AW Conc, ppb	S-5AS Conc, ppb	S-5AE Conc, ppb	Total Conc, ppb	Coef. Of Variation
1995	323	84	76	132	0.87
1996	97	109	76	84	0.18
1997	30	0	62	56	1.02
1998	24	145	64	62	0.80
1999	49	171	76	82	0.65
2000	105	184	108	119	0.34
2001	51	49	117	73	0.54
2002	37	59	50	50	0.23
2003	88	137	113	112	0.21
2004	56	169	98	99	0.53
2005	169	180	183	181	0.04
2006	178	181	142	143	0.13
2007	119	0	97	102	0.88
2008	66	181	83	69	0.56
2009	105	0	126	125	0.88
2010	80	181	124	122	0.39
2011	75	0	99	99	0.89
Total	***133***	***127***	***103***	***109***	

Figure A-1. Annual FWM Concentrations Using Standard LOAD Program Algorithm.

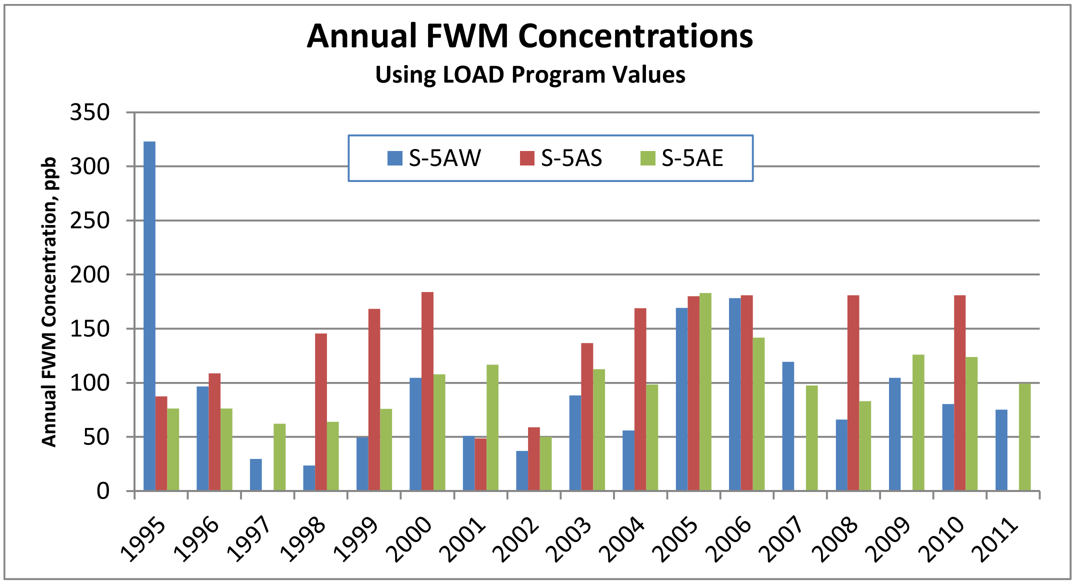


Table A-2. Summary Statistics for Southern L-8 Canal Structures During WY1995-2011.

Station	Days with Flow days	Days with Flow % of POR	Number of grab samples	# of grab samples on days with flow	% of days with flow that have grab samples	% of grab samples on days with flow	Maximum # of days between grab samples on days with flow
S-5AW	729	12%	93	29	4%	31%	602
S-5AS	309	5%	166	6	2%	4%	2294
S-5AE	3669	59%	425	293	8%	69%	532

Table A-3. Annual FWM TP Concentrations at the Southern L-8 Canal Structures, Using Common Time Series of Concentrations.

Water Year	S-5AW Conc, ppb	S-5AS Conc, ppb	S-5AE Conc, ppb	Total Conc, ppb	Coef. Of Variation
1995	51	59	79	70	0.24
1996	66	42	91	81	0.37
1997	53	0	64	62	0.88
1998	92	227	63	66	0.69
1999	89	167	74	84	0.46
2000	146	162	105	121	0.21
2001	58	46	117	76	0.52
2002	40	68	50	51	0.27
2003	90	130	109	109	0.18
2004	50	51	98	97	0.42
2005	155	191	180	177	0.10
2006	125	134	148	147	0.08
2007	79	0	90	88	0.87
2008	51	60	56	52	0.08
2009	78	0	125	122	0.93
2010	82	90	126	124	0.24
2011	111	0	99	100	0.87
Total	***78***	***107***	***104***	***101***	

Figure A-2. Annual FWM Concentrations Using Alternative Algorithm.

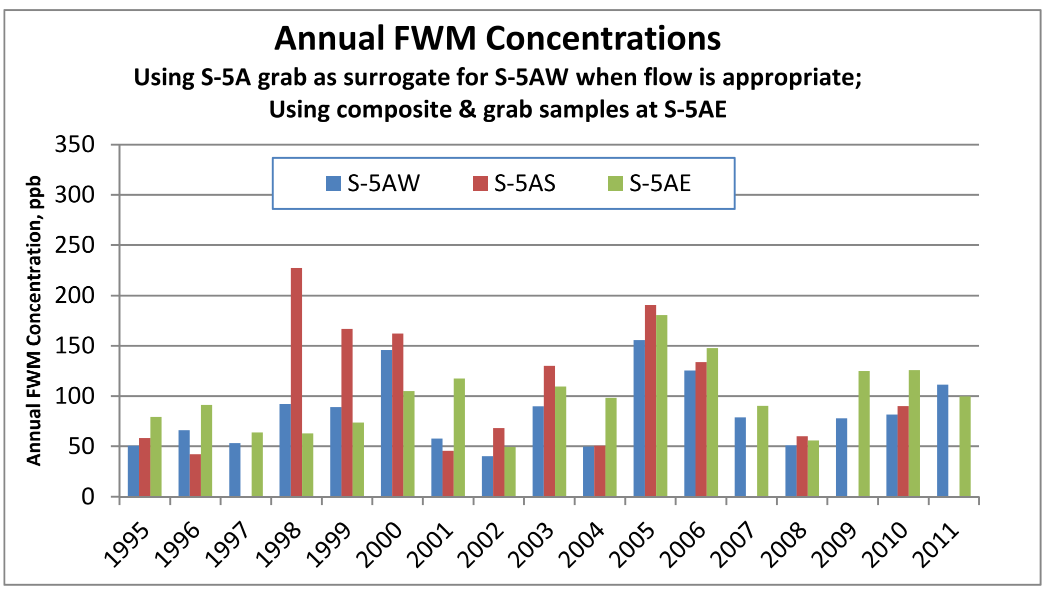
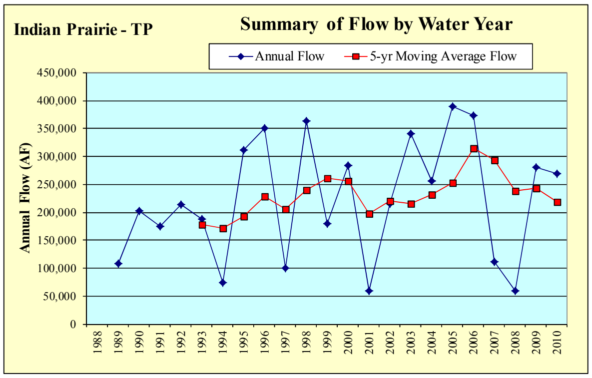
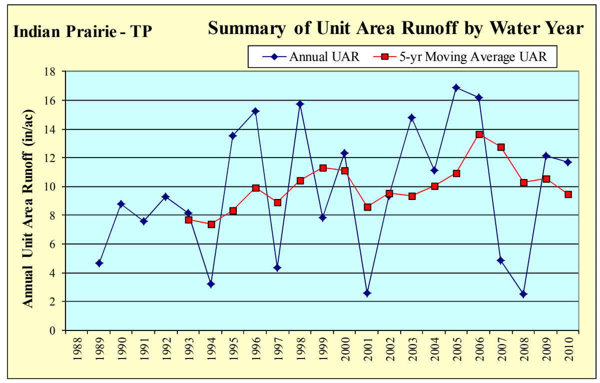


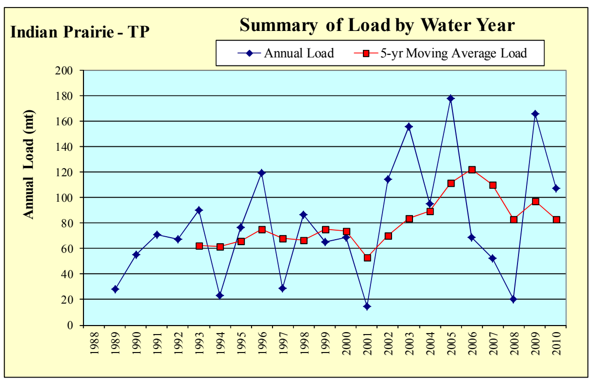
Table A-4. Comparison of Annual TP Loads.

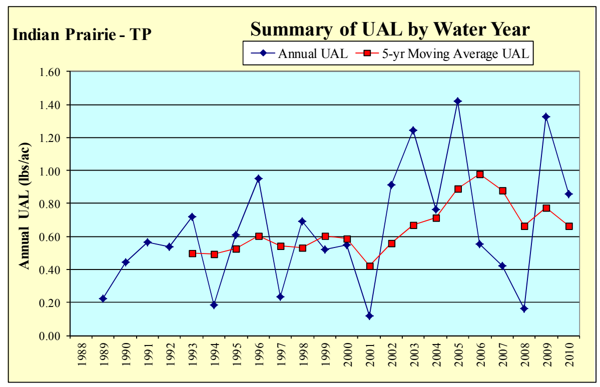
Water Year	Original				Using a Composite Daily Time Series			
	S-5AW Load, kg	S-5AS Load, kg	S-5AE Load, kg	Total Load, kg	S-5AW Load, kg	S-5AS Load, kg	S-5AE Load, kg	Total Load, kg
1995	32,759	5,926	21,703	60,388	5,141	4,121	22,526	31,789
1996	12,489	1,402	19,142	33,033	8,520	541	22,858	31,919
1997	721	0	5,879	6,600	1,293	0	6,037	7,330
1998	403	308	14,676	15,386	1,566	481	14,383	16,429
1999	858	2,709	10,586	14,153	1,546	2,645	10,249	14,441
2000	5,120	7,889	20,906	33,915	7,145	6,955	20,364	34,464
2001	1,354	585	2,340	4,280	1,533	549	2,353	4,434
2002	475	888	3,487	4,850	517	1,027	3,451	4,996
2003	1,777	1,529	27,187	30,493	1,803	1,451	26,399	29,653
2004	371	1,096	31,242	32,709	331	329	31,237	31,897
2005	6,748	4,301	35,118	46,167	6,190	4,557	34,574	45,321
2006	256	1,344	40,925	42,525	180	993	42,579	43,751
2007	992	0	3,113	4,105	652	0	2,889	3,541
2008	3,250	197	256	3,703	2,518	65	172	2,755
2009	1,116	0	18,901	20,018	832	0	18,694	19,525
2010	533	0	21,714	22,247	541	0	21,993	22,534
2011	137	0	14,491	14,628	204	0	14,501	14,705
Total	***69,359***	***28,174***	***291,666***	***389,199***	***40,511***	***23,714***	***295,259***	***359,484***
Average	***4,080***	***1,657***	***17,157***	***22,894***	***2,383***	***1,395***	***17,368***	***21,146***
Change from Original				***Total***	***-28,848***	***-4,460***	***3,593***	***-29,715***
				Average	***-1,697***	***-262***	***211***	***-1,748***
Percent Change from Original				***Total***	***-42%***	***-16%***	***1%***	***-8%***
				Average	***-42%***	***-16%***	***1%***	***-8%***

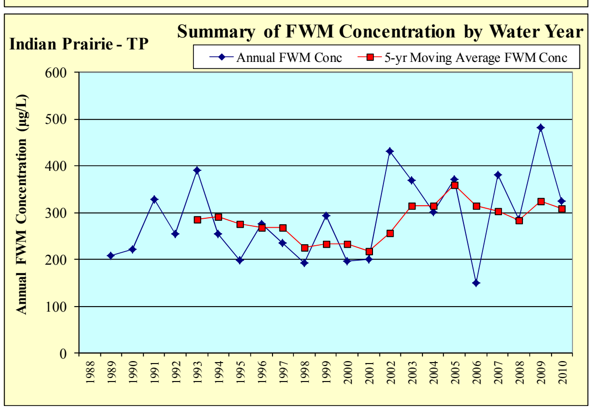
INDIAN PRAIRIE SUB-WATERSHED

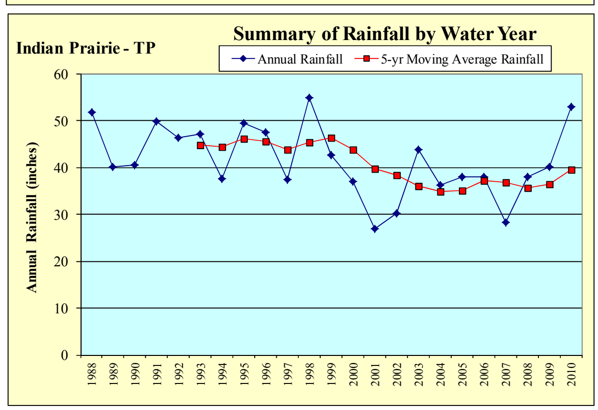












Calculation of Net Basin TP Loads for the Indian Prairie Sub-watershed

I_{IP} = total inflow to the Indian Prairie Sub-watershed
= $Q_{S\text{-}68}$
Q_{S68} = flow at S-68

O_{IP} = total outflow from the Indian Prairie Sub-watershed
= $Q_{S131} + Q_{S71} + Q_{S72} + Q_{S129} + Q_{S127} + Q_{S84} + Q_{LCanal}$
Q_{S131} = flow at S-131
Q_{S71} = flow at S-71
Q_{S72} = flow at S-72
Q_{S129} = flow at S-129[25]
Q_{S127} = flow at S-127
Q_{S84} = flow at S-84
Q_{LCanal} = total flow at L-59E, L-59W, L-60E, L-60W, L-61E, and L-61W

PT_{IP} = pass-through flow
= minimum (I_{IP} , O_{IP})
B_{IP} = net basin flow produced by local rainfall and runoff
= $O_{IP} - PT_{IP}$

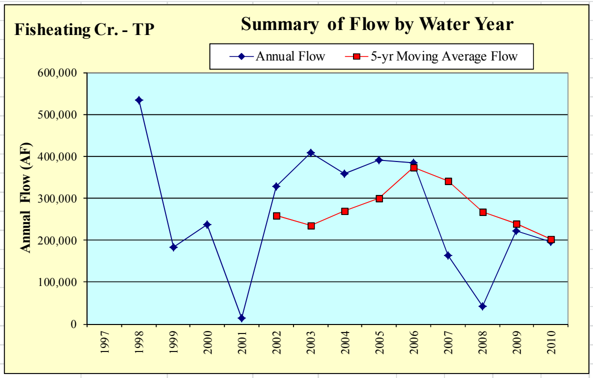
OL_{IP} = total outflow TP load from the Indian Prairie Sub-watershed
= $Q_{S131} * C_{S131} + Q_{S71} * C_{S71} + Q_{S72} * C_{S72} + Q_{S129} * C_{S129} +$
$Q_{S127} * C_{S127} + Q_{S84} * C_{S84} + Q_{LCanal} * C_{LCanal}$
C_{S131} = TP concentration at S-131
C_{S71} = TP concentration at S-71
C_{S72} = TP concentration at S-72
C_{S129} = TP concentration at S-129
C_{S127} = TP concentration at S-127
C_{S84} = TP concentration at S-84

