Water Quality Assessment of the St. Lucie River Watershed – Water Year 2016 - FINAL DRAFT

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Quis custodiet ipsos custodes? *(Who watches the Watchers?)*[2]

Key Findings:

1. Over the last year, the surface water entering the St. Lucie River and Estuary (SLRE) in general was of poor water quality. The best water quality entering the SLRE was from the highly urbanized Tidal Basins. The largest source of nitrogen and sediment pollution to the SLRE was Lake Okeechobee discharges. The largest phosphorus pollution source was the C-23 Canal Basin, which also exhibited the highest concentrations of phosphorus and nitrogen. The C-44 Canal Basin contributed poor water quality, and was the only basin demonstrating a worsening in water quality over the last ten years.
2. It was estimated that stormwater runoff from agricultural land use contributed more nutrient pollution than any other land use, even contributing more nutrient pollution than Lake Okeechobee discharges.
3. The annual Basin Management Action Plan (BMAP) progress reports produced by the Florida Department of Environmental Protection indicate water quality conditions in the tributaries of the SLRE are better than they actually are. Examples of flaws in the BMAP assessment process include the omission of Lake Okeechobee pollution loads, the use of simulated data instead of observed data, the inability to account for hydrologic variability, and the inability to assess individually each of the major basins contributing to the SLRE.
4. An alternative to the assessment approach presented in the BMAP progress reports was developed and used to evaluate water quality conditions of major inflows to the SLRE and assess progress towards achieving the TMDL load reduction goals. This alternative approach uses observed data, includes Lake discharges, accounts for hydrologic variability, and is applied to each of the major basins contributing pollution loads to the SLRE.
5. Recommendations for improving the BMAP progress reports are offered.

EXECUTIVE SUMMARY

The St. Lucie River and Estuary (SLRE), located along Florida's southeast coast, is one of the most biologically-diverse estuaries in the nation, and is home to more than three dozen threatened and endangered species (SFWMD et al. 2009). Unfortunately, the SLRE is also one of the most ecologically-stressed river and estuarine systems in Florida. For more than 90 years, the regions'

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[2] Satires of Juvenal, late 1st and early 2nd centuries A.D.

environmental and economic health has been sacrificed by state and federal agencies through diversion of polluted water from Lake Okeechobee in order to provide flood protection and irrigation benefits to farms and communities south of Lake Okeechobee. This "tragedy of the commons" has played out in national and international media during 2016, as more than 200 billion gallons of polluted Lake Okeechobee overflow containing tons of nutrients, sediment, toxic blue-green algae, poorly oxygenated and low salinity water was diverted from its historical southerly flow pattern easterly to a major tributary to the Indian River Lagoon[3]. As of this writing (October 2016) there is no end in sight to the 2016 Lake discharges.

In addition, the spatial extent of the SLRE watershed has more than doubled in the last century as major agricultural canals were constructed (SFWMD 2002). These canals now contribute significant loadings of nutrient and unknown quantities of pesticides (FDEP 2008, FDEP 2013). The dominant land uses in the watershed are agriculture (55%), natural areas (26%), urban areas (19%) and other (2%) (FDEP 2013, FDEP 2015, SFWMD 2016). To protect the designated uses of the SLRE, the Florida Department of Environmental Protection (FDEP) established total maximum daily loads (TMDLs) for total phosphorus (TP), total nitrogen (TN) and biological oxygen demand (BOD), with concentration endpoints of 81 parts per billion (ppb) for TP, 720 ppb for TN and 2,000 ppb for BOD (FDEP 2008). A Basin Management Action Plan (BMAP) was developed in 2013 which established target load reductions for TP and TN. Unfortunately, the BMAP did not include load reduction targets or projects for Lake Okeechobee discharges, and the FDEP intentionally ignores pollution loading from the lake in their annual progress report for the BMAP (FDEP 2015). Further, the BMAP did not use readily available monitoring data when establishing "Starting Loads," but instead relied on simulated flows and loads. The FDEP Starting Loads underestimated loads from basins contributing to the SLRE by up to 36 percent compared to individual basin monitoring data, creating not only flawed reference conditions but incorrect load reduction targets and subsequently flawed assessments of annual progress towards achieving the TMDL. As an example of this flawed assessment, despite an admitted lack of field verification and monitoring data, all discharges from agricultural land use are assumed to achieve 100 percent of their load reduction goals once a Notice of Intent has been signed – clearly an optimistic assumption (FDEP 2015). When presented with this information in 2015, FDEP's response was that they plan to start using actual data in 2017 (FDEP 2015).

In lieu of relying on FDEP's annual progress report, levels of TP, TN and total suspended sediment (TSS) from Lake Okeechobee and from the SLRE watershed were summarized for the most recent water year (May 1, 2015 to April 30, 2016, "WY2016"), and are presented in **Table ES-1**.

[3] A similar environmental catastrophe has occurred in the Caloosahatchee Estuary on Florida's west coast, which has received even greater volumes of polluted Lake Okeechobee overflow.

As an alternative to the FDEP BMAP targets, hydrologically-adjusted performance measures were developed to assess progress towards achieving the TMDL for the SLRE. These performance measures were developed in a manner similar to those utilized in the predominantly agricultural areas south of the Lake (SFWMD 2016). These performance measures utilized the same concentration endpoints for TP and TN as the BMAP and were used to assess performance of the source basins contributing to the SLRE. The results are summarized in **Tables ES-2 and ES-3** and **Figures ES-1 and ES-2**. For the Tidal Basins, reliable flow measurements are not available so the assessment was based on observed concentrations measured at 29 stations.

Table ES-1. Summary of WY2016 Flows and Loads from SLRE Watershed and Lake Okeechobee.

Parameter	C-23 Canal	C-24 Canal	C-44 Canal to SLRE	Entire C-44 Canal Basin	Ten Mile Creek	Tidal Basins	Lake Okeechobee
Inflow to SLRE, AF	106,699	176,612	188,565	203,111	114,436	Not measured	369,839
Total Nitrogen load, pounds/yr	571,498	677,064	750,977	817,357	337,660	Not measured	1,590,329
Total Nitrogen concentration, ppb	1,970	1,410	1,465	1,480	1,085	908	1,581
Total Nitrogen TMDL concentration, ppb	720	720	720	720	720	720	720
Total Phosphorus load, pounds/yr	191,685	127,403	141,590	148,662	92,414	Not measured	183,297
Total Phosphorus concentration, ppb	661	265	276	269	297	100	182
Total Phosphorus TMDL concentration, ppb	81	81	81	81	81	81	81
TSS load, pounds/yr	1,215,143	1,382,692	313,516	534,457	483,117	Not measured	37,261,019
TSS concentration, ppb	4,188	2,879	611	968	1,552	Not measured	37,049

Note: The C-44 Canal Basin includes the smaller S-153 drainage area, which discharges into the C-44 on the west end near Lake Okeechobee. The FDEP and SFWMD refer to this combined area as the "C-44/S-153 Basin."

Table ES-2. Comparison of Total Nitrogen Performance Measures to TMDL Targets

	C-23 Canal	C-24 Canal	C-44 Canal to SLRE	Entire C-44 Canal Basin	Ten Mile Creek	Tidal Basins	Lake Okeechobee
FDEP TMDL and BMAP							
Simulated 1996-2005 Starting Load, pounds/yr	498,874	670,326	533,437	533,437	727,195		Excluded
TMDL Target Load, pounds/yr	242,202	348,957	242,929	242,929	302,545		Excluded
TMDL Percent Reduction	52%	52%	51%	51%	58%		Excluded
BMAP Ph. I target load, pounds/yr	421,872	573,915	446,285	446,285	671,736		Excluded
BMAP Ph. I target load reduction	16%	16%	15%	15%	18%		Excluded
Alternative performance measure							
Observed 1996-2005 Starting Load, pounds/yr[1]	614,536	746,862	643,023	832,560	490,477	N/A	1,672,706
Observed 1996-2005 Starting concentration, ppb	1,569	1,633	1,692	1,709	1,208	911	1,751
TMDL Target concentration, ppb	720	720	720	720	720	720	720
TMDL Percent Reduction	54%	56%	57%	58%	40%	21%	59%
TMDL Target Load, pounds/yr TMDL concentration, ppb	Percentage of Starting Load, adj. for hydrologic variability					720 ppb	720 ppb
BMAP Ph. I Target Reduction	16%	17%	17%	17%	12%	6%	18%
BMAP Ph. I Target Load, pounds/yr BMAP Ph. I Target Conentration, ppb	Percentage of Starting Load, adj. for hydrologic variability					842 ppb	1,442 ppb
Differences (FDEP values minus Observed)							
BMAP discrepancy in Starting Load, pounds/yr	-115,662	-76,536	-109,586	-299,123	N/A		1,672,706
BMAP discrepancy in Starting Load, %	-19%	-10%	-17%	-36%	N/A		100%
Difference in TMDL % reduction	-2%	-4%	-6%	-7%	N/A		100%
Difference in BMAP Ph. I % reduction	-1%	-1%	-2%	-2%	N/A		30%

Notes: 1. Base period for Ten Mile Creek was 2000-2010 2. Base period for Tidal Basins was 2003-2005
3. FDEP excluded C-44 Canal Basin loading to Lake Okeechobee, which is included in the alternative performance measure.

Table ES-3. Comparison of Total Phosphorus Performance Measures to BMAP Targets

	C-23 Canal	C-24 Canal	C-44 Canal to SLRE	Entire C-44 Canal Basin	Ten Mile Creek	Tidal Basins	Lake Okeechobee
FDEP TMDL and BMAP							
Simulated 1996-2005 Starting Load, pounds/yr	175,073	165,275	93,821	93,821	163,383		Excluded
TMDL Target Load, pounds/yr	27,248	39,258	27,330	27,330	33,180		Excluded
TMDL Percent Reduction	79%	72%	56%	56%	80%		Excluded
BMAP Ph. I target load, pounds/yr	116,869	119,531	67,514	67,514	172,389		Excluded
BMAP Ph. I target load reduction	24%	22%	17%	17%	24%		Excluded
Alternative performance measure							
Observed 1996-2005 Starting Load, pounds/yr[1]	185,864	156,276	91,575	119,007	156,681	N/A	150,561
Observed 1996-2005 Starting concentration, ppb	474	342	241	244	386	118	158
TMDL Target concentration, ppb	81	81	81	81	81	81	40
TMDL Percent Reduction	83%	76%	66%	67%	79%	32%	75%
TMDL Target Load, pounds/yr TMDL concentration, ppb	Percentage of Starting Load, adj. for hydrologic variability					81 ppb	81 ppb
BMAP Ph. I Target Reduction	25%	23%	20%	20%	24%	9%	22%
BMAP Ph. I Target Load, pounds/yr BMAP Ph. I Target Conentration, ppb	Percentage of Starting Load, adj. for hydrologic variability					108 ppb	122 ppb
Differences (FDEP values minus Observed)							
BMAP discrepancy in Starting Load, pounds/yr	-10,791	8,999	2,246	-25,186	N/A		-150,561
BMAP discrepancy in Starting Load, %	-6%	6%	2%	-21%	N/A		-100%
Difference in TMDL % reduction	-4%	-4%	-11%	-11%	N/A		-100%
Difference in BMAP Ph. I % reduction	-1%	-1%	-3%	-3%	N/A		-30%

Notes: 1. Base period for Ten Mile Creek was 2000-2010 2. Base period for Tidal Basins was 2003-2005
3. FDEP excluded C-44 Canal Basin loading to Lake Okeechobee, which is included in the alternative performance measure.

Figure ES-1. Progress Towards The St. Lucie River And Estuary TN TMDL For Water Year 2016

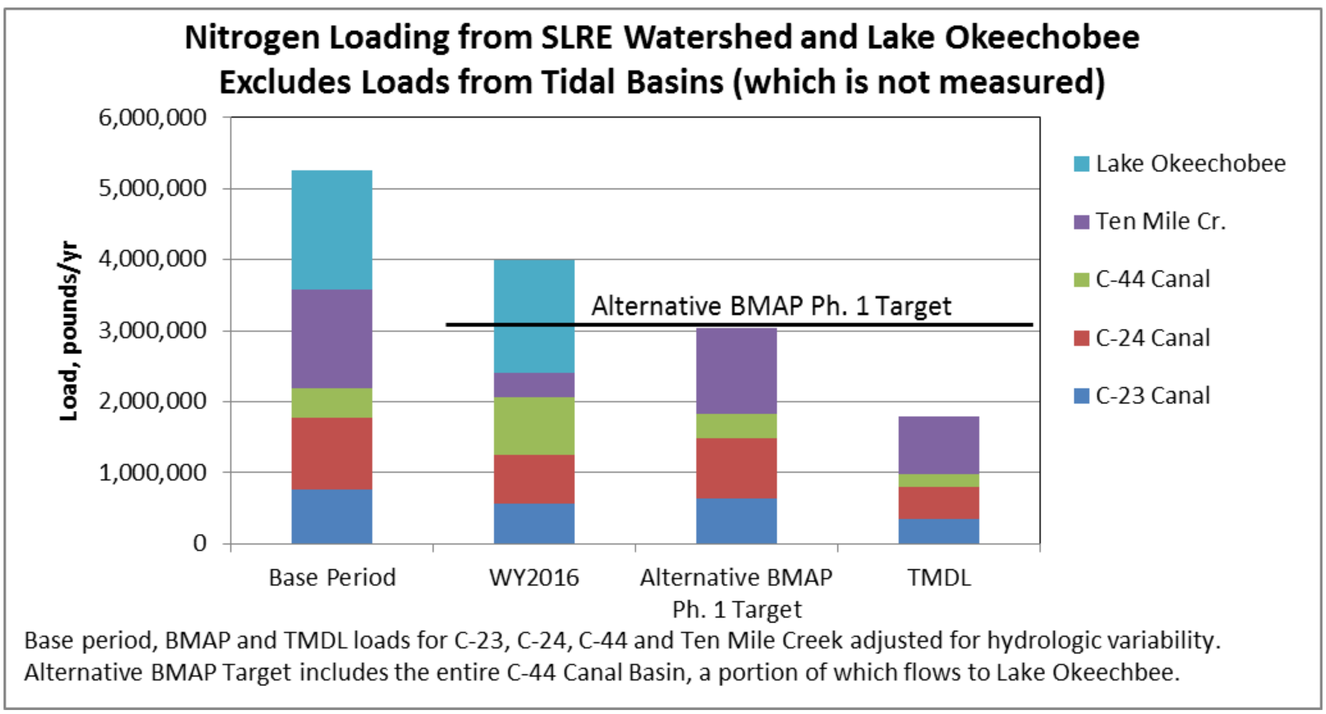
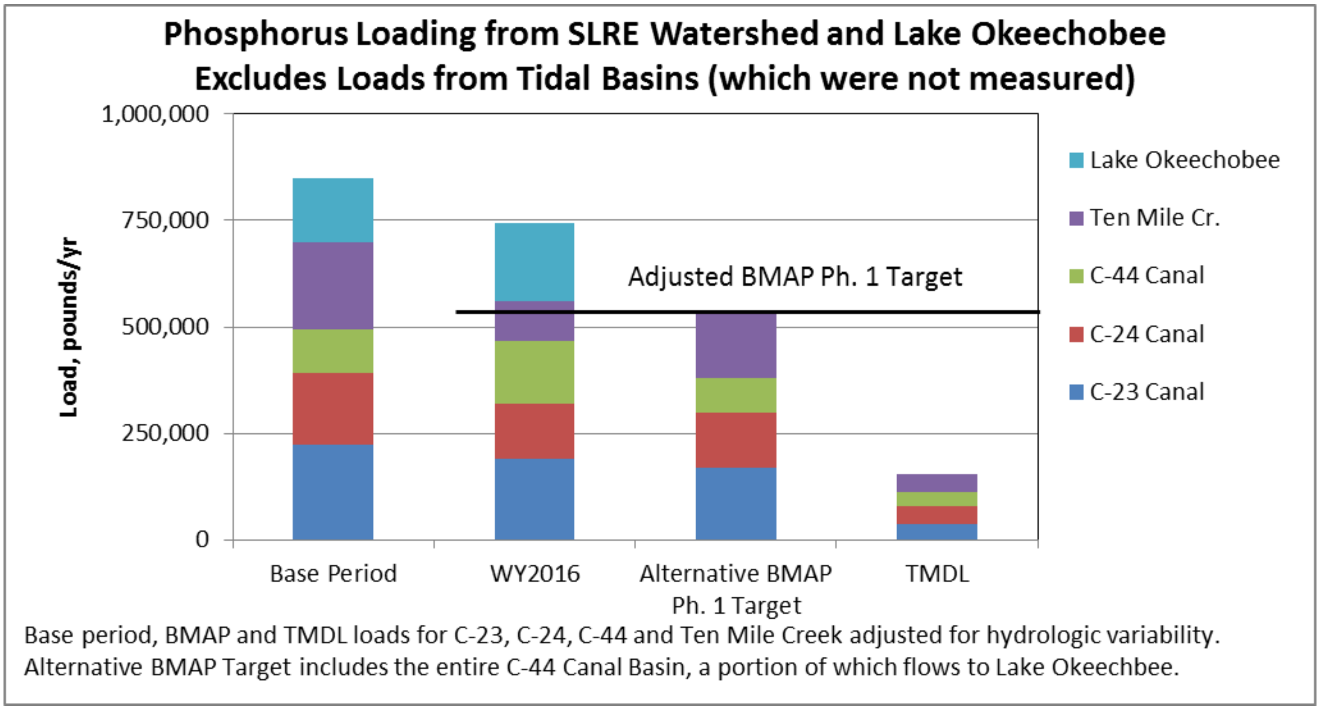


Figure ES-2. Progress Towards The St. Lucie River And Estuary TP TMDL For Water Year 2016



The largest single source of TN and sediment load to the SLRE was Lake Okeechobee discharges. Phosphorus concentrations in Lake Okeechobee discharges to the SLRE remained almost four times the lake's TMDL in-lake target level of 40 parts per billion (ppb). In 2016, the South Florida Water Management District (SFWMD) reported that phosphorus loading to the lake from surrounding watersheds was almost 4 times the Lake's TMDL of 105 metric tons, yet staff acknowledged the agency does not enforce permits that set numeric limits on phosphorus discharges to the lake[4] (SFWMD 2015, SFWMD 2016). Unfortunately, despite the continued and well-publicized pollution of the lake, the Florida legislature in 2016 enacted a water bill that pushed back deadlines for achieving the lake's TMDL by decades (Ch. 2016-1).

The best water quality entering the SLRE during WY2016 was observed in the highly urbanized Tidal Basins, with concentrations of 100 ppb and 908 ppb for TP and TN, respectively. Each of the remaining source basins, except the C-44 Canal Basin[5], exhibited a slight improvement in nutrient levels compared to their base periods, however, collectively these WY2016 loads did not achieve the alternative BMAP Phase I load target (**Figures ES-1 and ES-2**). Only the Ten Mile Creek Basin met the alternative BMAP Phase I target for TP, while the C-23, C-24 and Ten Mile Creek basins met the alternative BMAP Phase I target for TN. ***The predominantly agricultural C-44 Canal Basin exhibited poor nutrient conditions, and in fact, demonstrated a trend of deteriorating***

[4] Works of the District permits (40E-61, F.A.C.)
[5] The C-44 Canal Basin is also known as the "C-44/S-153 Basin."

nutrient conditions compared to its 1996-2005 base period. As a whole, the water quality entering the SLRE remains poor, although a slight improvement over the 1996-2005 period was observed (**Table ES-4**).

The assessment described herein highlights areas of potential improvement in the state's BMAP annual assessment and reporting program, and suggests that implementation of regional nutrient control programs has had variable degrees of success.

Table ES-4. Summary of Water Quality Conditions Entering the St Lucie River and Estuary

Source Basin	Total Phosphorus		Total Nitogen	
	WY2016 Status	10-yr Trend	WY2016 Status	10-yr Trend
C-23 Canal	Poor	Improving	Poor	Improving
C-24 Canal	Poor	Improving	Poor	Improving
C-44 Canal	*Poor*	*Worsening*	*Poor*	*Worsening*
Ten Mile Creek	Poor	Improving	Good	Improving
Tidal Basins	Fair	Improving	Fair	Improving
Lake Okeechobee	Poor	Improving	Poor	Improving
Total Inflow	***Poor***	***Improving***	***Poor***	***Improving***

Notes: See text for details. The Tidal Basins and Lake Okeechobee assessment were based on observed concentrations; other source basin assessments were based on observed loads compared to hydrologically-adjusted base period loads.

1. BACKGROUND

Florida is blessed with abundant surface and groundwater resources, however, decades of excessive water use consumption and weakening environmental policies have resulted in water quantity and water quality issues in virtually every major river system in the state (FDEP 2016). The St. Lucie River and Estuary (SLRE), located along Florida's southeast coastline, is one of the most biologically-diverse estuaries in the nation, and is home to more than three dozen threatened and endangered species (SFWMD et al. 2009). Unfortunately, the SLRE is also one of the most ecologically-stressed river and estuarine systems in Florida.

At the turn of the 20th century, the city of Stuart was not yet incorporated, the area south of the River was part of Palm Beach County, and the St. Lucie River flowed deep and clear (Lyons 1975). The estuary was renowned for its inshore tarpon fishing, and was known as the "Tarpon Fishing Capital of the World." The watersheds of the North Fork and South Fork of the River extended a few miles west to a ridge that separated Allapattah Slough, Cane Slough and other areas that flowed north to the St. John's River or south to the Loxahatchee River (**Figure 1** from SFWMD 2002). In 1913, the State of Florida decided to construct a canal between Lake Okeechobee and the SLRE to divert overflow water from the lake in order to encourage and enhance agricultural and community development south of the Lake (Blake 1980). Prior to that time, there was no natural connection between the Lake and the SLRE. The first discharge of Lake water into the SLRE is reported to have occurred on June 13, 1923 (Osborn 2012). It wasn't long before fishing guides, residents and local governments began to realize the significant environmental consequences of the destructive Lake releases, and by 1930 Martin County Commissioners forwarded the first of many requests to terminate the discharges (MBOCC 1930). As tons of sediment from the Lake muddied the once-clear river and estuary, the inshore tarpon fishing industry collapsed, and the area re-cast itself as the "Sailfish Capital of the World." Discharges from Lake Okeechobee were initially unregulated, however, a series of operating schedules were eventually put into place by the U.S. Army Corps of Engineers, leading up to today's Lake Okeechobee Regulation Schedule 2008 (aka "LORS2008") (USACE 2016).

For more than 90 years, the regions' environmental and economic health has been sacrificed by state and federal agencies through diversion of polluted water from Lake Okeechobee in order to provide flood protection and irrigation benefits to farms and communities south of Lake Okeechobee. This "tragedy of the commons" has played out in national and international media during 2016, as more than 200 billion gallons of polluted Lake Okeechobee overflow containing tons of nutrients, sediment, toxic blue-green algae and low salinity water was diverted from its historical southerly flow pattern easterly to a major tributary to the Indian River Lagoon[6]. As of this writing (October 2016) there is no end in sight to the 2016 Lake discharges.

During the 1920s through 1960s, the area of the SLRE watershed more than doubled as large agricultural drainage canals were constructed by regional drainage districts and the U.S. Army Corps of Engineers. These canals allowed the waters of Allapattah Slough and Cane Sloughs to be quickly re-directed to the SLRE, increasing the volume and rapidity of stormwater runoff into the river and estuary.

Today, nutrient and sediment loads to the SLRE come from Lake Okeechobee, the C-23 Canal Basin, the C-24 Canal Basin, the C-44 Canal Basin, the Ten Mile Creek Basin and direct runoff from tidally-influenced portions of the North Fork, South Fork and smaller basins – collectively referred to as the "Tidal Basins" (**Figure 2**). In addition, stormwater runoff from the adjacent C-25 Canal Basin periodically is discharged through the C-24 Canal into the North Fork of the SLRE.

