

East Beach Water Control District Data Summary and Evaluation

PREPARED FOR: South Florida Water Management District (SFWMD)
COPY TO: File
PREPARED BY: CH2M HILL Engineers, Inc. (CH2M)
DATE: November 8, 2016
DISTRICT CONTRACT: 4600003014
DELIVERABLE: 3.3 Final Technical Memorandum
CH2M PROJECT NUMBER: 666937

1.0 Introduction and Background

1.1 Introduction

CH2M is under contract with the SFWMD to deliver professional services associated with Everglades Restoration Strategy Contract No: 4600003014 entitled "SFWMD Data and Documentation Summary for the Eastern Flow Path Water Quality". The 2012 Restoration Strategies document defines the Eastern Flow Path as the area comprised by the S5A Sub-basin, the East Beach Water Control District (EBWCD) and the C-51 West basin.

The goal of this contract is to consolidate historic information and water quality data in the S5A Sub-basin and the EBWCD into a report that facilitates development of sub-regional source control projects to reduce phosphorus discharges in runoff from these basins. Specific tasks of this contract are:

- Task 2: Summarize existing information on historic activities and assessments of water quality data related to tracking phosphorus trends in discharges from the S-5A Sub-basin and the EBWCD.
- Task 3: Evaluate water quality and flow associated with the recent canal cleaning project effort in the EBWCD. This report is the final deliverable (Deliverable 3.3) associated with this task.
- Task 4: Evaluate water quality and flow data collected along the West Palm Beach Canal (WPB Canal) for characterizing phosphorus forms and transport mechanisms.

Pursuant to the scope of work, Deliverable 3.3 shall summarize and evaluate available water quality and flow within and from EBWCD related to trends and recent canal cleaning project efforts. The summary shall characterize concentration data, including trends for total phosphorus (TP) and other available phosphorus species for the entire period of record and by water year (WY)¹, wet and dry season², pre- and post-diversion project, pre- and post-canal cleaning project; discharge conditions; and operation of internal structures.

¹ Water year is the period from May 1 of one year to April 30 of the next year.

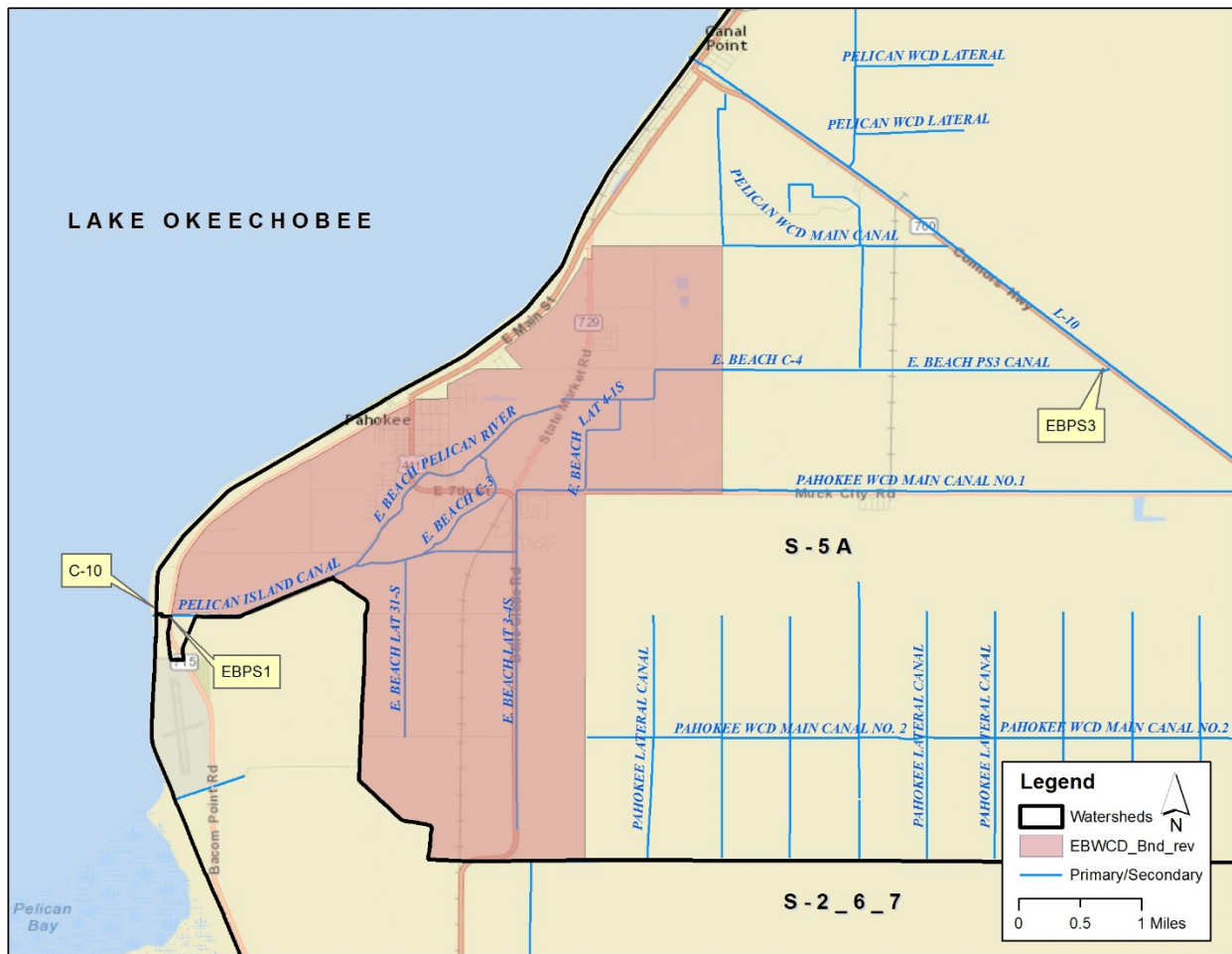
² Wet season is the period from May 1 to October 31 of each year, and dry season is the period from November 1 to April 30 of the next year.

1.2 Background

The EBWCD is a public entity established in 1945 pursuant to Chapter 298 of the Florida Statutes and is located along the southeast side of Lake Okeechobee. EBWCD discharges into the S-5A Sub-basin (See **Figures 1a and 1b**) of the Everglades Agricultural Area (EAA), which is located east of Lake Okeechobee (Lake) and south of the L-8 Canal. Discharges from EBWCD and the S-5A Sub-basin drain primarily through the West Palm Beach Canal to the Stormwater Treatment Area 1 West (STA-1W)/STA-1E complex. Prior to 2001, the EBWCD primarily discharged to Lake Okeechobee, however, diversion projects were implemented in response to legislative mandates aimed at improving water quality.



Figure 1a: S-5A Sub-basin Location Map



Source: Figure 1. S-5A Sub-basin and EBWCD Location Map, excerpt from SFWMD, 2015.

Figure 1b: EBWCD Canals and Structures

In 1987, the Florida Legislature passed the Surface Water Improvement and Management (SWIM) Act creating the first Everglades cleanup plan and serving as the state’s basis for Everglades restoration. In March of 1992, SFWMD proposed a SWIM Plan, which was challenged by stakeholders. The Technical Mediation Group was formed to address the issues under contention culminating in a technical plan with mutually acceptable approaches for amending the original SFWMD SWIM Plan. These activities defined the Everglades Construction Project (ECP) and consisted of the construction of Stormwater Treatment Areas (STAs) and Best Management Practices (BMPs) implementation in the EAA. Subsequently, Chapter 40E-63, Florida Administrative Code (F.A.C.) was adopted in 1992 requiring implementation of BMPs to achieve a 25 percent reduction in total phosphorus (TP) load in EAA runoff.

In February 1994, the *Conceptual Design for the Everglades Protection Project* was completed by Burns & McDonnell based on the technical plan agreed to through the Technical Mediation Group. This was followed by the Everglades Forever Act (EFA), which was signed into law in May of that same year, setting into action the restoration plan. The EFA established that the SFWMD shall operate the Everglades Construction Project, as specified in the February 15, 1994 Conceptual design Document. The Conceptual Design discussed the water quality datasets and assumptions for the initial design for the six STAs being proposed, and estimated preliminary capital, and operation and maintenance costs.