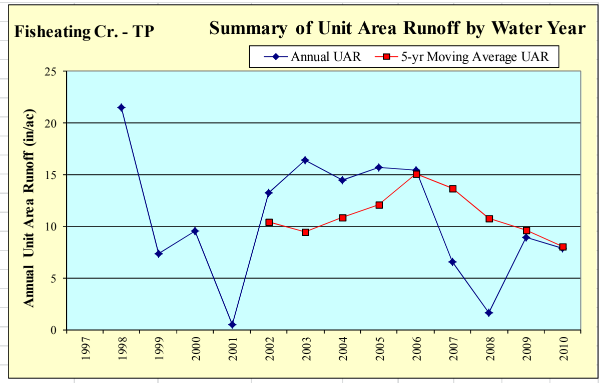
PTL_{IP} = pass through TP load
= $PT_{IP} * C_{S68}$
C_{S68} = TP concentration at S-68

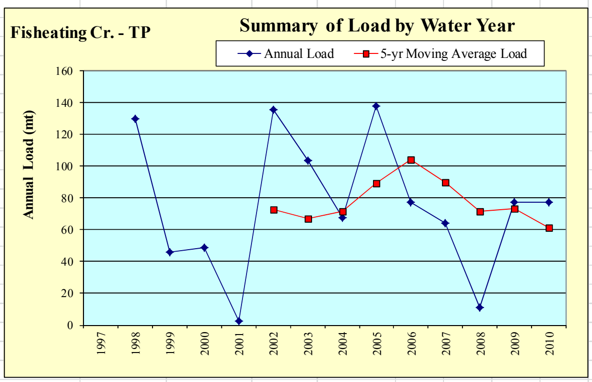
BL_{IP} = net basin load produced by local rainfall and runoff
= $OL_{IP} - PTL_{IP}$

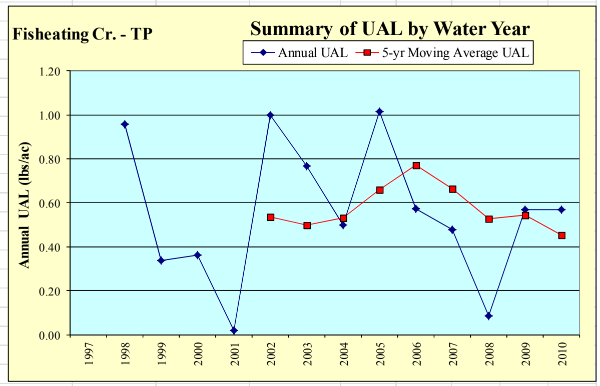
[25] After a review of the S-129 spillway data, it was determined that the negative flows were not reliable, and therefore, they were omitted from the analyses.

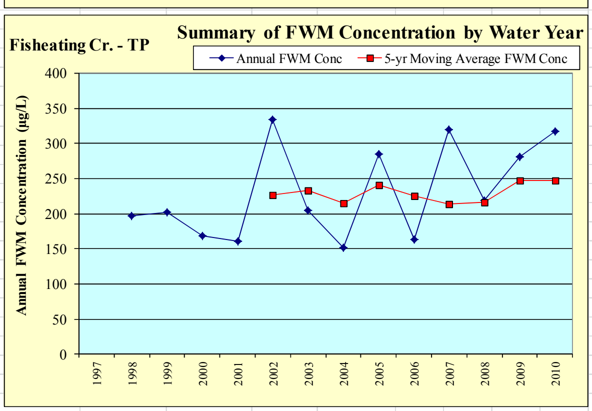
Fisheating Creek Summary Basin

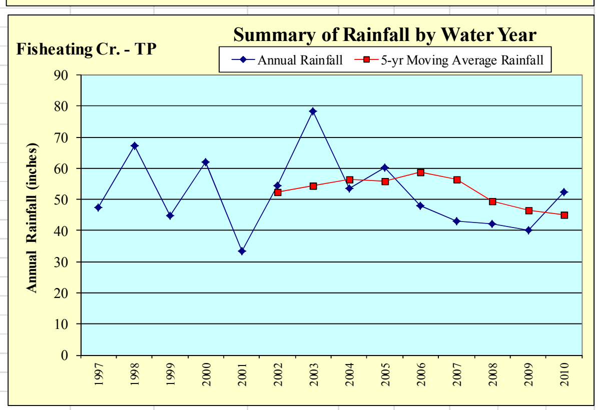






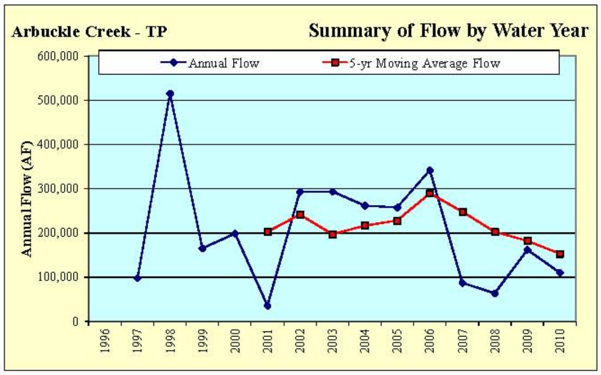


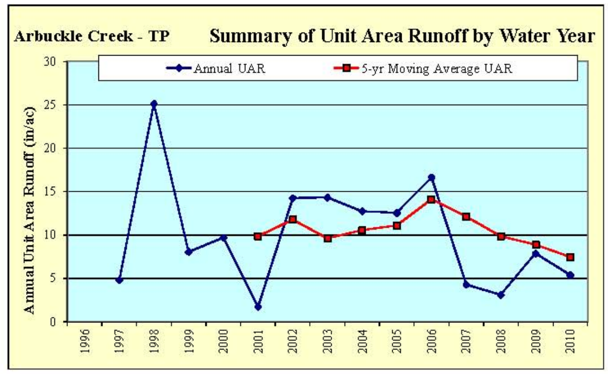


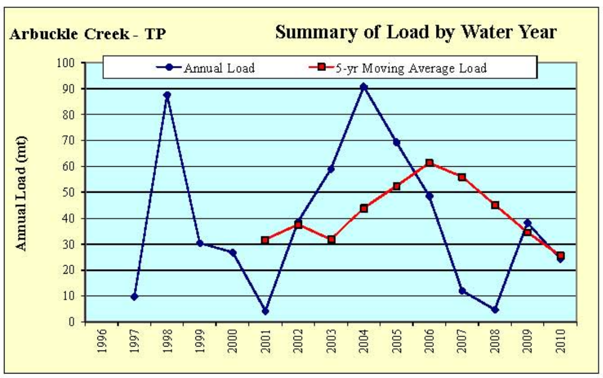


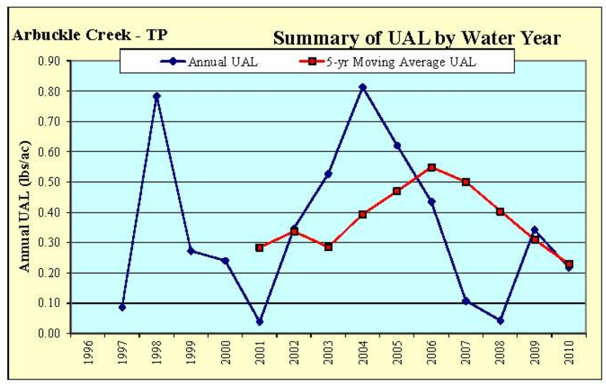
LAKE ISTOKPOGA SUB-WATERSHED

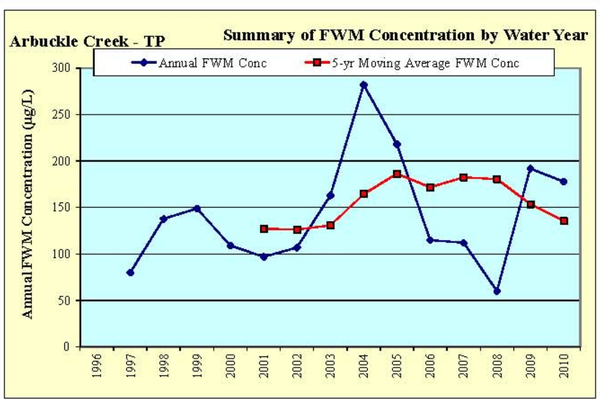
Summary of annual flow, TP and rainfall for Arbuckle Creek

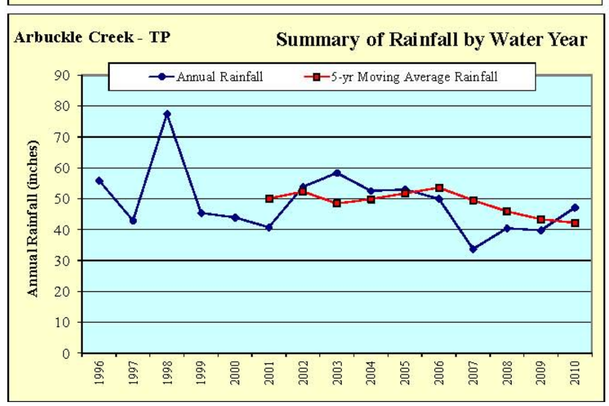








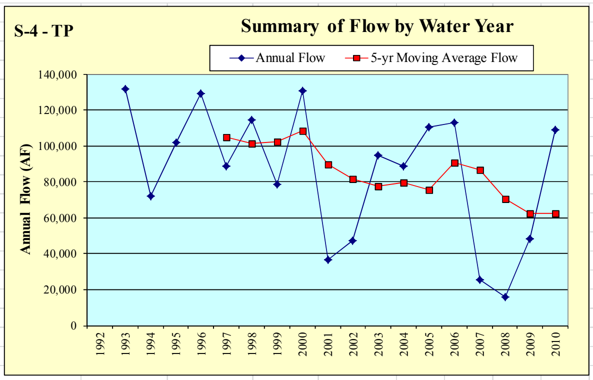


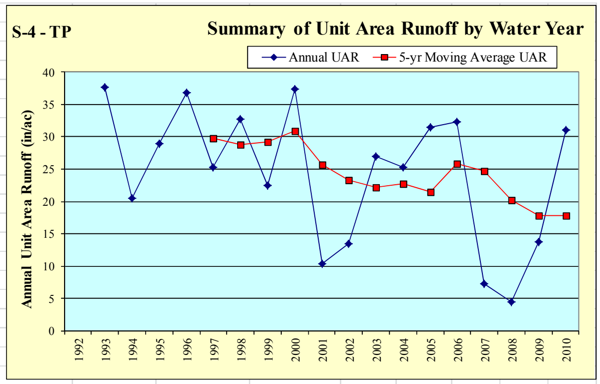


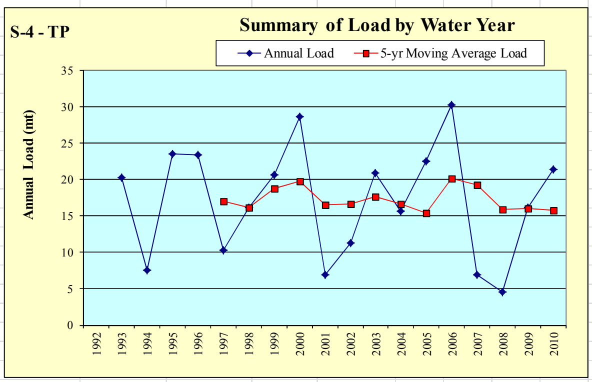
Summary of annual flow, TP and rainfall for Josephine Creek

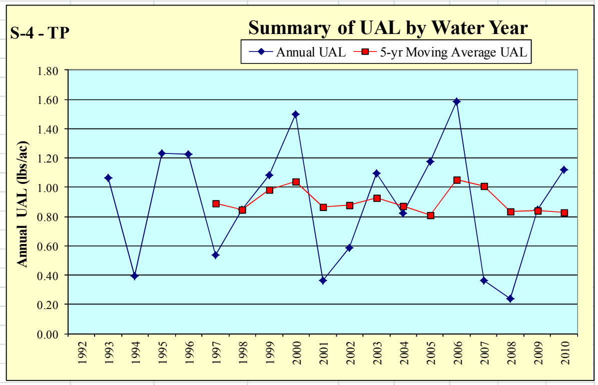
WEST CALOOSAHATCHEE SUB-WATERSHED

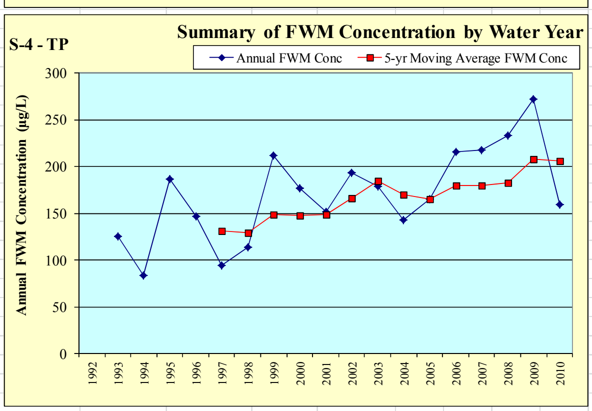
S-4/Industrial Canal Hydrologic Unit

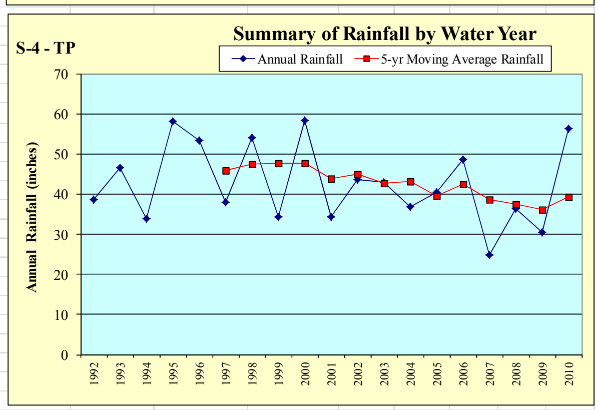












Calculation of Net Basin TP Loads for the S-4/Industrial Canal Hydrologic Unit

The S-4/Industrial Canal Hydrologic Unit receives inflows from Lake Okeechobee, the East Caloosahatchee Hydrologic Unit, and from Unit 5 of the South Florida Conservancy District (EPD-07 of the SFCD). The S-4/Industrial Canal Hydrologic Unit discharges to Lake Okeechobee and the East Caloosahatchee Hydrologic Unit. Some or all of the total inflows to the S-4/Industrial Canal Hydrologic Unit may be retained in the basin as a result of meeting agricultural and urban water supply demands, evapotranspiration, groundwater infiltration, or increasing internal storage. Pass-through flows and loads are the portion of the total inflows that are discharged from the hydrologic unit. Because S-169 controls flow between the S-4 Sub-basin and the Industrial Canal Sub-basin, flow through S-169 must be considered in the calculation of the hydrologic unit's pass-through flows and loads. Failure to do so will result in overestimates of pass through, e.g., on days when S-169 is closed, inflows to the hydrologic unit through S-310 cannot physically reach S-235 and therefore, cannot contribute to pass through at that structure. Basin flows and loads result from rainfall and runoff from the hydrologic unit and do not include pass-through flows and loads.