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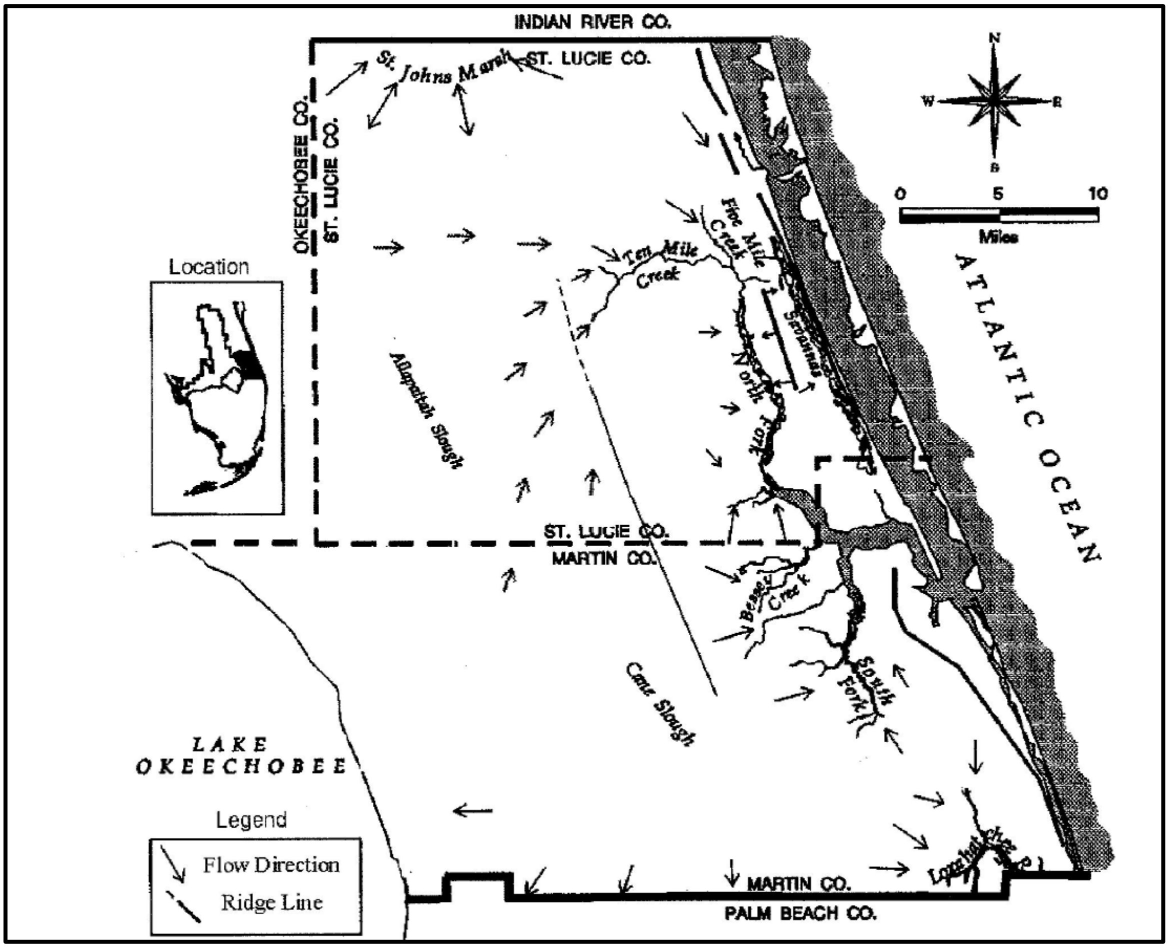
[6] A similar environmental catastrophe has occurred in the Caloosahatchee Estuary on Florida's west coast, which has received even greater volumes of polluted Lake Okeechobee overflow.

Figure 1. Historical drainage of the St. Lucie River Watershed (SFWMD 2002).

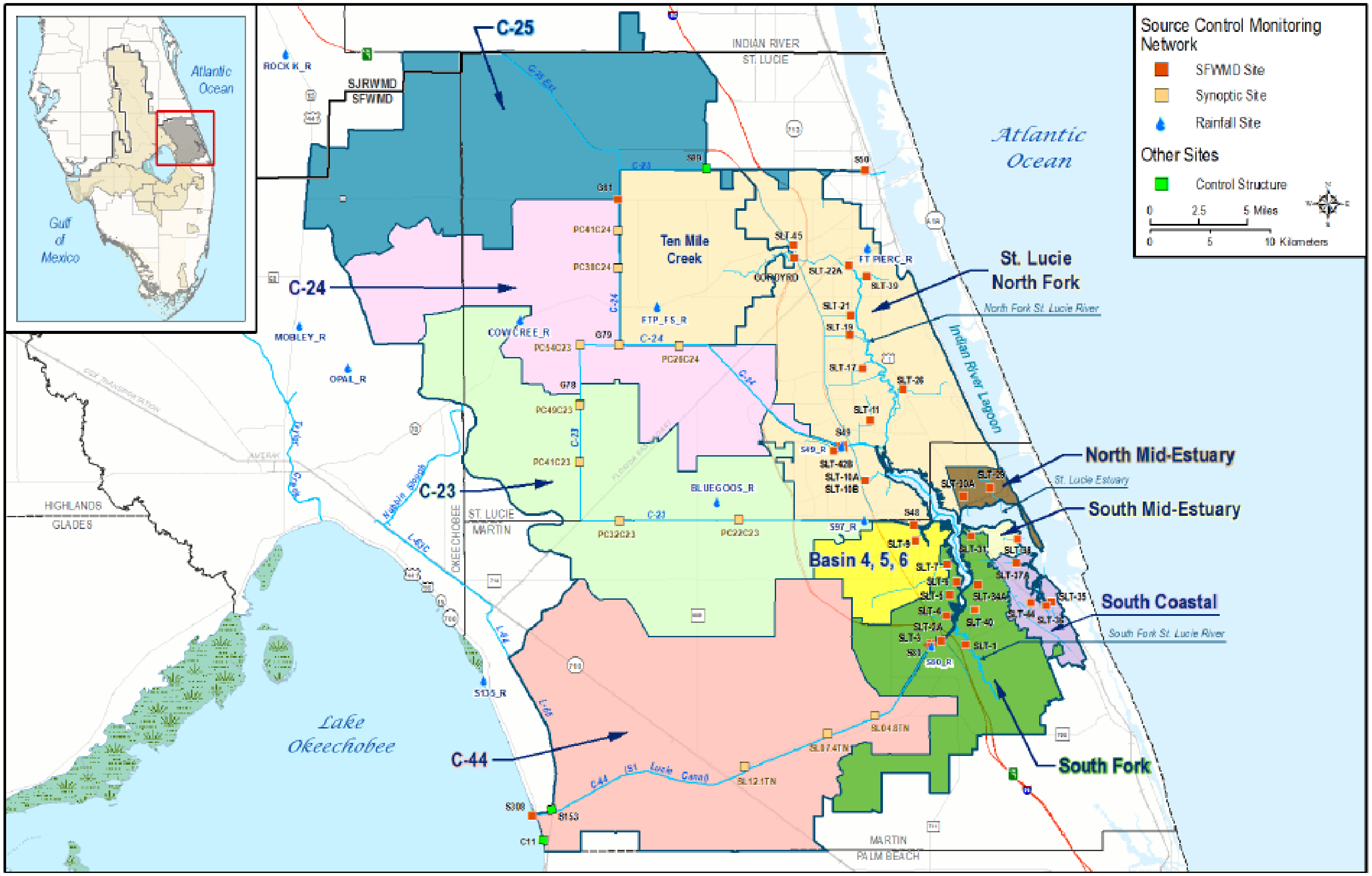


Land use. The dominant land use in the SLRE watershed is agriculture, comprising 55 percent of the contributing area (**Table 1**). Approximately 26 percent of the watershed is natural (uplands, wetlands, water, and barren land); while less than 20 percent is urban and built-up area. The total area for the SLRE excludes the South Coastal basin (approximately 12,000 acres) which does not drain to the St. Lucie River or Estuary, but to the St. Lucie Inlet area.

Table 1. Characteristics of Basins Contributing to the SLRE (from FDEP 2014, SFWMD 2016)

Basin	Area (acres)	Ag Area (acres)	Ag Area (%)	Natural Area (acres)	Natural Area (%)	Urban & Other (acres)	Urban & Other (%)
C-23 Canal Basin	112,160	84,744	76%	23,706	21%	3,710	3%
C-24 Canal Basin	83,373	67,516	81%	15,701	19%	156	0%
C-44 Canal Basin	132,717	78,351	59%	37,163	28%	17,203	13%
Ten Mile Creek	39,726	32,491	82%	0	0%	7,235	18%
Tidal Basins, composed of the following:	157,840	26,533	17%	59,945	38%	71,362	45%
North Fork, excl. Ten Mile Cr.	*92,138*	*3,968*	*4%*	*33,129*	*36%*	*55,041*	*60%*
South Fork	*50,121*	*20,120*	*40%*	*18,987*	*38%*	*11,014*	*22%*
Basin 4-5-6	*15,581*	*2,445*	*16%*	*7,830*	*50%*	*5,306*	*34%*
Total SLRE Watershed	**525,816**	**289,635**	**55%**	**136,516**	**26%**	**99,665**	**19%**

Figure 2. St. Lucie River Watershed (from SFWMD 2016)



Notes: 1. The runoff from the C-25 Basin generally flows east to the Indian River Lagoon, but at times may be directed south into the C-24 Basin. 2. The Tidal Basins include areas downstream of water control structures and includes the South Fork, Basin 4-5-6, North and South Mid-Estuary, and the North Fork Basin, excluding the Ten Mile Creek Basin. 3. The South Coastal Basin does not contribute to the St. Lucie River and Estuary, but rather, to the St. Lucie Inlet area.

2. DATA ANALYSIS

Monitoring data for flow and water quality from the Lake and the agricultural drainage canal basins are available from the SFWMD public database (DBHYDRO). The periods of record for flow, water quality and rainfall vary among the contributing basins; for example flow records extend from April 1931 for discharges from Lake Okeechobee but begin in September 1999 for the Ten Mile Creek Basin. In general, water quality data for the Lake discharges are available after 1973 and for the other basins after 1979. For the Tidal Basins, reliable flow data are not available, however water quality is monitored at 29 stations; see **Figure 2** for monitoring locations.

Daily flow data were downloaded from DBHYDRO for representative stations for each of the source basins; missing data were filled in using appropriate algorithms. Available water quality data for TP, TN and TSS were also downloaded from DBHYDRO. Calculations of load followed the methods used by the SFWMD as described in the 2016 South Florida Environmental Report (SFWMD 2016). Daily rainfall data were downloaded from DBHYDRO, and precipitation estimates for each basin were obtained using representative stations and weighting factors as described in the *Draft Technical Support Document: St. Lucie River Watershed Performance Metric Methodologies* (SFWMD et al. 2013). Annual summaries of historical flows and loads for each of the source basins and Lake Okeechobee are presented in **Appendix 1.**

C-44 Canal Basin. Runoff from the C-44 Canal Basin can flow either to the SLRE through the S-80 structure or to Lake Okeechobee through the S-308 structure, depending on decisions by the U.S. Army Corps of Engineers (USACE) and the South Florida Water Management District (SFWMD). Over the long-term (1980-2016), approximately two-thirds of the C-44 Canal Basin runoff flowed to the SLRE and one-third flowed to the lake. However the annual proportion varied significantly: from one percent to the SLRE in 2008 (with the balance to the Lake) to 100 percent in 2004. Unfortunately, the FDEP TMDL and BMAP did not account for this annual variability, and erroneously assumed a constant proportion of "*only 76.5% of the runoff in the C-44/ S-153 sub-basin runoff flows to the St. Lucie Estuary*." (FDEP 2013). This led to the incorrect decision that "only 76.5% of the C-44/S-153 sub-basin runoff was applied in the St. Lucie River and Estuary BMAP allocations." This unnecessary assumption utilized by FDEP resulted in nutrient TMDL allocations and associated BMAP goals that are too high roughly half the years and too low the other years. To accurately characterize flow and loads from the C-44 Canal Basin, **total** basin flows and loads, that is, combining flow to both the SLRE and to the Lake, were calculated in this present analysis and used to develop basin performance measures.

Lake Okeechobee Pass-through Flows and Loads. The calculation of Lake Okeechobee discharges through the C-44 Canal, referred to as "pass-through flows," followed the algorithm used by the SFWMD (SFWMD 2013). However, the SFWMD algorithm for calculating the remaining C-44 Canal Basin loads generates excessive negative loads and concentrations, which are physically impossible. Hence a modified algorithm was used in this analysis that maintained the daily mass balance at the S-80 and S-308 structures, avoided negative values and were within 10% of the values obtained using the SFWMD algorithm.

Tidal Basins. The Tidal Basins encompass the area within Basin 4-5-6, South Fork Basin, portions of North Fork (excluding the Ten Mile Creek Basin), and other small basins; this area encompasses approximately 158,000 acres. Water quality data were obtained from 29 monitoring stations for the period November 2001 to April 2016 from DBHYDRO. While flow is monitored at some of these locations, the lack of reliable flow data for all stations prevented calculations of nutrient loads, and hence the water quality assessment was based on measured concentrations. To ensure data were representative of basin runoff and not tidal flow, only data collected when positive outflow was observed and when specific conductance values were below 2,500 µmhos/cm were used in the analysis; for further details see SFWMD et al. 2013. A single monthly composite concentration for the Tidal Basins was calculated based on an area weighting of available data during that month. The median monthly composite concentrations were calculated for each water year as representative of the Tidal Basins.

Water Quality Conditions for WY2016 and for the Most Recent 10-yr period (WY2007-2016)

A summary of the WY2016 nutrient and sediment levels from the SLRE watershed and from Lake Okeechobee is presented in **Table 2**. For the year, 92-95 percent of the C-44 Canal Basin flows and nutrient loads entered the SLRE while less than 10 percent entered the lake.

Table 2. Summary of WY2016 Surface Inflows from SLRE Watershed and Lake Okeechobee.

Parameter	C-23 Canal	C-24 Canal	C-44 Canal to SLRE	Entire C-44 Canal Basin	Ten Mile Creek	Tidal Basins	Lake Okeechobee
Inflow to SLRE, AF	106,699	176,612	188,565	203,111	114,436	Not measured	369,839
Total Nitrogen load, pounds/yr	571,498	677,064	750,977	817,357	337,660	Not measured	1,590,329
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Total Nitrogen TMDL concentration, ppb	720	720	720	720	720	720	720
Total Phosphorus load, pounds/yr	191,685	127,403	141,590	148,662	92,414	Not measured	183,297
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TSS load, pounds/yr	1,215,143	1,382,692	313,516	534,457	483,117	Not measured	37,261,019
TSS concentration, ppb	4,188	2,879	611	968	1,552	Not measured	37,049

Average annual flows and loads for each source basin were calculated for the most recent 10-yr period[7] (**Table 3 and Figure 4**). Lake Okeechobee was the largest single source of flow,

[7] Monthly surface runoff flows for the Tidal Basin were estimated from SFWMD's SLE Tidal Basin Lin-Res Model calibrated to the SLE WaSh Model results. For periods outside the Lin-Res Model simulation period, a regression model was used based on measured monthly rainfall (R^2=85%). Flows and loads were thus estimated for the Tidal Basins.

nitrogen and suspended sediment to the SLRE for the most recent 10-yr period. The C-24 Canal Basin was the single largest source of phosphorus load to the SLRE. The Tidal Basins exhibited the lowest concentration of nutrients of all sources to the SLRE. Discharges from Lake Okeechobee accounted for more than three-quarters of the sediment load to the SLRE.

Table 3. Summary of recent 10-yr average annual flows and loads.

WY2007-2016 Average	C-23 Canal	C-24 Canal	C-44 Canal to SLRE	Ten Mile Creek	Tidal Basins	Lake Okeechobee	Total	Entire C-44 Canal Basin
Flow, AF	92,498	188,109	173,357	86,112	135,795	280,833	956,703	229,615
Percent of total	10%	20%	18%	9%	14%	29%	100%	
Total Nitrogen load, pounds	427,666	825,923	673,071	236,034	141,592	1,307,962	3,612,247	907,051
Percent of total	12%	23%	19%	7%	4%	36%	100%	
Total Nitrogen concentration, ppb	1,700	1,615	1,428	1,008	845	1,713	1,388	1,388
Total Phosphorus load, pounds	117,645	156,785	81,926	55,928	16,135	113,232	541,652	106,271
Percent of total	22%	29%	15%	10%	3%	21%	100%	
Total Phosphorus concentration, ppb	468	306	174	239	96	148	208	208
Total Suspended Solids load, pounds	1,212,595	1,873,593	481,801	571,767	795,353	19,288,113	24,223,221	892,057
Percent of total	5%	8%	2%	2%	3%	80%	100%	
TSS concentration, ppb	4,821	3,663	1,022	2,442	4,748	25,256	9,311	9,311

See footnote on flow estimation for Tidal Basins.

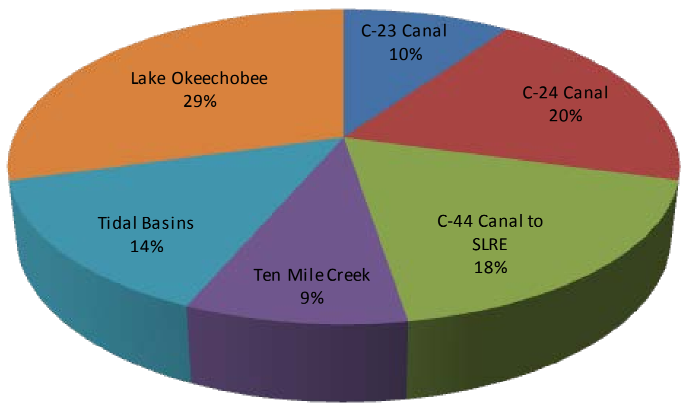
Flows and loads were also distributed based on land use[8] (**Figure 5**). **Stormwater runoff from agricultural lands represented the single largest source of flow and nutrient loading of all the sources to the SLRE, accounting for two-thirds of the phosphorus loads and more than half of the nitrogen loading.**

By contrast, runoff from urban and natural areas contributed the smallest amount of pollution loading, ranging from three to eight percent.

[8] Land use data from FDEP BMAP spreadsheets. Allocation among different land uses assumed similar load reductions across land uses within a basin.

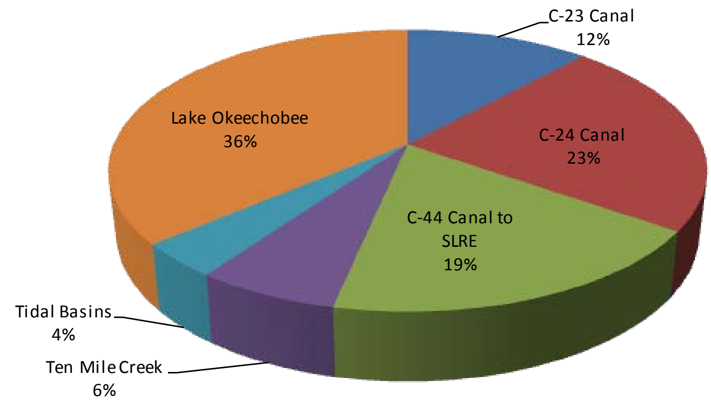
Figure 4. Distribution of Inflows to the SLRE by Source Basin.

WY2007-2016 Average Annual Surface Flow Entering the SLRE



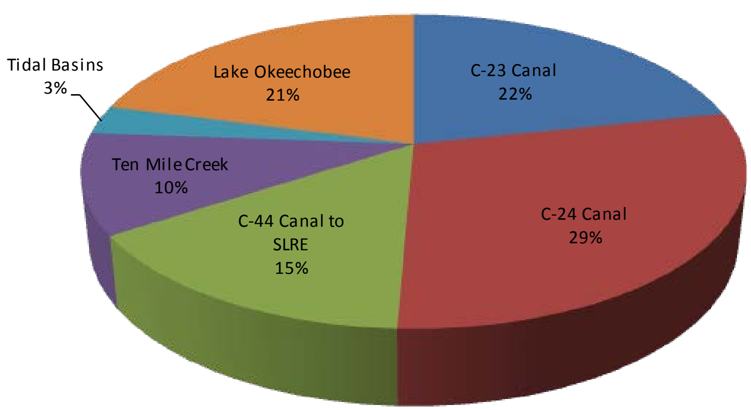
Flow data for Ten Mile Creek prior to July 1999 estimated from adjacent stations. Flow data for Tidal Basins estimated from SFWMD calculations.

WY2007-2016 Average Annual Nitrogen Loads



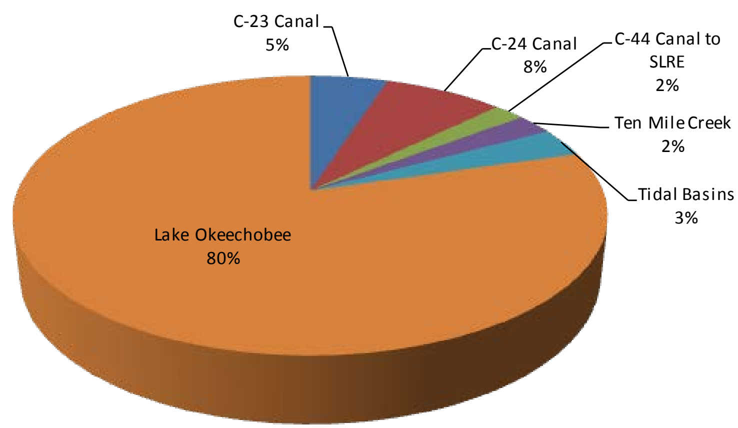
Flow and water quality data for Ten Mile Creek prior to July 1999 estimated from adjacent stations. Flow data for Tidal Basins estimated from SFWMD calculations.

WY2007-2016 Average Annual Phosphorus Loads



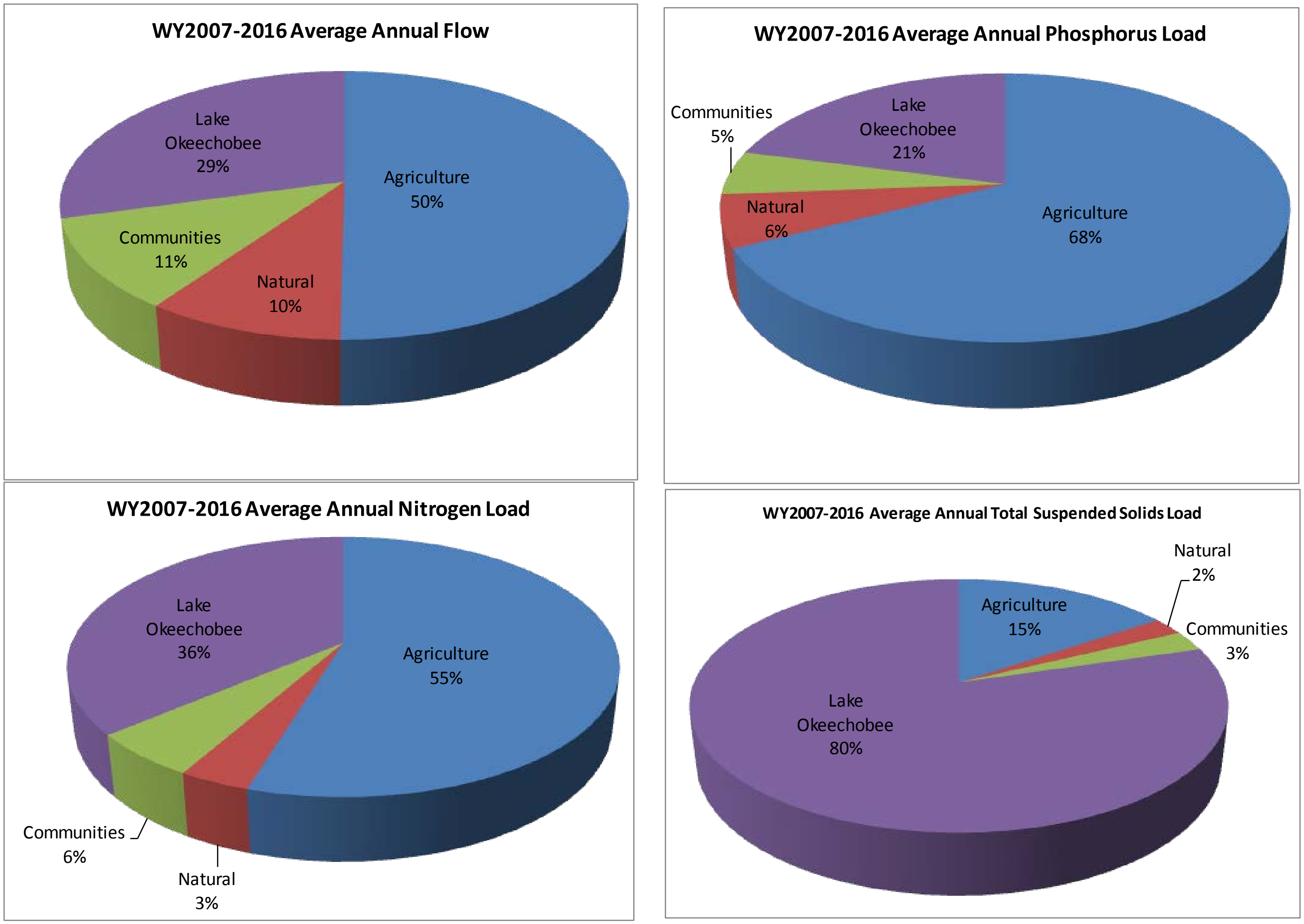
Flow and water quality data for Ten Mile Creek prior to July 1999 estimated from adjacent stations. Flow data for Tidal Basins estimated from SFWMD calculations.

WY2007-2016 Average Annual Total Suspended Solids Loads



Flow and water quality data for Ten Mile Creek prior to July 1999 estimated from adjacent stations. Flow data for Tidal Basins estimated from SFWMD calculations.

Figure 5. Distribution of Inflows to the SLRE by Land Use.



3. ASSESSMENT OF WATER QUALITY RELATIVE TO TMDL AND BMAP TARGETS

Accounting for Hydrologic Variability: Nutrient Loads. The volume of runoff from the basins contributing to the SLRE varies substantially from year to year in response to the region's highly variable rainfall. Therefore, comparing nutrient loads among two periods with considerably different rainfall without distinguishing the variance due to rainfall conditions will not provide a meaningful comparison. For example, if the recent period had higher rainfall, you would expect higher runoff and therefore higher loads; without adequately adjusting the base period loads to account for this additional rainfall would unfairly penalize the basin landowners during an assessment of load reduction programs within the basin. In order to distinguish changes in annual basin loading due variable rainfall/runoff from changes due to implementation of nutrient control measures (e.g., agricultural best management practices, or BMPs), the method used to assess nutrient loads needs to account for this hydrologic variability. Performance measures incorporating hydrologic variability are routinely used by the SFWMD for the EAA and C-139 Basins south of Lake Okeechobee (Rule 40E-63, SFWMD 2016). In 2013 the SFWMD drafted performance measures that incorporated hydrologic variability for the basins contributing to the SLRE, yet failed to finalize these (SFWMD 2013).