Among the restoration initiatives encompassed by the EFA and described in the Conceptual Design Document was the diversion of historic inflows into the Lake from the EBWCD, South Shore Drainage District, South Florida Conservancy District, East Shore Water Control District and the lessee of agricultural lease number 3420 (Closter Farms) towards STAs. The EFA noted that these areas were an important part

of Everglades Restoration, and therefore must participate in the system modifications specified by the ECP.

The water control districts and Closter Farms entered into a Consent Agreement with FDEP. The Consent Agreement allowed the EBWCD to continue discharges into the Lake if the operating conditions required by the agreement were followed. The operational conditions included specifications such as diversion plans, pumping BMPs, farming BMPs, water quantity and quality monitoring and reporting requirements, pump basin maintenance, canal maintenance, canal right-of-way litter prevention, canal weed control, annual reports, and access allowances. Additional guidelines regarding pumping practices for TP reduction were included in the Consent Agreement's exhibits.

The Consent Agreement authorized FDEP to "implement the provisions of the Everglades Forever Act, Chapter 94-115, Laws of Florida" and stated that it "constitutes final agency action in the 298 Districts' and Closter Farm's application for permit" (FDEP, 1994). Also, consistent with the EFA mandate, the SFWMD entered into an agreement with EBWCD on September 16, 1996, for the creation, funding, and implementation of the Diversion Project.

The EBWCD diversion structure into the EAA and associated improvements were completed in July 2001. Before July 2001, an approximate 1,280-acre portion of the east EBWCD was the only portion discharging to the WPB Canal through a 97-cubic-foot-per-second (cfs) pump (East Beach #3 [EB#3]) in combination with a booster pump (EB#2) of similar capacity (97 cfs) located 2.8 miles west of EB#3. The remaining EBWCD area discharged only to the Lake through a 334-cfs pump station known as EB#1 (i.e., C-10 or EBPS1). The diversion project completed in July 2001 included the replacement of EB#3 with a new 338-cfs pump station (151,700 gallons per minute [gpm]), known as EBPS or EBPS3; removal of the booster pump EB#2; and improvement to the conveyance system (canals, culverts, and two control structures separating east and west portions) upstream of EBPS3. The November 15, 2001, Environmental Resource Permit (ERP) (No. 50-05179-P) describes the pumping conditions at EBPS3 and EB#1, and the opening and closing elevations for the two internal control structures. Additionally, the District incorporated the lands previously discharging to the Lake into the source controls Everglades Works of the District (EWOD) permit No. 50-00033-E (Application 000428-2 approved December 31, 2001). The permit required the implementation of Best Management Practices and a discharge monitoring plan in accordance with Chapter 40E-63, F.A.C., requirements (SFWMD, 2001b):

"Chapter 40E-61, F.A.C., (hereinafter referred to as "Rule 40E-61"), establishes a Works of the District Best Management Practice (BMP) permitting program for the Lake Okeechobee Drainage Basin which is specifically designed to reduce phosphorus loads to the Lake. Similarly, Chapter 40E-63, F.A.C. (hereinafter referred to as "Rule 40E-63"), establishes a Works of the District BMP permitting program for the Everglades Agricultural Area (EAA). The Rule 40E-61 land added to this permit previously only discharged to the Lake through existing structure C-10 (aka EB#1). Structure C-10 has an authorized discharge capacity of 150,000 GPM. Under the Surface Water Operating permit (a SWM construction permit was not required), the included 40E-61 lands will also discharge to EAA structure WP16.8TS (aka EBPS3), and thus the reasons for the modification of this EAA permit. Because the land included in this permit will have the ability to discharge into both Lake Okeechobee and the EAA, it must be permitted under both BMP programs, that is in accordance with 40E-61 existing permit number 50-00001-E (EAA EPD Management Plan Master permit) for structure C-10 discharges, and according to the Rule 40E-63 program under this permit (50-00033-E) for discharges through structure WP16.8TS."

For more than 35 years there has been monitoring of water quality parameters occurring in the EBWCD. EBWCD is within the Eastern Flow Path referred to in the April 27, 2012, Restoration Strategies Regional Water Quality Plan. Because of its relatively higher phosphorus levels and its potential impacts to STA1W, EBWCD has historically been the focus of several investigative activities to evaluate other potential phosphorus sources (CH2M, 2016). The following sub-sections provide a comprehensive assessment of EBWCD water quality data up to the most recently collected data associated with canal cleaning efforts.

A chronology of events that need to be considered when reviewing water quality data for EBWCD is presented in Table 1.

Table 1
Chronology of Activities

Year	Activities
1979	Water quality (TP) and flow monitoring is initiated at structure C-10 into Lake Okeechobee
March 1990	The City of Pahokee started operation of an injection well eliminating surface water discharges from its municipal wastewater plant (EAAEPD, 2016).
1992	<p>Chapter 40E-61, F.A.C., Lake Okeechobee Management Plan Master Permit 50-00001-Q is issued encompassing EBWCD as well as other basins south of Lake Okeechobee. Specific requirements for the areas within EBWCD included implementation of pumping BMPs and the elimination of surface water discharges from the City of Pahokee municipal wastewater plant.</p> <p>This permit included the entire EBWCD area (6,020.46 acres), however, its focus was on reducing TP discharges to Lake Okeechobee which occurred through pump C-10. C-10 served approximately 80% of the EBWCD acreage.</p>
1992	<p>Chapter 40E-63, F.A.C., EWOD Permit 50-00033-E is issued establishing verification of implementation and water quality effectiveness of Water Management (1-inch detention), four particulate matter and sediment control BMPs, nutrient management BMPs for agricultural areas, and implementation of requirements of NPDES permit FLS000018 for non-agricultural areas.</p> <p>This permit includes the portion of the EBWCD area (1,280 acres) discharging to the EAA West Palm Beach Canal (Basin Id 50-033-01) and initiates TP and flow monitoring at structure EB#3 (aka WP16.8TS). EB#3 served approximately 20% of the EBWCD.</p>
1994	<p>A Consent Agreement with FDEP is executed for continued discharges to the Lake and refers to the Pumping BMPs approved under Lake Okeechobee WOD permit 50-00001-Q and adds farming BMPs, pump basin and canal maintenance, canal right-of-way litter prevention, and canal weed control activities.</p> <p>Encompasses the entire EBWCD area (6,020.46 acres) with focus on discharges to Lake Okeechobee.</p>
1995 - 2000	<p>Land use intensification was reported according to the District's Florida Land Use and Cover Classification System (FLUCCS) datasets:</p> <ul style="list-style-type: none"> Some sugarcane fields were converted to "truck crops³" in 1995, and to tree nurseries in 1999. The net increase of truck crops from 1988 to 1995 is 126 acres and the net increase of tree nurseries from 1995 to 1999 is 521 acres. Truck crops and nurseries are expected to have more phosphorus nutrients and water table management needs than sugarcane. Some agricultural areas within the City of Pahokee were converted to urban areas. Urban areas are expected to have larger impervious areas and need more water table management needs than agricultural areas. Over the period of 1988 through 2008, the urban area increased by 122 acres.

³ Truck crops include, but are not limited to, lettuce, celery, and radishes.