In order to properly account for the S-169 operations, it's necessary to make a minor modification to the standard algorithm for calculating pass-through flows and loads. Pass-through flows are calculated using applicable algorithms for four operational conditions:

1. On days when the total inflows or total outflows are zero;
2. On days when the total inflows and total outflows are nonzero and S-169 is closed;
3. On days when the total inflows and total outflows are nonzero and S-169 is discharging from the Industrial Canal Sub-basin to the S-4 Sub-basin (positive flow values in DBHYDRO);
4. On days when the total inflows and total outflows are nonzero and S-169 is discharging from the S-4 Sub-basin to the Industrial Canal Sub-basin (negative flow values in DBHYDRO);

The following equations describe how pass-through flows are calculated for each of these conditions.

1. If

$$\text{Total Inflow} = Q_{S310In} + Q_{EPD07} + Q_{S235In} = 0$$

or

$$\text{Total Outflow} = Q_{S310Out} + Q_{S4} + Q_{S235Out} = 0$$

then

$$PT_{S4IC} = \text{pass-through flow} = 0$$

where Q_{S310In} = Discharges at S-310 from Lake Okeechobee to the Industrial Canal

$Q_{S310Out}$ = Discharges at S-310 from the Industrial Canal to Lake Okeechobee

Q_{S235In} = Discharges at S-235 from the East Caloosahatchee Hydrologic Unit to the S-4 Sub-basin

$Q_{S235Out}$ = Discharges at S-235 from the S-4 Sub-basin to the East Caloosahatchee Hydrologic Unit

Q_{EPD07} = Discharges at pump station EPD-07 from SFCD to the Industrial Canal

Q_{S4} = Discharges at S-4 from the S-4 Sub-basin to Lake Okeechobee

PT_{S4IC} = Portion of the total inflow to the S-4/Industrial Canal Hydrologic Unit that is discharged from the hydrologic unit

Notes: $Q_{S4}$is unidirectional out of the hydrologic unit

Q_{EPD07} is unidirectional into the hydrologic unit

2. If

$$\text{Total Inflow} > 0$$

and

$$\text{Total Outflow} > 0$$

and

$$Q_{S169West} = 0$$

and

$$Q_{S169East} = 0$$

then

$$PT_{S4} = \text{minimum}\ (Q_{S235In}\ ,\ Q_{S4})$$

$$PT_{IC} = \text{minimum}\ (Q_{EPD07},\ Q_{S310Out})$$

$$PT_{S4IC} = PT_{S4} + PT_{IC}$$

where $Q_{S169West}$ = Discharges at S-169 from the Industrial Canal to the S-4 Sub-basin

$Q_{S169East}$ = Discharges at S-169 from the S-4 Sub-basin to the Industrial Canal Sub-basin

PT_{S4} = Portion of the total inflow to the S-4 Sub-basin that is discharged from the Sub-basin

PT_{IC} = Portion of the total inflow to the Industrial Canal Sub-basin that is discharged from the Sub-basin

3. If

$$\text{Total Inflow} > 0$$

and

$$\text{Total Outflow} > 0$$

and

$$Q_{S169West} > 0$$

then

$$PT_{IC} = \text{minimum}\ (Q_{S310In} + Q_{EPD07}\ ,\ Q_{S310Out})$$

$$PT_{S4} = \text{minimum}\ (Q_{S235In} + \text{minimum}\ (Q_{S169West}\ ,\ (Q_{S310In} + Q_{EPD07} - PT_{IC}))\ ,\ (Q_{S4} + Q_{S235Out}))$$

$$PT_{S4IC} = PT_{S4} + PT_{IC}$$

4. If

$$\text{Total Inflow} > 0$$

and

$$\text{Total Outflow} > 0$$

and

$$Q_{S169East} > 0$$

then

$$PT_{S4} = \text{minimum}\,(Q_{S235In}\,,\, Q_{S4} + Q_{S235Out}\,)$$
$$PT_{IC} = \text{minimum}\,(Q_{S310In} + Q_{EPD07} + \text{minimum}\,(Q_{S169East}\,,\,(Q_{S235In} - PT_{S4}),\, Q_{S310Out})$$
$$PT_{S4IC} = PT_{S4} + PT_{IC}$$

For all conditions,

B_{S4IC} = net basin flow produced by local rainfall and runoff
= $O_{S4IC} - PT_{S4IC}$

All calculations were performed on a daily time step and then summed to monthly and annual totals.

Pass through TP loads are calculated using the appropriate hydrologic unit flow weighted inflow concentrations, based on the applicable algorithms for the following three S-169 flow conditions:

1. On days when S-169 is closed;
2. On days when S-169 discharges to the west, from the Industrial Canal to the S-4 Sub-basin; and
3. On days when S-169 discharges to the east, from the S-4 Sub-basin to the Industrial Canal.

The following algorithms are used for the three conditions described above:

1. If

$$Q_{S169West} = Q_{S169East} = 0$$

Then

$$PTL_{IC} = PT_{IC} * C_{EPD07}$$
$$PTL_{S4} = PT_{S4} * C_{S235In}$$
$$PTL_{S4IC} = PTL_{IC} + PTL_{S4}$$

where PTL_{IC} = Portion of the total inflow load to the Industrial Canal Sub-basin that is discharged from the Sub-basin

C_{EPD07} = Concentration of discharges at pump station EPD-07

PTL_{S4} = Portion of the total inflow load to the S-4 Sub-basin that is discharged from the Sub-basin

C_{S235In} = Concentration of S-235 discharges from the East Caloosahatchee Hydrologic Unit to the S-4 Sub-basin

PTL_{S4IC} = Portion of the total inflow load to the S-4/Industrial Canal Hydrologic Unit that is discharged from the Hydrologic Unit

2. If

$$Q_{S169West} > 0$$

Then

$$PTL_{IC} = PT_{IC} * C_{EPD07}$$

$$PTC_{S4} = (Q_{S235In} * C_{S235In} + Q_{EPD07} * C_{EPD07} + Q_{S310In} * C_{S310In}) / (Q_{S235In} + Q_{EPD07} + Q_{S310In})$$

$$PTL_{S4} = PT_{S4} * PTC_{S4}$$

$$PTL_{S4IC} = PTL_{IC} + PTL_{S4}$$

where PTC_{S4} = Flow weighted inflow concentration of S-4 Sub-basin
C_{S235In} = Concentration of flows at S-235 from East Caloosahatchee Hydrologic Unit to the S-4 Sub-basin
C_{EPDO7} = Concentration discharged at pump station EPD-07 into the Industrial Canal Sub-basin
C_{S310In} = Concentration discharged at S-310 from Lake Okeechobee into the Industrial Canal Sub-basin

3. If

$$Q_{S169East} > 0$$

Then

$$PTL_{IC}=PT_{IC} * (Q_{S235In} * C_{S235In} + Q_{EPD07} * C_{EPD07}) / (Q_{S235In} + Q_{EPD07})$$

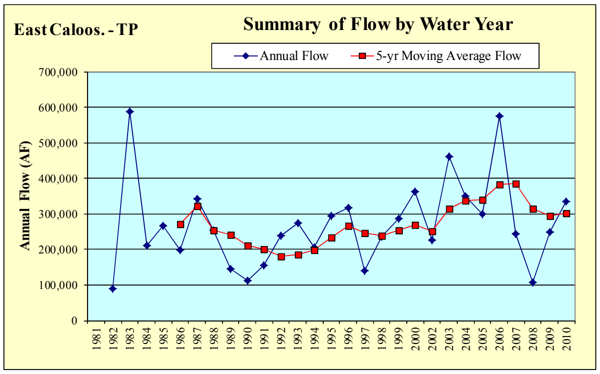
$$PTL_{S4} = PT_{S4} * C_{S235In}$$

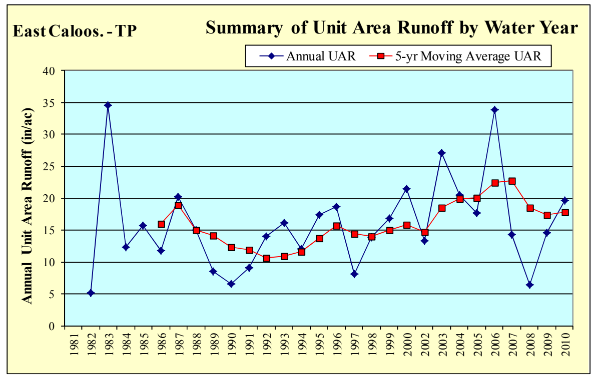
$$PTL_{S4IC} = PTL_{IC} + PTL_{S4}$$

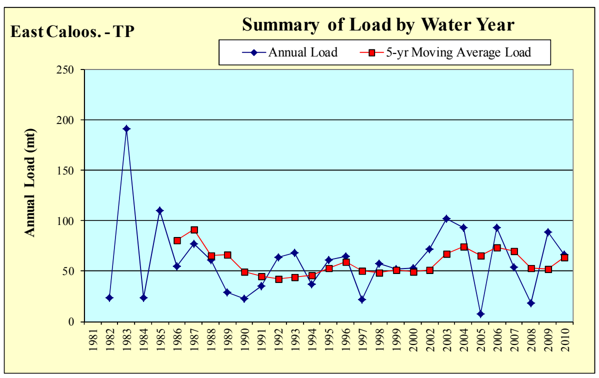
Once the pass-through loads are calculated, the hydrologic unit's net basin loads are calculated by subtracting pass-through loads from the total outflow loads as follows:

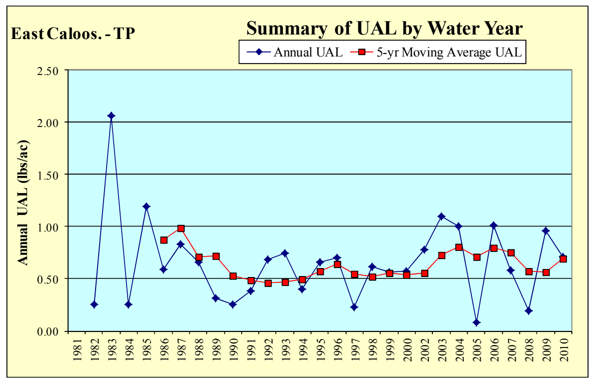
BL_{S4IC} = net basin load produced by local rainfall and runoff
= $OL_{S4IC} – PTL_{S4IC}$
OL_{S4IC} = $OL_{S235} + OL_{S4} + OL_{S310Out}$
OL_{S235} = load discharged at S-235 to the East Caloosahatchee Hydrologic Unit
OL_{S4} = load discharged at S-4 to Lake Okeechobee
$OL_{S310Out}$ = load discharged at S-310 to Lake Okeechobee

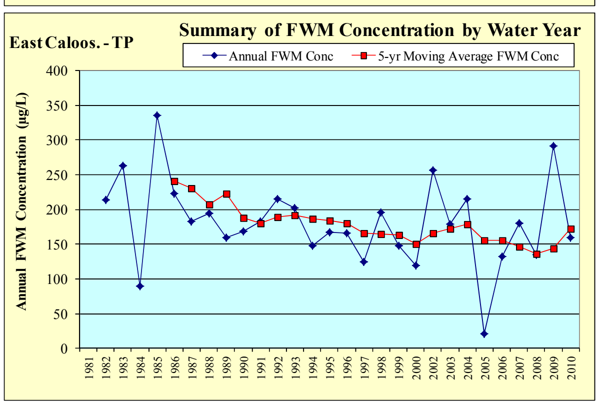
East Caloosahatchee Hydrologic Unit

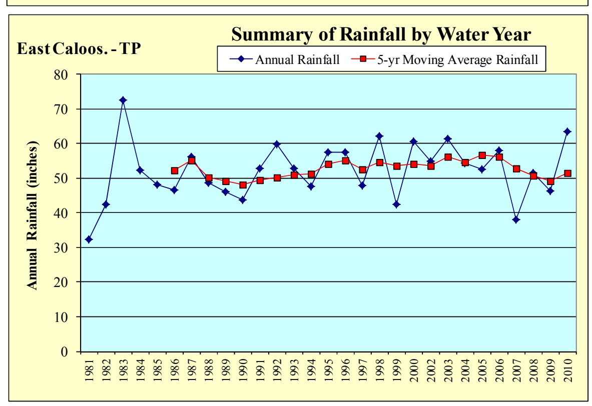












Calculation of Net Basin TP Loads for the East Caloosahatchee Hydrologic Unit

East Caloosahatchee Hydrologic Unit Flows

I_{EC} = total inflow to the East Caloosahatchee Hydrologic Unit
= $Q_{S77In} + Q_{S235In}$
$QS77_{In}$ = S-77 discharges from Lake Okeechobee into C-43
$QS235_{In}$ = S-235 discharges from the L-D3 Canal into C-43

O_{EC} = total outflow from the East Caloosahatchee Hydrologic Unit
= $Q_{S77Out} + Q_{S235Out} + Q_{S78}$
Q_{S77Out} = S-77 discharges from C-43 into Lake Okeechobee
$Q_{S235Out}$ = S-235 discharges from C-43 into the L-D3 Canal
Q_{S78} = S-78 discharges

PT_{EC} = pass through flow
= minimum (I_{EC}, O_{EC})

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

East Caloosahatchee Hydrologic Unit Loads

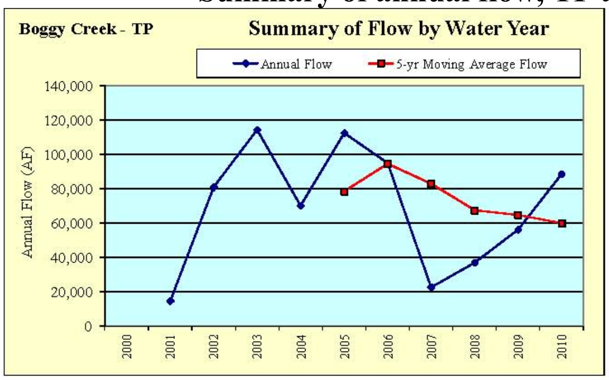
OL_{EC} = total outflow TP load
= $Q_{S77Out} * C_{S77Out} + Q_{S235Out} * C_{S235Out} + Q_{S78} * C_{S78}$
C_{S77Out} = S-77 TP outflow concentration
$C_{S235Out}$ = S-235 TP outflow concentration
C_{S78} = S-78 TP concentration