Using a similar approach, annual performance measures for both phosphorus and nitrogen were developed for the present analysis for the C-23 Canal, C-24 Canal, C-44 Canal and Ten Mile Creek basins. The performance measures for the C-23, C-24 and C-44 canal basins utilized the WY1996-2005 base period, which was the "starting period" used in the FDEP BMAP documents. For the Ten Mile Creek Basin, since data were not available until WY2000, the base period for that basin was selected as WY2000-2010. To account for hydrologic variability, a statistically significant regression relationship between annual rainfall and annual nutrient load was established for each basin during the base period for each nutrient. This approach allows an annual assessment of the overall effectiveness of regional nutrient control programs against the base period. Each year, nutrient loading from each basin can be assessed by applying that year's rainfall characteristics to the respective regression equation to establish a hydrologically-adjusted base load that represents zero reduction. The assessment year's observed load can then be compared to the hydrologically-adjusted base load, and a percent reduction can be calculated. The percent reduction can then be compared to the target percent reduction to assess progress towards achieving the BMAP and TMDL goals. Alternative TMDL and BMAP target load reductions were calculated based on the observed nutrient data for each basin and base period using the established TMDL concentrations (81 ppb for TP and 720 ppb for TN). The regression equations developed for the annual load targets are presented in **Appendix 2**.

Example: Total Nitrogen Loads from the C-23 Canal Basin

The relationship between annual rainfall and TN loads for the 1996-2005 base period was derived by identifying the best fitting regression equation using annual TN loads and annual rainfall characteristics:

$$\text{Base period load} = -2041.5699 + 604.07587 \ln(\text{Rain}) + 140.06288 \ln(\text{CV}) \qquad (1)$$

Where Base period load = hydrologically-adjusted load, in metric tons

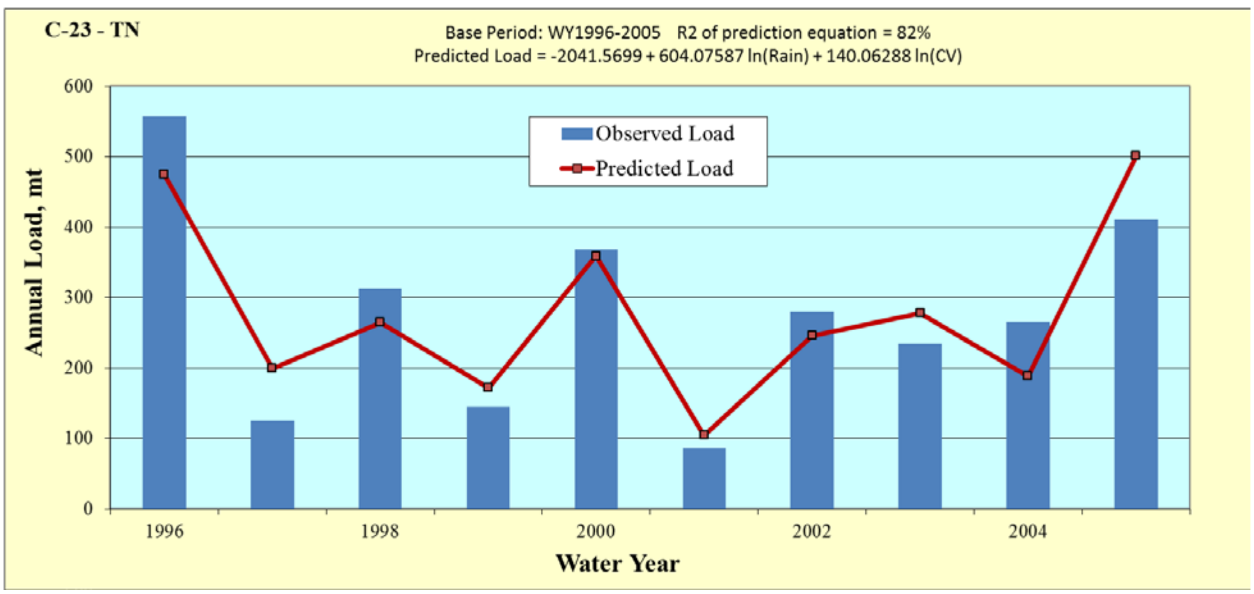
(1 metric ton = 2,205 pounds)

Rain = annual rainfall observed at area rain gauges, in inches

CV = coefficient of variation of the monthly rainfall values

This equation explained 82 percent of the variance in the annual loads (i.e., R^2 = 82%) and is depicted in **Figure 6**[9].

Figure 6. Relationship between C-23 Canal base period TN loads and rainfall.

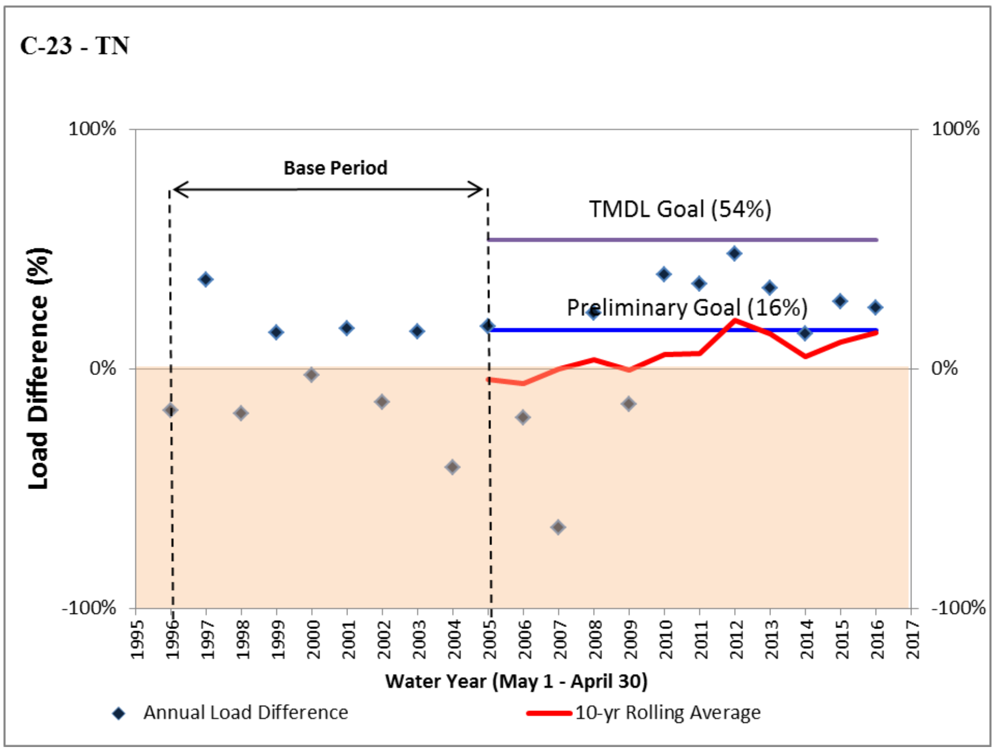


The flow-weighted mean TN concentration entering the SLRE from the C-23 Canal Basin during the 1965-2005 base period was 1,569 ppb. In order to achieve the TMDL goal of 720 ppb, a 54 percent reduction will be required. The BMAP Phase 1 goal set by FDEP was to achieve 30 percent of the TMDL reduction, or a 16 percent reduction from the base period. The annual rainfall for WY2016 for the C-23 Canal Basin was 56.88 inches, with a coefficient of variation of 0.696. Inserting the annual rain and coefficient of variation into equation (1) yields a

[9] To ensure the regression equation is applied within the calibration range, each year's rainfall should be within the range observed within the base period, adjusted as necessary for multiple parameters in the regression equation. The rainfall equations are also presented in Appendix 2.

hydrologically-adjusted base period load of 348.71 metric tons, or 768,758 pounds. The observed TN load for WT2016 was 571,498 pounds, which is a 26 percent reduction from the hydrologically adjusted base period load. The TMDL target is a 54 percent reduction, and the BMAP Phase 1 goal is a 16 percent reduction. Hence, for WY2016, the TN load from the C-23 Canal Basin achieved the BMAP Phase 1 goal (since 26% is greater than 16%), but not the TMDL goal (since 26% is less than 54%). This assessment is depicted in **Figure 7**, which shows the annual load reduction as a blue diamond, and the 10-yr trend as a red line[10].

Figure 7. C-23 Canal Basin TP Load Trends.



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

Nutrient Concentrations.

Tidal Basins. As discussed above, reliable flow data are not available for the Tidal Basins. Fortunately, extensive concentration data are collected at more than two dozen stations throughout the Tidal Basins and the annual assessment was based on observed concentrations (see sampling locations in **Figure 2** above). No statistically significant regression relationship between annual rainfall and concentration was observed, so there was no correction for

[10] Figure 7 follows the format used by the SFWMD in their annual SFER report, and depicts load reductions as an increase above zero, which may be counterintuitive. An alternative format will be examined for next year's report.

hydrologic variability. The nutrient concentrations for the Tidal Basins were assessed against the TMDL concentration targets for the SLRE, 81 ppb for TP and 720 ppb for TN.

Lake Okeechobee. The FDEP did not account for Lake discharges to the SLRE in developing the BMAP, and hence, did not identify any performance measure or nutrient load reduction projects to reduce the destructive impacts of Lake discharges on the estuary (FDEP 2013). FDEP established a TMDL for Lake Okeechobee with an in-lake TP concentration endpoint of 40 ppb. Hence, the 40 ppb concentration was adopted in the present assessment as the performance measure for lake discharges to the SLRE. FDEP did not set a TN TMDL for the lake, hence the SLRE TMDL endpoint TN concentration of 720 ppb was adopted in the present assessment as the performance measure for lake discharges to the SLRE.

The performance measures developed herein are compared to the TMDL and BMAP targets in **Tables 4 and 5.**

Table 4. Comparison of Total Nitrogen Performance Measures to TMDL Targets

	C-23 Canal	C-24 Canal	C-44 Canal to SLRE	Entire C-44 Canal Basin	Ten Mile Creek	Tidal Basins	Lake Okeechobee
FDEP TMDL and BMAP							
Simulated 1996-2005 Starting Load, pounds/yr	498,874	670,326	533,437	533,437	727,195		Excluded
TMDL Target Load, pounds/yr	242,202	348,957	242,929	242,929	302,545		Excluded
TMDL Percent Reduction	52%	52%	51%	51%	58%		Excluded
BMAP Ph. I target load, pounds/yr	421,872	573,915	446,285	446,285	671,736		Excluded
BMAP Ph. I target load reduction	16%	16%	15%	15%	18%		Excluded
Alternative performance measure							
Observed 1996-2005 Starting Load, pounds/yr[1]	614,536	746,862	643,023	832,560	490,477	N/A	1,672,706
Observed 1996-2005 Starting concentration, ppb	1,569	1,633	1,692	1,709	1,208	911	1,751
TMDL Target concentration, ppb	720	720	720	720	720	720	720
TMDL Percent Reduction	54%	56%	57%	58%	40%	21%	59%
TMDL Target Load, pounds/yr TMDL concentration, ppb	Percentage of Starting Load, adj. for hydrologic variability					720 ppb	720 ppb
BMAP Ph. I Target Reduction	16%	17%	17%	17%	12%	6%	18%
BMAP Ph. I Target Load, pounds/yr BMAP Ph. I Target Conentration, ppb	Percentage of Starting Load, adj. for hydrologic variability					842 ppb	1,442 ppb
Differences (FDEP values minus Observed)							
BMAP discrepancy in Starting Load, pounds/yr	-115,662	-76,536	-109,586	-299,123	N/A		1,672,706
BMAP discrepancy in Starting Load, %	-19%	-10%	-17%	-36%	N/A		100%
Difference in TMDL % reduction	-2%	-4%	-6%	-7%	N/A		100%
Difference in BMAP Ph. I % reduction	-1%	-1%	-2%	-2%	N/A		30%

Notes: 1. Base period for Ten Mile Creek was 2000-2010 2. Base period for Tidal Basins was 2003-2005
3. FDEP excluded C-44 Canal Basin loading to Lake Okeechobee, which is included in the alternative performance measure.

Table 5. Comparison of Total Phosphorus Performance Measures to BMAP Targets

	C-23 Canal	C-24 Canal	C-44 Canal to SLRE	Entire C-44 Canal Basin	Ten Mile Creek	Tidal Basins	Lake Okeechobee
FDEP TMDL and BMAP							
Simulated 1996-2005 Starting Load, pounds/yr	175,073	165,275	93,821	93,821	163,383		Excluded
TMDL Target Load, pounds/yr	27,248	39,258	27,330	27,330	33,180		Excluded
TMDL Percent Reduction	79%	72%	56%	56%	80%		Excluded
BMAP Ph. I target load, pounds/yr	116,869	119,531	67,514	67,514	172,389		Excluded
BMAP Ph. I target load reduction	24%	22%	17%	17%	24%		Excluded
Alternative performance measure							
Observed 1996-2005 Starting Load, pounds/yr[1]	185,864	156,276	91,575	119,007	156,681	N/A	150,561
Observed 1996-2005 Starting concentration, ppb	474	342	241	244	386	118	158
TMDL Target concentration, ppb	81	81	81	81	81	81	40
TMDL Percent Reduction	83%	76%	66%	67%	79%	32%	75%
TMDL Target Load, pounds/yr TMDL concentration, ppb	Percentage of Starting Load, adj. for hydrologic variability					81 ppb	81 ppb
BMAP Ph. I Target Reduction	25%	23%	20%	20%	24%	9%	22%
BMAP Ph. I Target Load, pounds/yr BMAP Ph. I Target Conentration, ppb	Percentage of Starting Load, adj. for hydrologic variability					108 ppb	122 ppb
Differences (FDEP values minus Observed)							
BMAP discrepancy in Starting Load, pounds/yr	-10,791	8,999	2,246	-25,186	N/A		-150,561
BMAP discrepancy in Starting Load, %	-6%	6%	2%	-21%	N/A		-100%
Difference in TMDL % reduction	-4%	-4%	-11%	-11%	N/A		-100%
Difference in BMAP Ph. I % reduction	-1%	-1%	-3%	-3%	N/A		-30%

Notes: 1. Base period for Ten Mile Creek was 2000-2010 2. Base period for Tidal Basins was 2003-2005
3. FDEP excluded C-44 Canal Basin loading to Lake Okeechobee, which is included in the alternative performance measure.

Annual water quality assessment. An assessment of the nutrient levels from the SLRE watershed and Lake Okeechobee was conducted focusing on two aspects:

1. WY2016 water quality conditions; and
2. The most recent 10-yr period compared to the base period.

WY2016 Water Quality Conditions

Nutrient levels for the most recent water year (WY2016, May 1, 2015 – April 30, 2016) are compared to base period levels (i.e., zero reduction), BMAP Phase 1 goals and TMDL goals in the figures below. The base period loads were adjusted for hydrologic variability using the regression equations in **Appendix 2**.

Total Phosphorus.

Loads (C-23, C-24, C-44 and Ten Mile Creek). Improvement from the base period loading was observed for WY2016 for all basins except the C-44 Canal Basin, which contributed approximately 45 percent more phosphorus load than during the base period even after adjusting for hydrologic variability (**Figure 8**). Only the Ten Mile Creek Basin met the alternative BMAP Phase 1 phosphorus load reduction goal during WY2016. The cumulative load reduction for these four basins did not meet the cumulative alternative BMAP Phase 1 goal. In addition, the Lake Okeechobee contributed more than 180,000 pounds of phosphorus during the year, which was 22 percent more than during the base period. The combined TP load from the C-44 Canal Basin and Lake Okeechobee that entered the SLRE through the C-44 Canal was almost 332,000 pounds – **more than 12 times the TMDL allocation established by FDEP for that entry point into the SLRE**.

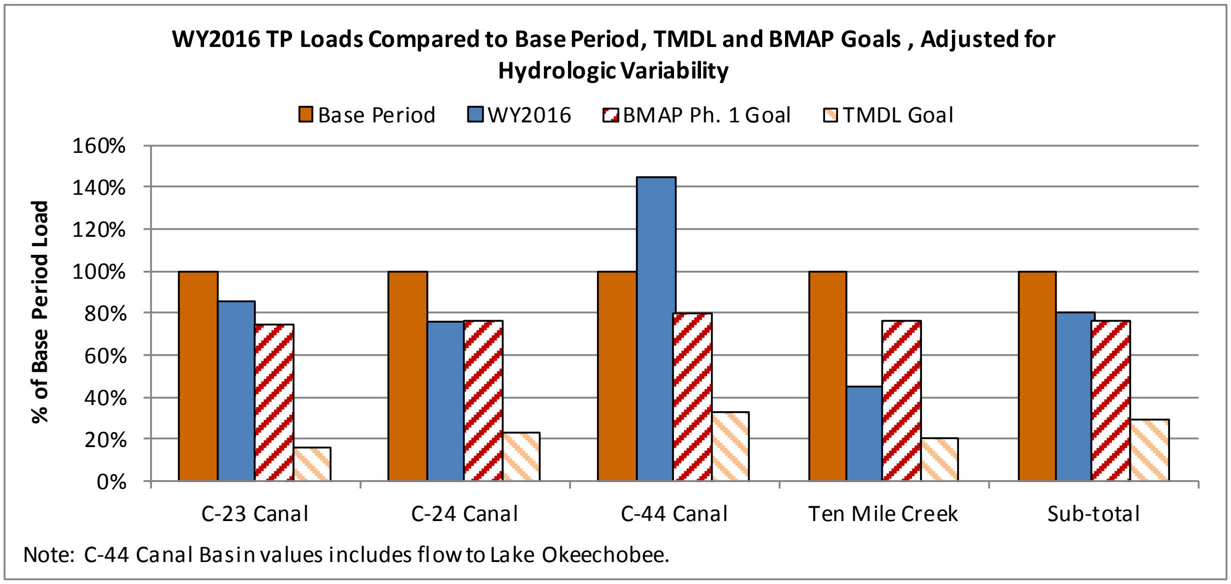
Concentrations. The Tidal Basins had the lowest TP concentration (100 ppb) of the SLRE source basins during WY2016. The WY2016 levels for the C-23 Canal Basin, C-44 Canal Basin and Lake Okeechobee exceeded the base period values. The Tidal Basins achieved the alternative BMAP Phase 1 goal, while Ten Mile Creek Basin was less than 1 percent above the alternative BMAP Phase 1 goal.

Total Nitrogen.

Loads (C-23, C-24, C-44 and Ten Mile Creek). Improvement from the base period loading was observed for WY2016 for all basins except the C-44 Canal Basin, which contributed almost twice the nitrogen load during WY2016 than during the base period, even after adjusting for hydrologic variability (**Figure 9**). Each basin except the C-44 Canal Basin met the alternative BMAP Phase 1 nitrogen load reduction goal during WY2016. The cumulative load reduction for these four basins met the cumulative alternative BMAP Phase 1 goal. Lake Okeechobee contributed almost 1.6 million pounds of TN during the year. The combined TN load from the C-44 Canal Basin and Lake Okeechobee that entered the SLRE through the C-44 Canal was 2.4 million pounds – **almost 10 times the TMDL allocation established by FDEP for that entry point into the SLRE**.

Concentrations. The Tidal Basins had the lowest TN concentration for WY2016 at 908 ppb. The WY2016 levels for the C-23 Canal Basin and the Tidal Basins exceeded the base period values, and no source basin achieved the alternative BMAP Phase 1 goal.

Figure 8. WY2016 Total Phosphorus Levels Compared to Base Period and Goals



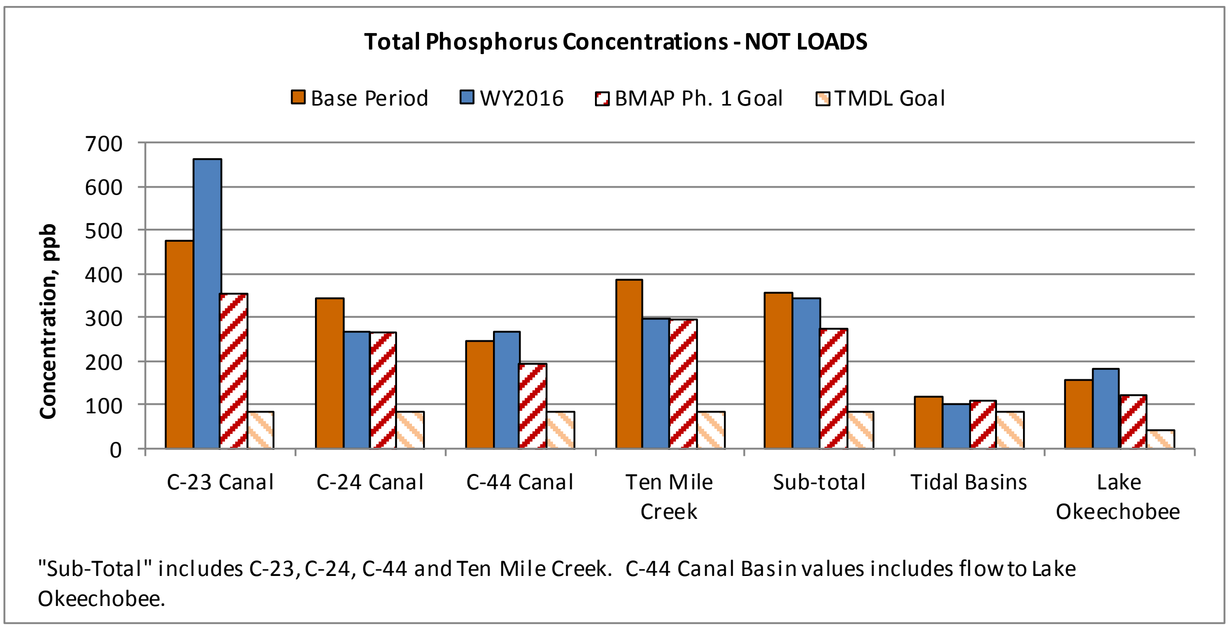
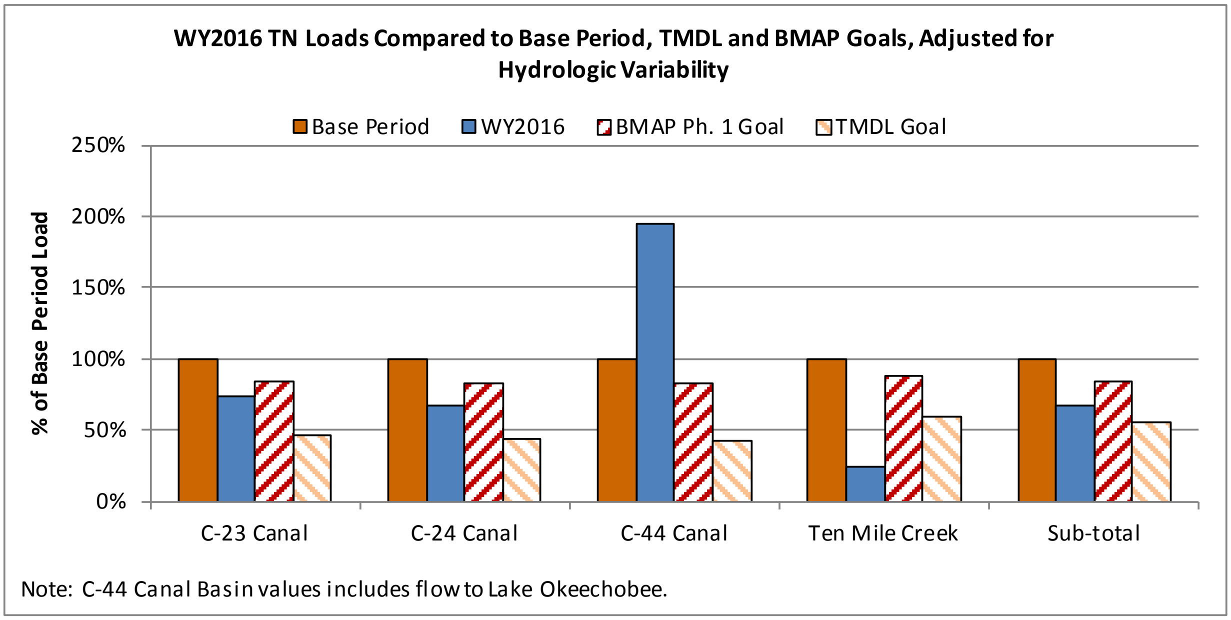
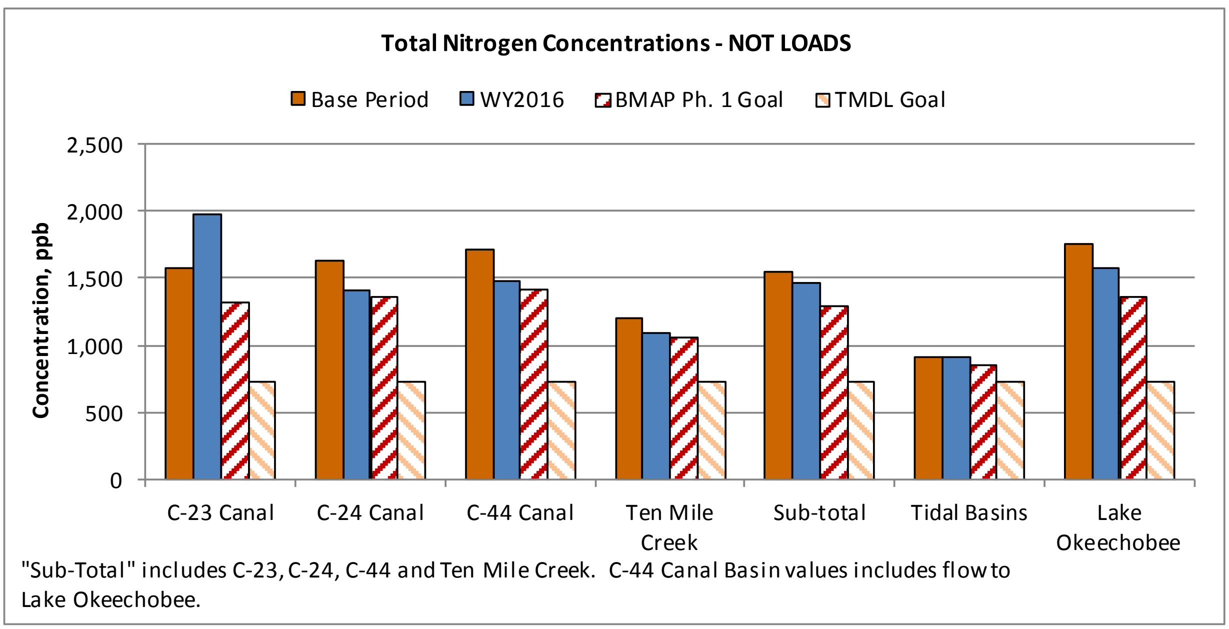


Figure 9. WY2016 Total Nitrogen Levels Compared to Base Period and Goals





Assessment of the most recent 10-yr period compared to the Base Period.