Year	Activities
2000	In the spring of 2000, a break and repair of the subaqueous sewer force main near the wastewater plant and crossing the Pelican River, which is part of the EBWCD canal system, was reported. See Figures 1 and 4 for general location.
2001	<p>EWOD Permit 50-00033-E is modified by expanding implementation of BMPs to the entire EBWCD area (6,020.46 acres).</p> <p>Pump EB#3 is replaced with new pump EBPS3 (or EBPS). The outfall canal is enlarged/widened to accommodate increased flow rates (pump station and canal are shown in Figures 2 and 3). EBPS3 is at the downstream end of the outfall canal. The lands adjacent to the outfall canal (Basin IDs 50-015-02 and 50-002-01) do not discharge to the canal. TP and flow monitoring at structure EBPS3 is initiated and reported under as water quality station name WP16.8TS. EBPS3 serves approximately 100% of the EBWCD except for incidental discharges to the Lake via pump EB#1 to culvert C-10.</p> <p>ERP No. 50-05179-P is issued indicating the pumping conditions at EBPS3 and EB#1, and the opening and closing elevations for the two internal control structures to divert at least 80% of the long-term average annual volume historically discharged to Lake Okeechobee.</p>
2001 - 2005	Review of TP data to determine potential effects of the U.S. Sugar Corp. Bryant Mill (Nearhoof, 2006, personal communication). FDEP concluded no significant influences (CH2M, 2016). The mill closed in 2007.
2005 - 2006	Florida Rural Water Association (FRWA) and FDEP conducted dye test to determine leaks from the City of Pahokee collection/transmission system in December 2005 (FDEP, 2006). No leaks were identified.
2005 - 2009	FDEP review of Palm Beach County inventory of waste sites in EBWCD identifies two closed landfills near Bryant Mill: City of Pahokee Incinerator and Ash Landfill, and the Palm Beach County LF#4 (Pahokee Landfill). Based on review of landfill descriptions combined with available water quality data it was concluded that these sites are potential sources of phosphorus for investigation (Nearhoof, 2009, personal communication).
2013 - current	SFWMD cost-shares implementation of a sub-regional canal cleaning demonstration project in partnership with EBWCD.



Figure 2: EBWCD EBPS3 Pump Station**Figure 3: EBWCD Outfall Canal**

2.0 Water Quality Monitoring Data Inventory

Water quality in discharges from EBWCD to Lake Okeechobee has been monitored since May 1979, and flows have been monitored since March 1972. Additionally, water quality and flow in discharges from EBWCD to the EAA started in 1993 at structure EB#3 to the West Palm Beach Canal. Monitoring at EB#3 was required as part of the EWOD permit issued pursuant to Chapter 40E-63, F.A.C., requiring monitoring of TP concentration and flow volume in offsite discharges.

In 2001, upon completion of diversion structure EBPS3 and replacement of EB#3, EWOD permit water quality monitoring requirements shifted to EBPS3. However, a discharge monitoring agreement was executed between EBWCD and the SFWMD by which the SFWMD would conduct water quality and flow monitoring at EBPS3 and provide these data to EBWCD (SFWMD, 2001). This is because EBPS3 became an inflow point to the EAA, which the SFWMD is required to monitor for EAA Basin compliance determination with Chapter 40E-63, F.A.C., requirements. Under the EBWCD EWOD, the terms EB#3 and EBPS3 may be used interchangeably, however, there are differences between the acreage and water management systems that each structure represents: EB#3 represented approximately 20% of the current EBWCD acreage until 2001 while EBPS3 represented the entire acreage starting in 2001.

Additionally, synoptic upstream surface water monitoring efforts have been conducted within the EBWCD to address potential phosphorus sources in coordination with FDEP (15 locations monitored in 2007 and 2009), and to evaluate the water quality benefits of a comprehensive canal management program in partnership with the EBWCD (eight locations monitored from 2013 to 2015). The monitoring locations and adjacent land uses are shown in **Figure 4**. Data collected during 2007 and 2009 have been presented in previous documents (Florida Atlantic University, 2008; SFWMD, 2009a; and CH2M 2016).

Tables 1 and **2** summarize current station names, sample parameters, and period of record for the discharge site and upstream monitoring sites. **Table 3** summarizes similar information pertaining to the synoptic upstream surface water monitoring.

Table 2. Summary of EBWCD Monitoring Stations

Station Name	Parameters	Period of Record in DBHYDRO or RegDB	Comment
CULV10 (C-10; EB#1)	TP	5/15/1979 – Current	Currently collected via grabs during off-site discharge and composited for no more than 21 days.
	Flow	3/1/1972 – Current	
EB#3 (WP16.8TS)	TP	1/2/1993 – 7/27/2001	Currently collected using a 21-day automatic sampler. Data are archived in EWOD regulatory database (RegDB). Represents historic areas discharging to the EAA prior to the diversion project.
	Flow	1/2/1993 – 6/30/2001	Data archived in RegDB
EBPS3 (WP16.8TS; EBPS3; EBEACH)	TP	7/25/2001 – Current	7-day automatic sampler. Represents the entire EBWCD areas: those historically discharging to Lake Okeechobee and those discharging to the EAA.
		2/13/2002 – Current	Weekly grab
	OPO4	10/23/2014 – Current	Biweekly grab, if flowing and monthly if not flowing.
	Flow	7/1/2001 – Current	
EASTBEACH_R	Rainfall	5/31/80 - Current	

Source: Start dates are based on Table 1. Summary of EBWCD monitoring stations for WY 1980 through WY 2014, excerpt from SFWMD, 2015.

Notes: OPO4= Ortho-Phosphate

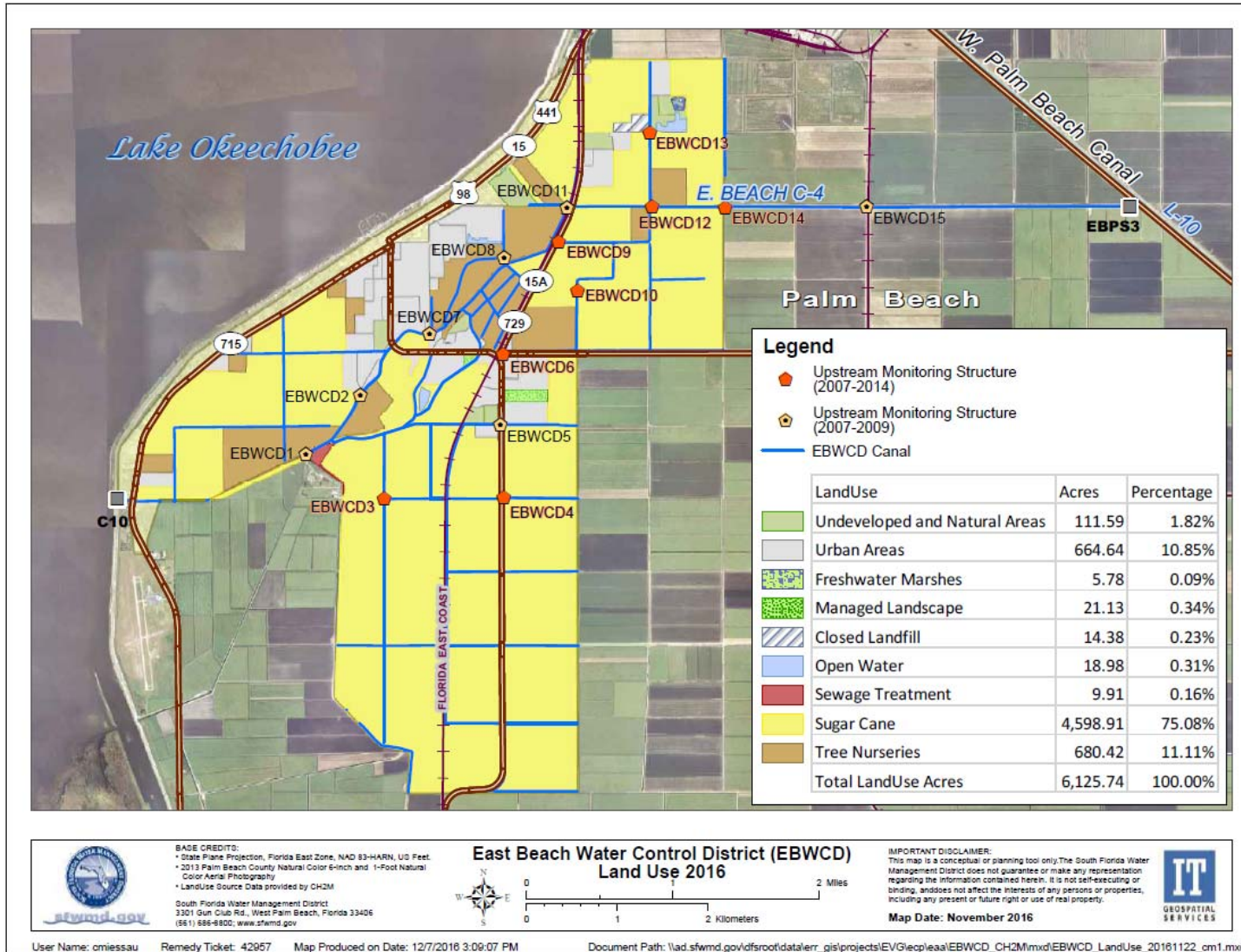


Figure 4. Upstream Monitoring Locations and Land Uses

Table 3a. Summary of SFWMD EBWCD Upstream Monitoring Data¹ for 2007, 2009, 2013, and 2014.
SFWMD Data and Documentation Summary for the Eastern Flow Path Water Quality