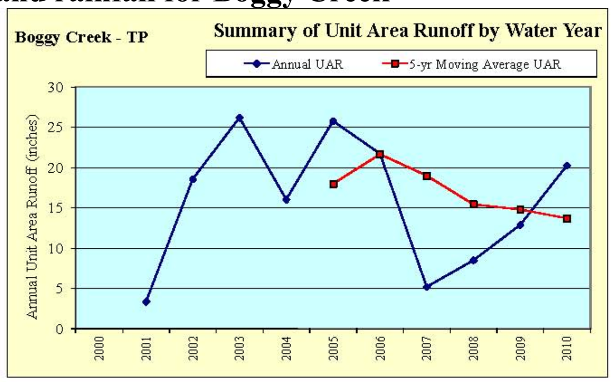
PTL_{EC} = pass through TP load
= $PT_{EC} * C_{In}$
C_{In} = cumulative flow weighted mean inflow concentration
= $(Q_{S77In} * C_{S77In} + Q_{S235In} * C_{S235In}) / I_{EC}$

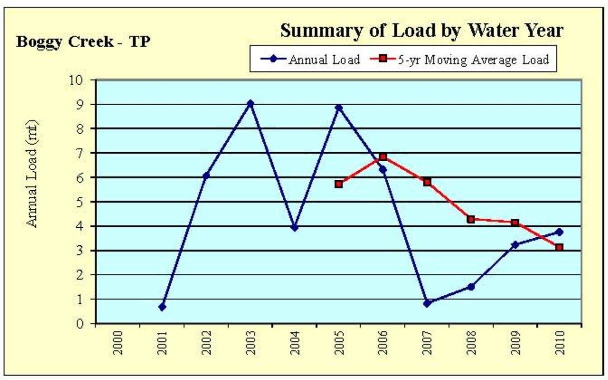
BL_{EC} = net basin load produced by local rainfall and runoff
= $OL_{EC} - PTL_{EC}$
C_{S77In} = S-77 TP inflow concentration
C_{S235In} = S-235 TP inflow concentration

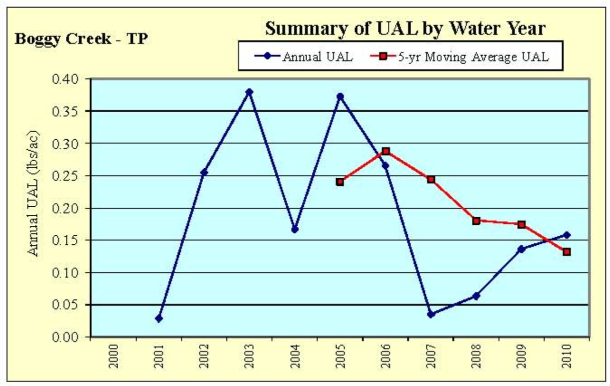
UPPER KISSIMMEE SUB-WATERSHED

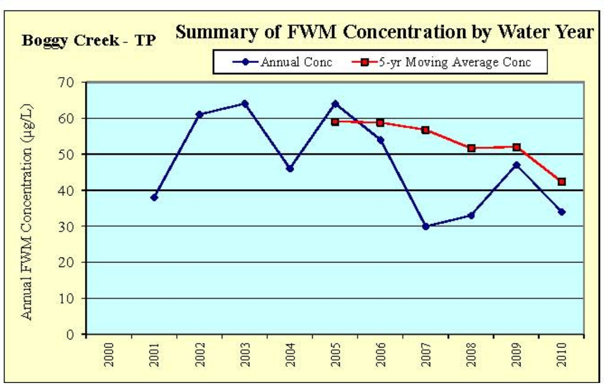
Summary of annual flow, TP and rainfall for Boggy Creek

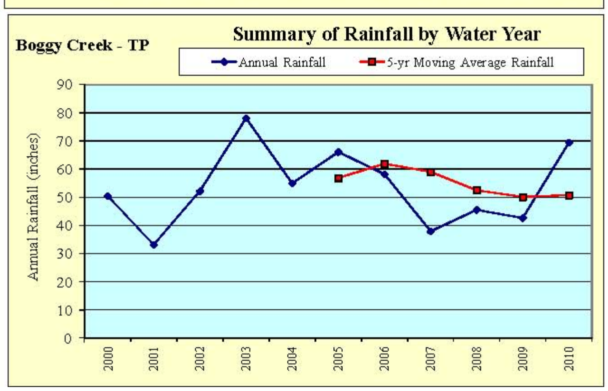




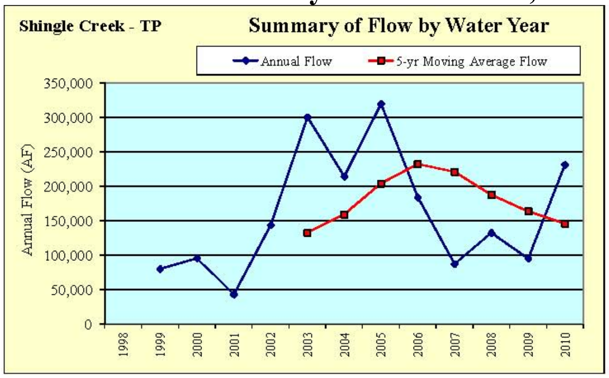


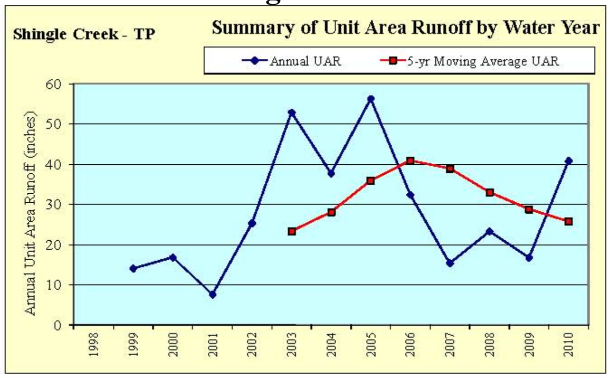


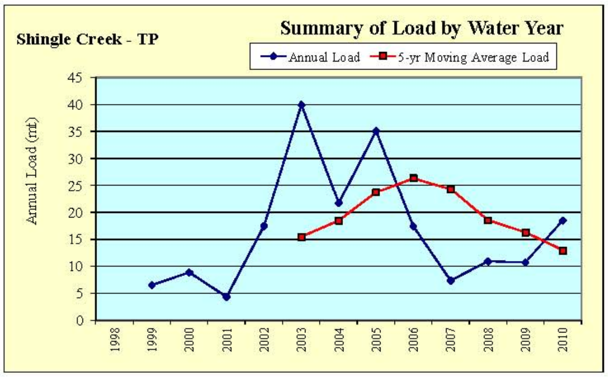


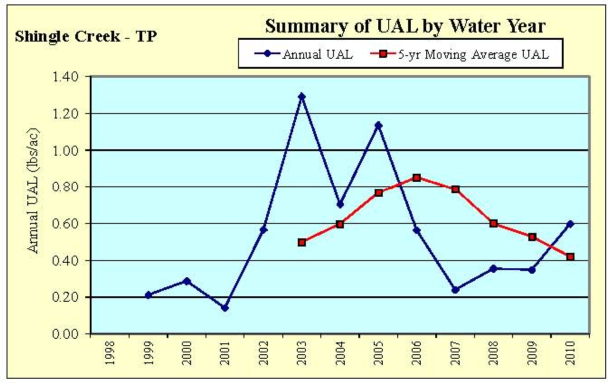


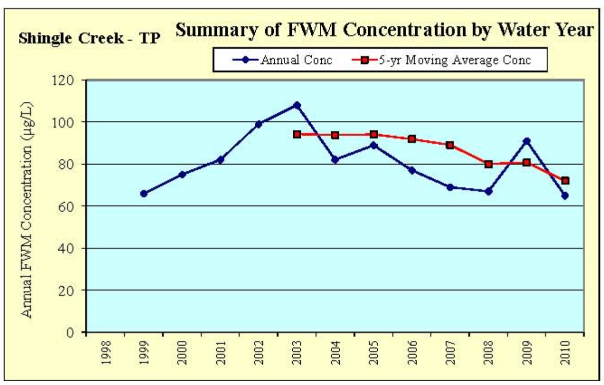
Summary of annual flow, TP and rainfall for Shingle Creek

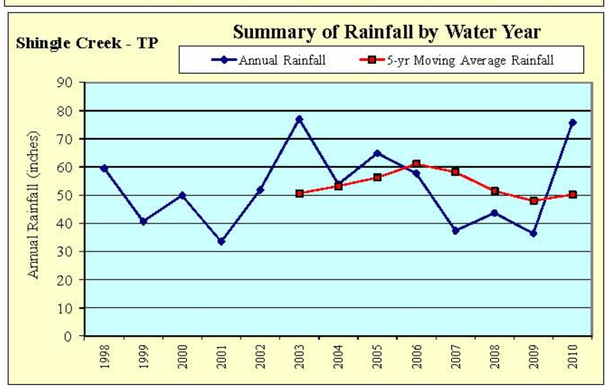












APPENDIX B – DERIVATION OF EQUATIONS FOR THE PERFORMANCE MEASURE METHODOLOGIES OF THE LAKE OKEECHOBEE WATERSHED

TAYLOR CREEK-NUBBIN SLOUGH SUB-WATERSHED

S-133 Summary Basin

Following the procedures described in Section 2.6, the annual load discharged from S-133 was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = L = a + b_1X + b_2P + b_3C$$

Where L = 12-month load (mt),

- a = the intercept of the regression line
- b_1 = the regression coefficient for X
- b_2 = the regression coefficient for P
- b_3 = the regression coefficient for C
- X = the natural logarithm of the 12-month total rainfall (inches)
- P = natural logarithm of the previous year's rainfall, i.e., previous year's X
- C = the coefficient of variation calculated from 12 monthly rainfall totals

The predictors X, P and C are calculated from the first two moments (m_1 and m_2) of the 12 monthly rainfall totals for the Water Year:

- r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
- $m_1 = \text{Sum} [r_i] / 12$
- $m_2 = \text{Sum} [r_i - m_1]^2 / 12$
- $X = \ln(12\ m_1)$
- $C = [(12/11)\ m_2]^{0.5} / m_1$

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

$$\text{annual load}_{\text{prediction}} = -267.97167 + 26.1842\ \text{Ln(Rain)} + 39.22017\ \text{Ln(Prior Rain)} + 40.70221\ \text{CV}$$

The coefficient of determination (R^2) for the resulting equation was 0.791, with a standard error of regression of 5.181 mt. The standard error of regression was approximately 50 percent of the Base Period mean annual load. The coefficients of the regression line were significantly different from zero at the 90 percent confidence level, with p-values less than 10 percent for the coefficients b_1, b_2 and b_3.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction, with an associated theoretical Type I error (i.e., false positive) rate of 10 percent[26]. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted annual load, as expressed below:

$$\text{annual load UCL} = TP_{90\%\,CL} = \text{predicted Annual Load} + [(t_{\alpha,n-4})\ SE_p]$$

where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
$t_{\alpha,n-4}$ is the value of the one-tailed t statistic at significance level α, with n-4 degrees of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
n is the number of annual TP loads in the Base Period (= 10)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s\Big[\ 1 + \frac{1}{n} + \operatorname{var}(b_1)\frac{(X - X_m)^2}{s^2} + \operatorname{var}(b_2)\frac{(P - P_m)^2}{s^2} + \operatorname{var}(b_3)\frac{(C - C_m)^2}{s^2} +$$

$$2\operatorname{cov}(b_1, b_2)\frac{(X - X_m)(P - P_m)}{s^2} + 2\operatorname{cov}(b_1, b_3)\frac{(X - X_m)(C - C_m)}{s^2} + 2\operatorname{cov}(b_2, b_3)\frac{(P - P_m)(C - C_m)}{s^2}\ \Big]^{0.5}$$

where s is the standard error of the regression equation = 5.18054 mt
X_m = average value of the predictor in the Base Period = 3.79116
P_m = average value of the predictor in the Base Period = 3.77727
C_m = average value of the predictor in the Base Period = 0.75970
n = 10
$t_{\alpha,n-4}$ = 1.43976

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

$var(b_1) = 80.95311$
$var(b_2) = 107.40530$
$var(b3) = 282.32889$
$cov(b_1,b_2) = 5.10816$
$cov(b_1,b_3) = 39.16755$
$cov(b_2,b_3) = 116.41471$

Collecting terms yields

$$SE = 5.18054 [1 + 1/10 + 3.01636 (X\text{-}X_m)^2 + 4.00199 (P\text{–}P_m)^2 + 10.51975 (C\text{-}C_m)^2 +$$

$$0.38068 (X\text{-}X_m) (P\text{–}Pm) + 2.91882 (X\text{-}X_m) (C\text{-}C_m) + 8.67536 (P\text{-}P_m) (C\text{-}C_m)]^{0.5}$$

The above equations can be converted to a performance measure by means of the following conversions to incorporate the load reduction for the collective source controls[27].

For an Annual Load Target with Y percent load reduction, e.g., using a 25 percent reduction (Y = 0.25), based on untransformed annual loads,

Target equation intercept = intercept at 0% reduction * (1 – Y)

Target equation coefficients (b_i) = b_i at 0% reduction * (1 – Y)

For an Annual Load Limit with Y percent load reduction based on untransformed annual loads,

s and SE_p = value at 0% reduction * (1 - Y)

$var(b_i)$ & $cov(b_i,b_j)$ = value at 0% reduction * $(1 – Y)^2$

[27] Because of the potential for round-off errors in the calculations, it is recommended to use the accompanying spreadsheets rather than a calculator and the above values.

S-154 Summary Basin

Following the procedures described in Section 2.6, the annual load discharged from S-154 was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

annual load prediction (mt) = L = exp $(a + b_1X)$

Where L = 12-month load (mt)
a = the intercept of the regression line
b_1 = the regression coefficient for X
X = the 12-month total rainfall (inches)

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals for the Water Year:
r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
m_1 = Sum [r_i] / 12
X = 12 m_1

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

annual load prediction = exp (-4.77448 + 0.16555 Rain)

The coefficient of determination (R^2) for the resulting equation was 0.802, with a standard error of regression of 0.74115. Since a transformation of load was required in deriving the prediction equation, a "back-transformed" standard error of the regression equation was calculated after the predictions were transformed back to the original units (mt): 24.108 mt. The back-transformed standard error of regression was approximately 80 percent of the Base Period mean annual load. The coefficient of the regression line was significantly different from zero at the 90 percent confidence level, with a p-value less than 10 percent for the coefficient b_1.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction, with an associated theoretical Type I error (i.e., false positive) rate of 10 percent. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted annual load:

annual load UCL = $TP_{90\%\ CL}$ = predicted Annual Load * exp[$(t_{\alpha,n-2})$ SE_p]

where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
$t_{\alpha,n-2}$ is the value of the one-tailed t statistic at significance level α, with n-2 degrees of freedom (for 90 percent confidence level, α = 0.10), and
n is the number of annual TP loads in the Base Period (= 8)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s\left[\ 1 + \frac{1}{n} + \frac{(X - X_m)^2}{\sum (X_i - X_m)^2}\ \right]^{0.5}$$

where s is the standard error of the regression equation = 0.74115
X_m = average value of the predictor in the Base Period = 43.2588
n = 8
$t_{\alpha,n-2}$ = 1.43976
$1 / \Sigma(X_i - X_m)^2 = 1 / 485.64409$

Collecting terms yields

$SE_p = 0.74036\ [\ 1 + 1/8 + (X\text{-}Xm)^2 / 485.64409\ ]^{0.5}$

The above equations can be converted to a performance measure by means of the following conversions after a load reduction for the collective source controls has been determined.