Assessments of the water quality entering the SLRE for the most recent 10-yr period compared to the base periods, adjusted for hydrologic variability using the performance measures described above, are summarized in **Figures 10-15** and discussed below. More details are provided in **Appendix 3**.

Total Nitrogen

Loads (C-23, C-24, C-44 and Ten Mile Creek). Using the 10-year average loads and adjusting for hydrologic variability, the Phase I BMAP TN load reduction goals were met for the C-23 Canal Basin, the C-24 Canal Basin and the Ten Mile Creek Basin, but was not met for the C-44 Canal Basin. 10-yr trends indicate improving water quality for all basins except the C-44 Canal Basin.

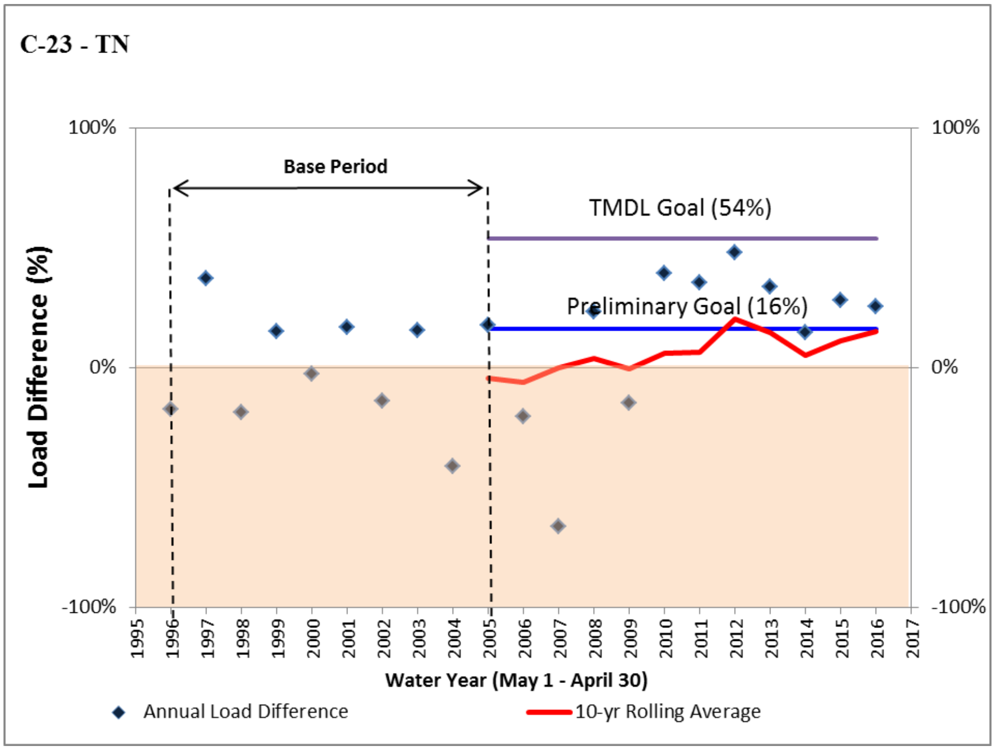
Concentrations (Tidal Basins and Lake Okeechobee). The 10-year flow-weighted mean concentration for lake discharges met the BMAP Phase 1 goal of 18 percent reduction from the base period. Similarly, the 10-yr concentration for the Tidal Basins achieved the BMAP Phase 1 goal of 6 percent reduction. The 10-year trends in concentrations for the Tidal Basins and Lake Okeechobee discharges indicate improving water quality for these sources to the SLRE.

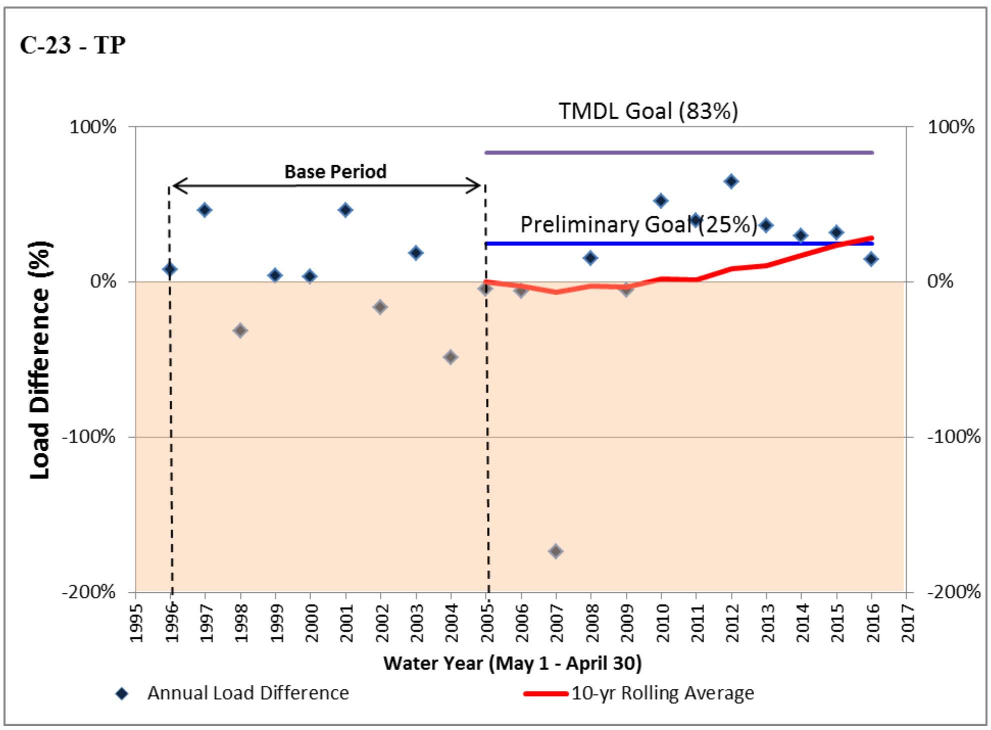
Total Phosphorus

Loads (C-23, C-24, C-44 and Ten Mile Creek). Using the 10-year average loads and adjusting for hydrologic variability, the Phase I BMAP phosphorus load reduction goals were met for the C-23 Canal Basin and the Ten Mile Creek Basin, but were not met for the C-23 Canal Basin and the C-44 Canal Basin. 10-yr trends indicate improving water quality for all basins except the C-44 Canal Basin.

Concentrations (Tidal Basins and Lake Okeechobee). The 10-year flow-weighted mean concentration for lake discharges did not met the BMAP Phase 1 goal of 22 percent reduction from the base period. By contrast, the 10-yr concentration for the Tidal Basins achieved the BMAP Phase 1 goal of 9 percent reduction. The 10-year trend in concentrations for the Tidal Basins indicates improving water quality, however, the 10-year concentration of Lake Okeechobee discharges remains essentially unchanged since the base period.

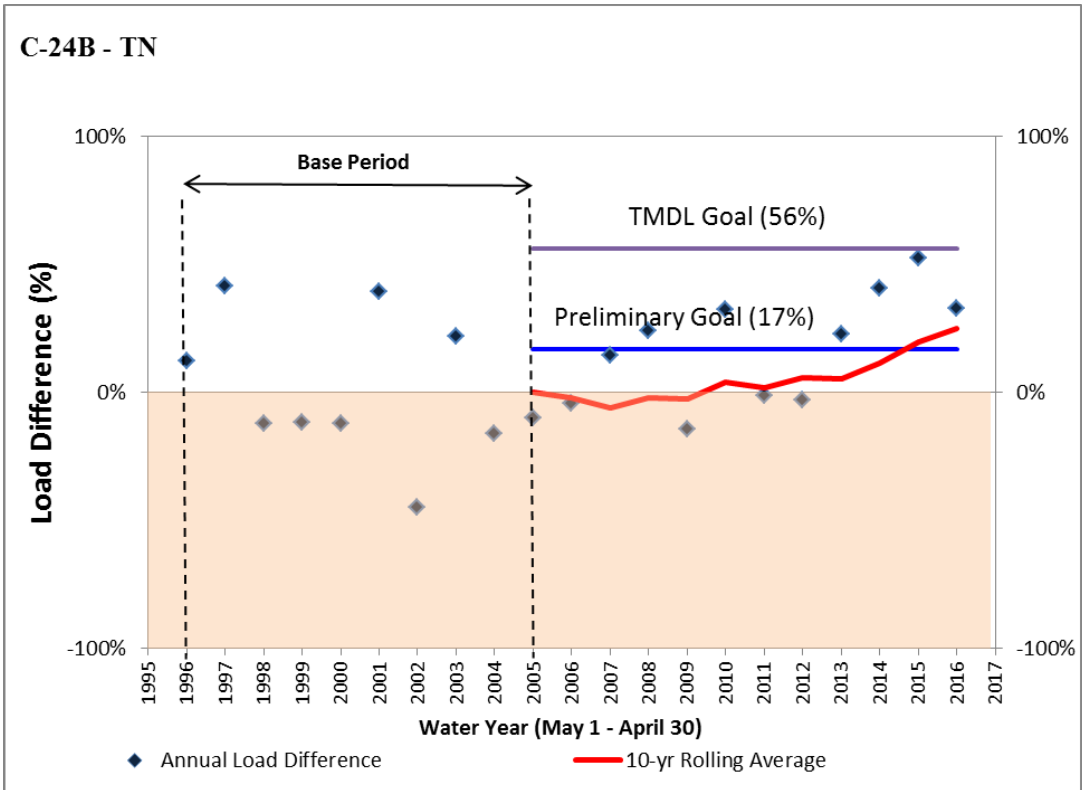
Figure 10. C-23 Canal Basin Nutrient Load Trends.

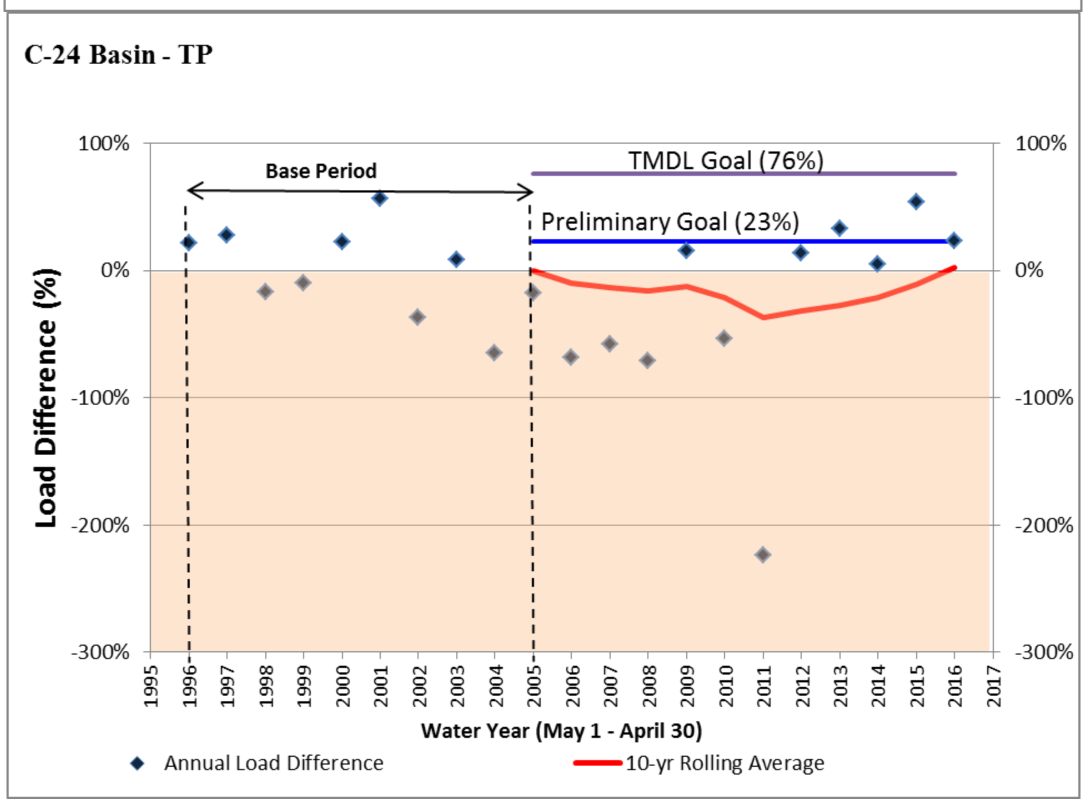




Notes: A positive load difference denotes a reduction in load in comparison to the base period, adjusted for hydrologic variability. An upward trend in the solid line denotes a reduction in loads.

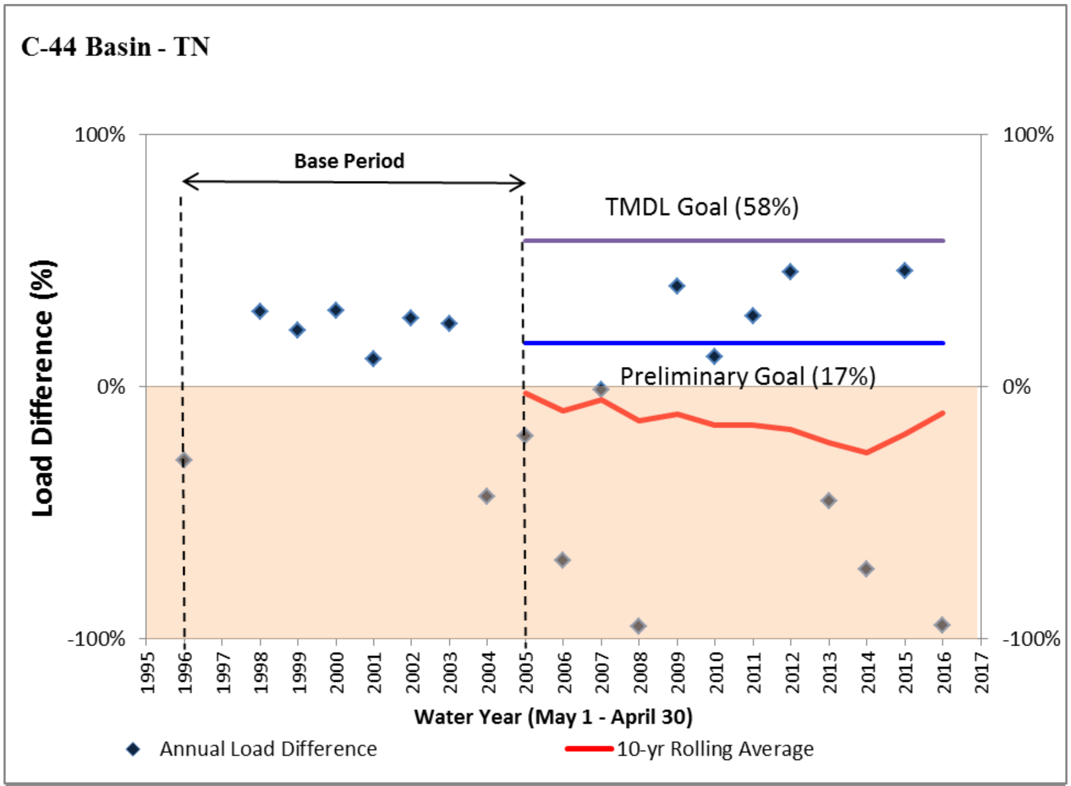
Figure 11. C-24 Basin Nutrient Load Trends.

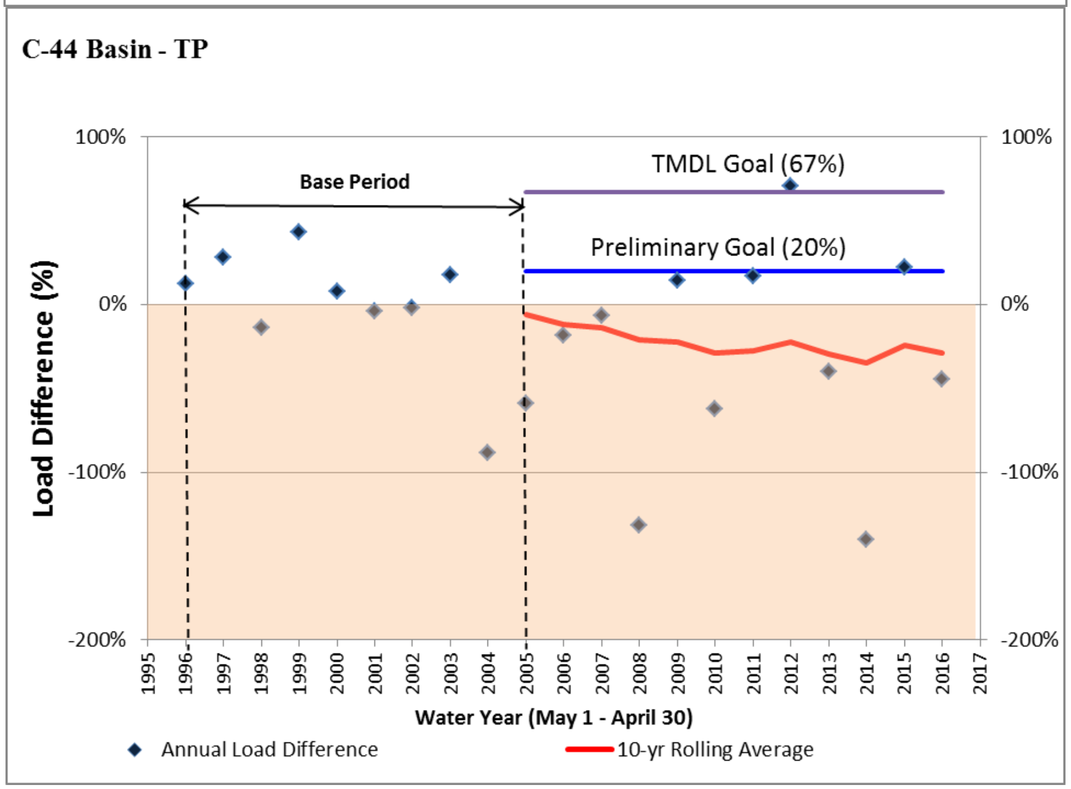




Notes: A positive load difference denotes a reduction in load in comparison to the base period, adjusted for hydrologic variability. An upward trend in the solid line denotes a reduction in loads.

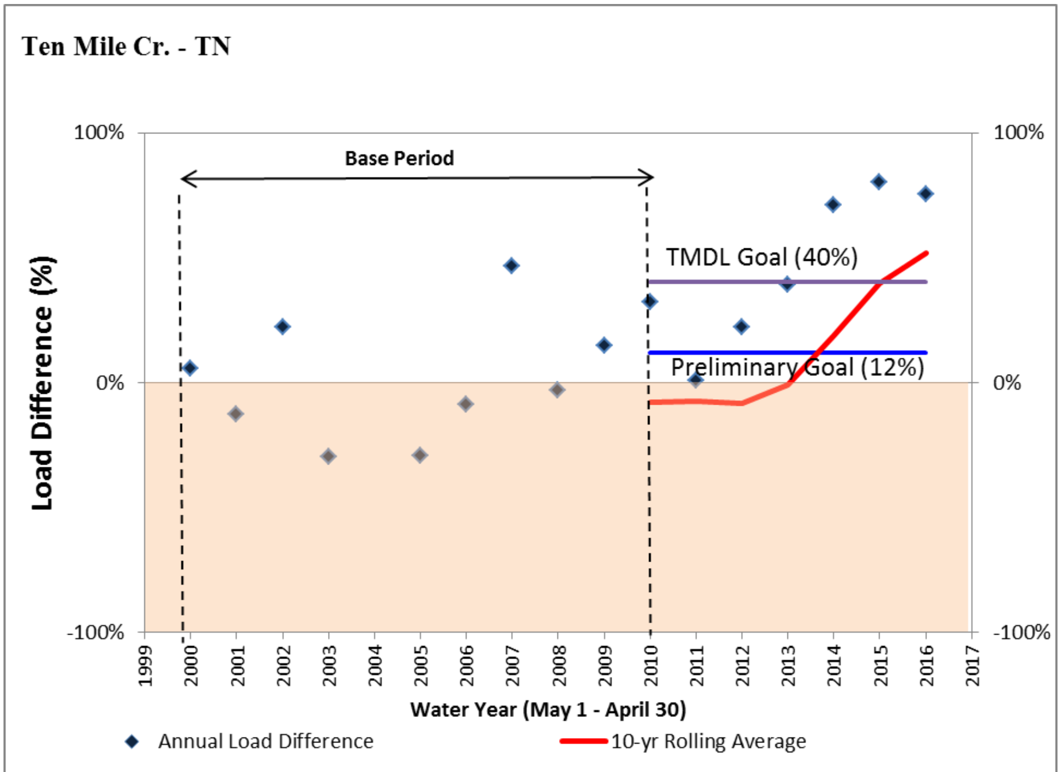
Figure 12. C-44 Basin Nutrient Load Trends.

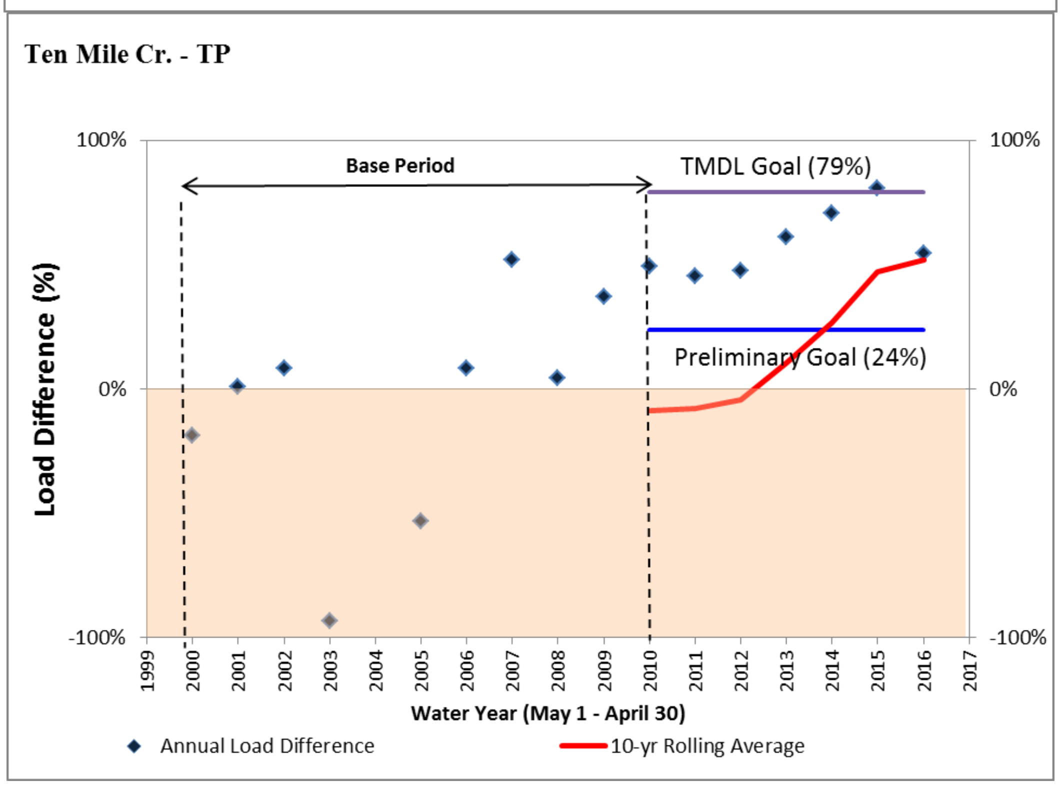




Notes: A positive load difference denotes a reduction in load in comparison to the base period, adjusted for hydrologic variability. An upward trend in the solid line denotes a reduction in loads.