Station Name	Parameters	Period of Record in DBHYDRO	Comment
EBWCD1, EBWCD2, EBWCD3, EBWCD4, EBWCD5, EBWCD6, EBWCD7, EBWCD8, EBWCD9, EBWCD10, EBWCD11, EBWCD12, EBWCD13, EBWCD14, EBWCD15	TP, OPO4, TDP, NOX, NH4, SO4, TURB, TEMP, DO, COND, PH	1/18/2007 – 9/27/2007	Grab
EBWCD1, EBWCD2, EBWCD3, EBWCD4, EBWCD5, EBWCD6, EBWCD7, EBWCD8, EBWCD9, EBWCD10, EBWCD11, EBWCD12, EBWCD13 ² , EBWCD14, EBWCD15	TP, OPO4, TDP, NOX, NO3, NH4, SO4, TURB, TEMP, DO, COND, PH	1/8/2009 – 9/28/2009	Grab
EBWCD3, EBWCD4, EBWCD6, EBWCD9, EBWCD10, EBWCD12, EBWCD13, EBWCD14	TP, OPO4, TDP, NOX, NH4, TKN	5/6/2013 – 11/30/2015	Grab

¹Data provided under the Statement of Work, (SFWMD, 2015), however this dataset ended on 12/1/2014. Additional water quality data was collected from 12/2/2014 to 11/30/2015 and included in this report.

²A one-time sampling event occurred on January 10, 2009 at Station EBWCD13 for the following parameters: Na, K, Ca, Mg, Hardness, Total Cr, NO3, Total Cu, and Total As.

Notes:

TDP= Total Dissolved Phosphorus
 OPO4= Orthophosphate
 NOX= Nitrate+Nitrite Nitrogen
 SO4= Sulfate
 TURB= Turbidity
 TEMP= Temperature
 DO= Dissolved Oxygen
 COND= Conductivity
 PH= Measure of the hydrogen ion concentration of a solution
 NO3= Nitrate
 TKN= Total Kjeldahl Nitrogen

Table 3b. Summary of SFWMD EBWCD Upstream Monitoring Stations for 2007, 2009, 2013, and 2014.

Site Name	Location	Latitude	Longitude
EBWCD1	East Beach Canal #1 at bridge near entrance to Pahokee WWTP	26 48' 10.052"	80 40' 30.141"
EBWCD2	Canal at wooden bridge on SE side of McClure Road	26 48' 31.189"	80 40' 08.427"
EBWCD3	Culvert 0.8 miles west of US441 on Section 20 Road	26 47' 54.316"	80 39' 58.977"

Site Name	Location	Latitude	Longitude
EBWCD4	Culvert 1 mile south of State Market Road on US441	26 47' 54.584"	80 39' 11.382"
EBWCD5	Culvert 0.5 miles south of State Market Road on US441	26 48' 20.782"	80 39' 12.598"
EBWCD6	Culvert at intersection of Muck City Road and State Market Road	26 48' 45.653"	80 39' 11.487"
EBWCD7	Culvert on S Barfield Hwy 700' north of E 7th Street	26 48' 53.263"	80 39' 40.860"
EBWCD8	Culvert with riser boards on Lime Avenue, 0.35 miles south of Larrimore Road, on Oasis Tree Farm	26 49' 20.055"	80 39' 11.044"
EBWCD9	Screw gate culvert on east side of N State Market Road, 0.25 miles south of Larrimore Road	26 49' 25.710"	80 38' 49.310"
EBWCD10	Double screw gate culvert 0.5 miles north of Muck City Road, on Oasis Tree Farm	26 49' 08.512"	80 38' 41.787"
EBWCD11	Canal 200' WSW of intersection of N State Market Road and Larrimore Road	26 49' 38.100"	80 38' 45.800"
EBWCD12	Culvert 0.5 miles east of intersection of N State Market Road and Larrimore Road	26 49' 38.353"	80 38' 12.058"
EBWCD13	Canal 0.5 north of EBWCD12	26 50' 04.789"	80 38' 12.758"
EBWCD14	Canal 1 mile east of intersection of N State Market Road and Larrimore Road	26 49' 37.758"	80 37' 42.919"
EBWCD15	Culvert 2 miles east of intersection of N State Market Road and Larrimore Road	26 49' 37.981"	80 36' 46.567"

Source: Florida Atlantic University 2008

3.0 East Beach Water Control District Canal Cleaning

The Restoration Strategies Regional Water Quality Plan (SFWMD, 2012) provides funding for subregional source control projects that are intended to reduce phosphorus loads in flows entering STA-1E and STA-1W. In 2013, a sub-regional voluntary demonstration project to evaluate the water quality benefits of a comprehensive canal management program (SFWMD, 2013a) was conducted in partnership with the EBWCD.

The SFWMD provided funds toward the purchase of a long-arm backhoe, and water quality collection, analysis, and validation at representative locations within the EBWCD before, during, and after the canal cleaning effort. EBWCD provided the remaining funds for the backhoe as well as fuel, operation field personnel, and consulting services for progress reporting. Quarterly reports have been submitted to the SFWMD by MacVicar Consulting, Inc., on behalf of the EBWCD. Quarterly reports include a pre- and post-survey of the canal bottom sediment depths from the cleaned canal sections, and quarterly photographs of FAV, estimated percent coverage of FAV, and progress maps (MacVicar Consulting, Inc., 2013a-b, 2014a-e, 2015a-b). In order to evaluate the effect of canal cleaning activities on water quality the chronology of canal segments cleaned, as documented in the progress reports, was reviewed and summarized in **Figure 5 and Table 4**. During a subset of months from August, 2013 to January, 2015, approximately 17.8 miles of canal were cleaned of sediments and/or FAV vegetation, which is approximately 60 percent of EBWCD canals.