For an Annual Load Target with Y percent load reduction based on log transformed annual loads,

Target equation intercept (a) = intercept at 0% reduction - ln [1/(1 – Y)]
Target equation coefficient (b_i) = b_i at 0% reduction

For an Annual Load Limit with Y percent load reduction based on log transformed annual loads,

SE_p = value at 0% reduction

S-191 Summary Basin

Following the procedures described in Section 2.6, the annual load discharged from S-191 was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = L = a + b_1X + b_2C$$

Where L = 12-month load (mt)

a = the intercept of the regression line
b_1 = the regression coefficient for X
b_2 = the regression coefficient for C
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

The predictors X and C are calculated from the first two moments (m_1 and m_2) of the 12 monthly rainfall totals for the Water Year:

r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
$m_1 = \text{Sum}[\, r_i \,] / 12$
$m_2 = \text{Sum}[\, r_i - m_1 \,]^2 / 12$
$X = \ln(12\, m_1)$
$C = \ln\{[\,(12/11)\, m_2]^{0.5} / m_1\}$

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

annual load prediction = -1153.92264 + 351.50517 X + 141.49588 C

The coefficient of determination (R^2) for the resulting equation was 0.894, with a standard error of regression of 23.325 mt. The standard error of regression was approximately 17 percent of the Base Period mean annual load. The coefficients of the regression line were significantly different from zero at the 90 percent confidence level, with p-values less than 10 percent for the coefficients b_1, and b_2.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction, with an associated theoretical Type I error (i.e., false positive) rate of 10 percent. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted Annual Load, as expressed below:

$$\text{annual load UCL} = TP_{90\%\ CL} = \text{predicted Annual Load} + [(t_{\alpha,n-3})\ SE_p]$$

where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
$t_{\alpha,n-3}$ is the value of the one-tailed t statistic at significance level α, with n-3 degrees of freedom (for 90 percent confidence level, α = 0.10), and
n is the number of annual TP loads in the Base Period (= 12)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s\left[\ 1 + \frac{1}{n} + \mathrm{var}(b_1)\frac{(X - X_m)^2}{s^2} + \mathrm{var}(b_2)\frac{(C - C_m)^2}{s^2} + 2\,\mathrm{cov}(b_1, b_2)\frac{(X - X_m)(C - C_m)}{s^2}\ \right]^{0.5}$$

where s is the standard error of the regression equation = 23.32480 mt
X_m = average value of the predictor in the Base Period = 3.80143
C_m = average value of the predictor in the Base Period = -0.33003
n = 12
$t_{\alpha,n-3}$ = 1.38303
$\mathrm{var}(b_1)$ = 1699.21897
$\mathrm{var}(b_2)$ = 1152.79755
$\mathrm{cov}(b_1,b_2)$ = 419.10211

Collecting terms yields

$$SE_p = 23.3248\ [\ 1.08333 + 3.12333\ (X - X_m)^2 + 2.11893\ (C - C_m)^2 + 1.54068\ (X - X_m)\ (C - C_m)\ ]^{0.5}$$

The above equations can be converted to a performance measure by means of the following conversions to incorporate the load reduction for the collective source controls.

For an Annual Load Target with Y percent load reduction based on untransformed annual loads,
Target equation intercept = intercept at 0% reduction * (1 – Y)

Target equation coefficients (b_i) = b_i at 0% reduction * (1 – Y)

For an Annual Load Limit with Y percent load reduction based on untransformed annual loads,

s and SE_p = value at 0% reduction * (1 - Y)

$var(b_i)$ & $cov(b_i,b_j)$ = value at 0% reduction * $(1 – Y)^2$

LOWER KISSIMMEE SUB-WATERSHED

Following the procedures described in Section 2.6, the annual load discharged from the Lower Kissimmee Sub-watershed was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = L = (a + b_1X)^2$$

Where L = 12-month load (mt)
a = the intercept of the regression line
b_1 = the regression coefficient for X
X = the 12-month total rainfall (inches)

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals for the Water Year:
r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
$m_1 = \text{Sum} [r_i] / 12$
$X = (12\ m_1)$

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

$$\text{annual load prediction} = [-10.07535 + 0.37945\ \text{Rain}\ ]^2$$

The coefficient of determination (R^2) for the resulting equation was 0.751, with a standard error of the regression equation of 1.59630. Since a transformation of load was required in deriving the prediction equation, a "back-transformed" standard error of the regression equation was calculated after the predictions were transformed back to the original units (mt): 25.697 mt. The back-transformed standard error of regression was approximately 32 percent of the Base Period mean annual load. The coefficient of the regression line was significantly different from zero at the 90 percent confidence level, with a p-value less than 10 percent for the coefficient b_1.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction, with an associated theoretical Type I error (i.e., false positive) rate of 10 percent. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted annual load, as expressed below:

annual load UCL = $TP_{90\%CL}$ = [sqrt(predicted annual load) + ($t_{\alpha,n-2}$ SE_p)]^2

where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
$t_{\alpha,n-2}$ is the value of the one-tailed t statistic at significance level α, with n-2 degrees of freedom (for 90 percent confidence level, α = 0.10), and
n is the number of annual TP loads in the Base Period (= 14)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s\left[\ 1 + \frac{1}{\text{n}} + \frac{(X - X_m)^2}{\sum (X_i - X_m)^2}\ \right]^{0.5}$$

where s is the standard error of the regression equation = 1.59630
X_m = average value of the predictor in the Base Period = 48.77 inches
n = 14
$t_{\alpha,n-2}$ = 1.35622
1 / $\Sigma(X_i - X_m)^2$ = 1 / 641.63129

Collecting terms yields

SE_p = 1.59630 [1 + 1/14 + $(X-Xm)^2$ / 641.63129]$^{0.5}$

The above equations can be converted to a performance measure by means of the following conversions to incorporate the load reduction for the collective source controls.

For an Annual Load Target with Y percent reduction and sqrt-transformed annual load,
Target equation intercept = value at 0% reduction * sqrt(1 - Y)
Target equation coefficient (b_i) = value at 0% reduction * sqrt(1 - Y)

For an Annual Load Limit with Y percent load reduction and sqrt-transformed annual load,
s = value at 0% reduction * sqrt(1 - Y)

EAST LAKE OKEECHOBEE SUB-WATERSHED

C-44 Hydrologic Unit

Following the procedures described in Section 2.6, the annual load discharged from S-191 was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

annual load prediction (mt) = L = exp $[a + b_1 X + b_2 S]$

Where a = the intercept of the regression line
b_1 = the regression coefficient for X
X = the natural logarithm of the 12-month total rainfall (inches)
b_2 = the regression coefficient for S
S = skewness of annual rainfall

The predictors X and S are calculated from the first three moments (m_1, m_2 and m_3) of the 12 monthly rainfall totals for the Water Year:

r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
$m_1 = \text{Sum}[r_i] / 12$
$m_2 = \text{Sum}[r_i - m_1]^2 / 12$
$m3 = \text{Sum}[r_i - m_1]^3 / 12$
$X = \ln(12\, m_1)$
$S = (12/11)\, m_3 / m_2^{\ 1.5}$

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

annual load prediction = exp $[-5.90005 + 2.47871\, X + 0.32418\, S]$

The coefficient of determination (R^2) for the resulting equation was 83.9 percent, with a standard error of regression of 0.28226. Since a transformation of load was required in deriving the prediction equation, a "back-transformed" standard error of the regression equation was calculated after the predictions were transformed back to the original units (mt): 16.588 mt. The back-transformed standard error of regression was approximately 30 percent of the Base Period mean annual load. The coefficients of the regression line were significantly different from zero at the 90 percent confidence level, with p-values less than 10 percent for the coefficients b_1, b_2 and b_3.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction, with an associated theoretical Type I error (i.e., false positive) rate of 10 percent[28]. In deriving the upper 90 percent upper confidence limit on the predicted Annual Load, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted annual load, as expressed below:

Upper Conf. Limit on prediction = exp [ln(annual load) + (t-value * SE_p)]
= predicted annual load * exp (1.39682 * SE_p)

$$SE_p = 0.28226 \left[1 + 1/11 + 2.17746 (X-X_m)^2 + 0.37718 (S-S_m)^2 + -0.19128 (X-X_m)(S-S_m) \right]^{0.5}$$

Where X_m = mean of the log-transformed annual total rainfall for the Base Period = 3.82565
S_m = mean of the skewness of the annual total rainfall for the Base Period = 0.880
t = 1.39682

The above equations can be converted to a performance measure by means of the following conversions after a load reduction for the collective source controls has been determined.

For an Annual Load Target with Y percent load reduction based on log transformed annual loads,

Target equation intercept (a) = intercept at 0% reduction - ln [1/(1 – Y)]
Target equation coefficient (b_i) = b_i at 0% reduction

For an Annual Load Limit with Y percent load reduction based on log transformed annual loads,

SE_p = value at 0% reduction

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

L-8 Summary Basin

Following the procedures described in Section 2.6, the annual load discharged from the L-8 Summary Basin was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

annual load prediction (mt) = $L = (a + b_1X + b_2S + b_3C)^2$

Where L = 12-month load (mt)
- a = the intercept of the regression line
- b_1 = the regression coefficient for X
- X = the 12-month total rainfall (inches)
- b_2 = the regression coefficient for S
- S = the 12-month total rainfall skewness
- b_3 = the regression coefficient for C
- C = the 12-month total rainfall coefficient of variation

The predictors X, S and C are calculated from the first moment (m_1) of the 12 monthly rainfall totals for the Water Year:
- r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
- $m_1 = \text{Sum}\,[\,r_i\,] / 12$
- $m_2 = \text{Sum}\,[\,r_i - m_1\,]^2 / 12$
- $m3 = \text{Sum}\,[\,r_i - m_1\,]^3 / 12$
- $X = (12\, m_1)$
- $C = [\,(12/11)\, m_2]^{0.5} / m_1$
- $S = (12/11)\, m_3 / m_2^{\,1.5}$

Applying the coefficients derived using the ordinary least squares method yields the following prediction equation for the annual load

annual load Prediction = $(-5.6662 + 0.09213\,X - 1.72191\,S + 7.75787\,C)^2$

The coefficient of determination (R^2) for the resulting equation was 0.841, with a standard error of regression of 0.51599. Since a transformation of load was required in deriving the prediction equation, a "back-transformed" standard error of the regression equation was calculated after the predictions were transformed back to the original units (mt): 3.560 mt. The back-transformed standard error of regression was approximately 21 percent of the Base

Period mean annual load. The coefficients of the regression line were significantly different from zero at the 90 percent confidence level, with p-values less than 10 percent for the coefficients b_1, b_2 and b_3.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction, with an associated theoretical Type I error (i.e., false positive) rate of 10 percent[29]. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted Annual Load, as expressed below:

$$\text{annual load UCL} = TP_{90\%CL} = [\ \text{sqrt(predicted annual load)} + (t_{\alpha,n-4})\ SE_p\ ]^2$$

where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
$t_{\alpha,n-4}$ is the value of the one-tailed t statistic at significance level α, with n-4 degrees of freedom (for 90 percent confidence level, α = 0.10), and
n is the number of annual TP loads in the Base Period (= 9)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s[\ 1 + \frac{1}{n} + \text{var}(b_1)\frac{(X - X_m)^2}{s^2} + \text{var}(b_2)\frac{(S - S_m)^2}{s^2} + \text{var}(b_3)\frac{(C - C_m)^2}{s^2} +$$

$$2\,\text{cov}(b_1, b_2)\frac{(X - X_m)(S - S_m)}{s^2} + 2\,\text{cov}(b_1, b_3)\frac{(X - X_m)(C - C_m)}{s^2} + 2\,\text{cov}(b_2, b_3)\frac{(S - S_m)(C - C_m)}{s^2}\ ]^{0.5}$$

where s is the standard error of the regression equation = 0.51601
Where X_m = mean rainfall during Base Period (54.299 inches)
S_m = mean rainfall skewness during Base Period (0.557)
C_m = mean rainfall coefficient of variation during Base Period (0.720)
t-value = 1.47588
n = 9
var(b_1) = 0.00056
var(b_2) = 0.26130
var(b3) = 3.89591

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

$cov(b_1,b_2) = -0.00007$
$cov(b_1,b_3) = 0.02660$
$cov(b_2,b_3) = -0.58242$

Collecting terms yields

$$SE = 0.516 [1 + 1/9 + 0.0021 (X-X_m)^2 + 0.9814 (S–S_m)^2 + 14.6322 (C-C_m)^2 +-0.0006 (X-X_m) (S–S_m) + 0.1998 (X-X_m) (C-C_m) + -4.375 (S-S_m) (C-C_m)]^{0.5}$$

The above equations can be converted to a performance measure by means of the following conversions to incorporate the load reduction for the collective source controls.

For an Annual Load Target with Y percent reduction and sqrt-transformed annual load,
Target equation intercept = value at 0% reduction * sqrt(1 - Y)
Target equation coefficient (b_i) = value at 0% reduction * sqrt(1 - Y)

For an Annual Load Limit with Y percent load reduction and sqrt-transformed annual load,
s = value at 0% reduction * sqrt(1 - Y)

Indian Prairie Sub-watershed

Following the procedures described in Section 2.6, the annual load discharged from the Indian Prairie Sub-watershed was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = \ln(L) = \exp(a + b_1X + b_2C)$$

Where L = 12-month load (mt),
- a = the intercept of the regression line
- b_1 = the regression coefficient for X
- b_2 = the regression coefficient for C
- X = the natural logarithm of the 12-month total rainfall [ln(inches)]
- C = the 12-month total rainfall coefficient of variation

The predictors X and C are calculated from the first two moments (m_1 and m_2) of the 12 monthly rainfall totals for the Water Year:
- r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
- $m_1 = \text{Sum}[\,r_i\,] / 12$
- $m_2 = \text{Sum}[\,r_i - m_1\,]^2 / 12$
- $X = \ln(12\,m_1)$
- $C = [\,(12/11)\,m_2]^{0.5}/m_1$

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

$$\text{annual load prediction} = \exp[-12.48183 + 4.02125\ \ln(\text{Rain}) + 1.7627\ \text{CV}]$$

The coefficient of determination (R^2) for the resulting equation was 0.911, with a standard error of regression of 0.20346. Since a transformation of load was required in deriving the prediction equation, a "back-transformed" standard error of the regression equation was calculated after the predictions were transformed back to the original units (mt): 14.794 mt. The back-transformed standard error of regression was approximately 24 percent of the Base Period mean annual load. The coefficients of the regression line were significantly different from zero at the 90 percent confidence level, with p-values less than 10 percent for the coefficients b_1 and b_2.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction from Equation (1), with an associated theoretical Type I error (i.e., false positive) rate of 10%[30]. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted annual load, as expressed below:

annual load UCL = $TP_{90\%CL} = \exp [\ \ln(\text{predicted annual load}) + [\ (t_{\alpha,n-3})\ SE_p\ ]$

where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
$t_{\alpha,n-3}$ is the value of the one-tailed t statistic at significance level α, with n-3 degrees of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
n is the number of annual TP loads in the Base Period (= 13)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s[\ 1 + \frac{1}{n} + \text{var}(b_1)\frac{(X - X_m)^2}{s^2} + \text{var}(b_2)\frac{(C - C_m)^2}{s^2} + 2\,\text{cov}(b_1, b_2)\frac{(X - X_m)(C - C_m)}{s^2}\ ]^{0.5}$$

where s is the standard error of the regression equation = 0.20346
X_m = average value of the predictor in the Base Period = 3.74445
C_m = average value of the predictor in the Base Period = 0.788
$t_{\alpha,n-3} = 1.37218$
$\text{var}(b_1) = 0.16228$
$\text{var}(b_2) = 0.13236$
$\text{cov}(b_1,b_2) = 0.08990$

Collecting terms yields

$$SE = 0.20346\ [\ 1 + 1/13 + 3.92019\ (X-X_m)^2 + 3.19741\ (C-C_m)^2 + 4.34342\ (X-X_m)\ (C-C_m)\ ]^{0.5}$$

The above equations can be converted to a performance measure by means of the following conversions after a load reduction for the collective source controls has been determined.