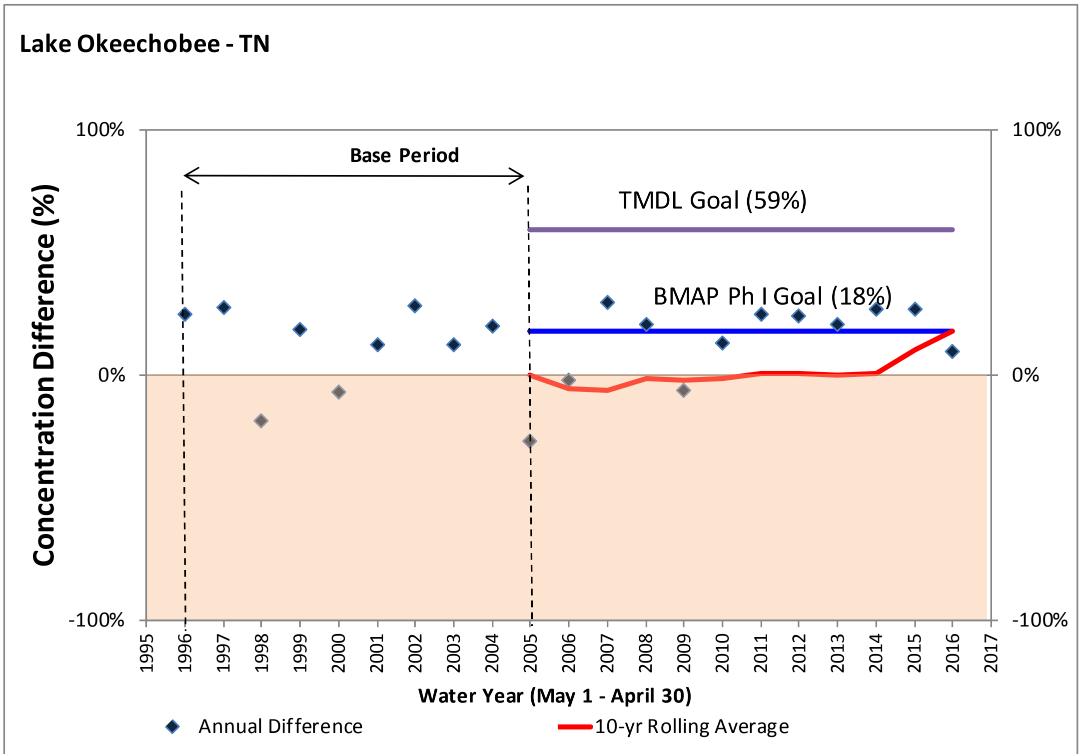
Figure 13. Ten Mile Creek Basin Nutrient Load Trends.

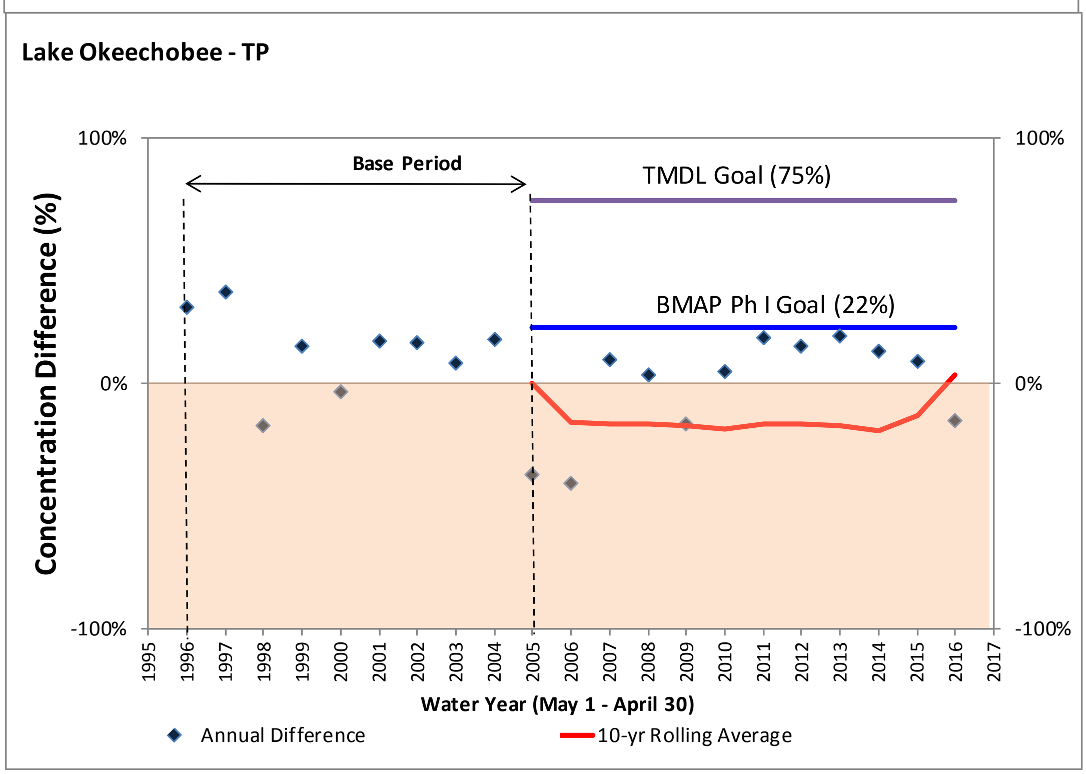




Notes: A positive load difference denotes a reduction in load in comparison to the base period, adjusted for hydrologic variability. An upward trend in the solid line denotes a reduction in loads.

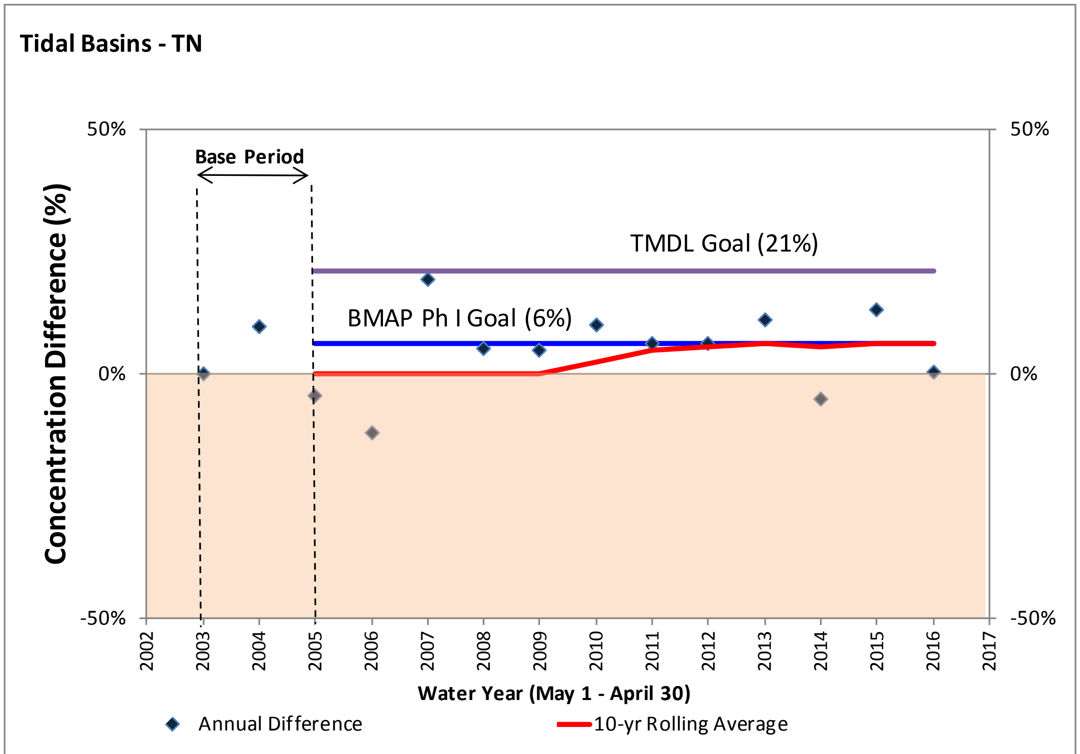
Figure 14. Comparison of observed annual concentrations to TMDL and BMAP Goals: Lake Okeechobee Discharges.

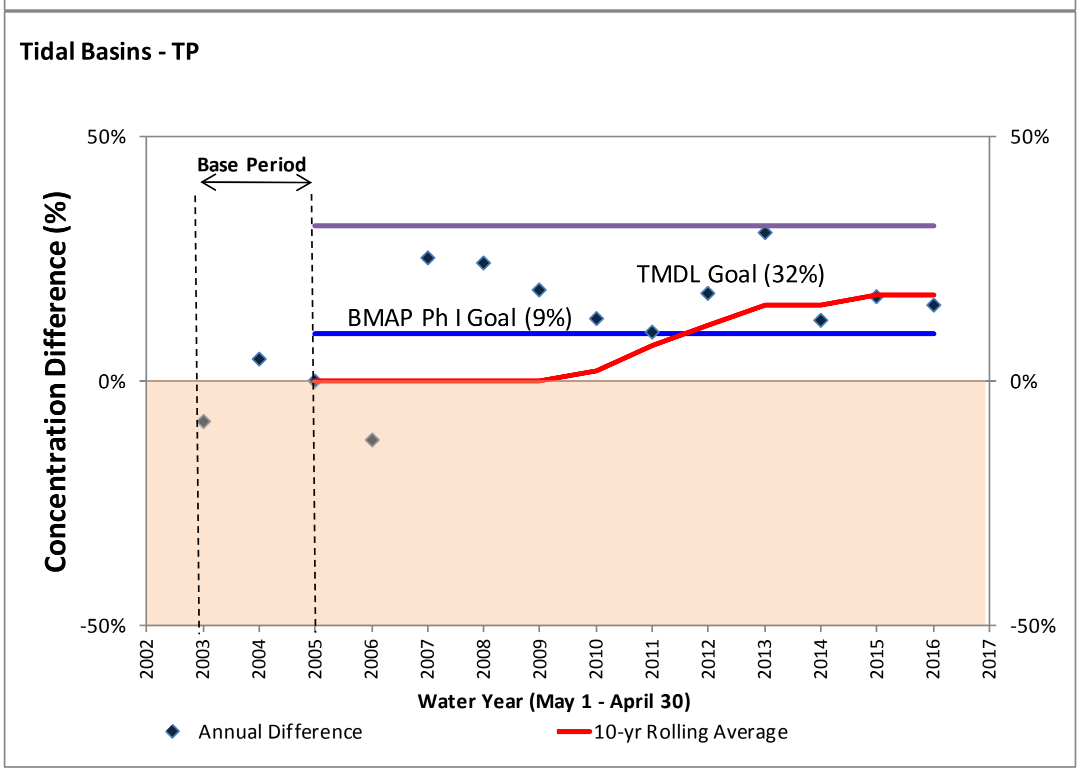




Notes: A positive difference denotes a reduction in concentration in comparison to the base period. An upward trend in the solid line denotes a reduction in concentration.

Figure 15. Comparison of observed annual concentrations to TMDL and BMAP Goals: Tidal Basins.





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

Nitrogen Loading from Septic Tanks. During 2016, several agricultural interests erroneously stated that the primary source of nutrient loads to the SLRE is the "200,000 septic tanks" that line Martin County waterways (e.g., saveourfarms.com 2016). In fact, the Florida Department of Health notes there are less than 1/10th the number of alleged known septic tanks in Martin County: 16,172 (FDOH 2015). In addition, a SFWMD Governing Board member erroneously stated that 80 percent of the nutrient loading to the SLRE was due to local septic tanks (Smith 2016).

The fact is that Martin County and the City of Stuart have significantly reduced nutrient loading to the SLRE from individual and community septage systems and through other local projects. These include:

• Elimination of seventy (70) wastewater package plants, which annually prevent the discharge of more than 560,000 pounds of nitrogen and more than 140,000 pounds of phosphorus (Polley 2014).

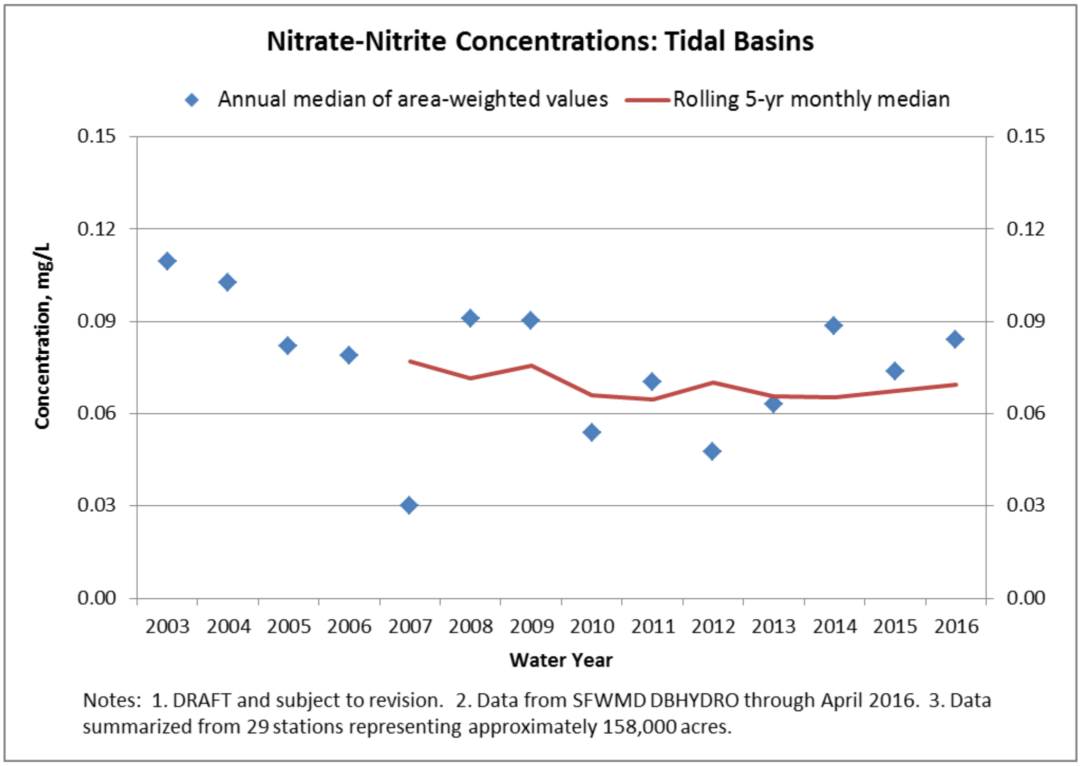
• Conversion of more than 1,700 septic tanks to centralized sanitary sewers, removing an estimated 15,400 pounds per year of nitrogen (Fielding 2015).

• Since 2000 Martin County has invested $50+ million in 25 stormwater projects, with approximately 30,000 pounds per year of nitrogen removal (Fielding 2015).

As a result of these projects, Martin County has exceeded all the nitrogen load reductions required under the State's Basin Management Action Plan (BMAP); nonetheless, the County is actively planning additional septic to sewer conversion projects that will further reduce nutrient loading to the River (FDEP 2015).

Researchers at Florida Atlantic University (FAU) postulated that malfunctioning septic tanks are a primary source of nutrient loading to the SLRE (LaPointe and Herren 2016). However, estimates prepared by consultants to FDEP suggest loadings from septic tanks are about one-third estimates from FAU, and previous BMAP progress reports have documented that prior septic-to-sewer conversion projects have been very effective in reducing nutrient loads from septic systems, particularly in Martin County (Ye and Sun 2013, FDEP 2015). The documented decline in nutrient concentrations, particularly nitrate-nitrite, in the Tidal Basins shown in **Figure 16** provide further documentation of the effectiveness of these projects. Additional septic-to-sewer projects in Martin and St. Lucie Counties are underway.

Figure 16. Reduction in nitrate-nitrite concentrations in the Tidal Basins.



4. SUMMARY

An overall assessment of the water quality entering the SLRE is summarized in **Table 6** and described below.

Table 6. Water Quality Conditions Entering the SLRE.

Source Basin	Total Phosphorus		Total Nitogen	
	WY2016 Status	10-yr Trend	WY2016 Status	10-yr Trend
C-23 Canal	Poor	Improving	Poor	Improving
C-24 Canal	Poor	Improving	Poor	Improving
C-44 Canal	*Poor*	*Worsening*	*Poor*	*Worsening*
Ten Mile Creek	Poor	Improving	Good	Improving
Tidal Basins	Fair	Improving	Fair	Improving
Lake Okeechobee	Poor	Improving	Poor	Improving
Total Inflow	***Poor***	***Improving***	***Poor***	***Improving***

Status. The assessment of "status" in each source basin was based on the WY2016 nutrient levels. For the Tidal Basins and Lake Okeechobee, concentrations were assessed; for all other source basins loads were assessed.

- "Good" indicates the WY2016 level achieved the TMDL;
- "Fair" indicates the WY2016 level exceeded the TMDL by less than 33%;
- "Poor" indicates the WY2016 level exceeded the TMDL by more than 33%.

Every source basin except the Tidal Basins and Ten Mile Creek demonstrated a "Poor" status for both total phosphorus and total nitrogen. The Tidal Basins demonstrated a status of "Fair" for both nutrients, while Ten Mile Creek demonstrated "Poor" for TP and "Good" for TN. The overall status of nutrient levels entering the SLRE was "Poor".

Trend. The assessment of trend in each source basin was based on the most recent 10-yr average nutrient level compared to its base period. For the Tidal Basins and Lake Okeechobee, concentrations were assessed; for all other source basins loads were assessed.

- "Improving" indicates the 10-yr average nutrient level was below the base period value, adjusted for hydrologic variability;
- "Worsening" indicates the 10-yr average nutrient level was above the base period value, adjusted for hydrologic variability.

All the source basins except the C-44 Canal Basin exhibited an "Improving" trend for both nutrients. The C-44 Canal Basin demonstrated a "Worsening" trend in TP and TN when comparing the recent loads against the base period loads. The overall trend for both nutrients entering the SLRE exhibited improvement.

As a result of this assessment, FDEP and other agency staff should identify the successful load reduction measures being implemented in the Tidal Basins and Ten Mile Creek for potential application to other basins. In addition, agency staff should prioritize the other basins, particularly the C-44 Canal Basin, for follow-up with landowners to improve nutrient control measures. During the 2015 stakeholder meeting, SFWMD staff acknowledged that the SFWMD was not enforcing Works of the District permits (Rule 40E-61) in the C-44 Canal Basin. The SFWMD is encouraged to start enforcing these permits in the C-44 Canal Basin and other basins around Lake Okeechobee.

5. COMPARISON TO FDEP BMAP ASSESSMENT APPROACH

The development and application of the performance measures described above offer sharp contrasts to the methods being utilized by the FDEP in their development of TMDLs and implementation of the BMAP for the SLRE, including the following.

1. The FDEP TMDL and BMAP method ignored pollution loading from Lake Okeechobee.
2. The FDEP BMAP method used simulated nutrient levels, and ignored abundant available flow and water quality data for the source basins.
3. The FDEP BMAP method has no annual assessment method.
4. The FDEP BMAP method has no means to account for hydrologic variability.
5. The FDEP BMAP method gives no information on the status and water quality conditions within individual basins.
6. The FDEP BMAP method ignores the annual variability in the proportion of C-44 Canal Basin runoff that flows to the SLRE (as opposed to Lake Okeechobee).

Based on these contrasts, the following recommendations are made.

1. BMAP progress reports should present the observed nutrient and suspended sediment loads contained in Lake Okeechobee discharges to the St. Lucie River and Estuary.
2. The SLRE BMAP should be revised to identify projects to capture and treat Lake discharges to the St. Lucie River and Estuary sufficiently to achieve the watershed's TMDL and BMAP Goals.
3. BMAP progress reports should utilize available flow and water quality data – and not simulated values - in assessing and documenting water quality conditions for each basin and in assessing progress towards achieving the TMDLs and Phase I BMAP Goals.
4. BMAP Progress Reports should show basin-specific Phase I BMAP Goals, measured loads and load reductions, and document the progress towards achieving the TMDLs and BMAP Goals.
5. BMAP Progress Reports should present the measured 1996-2005 (i.e., the "Starting Period") nutrient loads and concentrations for those basins with measured loads, and document actual load reductions by comparing measured loads/concentrations with the 1996-2005 values.
6. The TMDL and BMAP should be re-developed for the C-44 Canal Basin as a whole, recognizing the annual variability in the proportion of C-44 Canal Basin runoff that flows to the SLRE (as opposed to Lake Okeechobee).
7. The FDEP should recognize the limitations in establishing TMDLs and BMAP goals for the Tidal Basins and revise the TMDLs and BMAP goals to utilize concentrations: 81 ppb for TP and 720 ppb for TN.

8. The BMAP method for assessing current water quality conditions and calculating load reductions should account for hydrologic variability in manner similar to that developed by the SFWMD.
9. The BMAP Progress Reports should clearly note that the projected load reductions from agricultural BMPs have not been field verified, and may overestimate the load reductions. A similar caveat may be necessary for non-agricultural projects.
10. There should be a balanced set of requirements for municipal and agricultural source control projects regarding monitoring their effectiveness.
11. BMAP progress reports should document compliance with all nutrient discharge limits of existing permits issued to landowners in the St. Lucie River and Estuary Basin.
12. BMAP progress reports should use an annual reporting period consistent with the precedent established by the SFWMD, utilizing a Water Year of May 1 to April 30.

Additional details for each recommendation are described in Goforth 2015.

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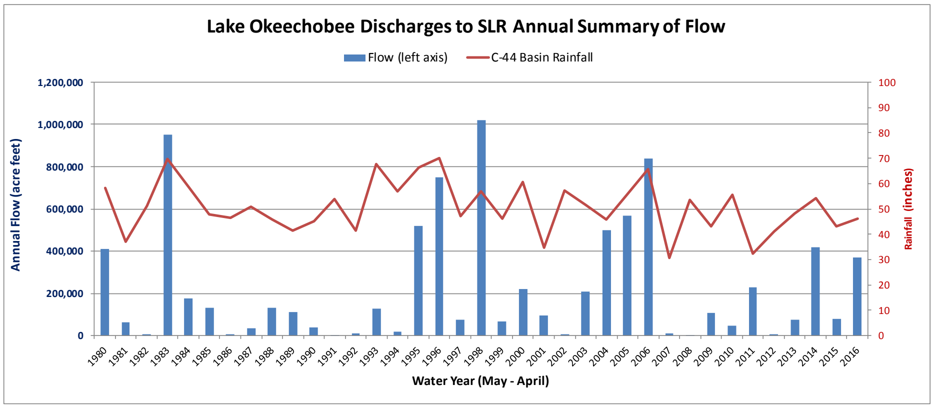
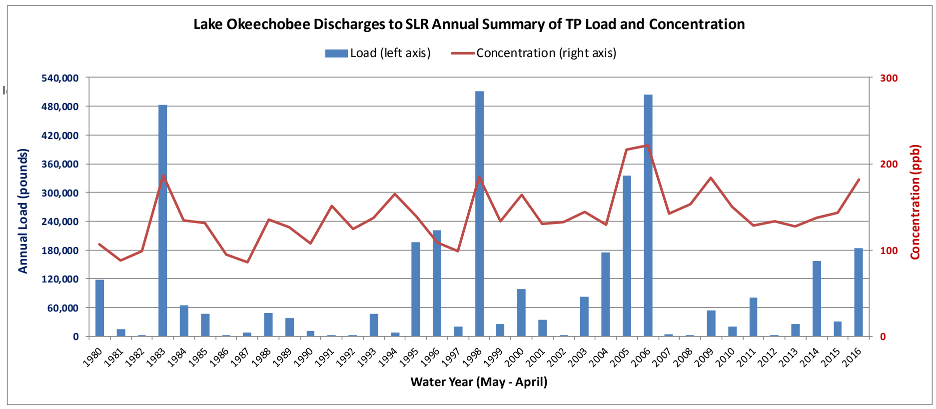
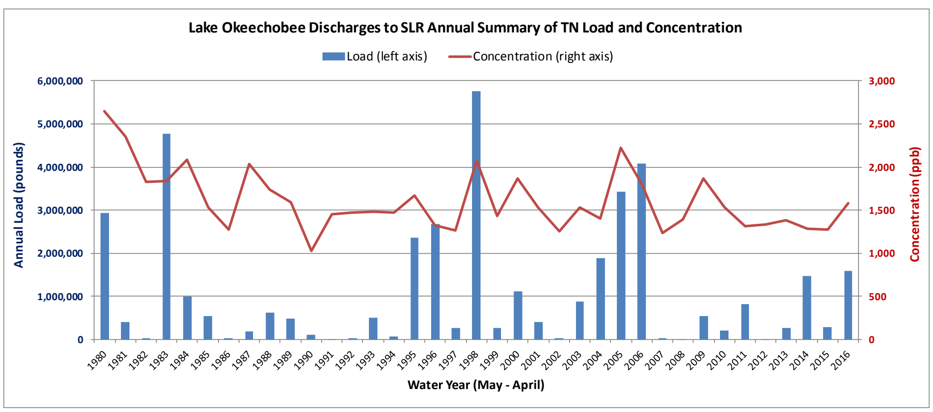
APPENDIX 1. HISTORICAL WATER QUALITY DATA

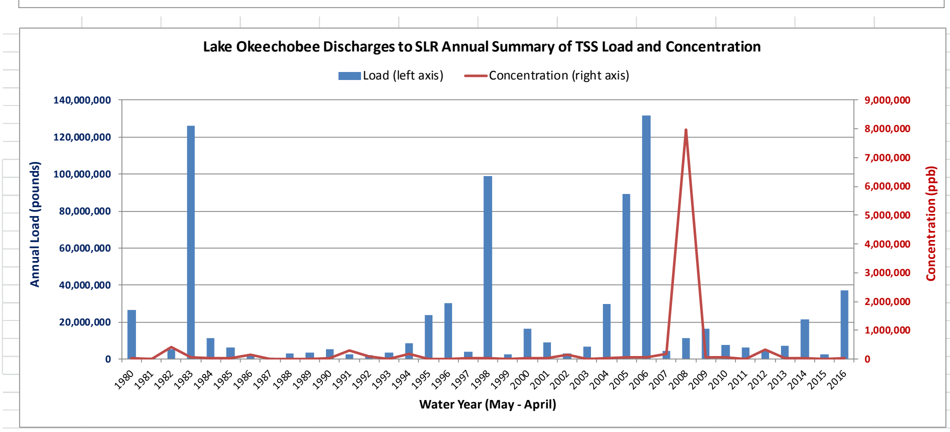
Annual Summary of Lake Okeechobee Discharges to the St Lucie River and Estuary