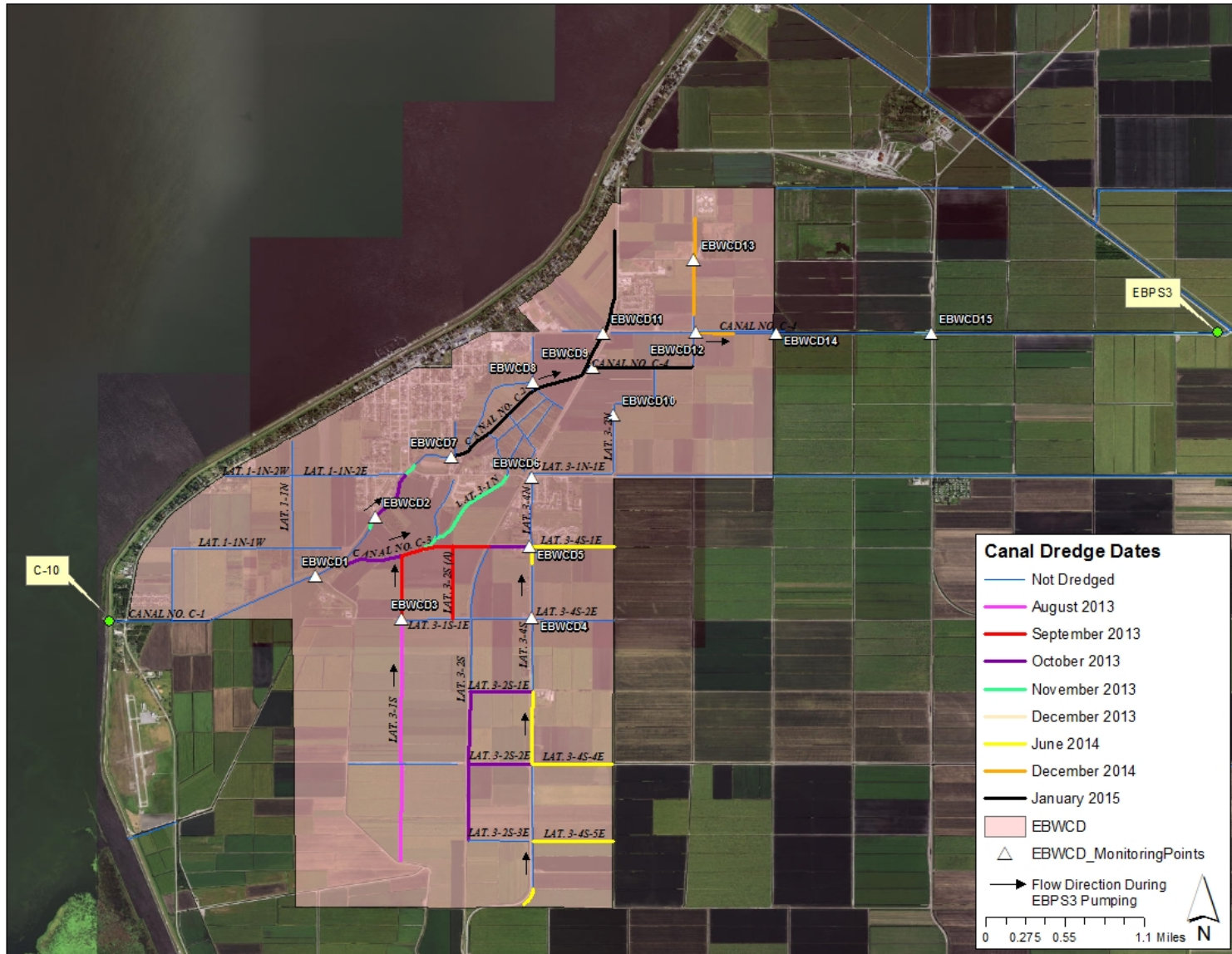


Figure 5: Canal Dredging Dates

4.0 Water Quality Analysis

The purpose of this water quality analysis is to summarize and evaluate available water quality and flow within and from EBWCD related to trends and the subregional canal cleaning project. Specific analyses include characterizing concentration data, including trends for TP and other available phosphorus species for the entire period of record and by water year, wet and dry season, pre- and post-diversion project, pre- and post-canal cleaning project; discharge conditions; and operation of internal structures. Three approaches were taken based on the available information:

- 1) A temporal assessment was performed by examining a) the long-term discharges at the EBWCD boundaries pre- and post-diversion project (macro-assessment) and b) the synoptic water quality monitoring data during and after the canal cleaning project (micro-assessment),
- 2) A statistical analysis was performed providing descriptive statistics for the 15 stations for which synoptic monitoring was conducted in 2007 – 2009 and 2013 – 2015, and
- 3) A spatial assessment was performed illustrating average TP, TDP, and total particulate phosphorus (TPP) levels for the eight stations for which synoptic monitoring was conducted in 2013 – 2015.

Water quality data for EWOD permitted basins, such as EBWCD, are reviewed with permittees during Best Management Practice verification visits and reported annually in the South Florida Environmental Report. However, this reports integrates and summarizes data previously presented.

4.1.1 Macro Assessment

This evaluation uses SFWMD data compiled from the DBHydro database, permits and algorithms developed by the District to estimate daily TP load based on monitored TP concentration and flow data. These algorithms are built into the District's Load Program. The Load Program used mode 2 which selects autosampler-measured data first, and if missing, selects grab samples collected on days with flow. The daily concentrations are interpolated between the selected measured data.

Figures 6a to 6c present EBWCD TP concentrations, flow volume, TP load per WY. Five-year rolling averages were produced to reduce the year-to-year hydrologic variations. Discharges from EBWCD include structures C-10 and EB#3 for the period WY1993-2001, and structures C-10 and EBPS3 from 2001 to date. Since EB#3 was not monitored for TP and flow volume prior to WY1993, flow volume and TP concentration were estimated for the period WY1980-1992. Flow volume was estimated based on the portion of EB#3 flow volume out of EBWCD for WY1993-2001 (27 percent). The TP concentrations at EB#3 were based on concentrations measured at C-10 for the period WY1980-1992. WY rainfall are presented in **Table 7** and is based on station EastBeach_R (DBKEY 05962). Pre- and post-diversion project data (i.e., WY1985-2000 and WY2001-2016) are presented in **Figures 8a to Figure 8b**.

Regarding long-term trends, the 5-year rolling average of TP concentration increased until WY2002, decreased until 2007 and rolled back up until 2010. Since 2010 the five-year TP concentration rolling average is within the 500-600 ppb range. The 5-year rolling average flow volume increased until WY2006, decreased to WY2012, and has hovered around 12,500 and 15,000 acre-feet since then. The combined effect of TP concentration and flow results in 5-year rolling average of TP load increasing until WY2002 and hovering around 10 metric tons since 2006. The five-year rolling average of rainfall decreased since WY1996, and is hovering around 50 inches since WY2001. Review of monthly data indicates higher TP concentrations during the wet season months, and higher wet season TP concentrations post-diversion.