For an Annual Load Target with Y% load reduction and log-transformed annual load,

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

Target Equation intercept = value at 0% reduction – ln[1/(1-Y)]

Target Equation coefficients (b_i) = value at 0% reduction

For example, if the load reduction = 30 percent, the Annual Load Target becomes

Annual Load Target = exp [-12.48183 – ln[1/(1-0.3)] + 4.02125 ln(Rain) + 1.7627 CV]

Annual Load Target = exp (-12.83843 + 4.02125 X + 1.7627 C)

For an Annual Load Limit with Y percent load reduction based on log transformed annual loads,

SE_p = value at 0% reduction

Fisheating Creek Summary Basin

Following the procedures described in Section 2.6, the annual load discharged from the Fisheating Creek Summary Basin was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = L = a + b_1X$$

Where L = 12-month load (mt),

- a = the intercept of the regression line,
- b_1 = the regression coefficient for X,
- X = the natural logarithm of the 12-month total rainfall (inches)

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals for the Water Year:

- r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
- $m_1 = \text{Sum} [r_i] / 12$
- $X = \ln(12\ m_1)$

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

$$\text{annual load prediction} = -486.14648 + 142.06268 \ln(\text{Rain})$$

The coefficient of determination (R^2) for the resulting equation was 0.535, with a standard error of regression of 34.040 mt. The standard error of regression was approximately 45 percent of the Base Period mean annual load. The coefficient of the regression line was significantly different from zero at the 90 percent confidence level, with a p-value less than 10 percent for the coefficient b_1.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction from Equation (1), with an associated theoretical Type I error (i.e., false positive) rate of 10%[31]. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the

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

product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted annual load, as expressed below:

annual load UCL = $TP_{90\%\ CL} = \text{predicted Annual Load} + [(t_{\alpha,n-2})\ SE_p]$

where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
$t_{\alpha,n-2}$ is the value of the one-tailed t statistic at significance level α, with n-2 degrees of freedom (for 90 percent confidence level, α = 0.10), and
n is the number of annual TP loads in the Base Period (= 11)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s[\ 1 + \frac{1}{\text{n}} + \frac{(X - X_m)^2}{\sum (X_i - X_m)^2}\ ]^{0.5}$$

where s is the standard error of the regression equation = 34.04011
X_m = average value of the predictor in the Base Period = 3.9502
n = 11
$t_{\alpha,n-2}$ = 1.38303
$1 / \Sigma(X_i-X_m)^2 = 1 / 0.59477$

Collecting terms, Eqn (4) becomes

$SE_p = SE = 34.04011\ [\ 1 + 1/11 + (X\text{-}Xm)^{2} / 0.59477\ ]^{0.5}$

The above equations can be converted to a performance measure by means of the following conversions after a load reduction for the collective source controls has been determined.

For an Annual Load Target with Y percent reduction based on untransformed annual loads,

Target Eqn. Intercept = intercept at 0% reduction * (1 – Y)

Target Equation coefficients (b_i) = b_i at 0% reduction * (1 – Y)

For an Annual Load Limit with Y percent reduction based on untransformed annual loads,

s and SE_p = value at 0% reduction * (1 - Y)

var(b_i) & cov($b_{i,bj}$) = value at 0% reduction * $(1 – Y)^2$

WEST LAKE OKEECHOBEE SUB-WATERSHED

S-4/Industrial Canal Hydrologic Unit

Following the procedures described in Section 2.6, the annual load discharged from the S-4 Hydrologic Unit was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load was derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = L = a + b_1X + b_2C$$

Where: L = 12-month load (mt)
- a = the intercept of the regression line
- b_1 = the regression coefficient for X
- b_2 = the regression coefficient for C
- X = the 12-month total rainfall (inches)
- C = the coefficient of variation calculated from 12 monthly rainfall totals

The predictors X and C are calculated from the first two moments (m_1 and m_2) of the 12 monthly rainfall totals for the Water Year:
- r_i = monthly rainfall, for i=1 to 12 months of 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 coefficient of determination (R^2) for the resulting equation was 0.762, with a standard error of regression of 4.323 mt. The standard error of regression was approximately 25 percent of the Base Period mean annual load. The slope coefficients of the regression equation were significantly different from zero at the 90 percent confidence level, with p-values less than ten percent for the coefficients b_1 and b_2.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit was derived as the upper 90 percent confidence limit above the annual load prediction described above, with an associated theoretical Type I error (i.e., false positive) rate of 10%. In deriving the upper 90 percent upper confidence limit (UCL), the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted annual load:

$$\text{UCL on the annual load Limit} = TP_{90\%\,CL} = \text{Target} + [(t_{\alpha,n-3})\, TP_{90\%\,CL} = \text{Target} + [(t_{\alpha,n-3})\ SE_p\,]$$

where: $TP_{90\%CL}$ is the UCL corresponding to the upper 90 percent confidence limit,
$t_{\alpha,n-3}$ is the value of the one-tailed t statistic at significance level α, with n-3 degrees of freedom (for 90 percent confidence level, α = 0.10), and
n is the number of annual TP loads in the Base Period (= 9)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s[\ 1 + \frac{1}{n} + \text{var}(b_1)\frac{(X - X_m)^2}{s^2} + \text{var}(b_2)\frac{(C - C_m)^2}{s^2} + 2\,\text{cov}(b_1, b_2)\frac{(X - X_m)(C - C_m)}{s^2}\ ]^{0.5}$$

where: s is the standard error of the regression equation = 4.323 mt
X_m = average value of the predictor in the Base Period = 45.7044 inches
C_m = average value of the predictor in the Base Period = 0.9137
n = 9
$t_{\alpha,n-3}$ = 1.43976
$\text{var}(b_1)$ = 0.02094
$\text{var}(b_2)$ = 38.08623
$\text{cov}(b_1,b_2)$ = 0.08270

Collecting terms yields
$SE_p = 4.32303\ [\ 1 + 1/9 + 0.00112\ (X-X_m)^2 + 2.03794\ (C–C_m)^2\ + 0.00886\ (X-X_m)\ (C–C_m)\ ]^{0.5}$

The above equations can be converted to a performance measure by means of the following conversions after a load reduction for the collective source controls has been determined.

For an Annual Load Target with Y percent reduction based on untransformed annual loads,
Target Eqn. Intercept = intercept at 0% reduction * (1 – Y)
Target Equation coefficients (b_i) = b_i at 0% reduction * (1 – Y)
For an Annual Load Limit with Y percent reduction based on untransformed annual loads,
s and SE_p = value at 0% reduction * (1 - Y)
$\text{var}(b_i)$ & $\text{cov}(b_{i,bj})$ = value at 0% reduction * $(1 – Y)^2$

East Caloosahatchee Hydrologic Unit

Following the procedures described in Section 2.6, the annual load discharged from the East Caloosahatchee Hydrologic Unit was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = L = a + b_1 X$$

Where L = 12-month load (mt),
a = the intercept of the regression line,
b_1 = the regression coefficient for X,
X = the 12-month total rainfall (inches)

The predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals for the Water Year:
r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
$m_1 = \text{Sum}\ [\ r_i\ ] / 12$
$X = (12\ m_1)$

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

$$\text{annual load prediction} = -195.41118 + 5.12752\ (\text{Rain})$$

The coefficient of determination (R^2) for the resulting equation was 0.726, with a standard error of regression of 31.138 mt. The standard error of regression was approximately 47 percent of the Base Period mean annual load. The coefficient of the regression line was significantly different from zero at the 90 percent confidence level, with a p-value less than 10 percent for the coefficient b_1.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction from Equation (1), with an associated theoretical Type I error (i.e., false positive) rate of 10%[32]. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the product of the appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to the predicted annual load, as expressed below:

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

annual load UCL = $TP_{90\%\ CL} = \text{predicted Annual Load} + [(t_{\alpha,n-2})\ SE_p]$

where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
$t_{\alpha,n-2}$ is the value of the one-tailed t statistic at significance level α, with n-2 degrees of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
n is the number of annual TP loads in the Base Period (= 9)

The standard error of the prediction (SE_p) is comprised of the standard error of the regression equation and the standard error of the predicted mean value, expressed in the equation below (Haan 1977)

$$SE_p = s[\ 1 + \frac{1}{n} + \frac{(X - X_m)^2}{\sum (X_i - X_m)^2}\ ]^{0.5}$$

where s is the standard error of the regression equation = 31.13751
X_m = average value of the predictor in the Base Period = 3.9502
n = 9
$t_{\alpha,n-2} = 1.41492$
$1 / \Sigma(X_i - X_m)^2 = 1 / 675.50602$

Collecting terms yields

$SE_p = SE = 31.13751\ [\ 1 + 1/9 + (X-Xm)^2 / 675.50602\ ]^{0.5}$

The above equations can be converted to a performance measure by means of the following conversions after a load reduction for the collective source controls has been determined.

For an Annual Load Target with Y percent reduction based on untransformed annual loads,

Target Eqn. Intercept = intercept at 0% reduction * (1 – Y)

Target Equation coefficients (b_i) = b_i at 0% reduction * (1 – Y)

For an Annual Load Limit with Y percent reduction based on untransformed annual loads,

s and SE_p = value at 0% reduction * (1 - Y)
$var(b_i)$ & $cov(b_i, b_j)$ = value at 0% reduction * $(1 – Y)^2$

APPENDIX C – SUMMARY OF DATA SOURCES USED FOR THE DEVELOPMENT OF THE PERFORMANCE MEASURE 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 Lake Okeechobee Watershed. Water control structures include pumps, gated spillways, and gated culverts.

The District's hydrologic database (DBHYDRO) stores one or more flow data sets at each structure. Each flow data set is created using a unique combination of sources of stage and control operations data. The District uses its data to perform water budget analyses and flow estimation techniques to obtain a "preferred" flow data set at each structure. **Table C-1** shows the basin discharge flow data sets used in the annual phosphorus load calculation for those basins with a load-based performance measure[33]; these are available in the District's hydrologic database. The list of outfall structures used in the annual phosphorus load calculation will be adjusted by the District to account for any changes in outflow structures from the individual basins, including those changes caused by construction of regional projects.

Water Quality

Raw water samples for the Lake Okeechobee Watershed phosphorus load calculations are collected by automatic samplers or grab samples. Current raw water sample collecting methods at structures utilized in the Lake Okeechobee Watershed basins phosphorus load calculation are listed in **Table C-2**.

[33] A similar table will be prepared at a later date for those basins where a performance indicator is recommended.

Table C-1. Database keys for structure flow data.

Sub-watershed	Summary Basin or Hydrologic Unit	Structure	DBKEY	Type*
Taylor Creek/Nubbin Slough	S-133 Summary Basin	S-133	15637	PREF
Taylor Creek/Nubbin Slough	S-154 Summary Basin	S-154	15629	PREF
Taylor Creek/Nubbin Slough	S-191 Summary Basin	S-191	15639	PREF
Lower Kissimmee		S-65E	15631	PREF
East Lake Okeechobee	C-44	S-308	15626	PREF
East Lake Okeechobee	C-44	S-80	JW224	PREF
East Lake Okeechobee	L-8	Culv 10A	15640	PREF
East Lake Okeechobee	L-8	S-5AW	MG614	N/A
East Lake Okeechobee	L-8	S-5AS	TA410	PREF
East Lake Okeechobee	L-8	S-5AE	L7443	TELE
East Lake Okeechobee	L-8	City of WPB #2	TW079	TELE
Indian Prairie Sub-watershed		G-33	US349	TELE
Indian Prairie Sub-watershed		G-34	W3841	TELE
Indian Prairie Sub-watershed		G-74	88187	TELE
Indian Prairie Sub-watershed		G-75	87646	TELE
Indian Prairie Sub-watershed		G-76	87645	TELE
Indian Prairie Sub-watershed		L-61 E	15654	N/A
Indian Prairie Sub-watershed		S-68	15632	PREF
Indian Prairie Sub-watershed		S-71	15633	PREF
Indian Prairie Sub-watershed		S-72	15634	PREF
Indian Prairie Sub-watershed		S-84	15636	PREF
Indian Prairie Sub-watershed		S-127 (Pump)	15641	PREF
Indian Prairie Sub-watershed		S-127 (Spillway)	15819	TELE
Indian Prairie Sub-watershed		S-129 (Pump)	15642	PREF
Indian Prairie Sub-watershed		S-129 (Spillway)	15823	TELE
Indian Prairie Sub-watershed		S-131 (Pump)	15643	PREF
Indian Prairie Sub-watershed		S-131 (Spillway)	M2931	TELE
Fisheating Creek/Nicodemus Slough	Fisheating Creek	FISHCR	WH036	USGS
West Lake Okeechobee	S-4 / Industrial Canal	EPD-07	EAA EPD	
West Lake Okeechobee	S-4 / Industrial Canal	S-310	15628	PREF
West Lake Okeechobee	S-4 / Industrial Canal	S-169	15590	NA
West Lake Okeechobee	S-4 / Industrial Canal	S-4	15630	PREF
West Lake Okeechobee	S-4 / Industrial Canal	S-235	15564	SP01
West Lake Okeechobee	East Caloosahatchee	S-77	DJ235	COE
West Lake Okeechobee	East Caloosahatchee	S-78	DJ236	COE
West Lake Okeechobee	East Caloosahatchee	CULV5A	TA604	CR10
South Lake Okeechobee	EAA	See 40E-61, F.A.C.		
South Lake Okeechobee	Ch 298 Districts	C-10	15645	PREF
South Lake Okeechobee	Ch 298 Districts	C-12	15646	PREF
South Lake Okeechobee	Ch 298 Districts	C-12A	15647	PREF
South Lake Okeechobee	Ch 298 Districts	C-4A	15648	PREF
South Lake Okeechobee	Ch 298 Districts	S-236	15644	PREF

* Flow data type:

PREF	PREFERRED VALUE
CR10	CAMPBELL SCIENTIFIC INC. MEASUREMENT AND CONTROL MODULE
TELE	TELEMETRY (RADIO NETWORK)
102	UNKNOWN CHART-TYPE RECORDER
NA	NOT APPLICABLE
SP01	SOLID STATE LOGGER
COE	U.S. ARMY CORPS OF ENGINEERS
USGS	U.S. GEOLOGICAL SERVICE

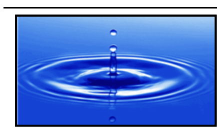


Table C-2. Sampling methods for structure water quality data.