Water Year	C-44 Basin Rainfall inches	Lake Discharges AF	TP Load pounds	FWM TP Conc µg/L	TN Load pounds	FWM TN Conc µg/L	TSS Load pounds	FWM TSS Conc µg/L
1980	58.25	408,675	118,931	107	2,938,947	2,645	26,470,394	23,818
1981	37.19	63,084	15,027	88	404,360	2,357	825,914	4,814
1982	51.02	4,604	1,233	98	22,878	1,827	5,248,516	419,168
1983	69.84	952,232	483,492	187	4,764,127	1,840	126,107,899	48,700
1984	58.74	177,419	64,988	135	1,007,620	2,088	11,495,846	23,827
1985	47.69	130,776	46,652	131	543,499	1,528	6,219,661	17,489
1986	46.42	6,319	1,620	94	21,993	1,280	2,374,092	138,152
1987	50.94	35,011	8,177	86	194,181	2,040	872,468	9,164
1988	45.94	131,823	48,395	135	625,095	1,744	3,032,427	8,459
1989	41.42	110,357	37,811	126	476,203	1,587	3,544,287	11,810
1990	45.18	40,252	11,750	107	112,164	1,025	5,140,110	46,959
1991	53.84	3,243	1,333	151	12,808	1,452	2,706,317	306,860
1992	41.47	8,894	2,998	124	35,727	1,477	2,271,675	93,924
1993	67.53	125,944	46,909	137	506,692	1,479	3,337,961	9,746
1994	56.85	17,083	7,643	165	68,590	1,477	8,563,721	184,348
1995	66.40	520,631	196,699	139	2,363,613	1,669	23,745,118	16,772
1996	69.99	748,625	221,851	109	2,688,173	1,320	30,256,538	14,862
1997	47.11	74,968	20,169	99	258,973	1,270	3,862,713	18,947
1998	56.93	1,020,158	511,820	184	5,758,028	2,076	98,993,658	35,684
1999	46.22	68,661	24,953	134	267,275	1,431	2,614,497	14,003
2000	60.74	220,120	97,944	164	1,119,743	1,871	16,528,935	27,613
2001	34.60	95,831	34,095	131	398,908	1,531	9,187,068	35,253
2002	57.14	7,622	2,738	132	26,090	1,259	2,843,045	137,162
2003	51.51	210,133	82,484	144	876,800	1,534	6,790,783	11,884
2004	45.70	497,599	175,182	129	1,897,219	1,402	29,945,184	22,130
2005	55.91	568,903	334,378	216	3,435,851	2,221	89,311,749	57,730
2006	65.64	837,413	504,434	222	4,087,935	1,795	131,699,956	57,833
2007	30.61	8,800	3,413	143	29,615	1,238	4,370,521	182,628
2008	53.60	519	215	153	1,964	1,391	11,239,562	7,961,770
2009	42.95	109,296	54,584	184	554,227	1,865	16,508,436	55,544
2010	55.70	48,781	19,916	150	202,622	1,527	7,562,974	57,013
2011	32.28	229,568	80,370	129	822,212	1,317	6,153,579	9,857
2012	40.94	5,094	1,850	134	18,420	1,330	4,717,870	340,593
2013	48.06	73,136	25,325	127	275,894	1,387	7,115,212	35,776
2014	54.19	419,378	156,877	138	1,468,198	1,287	21,409,471	18,773
2015	43.18	80,249	31,315	143	279,058	1,279	2,653,241	12,158
2016	46.19	369,839	183,297	182	1,590,329	1,581	37,261,019	37,049
WY1980-2016 Average	*50.75*	*227,866*	*98,942*	*160*	*1,085,298*	*1,751*	*20,891,417*	*33,715*
WY1996-2005 Average	*52.58*	*351,262*	*150,561*	*158*	*1,672,706*	*1,751*	*29,033,417*	*30,395*
WY2007-2016 Average	*56.71*	*280,833*	*113,232*	*148*	*1,307,962*	*1,713*	*19,288,113*	*25,256*
Difference	8%	-20%	-25%	-6%	-22%	-2%	-34%	-17%


Lake Okeechobee Discharges to SLR Annual Summary of Flow
Flow (left axis)
C-44 Basin Rainfall
Annual Flow (acre feet)
Rainfall (inches)
Water Year (May - April)

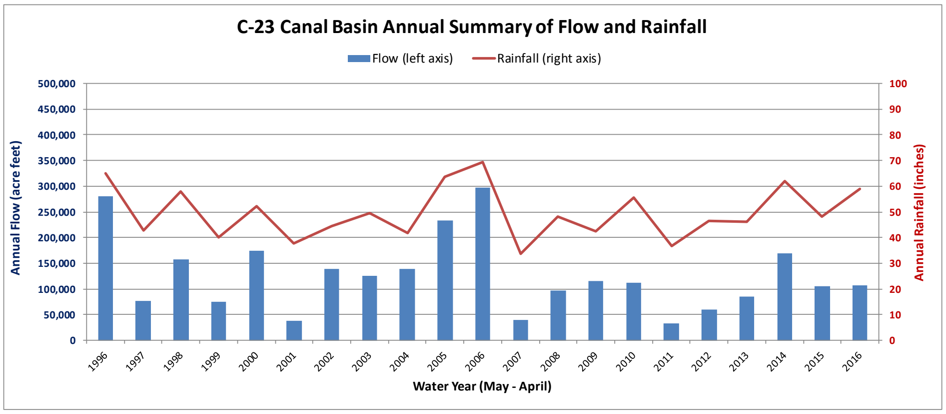

Lake Okeechobee Discharges to SLR Annual Summary of TP Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

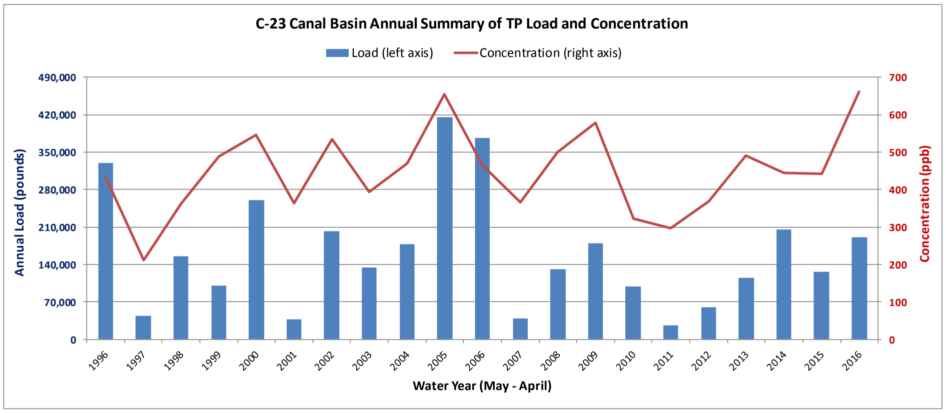

Lake Okeechobee Discharges to SLR Annual Summary of TN Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

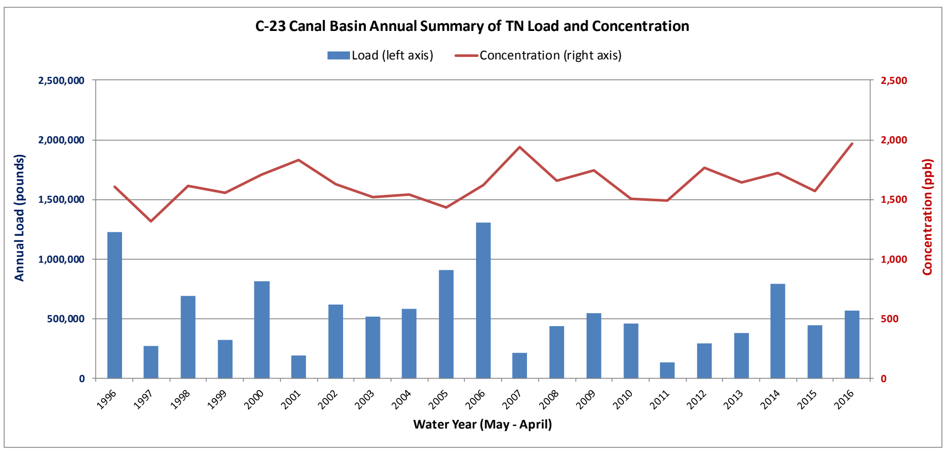

Lake Okeechobee Discharges to SLR Annual Summary of TSS Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

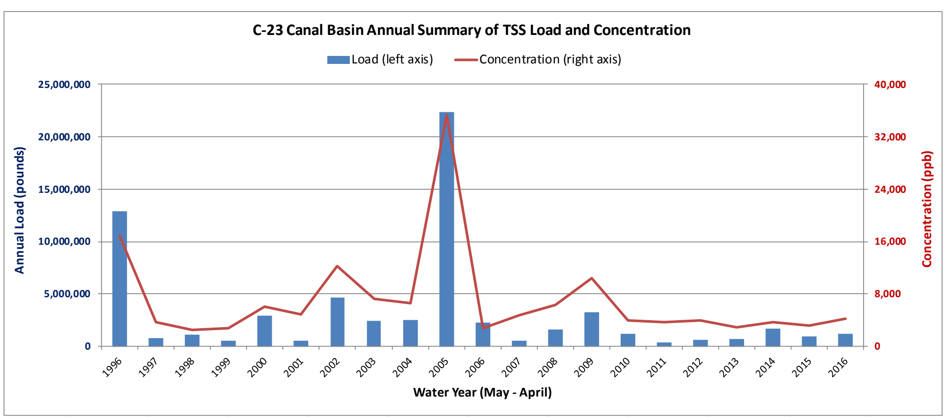
Annual Summary of Flows and Loads from the C-23 Canal Basin

Water Year	Basin Rainfall inches	Basin Flow AF	TP Load pounds	FWM TP Conc µg/L	TN Load pounds	FWM TN Conc µg/L	TSS Load pounds	FWM TSS Conc µg/L
1996	65.12	280,757	330,423	433	1,227,990	1,608	12,922,421	16,926
1997	42.75	76,826	44,094	211	275,330	1,318	777,968	3,724
1998	57.93	157,211	155,006	363	691,302	1,617	1,100,725	2,575
1999	40.02	75,674	100,720	489	320,679	1,558	571,796	2,779
2000	52.23	175,031	260,173	547	811,320	1,705	2,917,375	6,129
2001	37.70	38,331	37,882	363	191,091	1,833	506,625	4,860
2002	44.36	139,212	202,463	535	616,797	1,629	4,640,951	12,259
2003	49.59	125,215	134,302	394	517,426	1,520	2,449,136	7,193
2004	41.78	139,689	178,613	470	585,625	1,542	2,518,307	6,629
2005	63.72	232,805	414,965	655	907,802	1,434	22,321,213	35,258
2006	69.52	297,209	376,213	465	1,307,351	1,618	2,296,280	2,841
2007	33.61	39,871	39,798	367	210,552	1,942	516,026	4,759
2008	48.30	96,813	131,876	501	436,109	1,657	1,653,257	6,280
2009	42.48	114,820	180,602	578	545,325	1,747	3,238,415	10,372
2010	55.45	112,338	98,382	322	459,942	1,506	1,228,895	4,023
2011	36.61	33,643	27,122	296	136,294	1,490	344,187	3,762
2012	46.38	60,600	60,666	368	291,478	1,769	649,029	3,938
2013	46.26	85,776	114,702	492	383,126	1,643	674,920	2,893
2014	61.87	169,434	205,469	446	795,045	1,726	1,681,869	3,650
2015	47.99	104,991	126,147	442	447,289	1,567	924,204	3,237
2016	59.05	106,699	191,685	661	571,498	1,970	1,215,143	4,188
WY1996-2016 Average	*49.65*	*126,807*	*162,443*	*471*	*558,542*	*1,620*	*3,102,321*	*8,997*
WY1996-2005 Average	*49.52*	*144,075*	*185,864*	*474*	*614,536*	*1,569*	*5,072,652*	*12,947*
WY2007-2016 Average	*47.80*	*92,498*	*117,645*	*468*	*427,666*	*1,700*	*1,212,595*	*4,821*
Difference	-3%	-36%	-37%	-1%	-30%	8%	-76%	-63%


C-23 Canal Basin Annual Summary of Flow and Rainfall
Flow (left axis)
Rainfall (right axis)
Annual Flow (acre feet)
Annual Rainfall (inches)
Water Year (May - April)

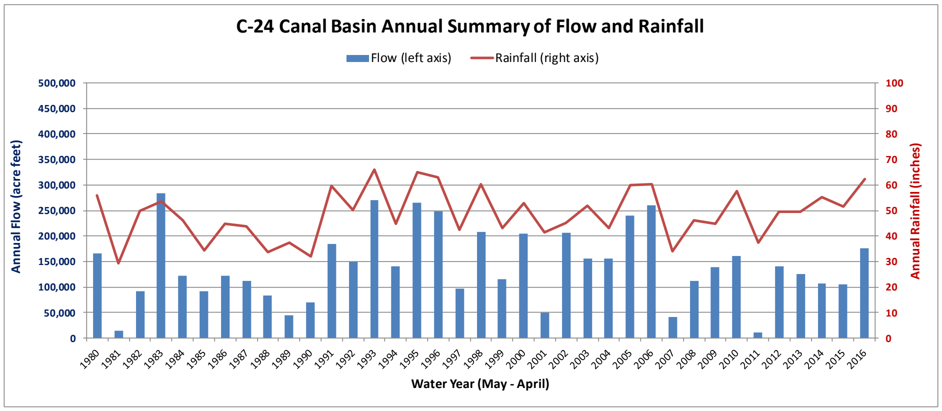

C-23 Canal Basin Annual Summary of TP Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

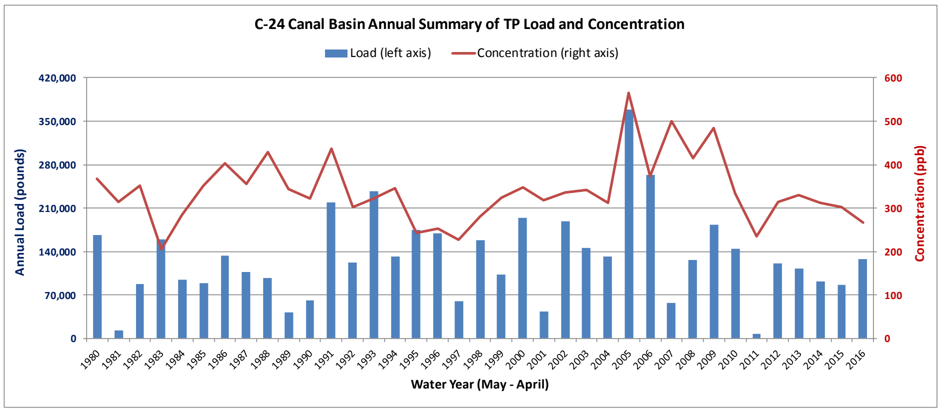

C-23 Canal Basin Annual Summary of TN Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

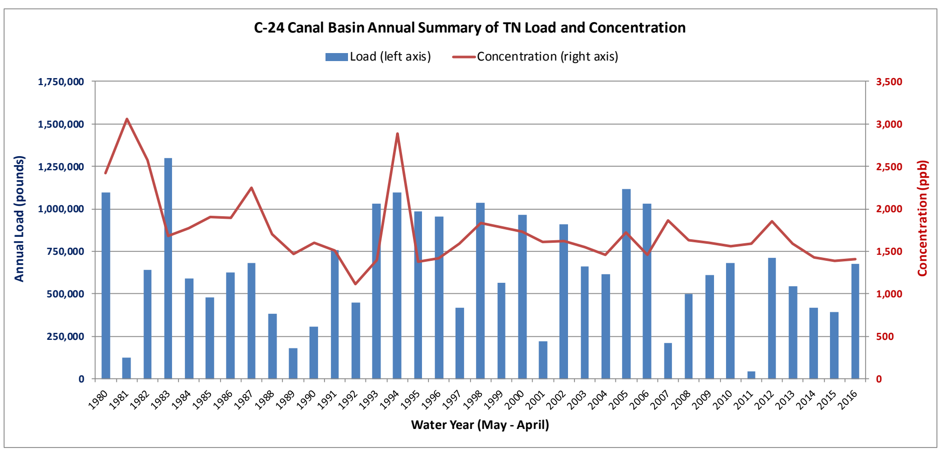

C-23 Canal Basin Annual Summary of TSS Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

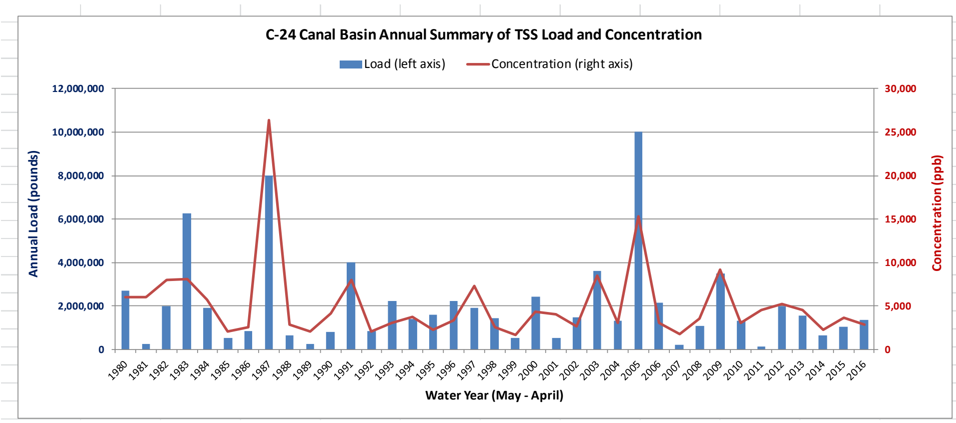
Annual Summary of Flows and Loads from the C-24 Canal Basin

Water Year	Basin Rainfall inches	Basin Flow AF	TP Load pounds	FWM TP Conc µg/L	TN Load pounds	FWM TN Conc µg/L	TSS Load pounds	FWM TSS Conc µg/L
1980	55.90	166,563	166,037	367	1,097,441	2,423	2,717,690	6,000
1981	29.17	15,174	12,940	314	126,328	3,061	247,585	6,000
1982	49.70	91,552	87,747	352	640,549	2,573	1,983,392	7,967
1983	53.51	283,915	159,070	206	1,299,451	1,683	6,256,287	8,103
1984	46.11	122,741	94,838	284	591,753	1,773	1,920,968	5,755
1985	34.48	92,555	88,643	352	478,219	1,900	530,875	2,109
1986	44.80	121,639	133,241	403	625,405	1,891	868,503	2,626
1987	43.62	111,342	107,661	356	680,960	2,249	7,990,082	26,389
1988	33.71	82,858	96,681	429	383,721	1,703	652,193	2,894
1989	37.44	45,097	42,054	343	179,816	1,466	250,701	2,044
1990	32.14	70,470	61,841	323	306,941	1,602	803,424	4,193
1991	59.54	184,366	218,550	436	755,131	1,506	4,026,091	8,030
1992	50.06	148,502	121,688	301	449,087	1,112	838,929	2,077
1993	65.92	270,205	236,775	322	1,029,153	1,401	2,228,868	3,033
1994	44.95	140,065	131,316	345	1,098,965	2,885	1,425,071	3,741
1995	65.15	264,487	174,368	242	987,552	1,373	1,618,939	2,251
1996	62.96	247,902	169,917	252	956,073	1,418	2,245,266	3,331
1997	42.52	97,160	60,237	228	418,991	1,586	1,934,774	7,323
1998	60.28	207,496	158,714	281	1,035,086	1,834	1,457,914	2,584
1999	43.01	116,099	102,530	325	563,029	1,783	544,487	1,725
2000	52.75	204,809	193,757	348	966,161	1,735	2,415,590	4,337
2001	41.27	50,232	43,510	319	219,827	1,609	553,639	4,053
2002	45.28	206,299	188,233	336	911,650	1,625	1,480,212	2,639
2003	51.86	156,589	145,164	341	662,191	1,555	3,638,116	8,544
2004	42.99	155,813	132,635	313	616,305	1,455	1,316,684	3,107
2005	59.90	239,510	368,063	565	1,119,306	1,719	10,001,747	15,356
2006	60.29	259,530	263,728	374	1,028,892	1,458	2,137,437	3,029
2007	33.99	41,877	56,852	499	212,145	1,863	204,778	1,798
2008	46.22	112,262	126,497	414	497,732	1,630	1,101,947	3,610
2009	44.66	139,650	183,593	483	609,357	1,605	3,481,302	9,167
2010	57.48	160,080	144,994	333	681,202	1,565	1,321,548	3,036
2011	37.23	10,591	6,797	236	45,679	1,586	130,177	4,520
2012	49.61	140,925	120,577	315	710,442	1,854	2,000,480	5,220
2013	49.57	125,824	112,698	329	545,120	1,593	1,548,417	4,525
2014	55.36	107,677	91,183	311	417,676	1,426	655,195	2,238
2015	51.67	104,547	85,942	302	393,288	1,383	1,039,945	3,658
2016	62.21	176,612	127,403	265	677,064	1,410	1,382,692	2,879
WY1980-2016 Average	*48.58*	*142,514*	*130,175*	*336*	*649,127*	*1,675*	*2,025,728*	*5,227*
WY1996-2005 Average	*50.28*	*168,191*	*156,276*	*342*	*746,862*	*1,633*	*2,558,843*	*5,595*
WY2007-2016 Average	*54.71*	*188,109*	*156,785*	*306*	*825,923*	*1,615*	*1,873,593*	*3,663*
Difference	9%	12%	0%	-10%	11%	-1%	-27%	-35%


C-24 Canal Basin Annual Summary of Flow and Rainfall
Flow (left axis)
Rainfall (right axis)
Annual Flow (acre feet)
Annual Rainfall (inches)
Water Year (May - April)

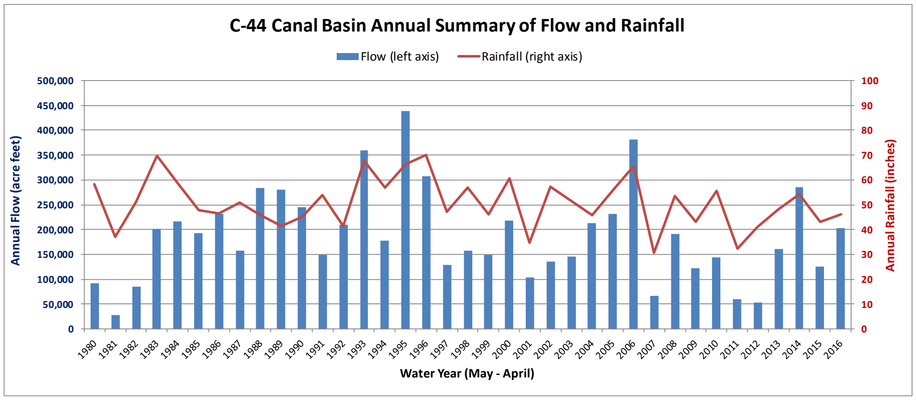

C-24 Canal Basin Annual Summary of TP Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

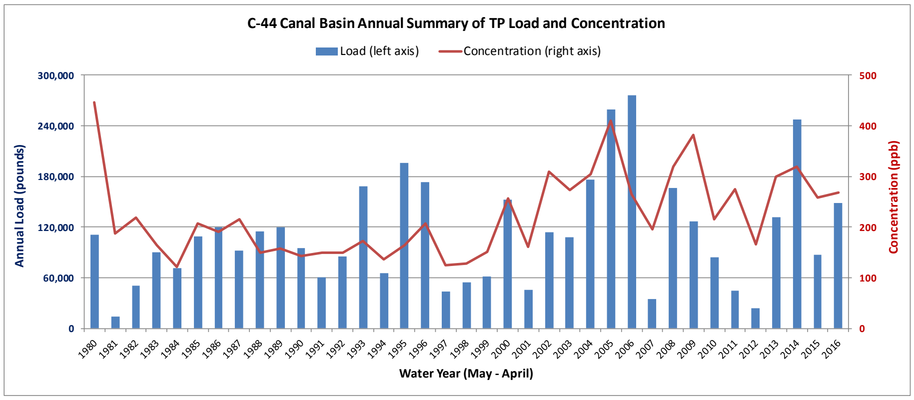

C-24 Canal Basin Annual Summary of TN Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

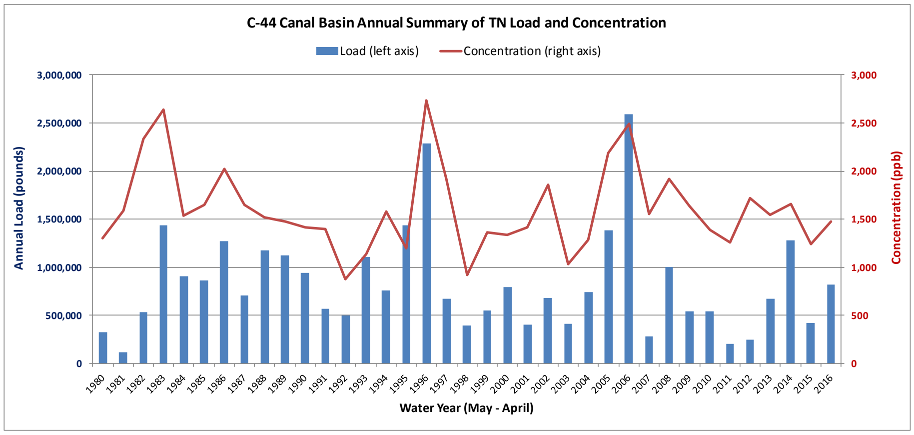

C-24 Canal Basin Annual Summary of TSS Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