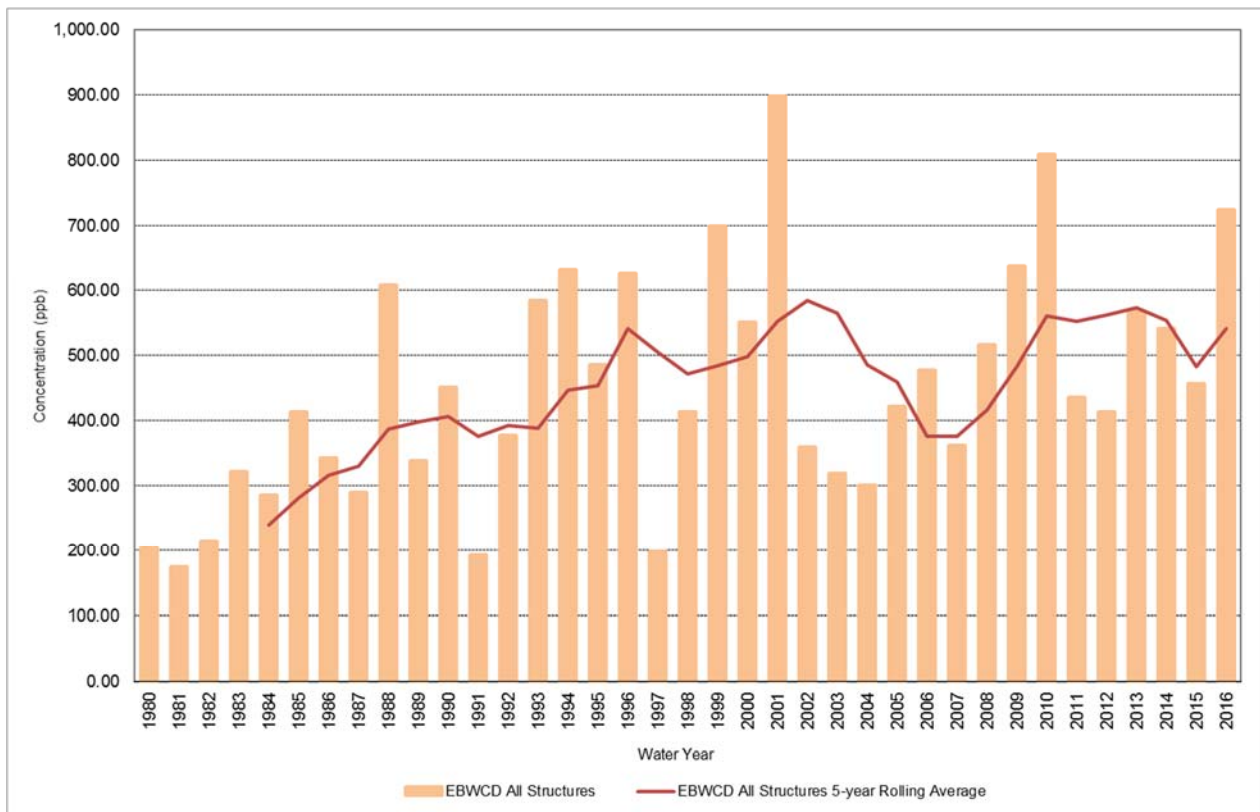


Figure 6a: TP Concentration per Water Year leaving EBWCD

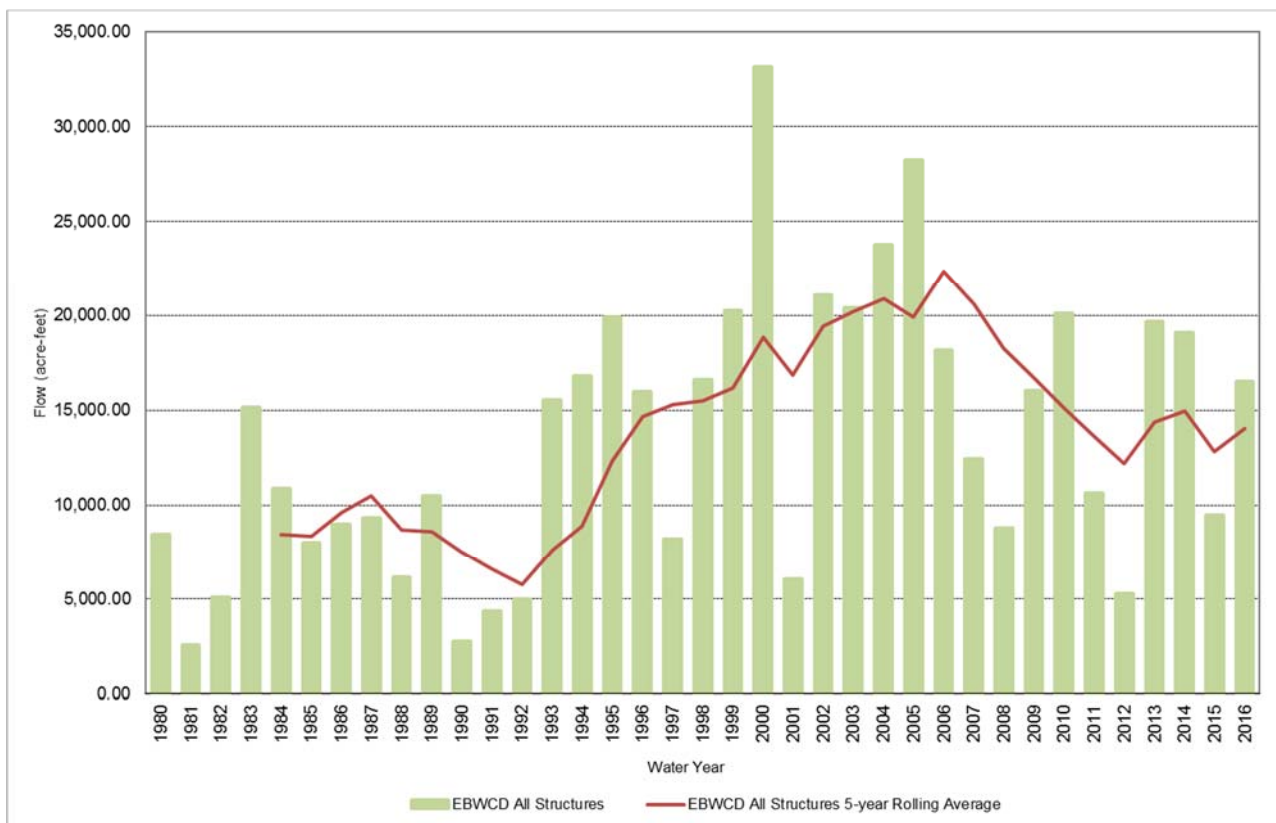


Figure 6b: Flow per Water Year leaving EBWCD

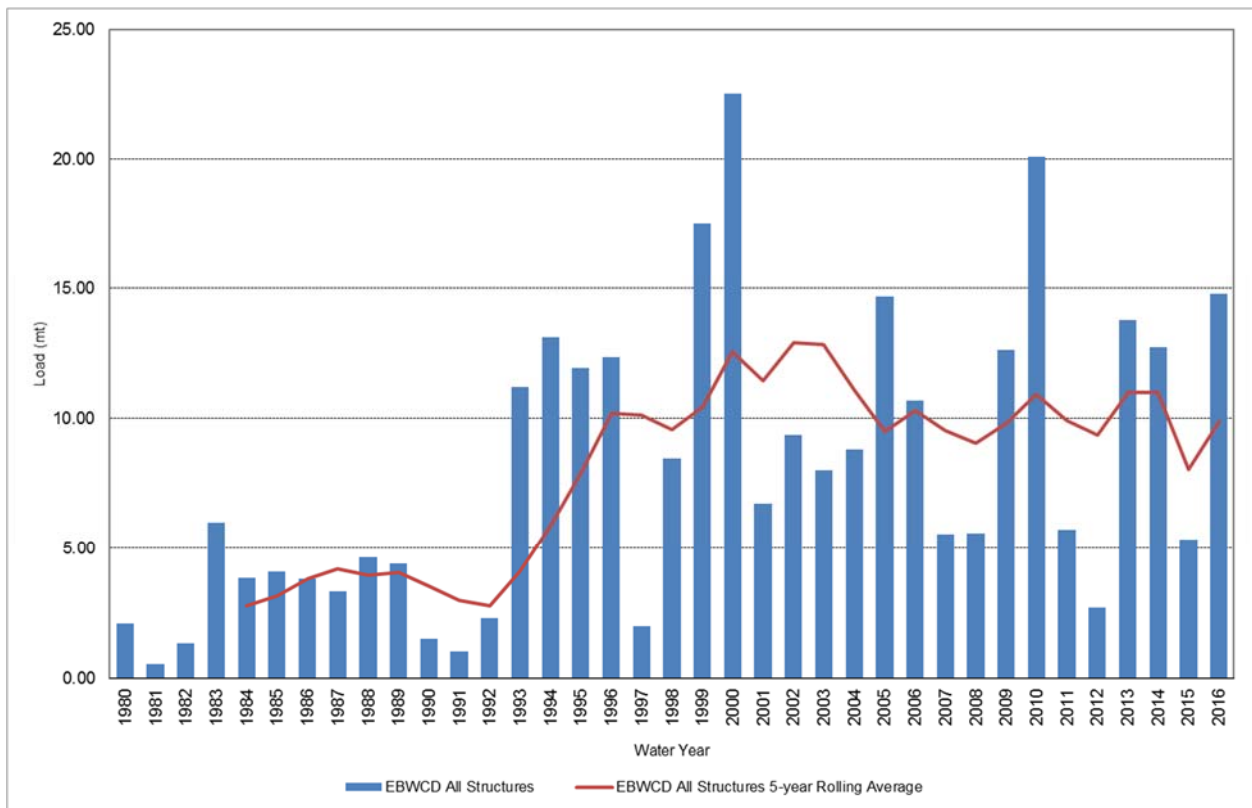


Figure 6c: TP Load per Water Year leaving EBWCD

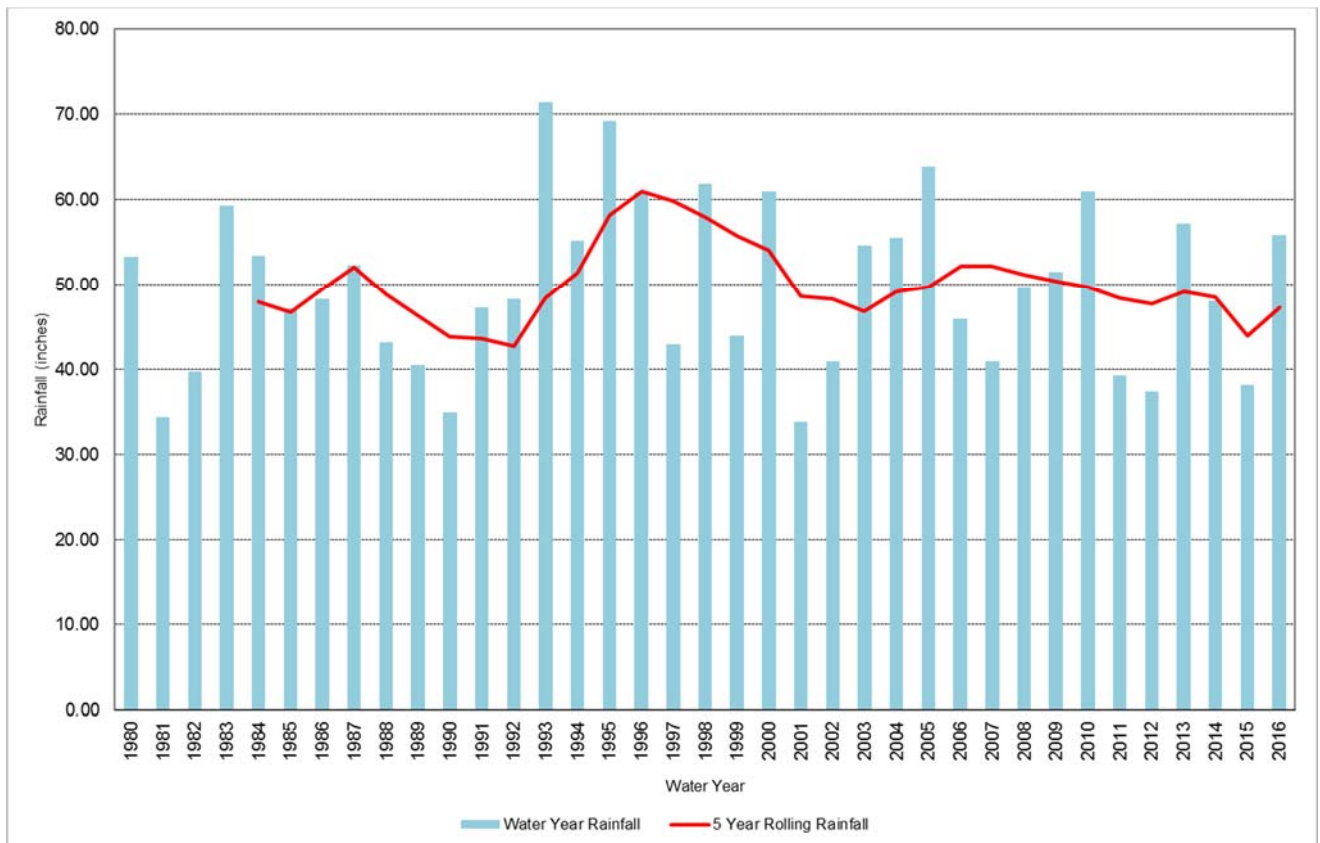


Figure 7: Rainfall per Water Year

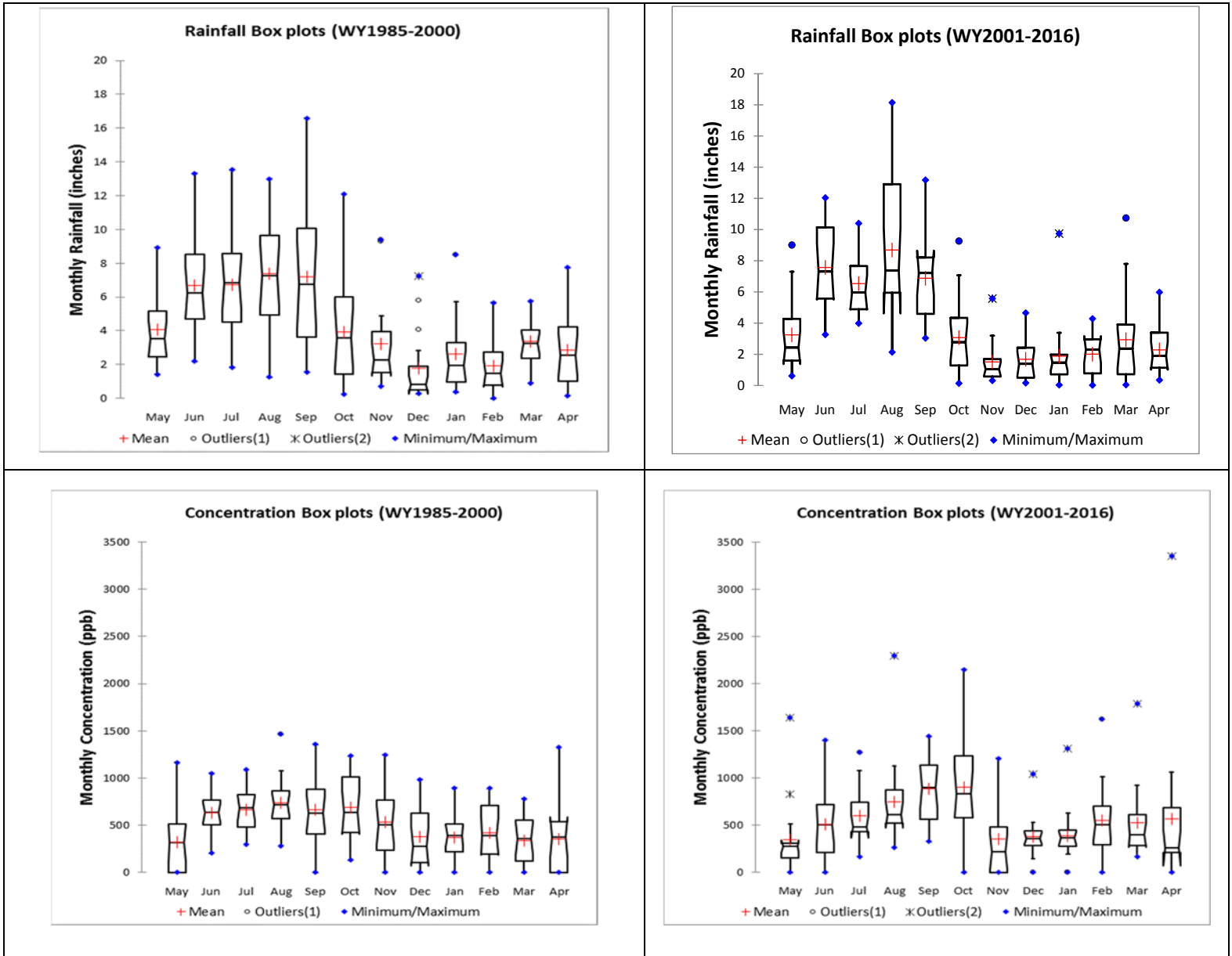


Figure 8a: Monthly Rainfall and TP Concentration

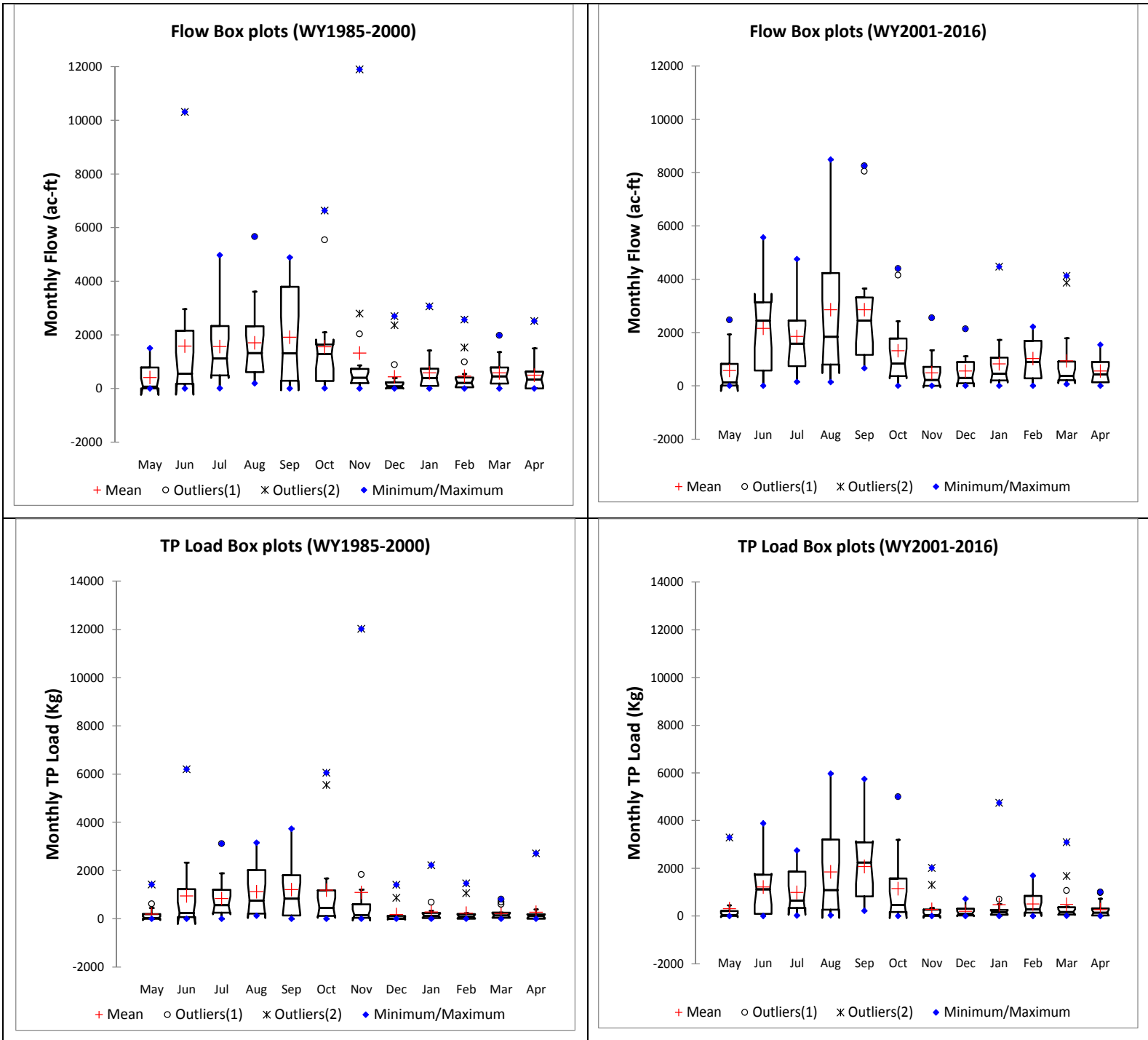


Figure 8b: Monthly Flow and TP Load

The effects of rainfall variability were also reviewed by plotting the accumulated rainfall in comparison to accumulated flow