Sub-watershed	Summary Basin or Hydrologic Unit	Structure or Station	TP Collection Site ID	TP Collection Site	Instrument
Taylor Creek/Nubbin Slough	S-133 Summary Basin	S-133	S133	Pump	Grab
Taylor Creek/Nubbin Slough	S-154 Summary Basin	S-154	S154	Gravity	A*
Taylor Creek/Nubbin Slough	S-191 Summary Basin	S-191	S191	Pump	A*
Lower Kissimmee		S-65E	S65E	Gravity	A*
East Lake Okeechobee	C-44	S-308	S308C	Gravity	Grab
East Lake Okeechobee	C-44	S-80	S80	Gravity	Grab
East Lake Okeechobee	L-8	Culv 10A	CLV10A	Gravity	Grab
East Lake Okeechobee	L-8	S-5AW	S5AW	Gravity	Grab (Note 1)
East Lake Okeechobee	L-8	S-5AS	S5AS	Gravity	Grab (Note 1)
East Lake Okeechobee	L-8	S-5AE	S5AE	Gravity	Grab (Note 1)
East Lake Okeechobee	L-8	City of WPB #2	None	Pump	None (Note 2)
Indian Prairie Sub-watershed		G-33	C38W	Gravity	Grab
Indian Prairie Sub-watershed		G-34	L59E	Gravity	Grab
Indian Prairie Sub-watershed		G-74	L59W	Gravity	Grab
Indian Prairie Sub-watershed		G-75	L60E	Gravity	Grab
Indian Prairie Sub-watershed		G-76	L60W	Gravity	Grab
Indian Prairie Sub-watershed		L-61 E	L61E	Gravity	Grab
Indian Prairie Sub-watershed		S-68	S68	Gravity	Grab
Indian Prairie Sub-watershed		S-71	S71	Gravity	A*
Indian Prairie Sub-watershed		S-72	S72	Gravity	A*
Indian Prairie Sub-watershed		S-84	S84	Gravity	Grab
Indian Prairie Sub-watershed		S-127 (Pump)	S127	Pump	Grab
Indian Prairie Sub-watershed		S-127 (Spillway)	S127	Gravity	Grab
Indian Prairie Sub-watershed		S-129 (Pump)	S129	Pump	Grab
Indian Prairie Sub-watershed		S-129 (Spillway)	S129	Gravity	Grab
Indian Prairie Sub-watershed		S-131 (Pump)	S131	Pump	Grab
Indian Prairie Sub-watershed		S-131 (Spillway)	S131	Gravity	Grab
Fisheating Creek/Nicodemus Slough	Fisheating Creek	FISHCR	FECSR78	Gravity	Grab
West Lake Okeechobee	S-4 / Industrial Canal	EPD-07	EPD-07	Pump	Grab
West Lake Okeechobee	S-4 / Industrial Canal	S-310	S310	Gravity	Grab
West Lake Okeechobee	S-4 / Industrial Canal	S-169	S169	Gravity	Grab
West Lake Okeechobee	S-4 / Industrial Canal	S-4	S4	Pump	Grab
West Lake Okeechobee	S-4 / Industrial Canal	S-235	S235	Gravity	Grab
West Lake Okeechobee	East Caloosahatchee	S-77	S77	Gravity	Grab
West Lake Okeechobee	East Caloosahatchee	S-78	S78	Gravity	Grab
West Lake Okeechobee	East Caloosahatchee	CULV5A	CULV5A	Gravity	Grab
South Lake Okeechobee	EAA	See 40E-61, F.A.C.			
South Lake Okeechobee	Ch 298 Districts	C-10	C-10	Pump	Grab (Note 3)
South Lake Okeechobee	Ch 298 Districts	C-12	C-12	Pump	Grab (Note 3)
South Lake Okeechobee	Ch 298 Districts	C-12A	C-12A	Pump	Grab (Note 3)
South Lake Okeechobee	Ch 298 Districts	C-4A	C-4A	Pump	Grab (Note 3)
South Lake Okeechobee	Ch 298 Districts	S-236	S-236	Pump	Grab (Note 3)

Notes:
* A = autosampler primary method, grab sample back-up
(1) TP concentrations for S-5AW, S-5AS and S-5AE were calculated baed on the algorithm described in Appendix A.
(2) TP concentrations for City of WPB No. 2 are set to the cumulative basin flow-weighted mean inflow TP concentration.
(3) The EPD data is collected by daily grabs on flow composited for the sampling period. (J Madden e-mail 9/16/2011)

APPENDIX D – ESTIMATION OF NUTRIENT LOAD REDUCTIONS RESULTING FROM IMPLEMENTATION OF COLLECTIVE SOURCE CONTROL PROGRAMS IN BASINS WITH LOAD BASED PERFORMANCE MEASURES IN THE LAKE OKEECHOBEE WATERSHED

This appendix provides additional clarification on the technical sources, methods and assumptions for estimating source control effectiveness for the S-133, S-154, S-191, Lower Kissimmee, L-8, Indian Prairie, Fisheating Creek, S-4/Industrial Canal, and East Caloosahatchee basins. Details on the methods to estimate the nutrient reductions for the C-44 Hydrologic Unit are described in Appendix A of Deliverable 6.1 "Data Analysis and Performance Measure Development for the St. Lucie River Watershed Source Control Program." (HDR, Inc. 2011).

In order to estimate nutrient load 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 for BMPs and source control programs that were not implemented during the base period. To estimate the collective reduction, the reduction for each land use was weighted based on the land use acreage and land use unit load.

For validation, land uses between the base period and the most current period for which land use breakdown is available were compared to determine if there were substantial differences affecting the weighted effectiveness. Loads between the base period and current conditions were also compared to determine if statistical differences existed that warranted adjustment, e.g., if land uses conversions did not appear substantial based on acreage but could have affected loading contributions.

Finally, 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.

The following information is presented in this report:

1. Land use data for the historical and current conditions.
2. Unit area load coefficients that were used for this analysis 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 2008 when they

were modified for use in the St. Lucie River and Caloosahatchee Watershed River Protection Plans.

3. Descriptions of the estimates of source control reductions utilized for each land use category and how they were developed in support of the watershed protection plans.
4. Descriptions of how the appropriate 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.

Land Uses

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 total phosphorus (TP) loads could be applied. First, the availability and quality of the land use data had to be evaluated. A series of land use/ land cover (LCLU) maps have been produced by the South Florida Water Management District (SFWMD) since the early 1970s representing the following points in time:

- 1972
- 1988
- 1995
- 1999
- 2004
- 2008

After reviewing these land use datasets, the 1995 dataset was selected for the reduction calculations. The 1995 land use coverage was nearest to the time range of the base periods (**Table D-1**). This dataset was complemented with data from the St. Johns River Water Management District and Southwest Florida Water Management District, for the Upper Kissimmee and Lake Istokpoga Sub-watershed areas outside the SFWMD boundaries.

Once the 1995 land use coverage for the entire Lake Okeechobee Watershed was completed, it was overlaid with the GIS coverages of the Okeechobee Sub-watersheds and summary basins in order to generate a detailed land use distribution table for each basin (see Excel spreadsheets LU_SummaryBasins.xlsx and LU_Watersheds.1995.xlsx in **Attachment 1**). Standard ArcMap tools were used to complete this task.

Table D-1. Sub-watersheds and Basins Performance Measure Base Periods

Sub-watershed	Basin	Base Period
Taylor Creek – Nubbin Slough	S-133	WY1977 – 1986
	S-154	WY1977 – 1984
	S-191	WY1977 – 1988
Lower Kissimmee	N/A	WY1977 – 1990
East Lake Okeechobee	C-44	WY2000 – 2010
	L-8 (C-10A)	WY1995 – 2003
Indian Prairie	N/A	WY1989 – 2001
Fisheating Creek-Nicodemus Slough	Fisheating Creek	WY1998 – 2008
West Lake Okeechobee	S-4/Industrial Canal	WY1993 – 2001
	East Caloosahatchee	WY1982 - 1990

Table D-2 provides the land use areas in each of the basins for 1995 and 2008. In general, the land use that experienced the greatest decline in acreage was natural areas. The land use with the greatest gain was urban. However, there were not substantial differences affecting the weighted effectiveness between 1995 and the 2008 land use acreages, nor statistical significant differences in the loads observed during the baseline periods, including those dating back to 1977.

Unit Area Loads and BMP Effectiveness – Current Project

The major parameters that this analysis depends on are TP 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 a ratio of contribution among the land uses, which can proportionally change from year to year. 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.

Table D-2[1]. 1995 and 2008 land use acreages by basin.

Land use	S-133		S-154		S-191		Lower Kissimmee		L-8		Indian Prairie		Fisheating Creek		S-4/Industrial Canal	
	1995	2008	1995	2008	1995	2008	1995	2008	1995	2008	1995	2008	1995	2008	1995	2008
Abandoned Tree Crops	0	0	0	18	0	250	0	12	0	2,179	0	73	0	5	0	0
Aquaculture	11	5	0	0	35	90	0	24	0	0	205	306	60	62	0	0
Cattle Feeding Operations	0	0	0	0	0	628	0	498	0	0	0	0	0	0	0	0
Citrus	159	123	0	0	2,782	2,768	12,123	10,064	8,003	113	30,756	30,167	11,029	7,554	151	39
Communications and Utilities	0	43	0	0	73	76	0	37	2,248[4]	1,443	0	19	91	14	170	107
Dairies	20	0	1,728	767	6,848	3,494	4,347	1,796	0	0	393	0	0	18	34	0
Fallow Crop Land	0	0	158	0	589	86	1,370	429	345	2,441	1,182	1,170	725	741	42	0
Field Crops	0	355	420	817	1,418	3,397	2,674	15,540	0	33	2,143	393	1,817	732	72	0
Field Crops - Sugarcane	0	0	0	0	0	0	0	0	6,094	9,751	0	19,207	0	1	31,929	32,371
Horse Farms	0	143	109	38	54	240	609	265	285	360	53	25	20	0	0	0
Improved Pasture	10,864	8,524	17,020	17,921	60,013	67,590	133,849	128,001	0	489	120,064	121,134	81,933	95,152	1,859	883
Natural Areas[2]	4,615	3,371	5,942	5,234	27,592	15,230	149,724	95,431	65,818	62,929	64,512	44,547	119,120	96,855	2,285	2,011
Ornamentals	0	16	0	0	68	51	12	17	7	158	9	55	164	391	35	19
Other Groves	0	33	0	0	0	60	0	9	0	0	15	53	6	41	20	0
Poultry Feeding Operations	0	0	0	0	0	72	0	0	0	0	0	40	0	5	0	0
Residential High Density	624	60	136	0	0	0	33	25	0	0	96	0	0	0	0	75
Residential Low Density	1,729	1,666	2,054	1,374	4,597	4,786	1,883	4,152	18,998	20,049	2,279	1,874	2,280	2,275	345	574
Residential Medium Density	2,911	2,796	164	781	680	242	130	35	171	167	308	394	7	130	1,724	1,537
Row Crops	0	0	378	9	1,897	262	5,033	5,166	23	21	1,694	1,168	995	19	156	0
Sod Farms	0	1,521	0	0	0	0	267	0	0	0	2,086	0	555	737	179	0
Transportation	653	222	305	156	52	314	2,834	239	0	9	446	127	775	610	350	330
Tree Plantations	0	0	0	0	0	55	11,031	58	0	0	59	404	24,471	19,718	0	0
Unimproved Pastures	862	1,078	323	2,091	6,858	6,603	21,889	43,295	2,337	33	30,285	24,212	21,033	35,908	0	0
Urban[3]	1,741	2,751	287	354	291	839	1,128	50,816	147	364	976	970	100	293	1,240	2,363
Water	981	762	195	133	1,675	654	4,297	3,283	1,074	2,862	4,360	2,887	965	808	1,428	739
Woodland Pastures/Rangeland	397	2,147	2,297	1,881	2,957	11,331	76,837	69,986	98	1,723	14,660	27,081	32,395	36,186	51	445

[1]The landuse acreages for the C-44 basin are reported in Appendix A of Deliverable 6.1 "Data Analysis and Performance Measure Development for the St. Lucie River Watershed Source Control Program" (HDR Inc. 2011).

[2]Includes all categories that comprise Natural Areas except Water (FLUCCS Code 5000).

[3]Includes all categories that comprise Urban except the Residential landuses (FLUCCS Code 1100, 1200, and 1300).

[4]The L-8 basin acreage was calculated by taking the original acreage for each landuse and subtracting Basin 8's acreages from L-8. In the original landuse acreages for L-8 only transportation had an acreage greater than zero, so the acreages listed in this table reflect the original L-8 transportation acreage minus the acreage that Basin 8's transportation landuse consisted of.

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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 D-3** (see the column labeled, "Existing Unit Load (lbs-P/ac/yr").

Table D-3. Table 1 From Bottcher and Harper, 2003: Estimates of TP UAL and load reductions expected from implementation of source control programs in the Lake Okeechobee Watershed.