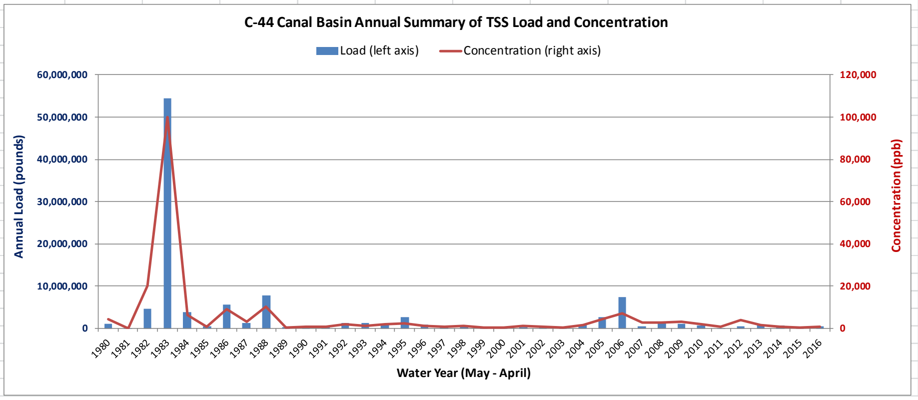
Annual Summary of Flows and Loads from the C-44 Canal Basin (to Lake and SLRE)

Water Year	Basin Rainfall inches	Basin Flow AF	TP Load pounds	FWM TP Conc µg/L	TN Load pounds	FWM TN Conc µg/L	TSS Load pounds	FWM TSS Conc µg/L
1980	58.25	91,598	111,221	447	324,585	1,303	1,090,623	4,378
1981	37.19	27,676	14,168	188	119,896	1,593	16,755	223
1982	51.02	84,775	50,504	219	538,072	2,334	4,631,969	20,092
1983	69.84	200,608	89,819	165	1,439,689	2,639	54,544,213	99,984
1984	58.74	216,422	71,877	122	906,326	1,540	3,825,464	6,500
1985	47.69	192,012	108,654	208	862,262	1,651	468,496	897
1986	46.42	231,132	120,430	192	1,273,371	2,026	5,747,074	9,144
1987	50.94	157,734	92,635	216	706,659	1,647	1,357,381	3,165
1988	45.94	283,533	114,811	149	1,174,569	1,523	7,869,706	10,207
1989	41.42	280,208	120,205	158	1,123,237	1,474	329,905	433
1990	45.18	245,568	95,382	143	946,214	1,417	575,195	861
1991	53.84	148,997	60,613	150	565,388	1,395	330,676	816
1992	41.47	209,541	85,690	150	497,605	873	1,239,199	2,175
1993	67.53	359,991	168,443	172	1,111,289	1,135	1,293,516	1,321
1994	56.85	177,178	65,464	136	760,889	1,579	1,047,128	2,173
1995	66.40	439,081	195,660	164	1,433,521	1,201	2,771,975	2,322
1996	69.99	307,565	173,363	207	2,283,833	2,731	938,733	1,122
1997	47.11	129,268	44,196	126	675,173	1,921	342,480	974
1998	56.93	157,242	55,000	129	395,149	924	466,281	1,090
1999	46.22	148,620	61,449	152	550,544	1,362	178,338	441
2000	60.74	218,669	152,829	257	797,115	1,340	312,248	525
2001	34.60	104,182	45,807	162	401,498	1,417	388,937	1,373
2002	57.14	135,035	113,746	310	682,648	1,859	341,719	931
2003	51.51	145,180	107,856	273	409,276	1,037	110,931	281
2004	45.70	213,456	176,683	304	746,505	1,286	849,225	1,463
2005	55.91	232,251	259,138	410	1,383,856	2,191	2,739,731	4,338
2006	65.64	381,862	275,750	266	2,587,689	2,492	7,362,561	7,090
2007	30.61	66,532	35,402	196	280,558	1,551	516,233	2,853
2008	53.60	191,652	166,372	319	999,321	1,917	1,401,970	2,690
2009	42.95	121,649	126,455	382	542,174	1,639	1,087,327	3,287
2010	55.70	143,443	84,195	216	542,082	1,390	726,761	1,863
2011	32.28	60,241	45,157	276	206,213	1,259	117,984	720
2012	40.94	53,882	24,256	166	251,376	1,716	576,794	3,936
2013	48.06	160,985	131,395	300	677,515	1,548	636,030	1,453
2014	54.19	284,575	247,135	319	1,280,958	1,655	646,049	835
2015	43.18	124,861	87,709	258	422,392	1,244	178,061	524
2016	46.19	203,111	148,662	269	817,357	1,480	534,457	968
WY1980-2016 Average	*50.75*	*187,306*	*111,571*	*219*	*830,184*	*1,630*	*2,907,895*	*5,709*
WY1996-2005 Average	*52.58*	*179,147*	*119,007*	*244*	*832,560*	*1,709*	*666,862*	*1,369*
WY2007-2016 Average	*56.71*	*229,615*	*106,271*	*170*	*907,051*	*1,453*	*892,057*	*1,429*
Difference	8%	28%	-11%	-30%	9%	-15%	34%	4%


C-44 Canal Basin Annual Summary of Flow and Rainfall
Flow (left axis)
Rainfall (right axis)
Annual Flow (acre feet)
Annual Rainfall (inches)
Water Year (May - April)

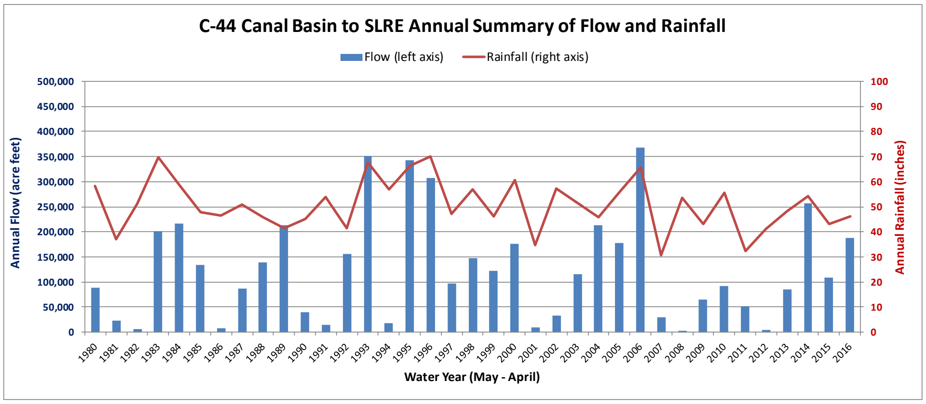

C-44 Canal Basin Annual Summary of TP Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

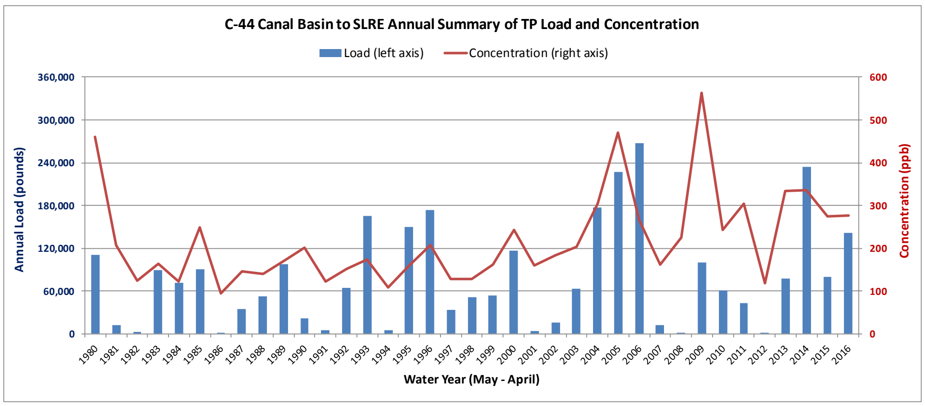

C-44 Canal Basin Annual Summary of TN Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

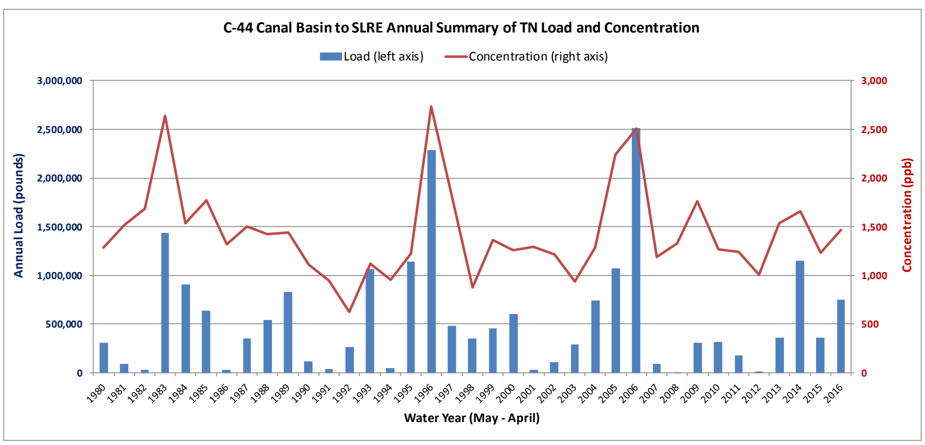

C-44 Canal Basin Annual Summary of TSS Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

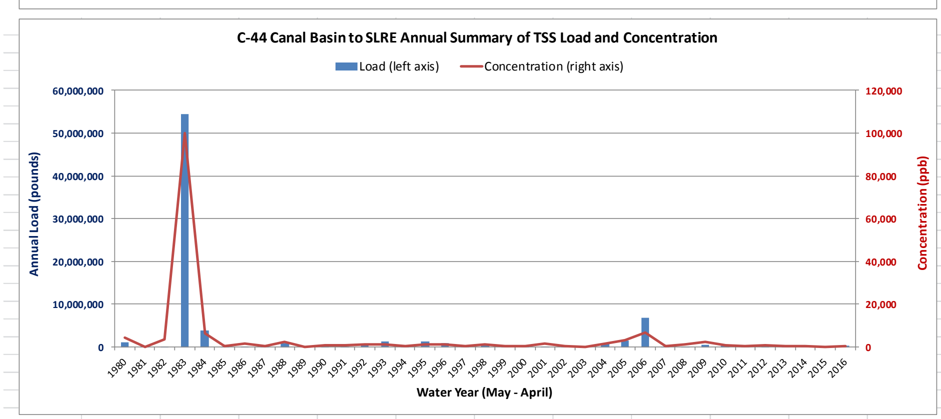
C-44 Canal Basin to SLRE

Water Year	Basin Rainfall inches	Basin Flow AF	TP Load pounds	FWM TP Conc µg/L	TN Load pounds	FWM TN Conc µg/L	TSS Load pounds	FWM TSS Conc µg/L
1980	58.25	88,221	110,390	460	308,027	1,284	1,084,507	4,521
1981	37.19	22,544	12,765	208	93,147	1,519	7,462	122
1982	51.02	6,840	2,300	124	31,367	1,686	68,167	3,665
1983	69.84	200,608	89,819	165	1,439,689	2,639	54,544,213	99,984
1984	58.74	216,422	71,877	122	906,326	1,540	3,825,464	6,500
1985	47.69	133,325	90,542	250	642,138	1,771	204,223	563
1986	46.42	8,160	2,088	94	29,354	1,323	36,958	1,666
1987	50.94	87,327	34,746	146	356,427	1,501	139,607	588
1988	45.94	139,353	52,868	140	540,107	1,425	840,369	2,218
1989	41.42	212,179	97,698	169	831,209	1,441	81,625	141
1990	45.18	40,392	22,126	201	122,023	1,111	79,862	727
1991	53.84	14,384	4,813	123	36,939	944	27,925	714
1992	41.47	156,565	64,954	153	264,779	622	544,834	1,280
1993	67.53	351,243	165,497	173	1,067,243	1,117	1,248,656	1,307
1994	56.85	18,263	5,381	108	47,491	956	26,745	539
1995	66.40	342,851	149,923	161	1,140,226	1,223	1,277,421	1,370
1996	69.99	307,565	173,363	207	2,283,833	2,731	938,733	1,122
1997	47.11	97,077	33,732	128	482,734	1,829	90,431	343
1998	56.93	146,824	51,375	129	349,943	876	441,924	1,107
1999	46.22	122,359	53,883	162	454,730	1,367	93,497	281
2000	60.74	176,437	116,344	242	602,790	1,256	127,842	266
2001	34.60	9,010	3,925	160	31,752	1,296	35,590	1,453
2002	57.14	32,802	16,343	183	108,481	1,216	22,222	249
2003	51.51	114,820	63,495	203	293,728	941	35,854	115
2004	45.70	213,456	176,683	304	746,505	1,286	849,225	1,463
2005	55.91	176,836	226,606	471	1,075,737	2,237	1,511,334	3,143
2006	65.64	367,369	266,947	267	2,510,611	2,513	6,864,511	6,871
2007	30.61	28,842	12,732	162	93,079	1,187	46,741	596
2008	53.60	1,991	1,214	224	7,182	1,327	6,538	1,208
2009	42.95	65,241	100,087	564	312,289	1,760	458,160	2,582
2010	55.70	92,428	61,142	243	319,323	1,270	216,226	860
2011	32.28	51,780	42,713	303	174,881	1,242	83,929	596
2012	40.94	3,652	1,181	119	9,976	1,004	8,653	871
2013	48.06	85,649	77,902	334	357,654	1,536	88,024	378
2014	54.19	256,335	233,596	335	1,154,698	1,657	338,557	486
2015	43.18	107,985	80,421	274	362,023	1,233	39,362	134
2016	46.19	188,565	141,590	276	750,977	1,465	313,516	611
WY1980-2016 Average	*50.75*	*126,641*	*78,731*	*229*	*549,714*	*1,596*	*2,071,592*	*6,015*
WY1996-2005 Average	*52.58*	*139,719*	*91,575*	*241*	*643,023*	*1,692*	*414,665*	*1,091*
WY2007-2016 Average	*56.71*	*173,357*	*81,926*	*174*	*673,071*	*1,428*	*481,801*	*1,022*
Difference	8%	24%	-11%	-28%	5%	-16%	16%	-6%


C-44 Canal Basin to SLRE Annual Summary of Flow and Rainfall
Flow (left axis)
Rainfall (right axis)
Annual Flow (acre feet)
Annual Rainfall (inches)
Water Year (May - April)


C-44 Canal Basin to SLRE Annual Summary of TP Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

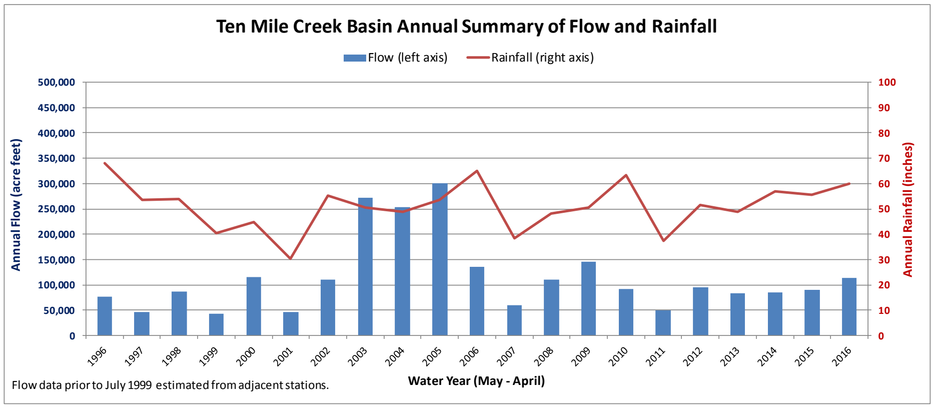

C-44 Canal Basin to SLRE Annual Summary of TN Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

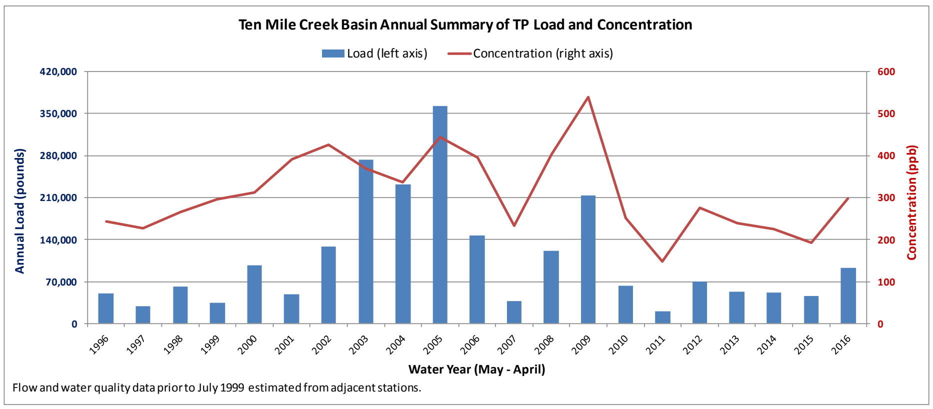

C-44 Canal Basin to SLRE Annual Summary of TSS Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)

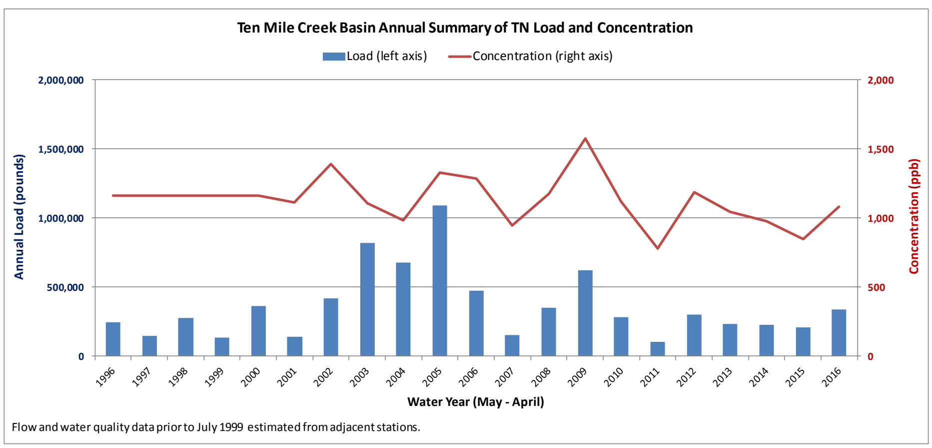
Annual Summary of Flows and Loads from the Ten Mile Creek Basin

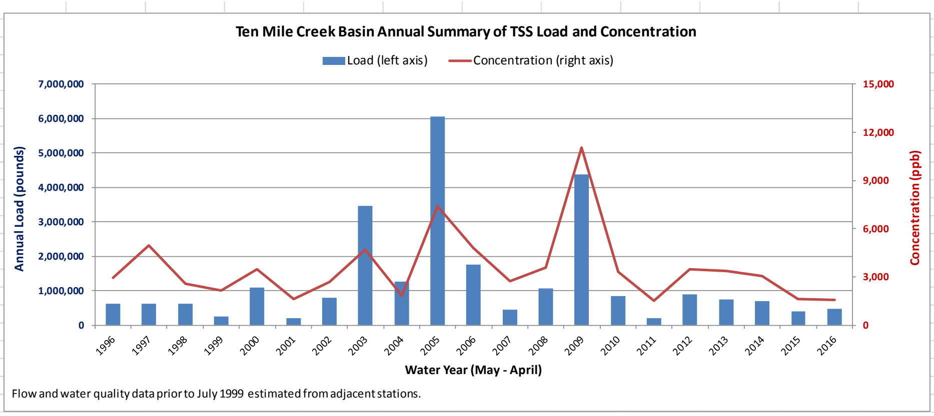
Water Year	Basin Rainfall inches	Basin Flow AF	TP Load pounds	FWM TP Conc µg/L	TN Load pounds	FWM TN Conc µg/L	TSS Load pounds	FWM TSS Conc µg/L
1996	68.09	*76,829*	*50,971*	*244*	*243,274*	*1,164*	*618,396*	*2,960*
1997	53.45	*46,572*	*28,731*	*227*	*147,466*	*1,164*	*626,181*	*4,944*
1998	54.02	*86,468*	*62,253*	*265*	*273,795*	*1,164*	*608,688*	*2,589*
1999	40.35	*42,737*	*34,361*	*296*	*135,323*	*1,164*	*251,208*	*2,162*
2000	44.68	*115,143*	*97,726*	*312*	*364,591*	*1,164*	*1,083,454*	*3,460*
2001	30.22	46,099	49,029	391	139,805	1,115	203,113	1,620
2002	55.31	110,997	128,292	425	419,349	1,389	802,333	2,658
2003	50.48	271,838	273,099	369	819,413	1,108	3,456,852	4,676
2004	48.67	253,018	231,788	337	676,280	983	1,271,027	1,847
2005	53.55	301,142	362,600	443	1,089,565	1,330	6,057,049	7,396
2006	65.01	136,353	146,349	395	475,830	1,283	1,769,843	4,773
2007	38.41	59,524	37,552	232	153,148	946	439,801	2,717
2008	48.01	110,235	120,599	402	352,551	1,176	1,071,333	3,574
2009	50.42	145,966	213,636	538	624,683	1,574	4,379,953	11,034
2010	63.14	91,964	62,820	251	280,036	1,120	831,537	3,325
2011	37.36	50,463	20,266	148	106,644	777	205,842	1,500
2012	51.55	94,488	70,616	275	304,340	1,184	893,846	3,479
2013	48.99	82,746	53,782	239	234,585	1,043	754,968	3,355
2014	57.07	85,081	51,840	224	226,043	977	704,446	3,045
2015	55.45	89,455	46,652	192	206,934	851	388,381	1,597
2016	59.84	114,436	92,414	297	337,660	1,085	483,117	1,552
WY2000-2016 Average	*50.48*	*126,997*	*121,121*	*351*	*400,674*	*1,160*	*1,458,641*	*4,224*
WY2000-2010 Average	*49.81*	*149,298*	*156,681*	*386*	*490,477*	*1,208*	*1,942,390*	*4,784*
WY2007-2016 Average	*51.71*	*86,112*	*55,928*	*239*	*236,034*	*1,008*	*571,767*	*2,442*
Difference	4%	-42%	-64%	-38%	-52%	-17%	-71%	-49%

Note: Flows and loads prior to WY2001 based on adjacent basins.


Ten Mile Creek Basin Annual Summary of Flow and Rainfall
Flow (left axis)
Rainfall (right axis)
Annual Flow (acre feet)
Annual Rainfall (inches)
Water Year (May - April)
Flow data prior to July 1999 estimated from adjacent stations.


Ten Mile Creek Basin Annual Summary of TP Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)
Flow and water quality data prior to July 1999 estimated from adjacent stations.


Ten Mile Creek Basin Annual Summary of TN Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)
Flow and water quality data prior to July 1999 estimated from adjacent stations.


Ten Mile Creek Basin Annual Summary of TSS Load and Concentration
Load (left axis)
Concentration (right axis)
Annual Load (pounds)
Concentration (ppb)
Water Year (May - April)
Flow and water quality data prior to July 1999 estimated from adjacent stations.

Annual Summary of Flows and Loads from the Tidal Basins

Water Year	Basin Rainfall inches	Basin Flow AF	TP Load pounds	FWM TP Conc µg/L	TN Load pounds	FWM TN Conc µg/L	TSS Load pounds	FWM TSS Conc µg/L
1995	64.11	209,412	67,352	118	518,854	911	2,975,949	5,226
1996	67.24	204,909	65,904	118	507,698	911	2,911,961	5,226
1997	52.99	147,561	47,460	118	365,609	911	2,096,993	5,226
1998	53.86	192,323	61,856	118	476,513	911	2,733,097	5,226
1999	39.79	139,088	44,734	118	344,616	911	1,976,583	5,226
2000	43.79	167,383	53,835	118	414,722	911	2,378,683	5,226
2001	29.84	90,793	29,201	118	224,956	911	1,290,261	5,226
2002	54.65	171,093	55,028	118	423,913	911	2,431,401	5,226
2003	50.70	93,580	32,646	128	231,861	911	943,883	3,709
2004	48.72	122,723	37,766	113	275,232	825	1,744,016	5,226
2005	53.58	142,713	45,900	118	370,230	954	2,551,184	6,574
2006	65.30	203,662	73,350	132	565,613	1,021	4,322,199	7,804
2007	38.80	76,179	18,394	89	152,766	737	710,542	3,430
2008	47.32	169,686	41,463	90	399,256	865	2,107,771	4,568
2009	50.87	142,576	37,325	96	336,771	869	2,835,350	7,313
2010	63.20	159,555	44,773	103	356,200	821	2,565,076	5,912
2011	37.70	84,663	24,535	107	196,776	855	1,414,223	6,143
2012	51.82	142,871	37,753	97	332,753	856	1,654,459	4,258
2013	48.58	118,440	26,627	83	261,484	812	1,371,547	4,258
2014	57.11	148,505	41,862	104	386,977	958	1,719,707	4,258
2015	54.05	148,971	39,664	98	320,775	792	1,725,105	4,258
2016	58.38	166,501	45,234	100	411,104	908	1,928,095	4,258
WY2003-2016 Average	*51.87*	*137,188*	*17,472*	*103*	*146,774*	*867*	*842,959*	*4,981*
WY2003-2005 Average	*51.00*	*119,672*	*17,459*	*118*	*134,496*	*911*	*771,414*	*5,226*
WY2007-2016 Average	*50.78*	*135,795*	*16,135*	*96*	*141,592*	*845*	*795,353*	*4,748*
Difference	0%	13%	-8%	-19%	5%	-7%	3%	-9%

Note: For the Tidal Basins, reliable flow data are not available, so flows were estimated based on SFWMD models (see text for additional details). Concentrations observed in WY2003-2005 were applied prior to that time.

APPENDIX 2. REGRESSION EQUATIONS FOR BASE PERIOD LOADS

C-23 Canal Basin

TP: Load = -733.81689 + 215.15898 ln(Rain) + 93.70176 ln(CV); R^2 = 92%

Adjusted rainfall = exp (ln(Rain) + 0.43550 (ln(CV) – $\ln(CV)_m$)), where C_m = -0.19000

Suspend assessment if adjusted rainfall < 38.17 or > 76.10 inches and load>Target

TN: Load = -2041.5699 + 604.07587 ln(Rain) + 140.06288 ln(CV); R^2 = 82%

Adjusted rainfall = exp (ln(Rain) + 0.23186 (ln(CV) – $\ln(CV)_m$)), where C_m = -0.19000

Suspend assessment if adjusted rainfall < 36.47 or > 70.36 inches and load>Target

C-24 Canal Basin

TP: Load = -596.54105 + 158.74237 ln(Rain) + 48.29738 S; R^2 = 75%

Adjusted rainfall = exp (ln(Rain) + 0.30425 (S – S_m)), where S_m = 0.97860

Suspend assessment if adjusted rainfall < 40.05 or > 77.05 inches and load>Target

TN: Load = -2086.47411 + 620.78797 ln(Rain); R^2 = 64%

Suspend assessment if rainfall < 37.52 or > 62.86 inches and load>Target

C-44 Canal Basin

TP: Load = exp [-4.94505 + 2.05694 ln(Rain) + 0.85864 S]; R^2 = 69%

Adjusted rainfall = exp (ln(Rain) + 0.41744 (S – S_m)), where S_m = 0.74460

Suspend assessment if adjusted rainfall < 38.17 or > 76.10 inches and load>Target

TN: Load = (-15.38273 + 0.39043 Rain + 17.68067 $CV)^2$); R^2 = 70%

Adjusted rainfall = Rain + b (CV – CV_m), where CV_m = 0.76020, b = 45.28595

Suspend assessment if adjusted rainfall < 36.29 or > 77.48 inches and load>Target

Ten Mile Creek Basin

TP: Load = exp [-3.28207 + 1.75506 ln(Rain) + 0.72294 S]; R^2 = 50%

Adjusted rainfall = exp (ln(Rain) + 0.41192 (S – S_m)), where Sm = 0.74627

Suspend assessment if adjusted rainfall < 28.08 or > 84.30 inches and load>Target

TN: Load = exp (5.1307 + 0.02915 Rain + 1.337 S + -2.73607 CV); R^2 = 68%

Adjusted rainfall = Rain + 45.87389 (S-S_m) - 93.87753 (CV – CV_m), where S_m = 0.74627, CV_m = 0.85427

Suspend assessment if adjusted rainfall < 7.36 or > 73.11 inches and load>Target

The variables used in the prediction equations are defined below:

Load = predicted base period load adjusted for hydrologic variability, in metric tons

(1 metric ton = 2,204.6 pounds)

Rain = 12-month total rainfall for the evaluation year (inches)

$Rain_m$ = average value of annual rainfall in the base period (inches)

CV = coefficient of variation calculated from 12 monthly rainfall totals

CV_m = average value of the rainfall coefficient of variation in the base period

S = skewness calculated from the 12 monthly rainfall totals

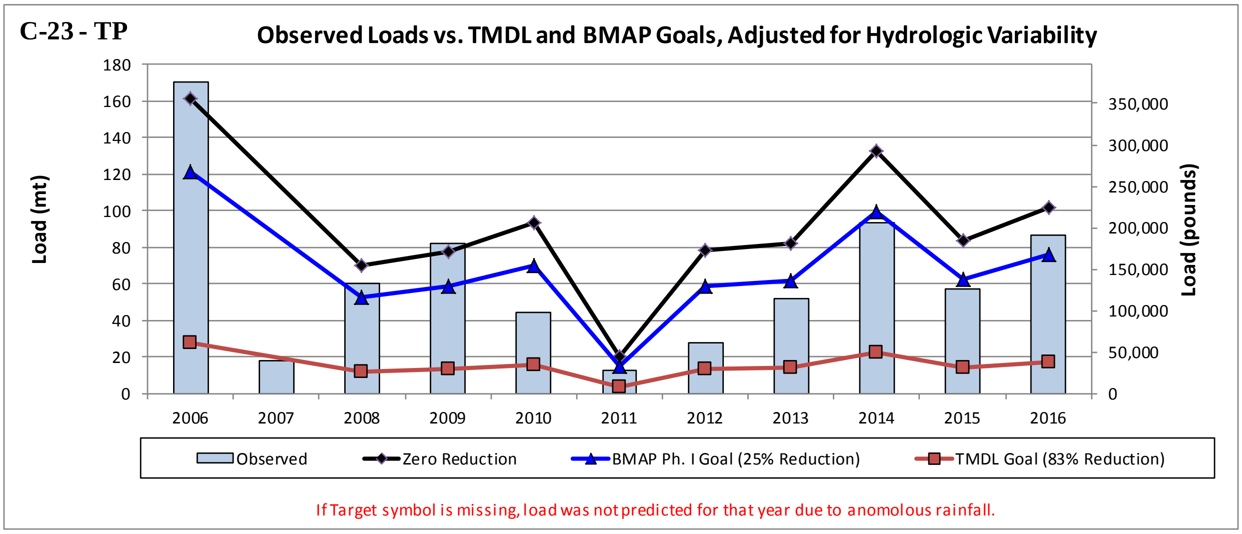
S_m = the average value of the rainfall skewness in the base period

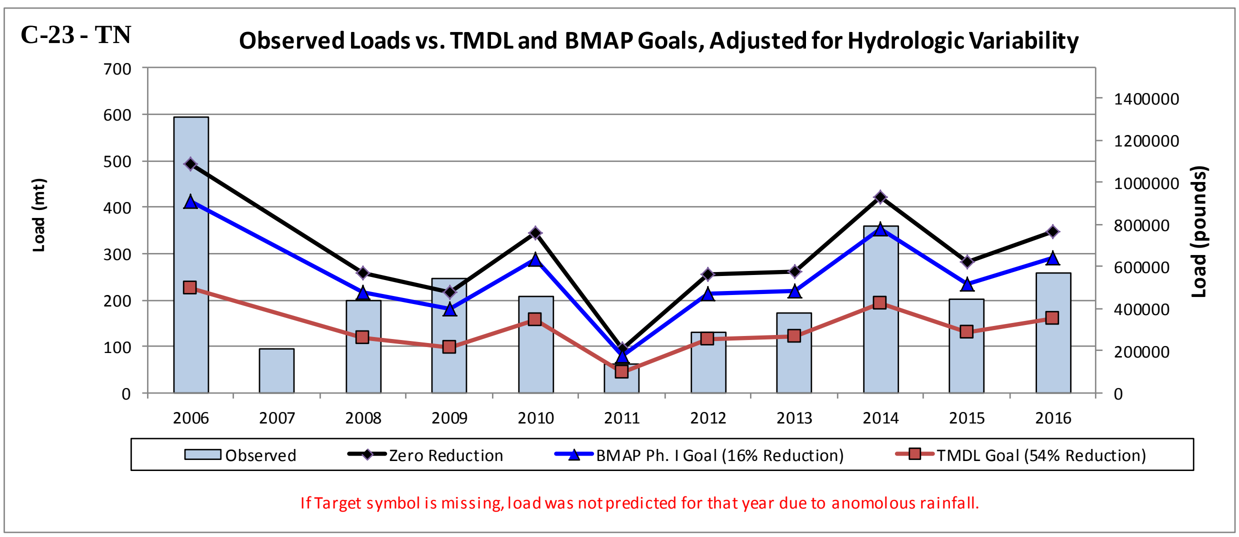
Ln(variable) = natural logarithm of variable

R^2 = Explained variance

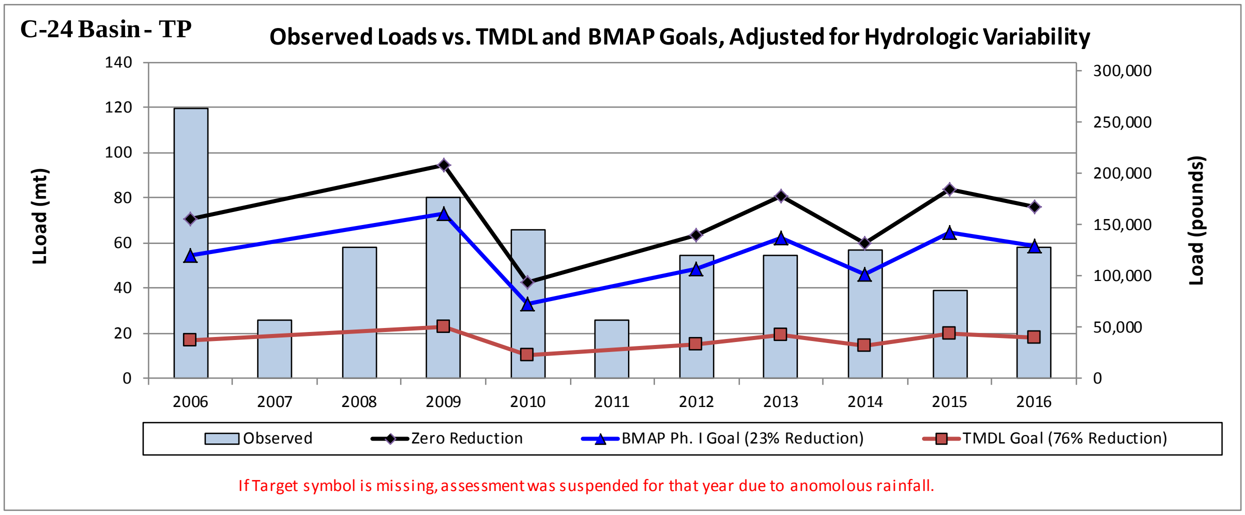
APPENDIX 3. WATER QUALITY COMPARISONS TO BMAP AND TMDL TARGETS

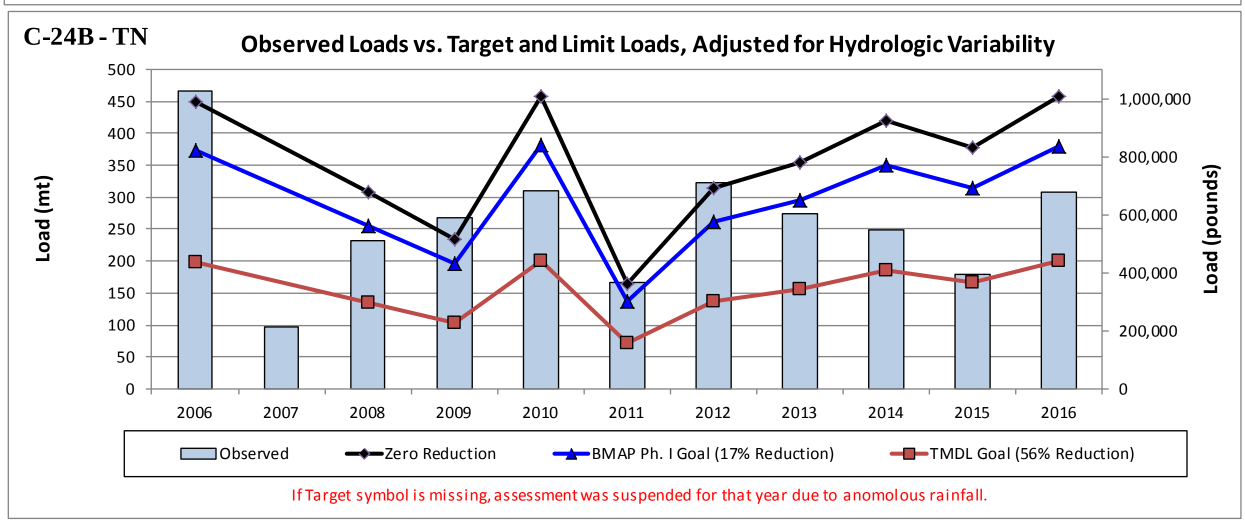
Comparison of annual loads to base period load (zero reduction), alternative TMDL and BMAP Goals: C-23 Canal Basin.



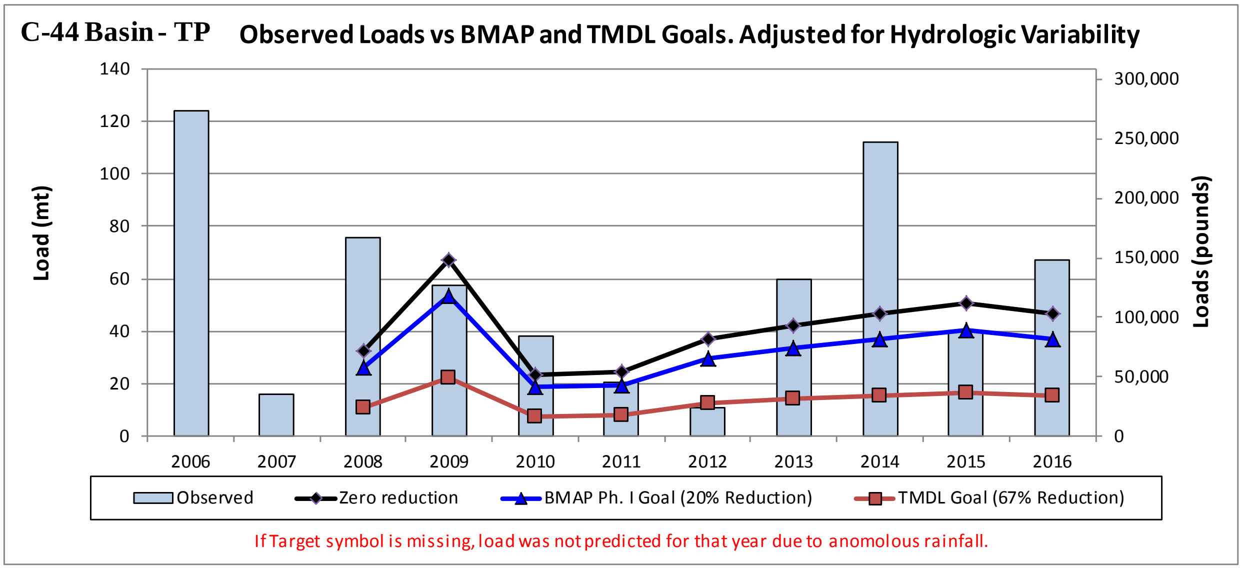


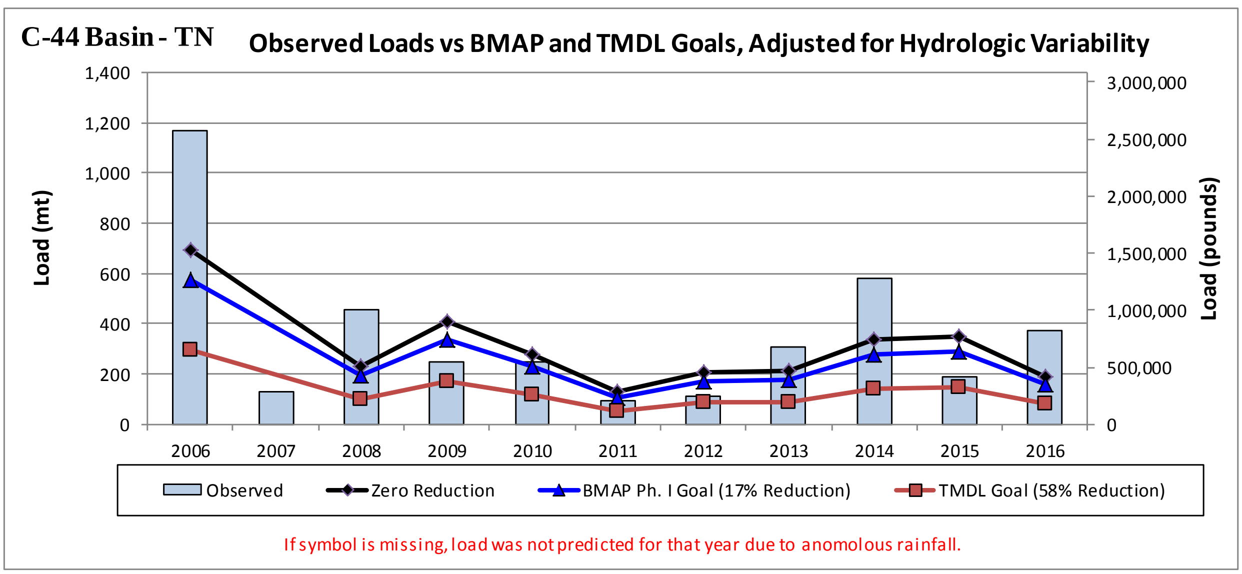
Comparison of annual loads to base period load (zero reduction), alternative TMDL and BMAP Goals: C-24 Canal Basin.



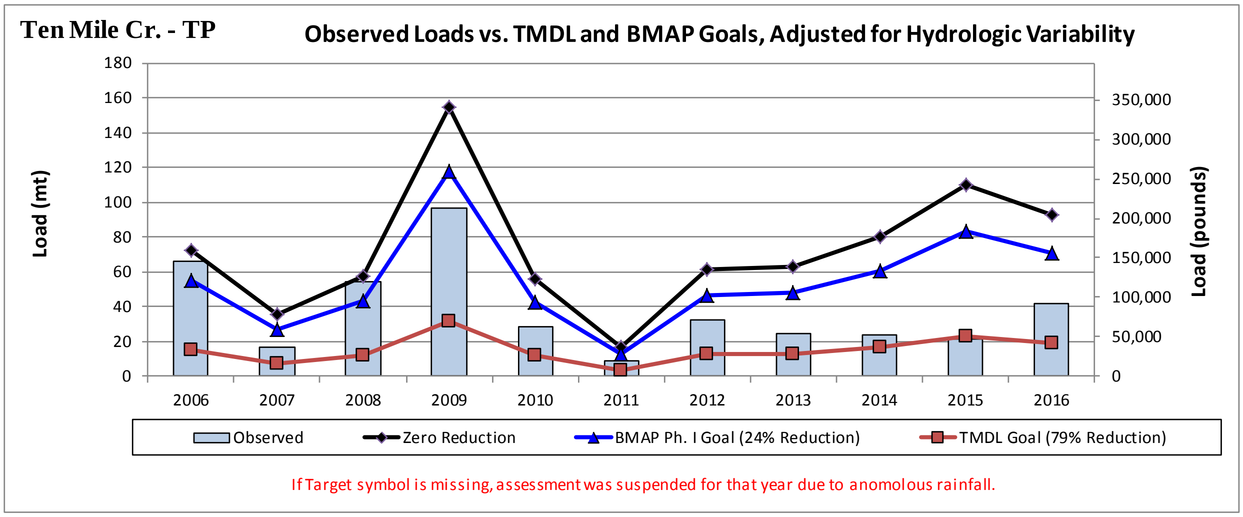


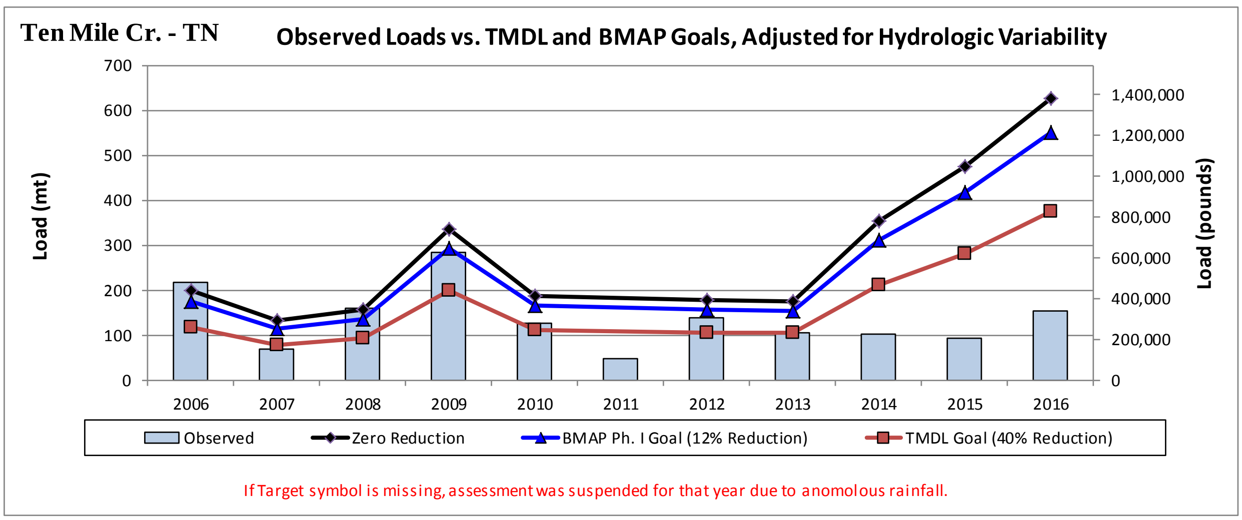
Comparison of annual loads to base period load (zero reduction), alternative TMDL and BMAP Goals: C-44 Canal Basin.



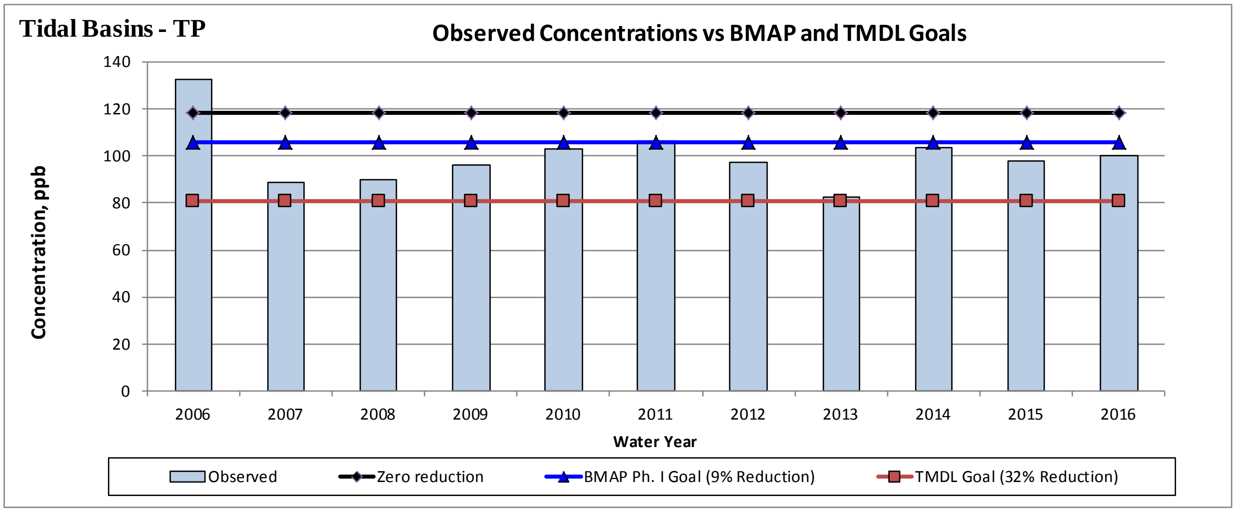


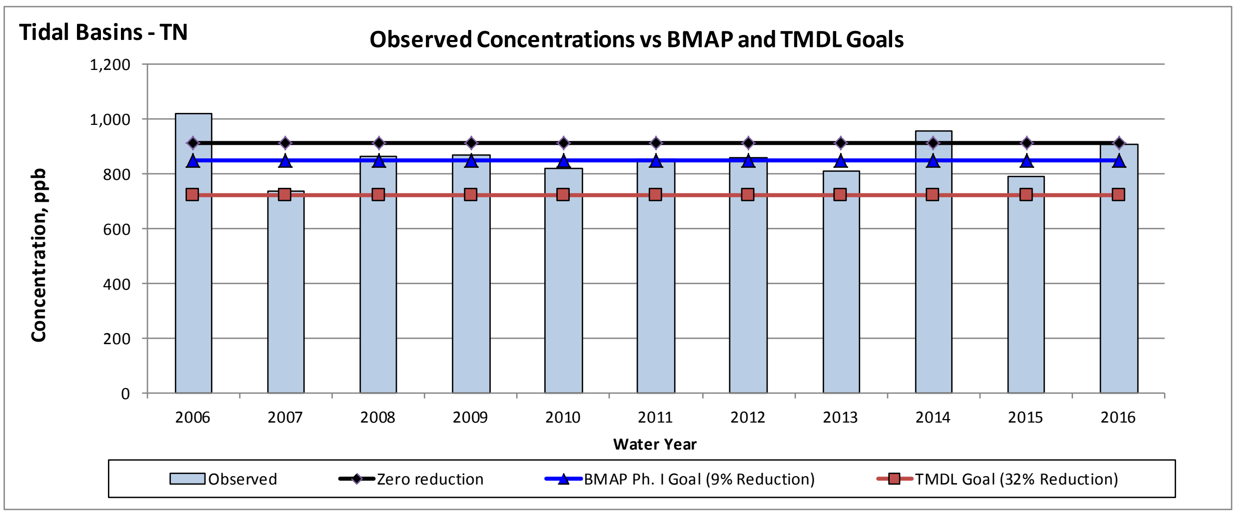
Comparison of annual loads to base period load (zero reduction), alternative TMDL and BMAP Goals: Ten Mile Creek Basin.





Comparison of annual loads to base period load (zero reduction), alternative TMDL and BMAP Goals: Tidal Basins.





Comparison of annual loads to base period load (zero reduction), alternative TMDL and BMAP Goals: Lake Okeechobee Discharges.