FLUCCS Description		Acres	% of Total Landuse Area	Existing Unit Load (lbs-P/ac/yr)	Total P Load (tons)	Estimated % Reduction	Total P after Reduction (tons)
Primary Agricultural Land Use							
	Improved Pastures	431,391	36.24%	0.72	155	30	109
	Unimproved Pastures	70,927	5.96%	0.27	10	20	8
	Woodland Pastures	8,652	0.73%	0.27	1	20	1
	Rangeland	110,579	9.29%	0.23	13	20	10
	Urban	27,280	2.29%	0.66	9	30	6
	Dairies	29,084	2.44%	3.38	49	32	33
	Citrus	54,763	4.60%	1.62	44	40	27
	Field Crops - Sugarcane	16,586	1.39%	0.63	5	25	4
	Sod Farms	10,652	0.89%	2.52	13	40	8
	Row Crops	7,024	0.59%	6.30	22	60	9
SUM OF "Primary Ag Land Uses"		**766,938**	**64.43%**	**Subtotal**	**322**	**33**	**215**
Other Land Uses							
	Field Crops	3,000	0.25%	0.50	1	10	1
	Fruit Orchards	6,665	0.56%	0.50	2	10	1
	Other Groves	16	0.00%	0.50	0	10	0
	Poultry Feeding Operations	49	0.00%	0.50	0	10	0
	Tree Nurseries	411	0.03%	0.50	0	10	0
	Ornamentals	7,320	0.61%	0.50	2	10	2
	Floriculture	21	0.00%	0.50	0	10	0
	Horse Farms	310	0.03%	0.50	0	10	0
	Aquaculture	833	0.07%	0.50	0	10	0
	Fallow Crop Land	2,477	0.21%	0.50	1	10	1
	Upland Forests	115,989	9.74%	0.50	29	0	29
	Pine Plantation	32,600	2.74%	0.18	3	11	3
	Water	12,966	1.09%	0.50	3	0	3
	Wetlands	224,117	18.83%	0.50	56	0	56
	Barren Land	10,646	0.89%	0.50	3	0	3
	Transportation, Communication, and Utilities	5,907	0.50%	0.50	1	0	1
	Special Classifications	0	0.00%	0.50	0	0	0
SUM OF "Other Land Use"		**423,326**	**35.57%**	**Subttotal**	**101**	**1**	**100**
	Grand Total	**1190264**	100.00%		**423**	**25**	**314**

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 and BMP 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 D-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 D-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				
	1100	Residential Low Density				
	1200	Residential Medium Density				
	1300	Residential High Density				
	1400	Commercial and Services	0.66	3%	0%	0%
	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%
	4000	Upland Forests (not including 4400's)				
	5000	Water				
	6000	Wetlands				
Natural Areas	7000	Barren Land	0.20	0%	0%	0%
	1900	Open Land				
	8000	Transportation, Communication, and Utilities				
	9000	Special Classifications				
	2150	Field Crops				
	2230	Other Groves				
	2220	Fruit Orchards				
	2320	Poultry Feeding Operations				
Other Areas	2410	Tree Nurseries	0.70	10%	0%	0%
	2450	Floriculture				
	2510	Horse Farms				
	2540	Aquaculture				
	2610	Fallow Crop Land				

Nutrient Loading Rates, Reduction Factors and Implementation Costs Associated with BMPs and Technologies, July 2008

This report was prepared in support of the St. Lucie River and Caloosahatchee River Watershed Protection Plans. Its purpose was to estimate TP and total nitrogen (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% of the measured flow volume from the watershed to the St Lucie Estuary.

The final TP 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 TP 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 D-5 and D-6** present TP UALs used in the development of the St. Lucie River and Caloosahatchee River Watershed Protection Plans, respectively.

The primary sources of agricultural BMP information were research and extension reports completed by Institute of Food and Agriculture Sciences, University of Florida (IFAS, UF) in association with various state agencies and grower groups, while urban BMP information was primarily from summary reports by Environmental Research and Design, Inc. and University of Central Florida. For citrus, the studies by Brian Bowman and David Calvert at the Indian River Research and Education Center and Ashok Alva and S. Paramasivam at the Citrus Research and Education Center were primarily used. For cow-calf production, studies by Paul Mislevy and F.G. Martin at the Cattle Research Station in Ona and by Joyce Zhang, Jeff Hiscock, Del Bottcher, B.M. Jacobson, and Patrick Bohlen at Buck Island Ranch were primarily used. 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 economical 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 D-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 D-8**.

Table D-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 D-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 D-7. BMPs assumed to be implemented for estimates of nutrient load reductions (based on Bottcher 2008)[1].

Land Use		Citrus	Improved Pastures	Residential and Urban	Dairies	Other agriculture
Watershed acreage Percentage	1995	7.0 %	22.4 %	6.9 %	0.5 %	18.3 %
	2008	4.6 %	21.4 %	13.0 %	0.2 %	23.3 %
Nutrient Mgt		*Typical:* • P: Soil testing • Includes implementation biosolids rule • Controlled application (timing & placement, fertigation) • Spill prevention *High End:* • Slow release fertilizer	*Typical:* • P: Soil testing • Includes implementation of biosolids rule, the animal manure implementation rule, and the septage application rule • Spill prevention • Grass management[2] and rotational grazing • Reduced cattle density • Alternate water sources, shade, restricted placement of feeders, supplements, and water, fencing *High End:* • Slow release fertilizer	*Typical:* • Reduced fertilization in accordance with the Urban Turf Fertilizer Rule • Controlled application (timing & placement) • Spill prevention *High End:* • Florida Friendly Landscape	*Typical:* • P: Soil testing • Includes implementation of the CAFO rule, • Feed management • Grass management[2] and rotational grazing • Improved forage/sprayfield management - P balanced with high P uptake crop rotations *High End:* • Solids separation for offsite disposal • Add housing to move animals off field[3]	*Typical:* • P: Soil testing • Includes implementation of biosolids rule • Controlled application (timing & placement, fertigation) • Spill prevention *High End:* Slow release fertilizer
Water Mgt		*Typical:* Storm water detention/retention because of improved irrigation and drainage or ERP permitted systems *High End:* • Water reuse from existing retention/detention ponds • Wetland restoration	*Typical:* • Wetland restoration • Retention basin by working pens *High End:* • Stormwater detention/retention	*Typical:* Dry detention swales (0.25 inch) and wet detention (0.25 inch) *High End:* • ERP permitted systems, when required • Regional projects for dry detention and wet detention	*Typical:* • Improved Irrigation and Drainage Management • Wetland restoration *High End:* • Expanded waste storage ponds • Expanded sprayfields • Storm water detention/retention	*Typical:* Storm water detention/retention because of improved irrigation and drainage, flooded fields, and riser board control or ERP permitted systems *High End:* • Wetland restoration
Particulate Matter and Sediment Controls		*Typical:* • Grass management between trees • Sediment traps[1] *High End:* • Grassed swales	Note: Grass management will also apply to particulate matter and sediment controls	*Typical:* • Street sweeping • Sediment/baffle boxes	*Typical:* • Buffer strips Note: Grass management and improved forage/sprayfield management will also apply to particulate matter and sediment controls	*Typical:* • Cover crops • Sediment traps

[1]Based on telephone conversation with Dr. Bottcher on 08/30/12.
[2]Includes selecting the appropriate grass variety and mowing to ensure healthy and uniform grass coverage.
[3]Includes associated waste pond and sprayfield expansions (this BMP would also be considered a Water Management BMP)

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Table D-8. Reduction values from the top 10 land uses based on Bottcher 2006 and SWET 2008 reports

Land Use	Expected Typical TP Reduction
Natural Areas	0
Improved Pasture	30
Urban[1]	10
Citrus	32
Rangeland	20
Unimproved Pasture	10
Sugarcane	33
Tree Plantations	11
Dairies	37
Row Crops	60

[1]SWET 2008.

Lake Okeechobee Watershed TP UALs and BMP Effectiveness

A spreadsheet model, consistent with the models developed for the Lake Okeechobee, Caloosahatchee River, and St. Lucie River Watershed Protection Plans, was used to calculate nutrient loads and reductions that could be reasonably expected from implementation of collective source control programs. The spreadsheet applies the unit area flow and unit area load for each land use to 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 Lake Okeechobee. 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 computed flows from all land uses were then added to calculate the flows from the sub-watershed. A global adjustment factor was applied to each land use coefficient so that the calculated flows matched the measured flows for the sub-watershed.
- The UALs developed for each land use in the SLRWPP from Bottcher 2008 report were used as a starting point for this analysis. The unit area load coefficients were adjusted based on expert best professional judgment. The UAL coefficients used in this analysis were developed to represent the relative differences in nutrient loads that would be discharged from each land use. For example, a land use with a unit area

load of 1 lb/acre/year would discharge half the nutrient load compared to 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.

Adjustment Factors to Account for Differences in Source Control Implementation for 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. For a number of basins, the base periods selected were for a time period prior to BMP implementation which was prior to 1990. Therefore, Dr. Bottcher provided a range of reductions that also considered the historical base periods. The consulting team and the District reviewed reduction ranges for the historical periods and the Bottcher 2006 and SWET 2008 assumptions and reduction estimates. The reductions were adjusted as appropriate to account for differences in source control implementation to determine the recommended value to be used.

- The S-133, S-154, and S-191 required adjustments due to the extent of source controls that have been in place since the respective base periods. For example in the S-191 Basin, source controls on dairies began in the 1970s. In 1987, the FDEP Dairy Rule required additional source controls on dairies and in 1989, the Lake Okeechobee Works of the District program began requiring phosphorus control on other land use types. The adjustments accounted for the reductions from these programs.
- The base period for C-44, L-8, Indian Prairie, Fisheating Creek, S-4/Industrial Canal, and East Caloosahatchee were all more recent periods and/or areas with more limited BMP implementation. Therefore, the source control reductions for typical BMPs developed in the Bottcher 2006 and SWET 2008 reports were used without adjustment for these basins.
- The Lower Kissimmee had a mix of BMP implementation with earlier implementation in the southern portion but very limited implementation in the northern portion so no adjustment was applied.

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 D-9**; the spreadsheets associated with the recommended reductions are included in Attachment 1.

Table D-9. Range of phosphorus load percent reductions relative to the base period anticipated for each basin.

Basin	Low Reduction, %	High Reduction, %	Typical Reduction, %	Recommended Reduction, %
S-133	8	54	38	25
S-154	41	81	68	35(1)
S-191	42	82	69	40(1)
Lower Kissimmee	22	72	55	30
C-44	9	51	33	35
L-8	19	51	32	20
Indian Prairie	16	62	41	30
Fisheating Creek	12	51	28	30
S-4/Industrial Canal	16	54	32	30
East Caloosahatchee	33	70	50	30

(1)These two basins are heavily influenced by dairy land use. The team decided to recommend a reduction below the low end of the range because BMPs such as chemical treatment for dairies were considered when the range was developed and these are not be considered to be a requirement for a regulatory program.

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 Unit flows and UALs are at the parcel level. To account for these differences, a parcel to basin adjustment factor was estimated for to determine the difference between basin measured and the parcel simulated flows and loads. While some attenuation is expected between the parcel and basin discharge levels (parcel loading based on unit flow and UAL and observed acreage, and basin loading based on measured data), the greater the difference, would suggest the higher uncertainty in the calculations.

References

Bottcher and Harper. 2003. Estimation of Best Management Practices and Technologies Phosphorus Reduction Performance and Implementation Costs in the Northern Watershed of Lake Okeechobee. Letter report to South Florida Water Management District, West Palm Beach, FL.

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Harper, H. H. 2003. Evaluation of Runoff Load Reductions from Urban Land Uses. Submitted to South Florida Water Management District as Attachment 2 to the Bottcher and Harper Letter Report (Bottcher and Harper, 2003).

Harper, H. H. and D.M. Baker. 2007. Evaluation of Current Stormwater Design Criteria within the State of Florida. Final Report prepared by Environmental Research and Design for the Florida Department of Environmental Protection, Tallahassee, FL.

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SFWMD (South Florida Water Management District). 2011. South Florida Environmental Report. West Palm Beach, FL.

SWET (Soil and Water Engineering Technology, Inc.). 2008. Final Report For Project Entitled Nutrient Loading Rates, Reduction Factors and Implementation Costs Associated with BMPs and Technologies, First Revision. Prepared for the South Florida Water Management District, West Palm Beach, FL.

APPENDIX E – ADJUSTMENTS TO ACCOUNT FOR REGIONAL PROJECTS

1. The Annual Load Target and Annual Load Limit will 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

ATTACHMENT 1 – Associated Excel Spreadsheets

The following Excel spreadsheets containing the relevant data analyses are attached by reference to this Draft *Technical Support Document*.

Taylor Creek-Nubbin Slough Sub-watershed spreadsheets:

DRAFT PM1 Stats S-133 - 9 15 2012
DRAFT PM2 Stats S-133 - 9 15 2012
MC 26 S-133 - 8 28 2012
SB-S133_LU_95_UnitLoads_BMPs alt method 3a

DRAFT PM1 Stats S-154 - 9 15 2012
DRAFT PM2 Stats S-154 - 9 15 2012
MC 17 S-154 - 8 28 2012
SB-S154_LU_95_UnitLoads_BMPs alt method 3a

DRAFT PM1 Stats S-191 - 9 15 2012
DRAFT PM2 Stats S-191 - 9 15 2012
MC 33 S-191 - 8 28 2012
SB-S191_LU_95_UnitLoads_BMPs alt method 3a

Lower Kissimmee Sub-watershed spreadsheets:

DRAFT PM1 Stats LK - 8 25 2012
DRAFT PM2 Stats LK - 8 25 2012
MC 1 sqrt(L) LK - 8 28 2012
SW-LowerKissimmee_LU_95_UnitLoads_BMPs alt method 4

East Lake Okeechobee Sub-watershed spreadsheets:

DRAFT PM1 Stats C-44 - 9 3 2012
DRAFT PM2 Stats C-44 - 8 27 2012
MC 3 C-44 - 8 28 2012

DRAFT PM1 Stats L8 - 8 25 2012
DRAFT PM2 Stats L8 - 8 25 2012
MC 8 sqrt(L) L-8 - 8 28 2012
SB-L-8_LU_95_UnitLoads_BMPs - WY95-03 alt method 4

Indian Prairie Sub-watershed spreadsheets:

DRAFT PM1 Stats IP - 8 27 2012
DRAFT PM2 Stats IP - 9 7 2012
MC 6 IP - 9 3 2012
SW-IndianPrairie_LU_95_UnitLoads_BMPs rev1 alt method 4

Fisheating Creek-Nicodemus Slough Sub-watershed spreadsheets:

DRAFT PM1 Stats FECR-LP - 8 25 2012
DRAFT PM2 Stats FECR-LP - 8 25 2012
MC 16 FECRLP - 8 28 2012
SB-FisheatingCreek_LU_95_UnitLoads_BMPs alt method 3a

Lake Istokpoga Sub-watershed spreadsheets:

DRAFT PM1 Stats Josephine Cr TP – 12 13 2012
DRAFT PM2 Stats Josephine Cr TP – 12 13 2012
MC 16 Josephine Cr TP – 1 25 2013
DRAFT PM1 Stats Arbuckle Cr TP – 12 13 2012
DRAFT PM2 Stats Arbuckle Cr TP – 12 13 2012
MC 16 Arbuckle Cr TP – 1 25 2013

West Lake Okeechobee Sub-watershed spreadsheets:

DRAFT PM1 Stats S4IC TP – 9 20 2012
DRAFT PM2 Stats S4IC TP - 10 25 2012
MC 14 S4IC – 10 30 2012
(07-12-12) Revised SB-S-4_LU_95_UnitLoads XP

DRAFT PM1 Stats EC TP – 9 20 2012
DRAFT PM2 Stats EC TP - 10 25 2012
MC 14 EC - 8 28 2012
(07-12-12) Revised SB-S-4_LU_95_UnitLoads XP

Upper Kissimmee Sub-watershed spreadsheets:

DRAFT PM1 Stats Boggy Cr TP – 11 29 2012
DRAFT PM2 Stats Boggy Cr TP – 12 13 2012
MC sqrt14 Boggy Cr TP – 1 25 2013
DRAFT PM1 Stats Shingle Cr TP – 11 26 2012
DRAFT PM2 Stats Shingle Cr TP – 12 13 2012
MC 19 Shingle Cr TP – 1 25 2013