for the period of record, as shown in **Figure 9**⁴. While the cumulative rainfall shows a steady linear increase throughout the period of record, the slope of the cumulative flow becomes steeper after 1992. Potential seepage effects from Lake Okeechobee due to higher stages were explored, as shown in **Figure 10**. Based on the available data, Lake Okeechobee was not managed at higher stages after 1992.

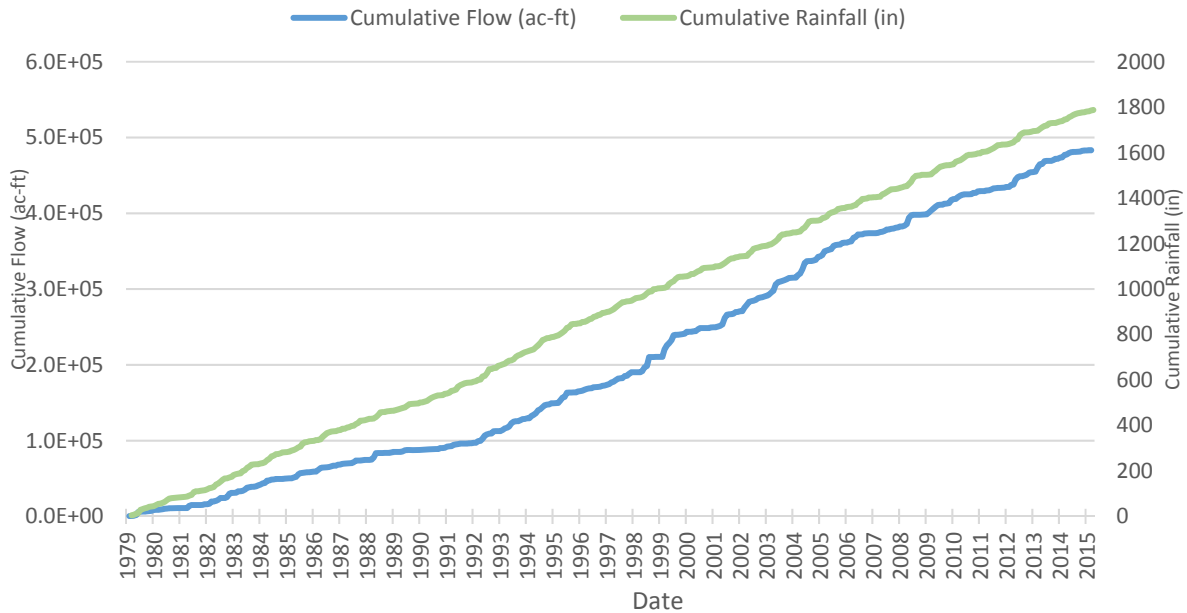


Figure 9: Cumulative Flow and Cumulative Rainfall in EBWCD between 1979 and 2015

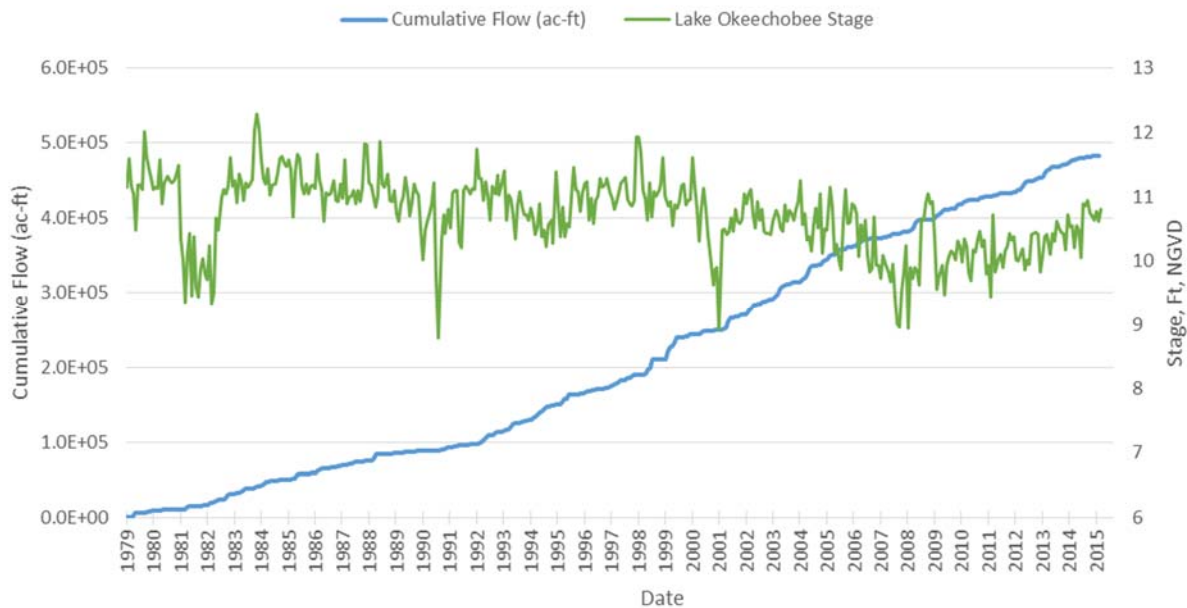


Figure 10: Cumulative Flow from EBWCD and Average Monthly Stages in Lake Okeechobee

⁴ Uses the raingage EastBeach_R from 5/31/80 to date, and the average of rain gages S308, RITTA_B_R, and LZ\$, and CLEW.FS prior to this date, as EASTBeach_R was not available.

4.1.2 Micro Assessment

Water quality data at upstream stations were reviewed to glean the potential effects of the comprehensive canal cleaning project that was implemented during a subset of months from August, 2013 to January, 2015. **Table 4** lists the canal segments that are represented by each station, canal cleaning periods, and the estimated percentage of cleaned canals upstream of each monitoring station that were cleaned.

TP, TDP and TPP for each station were reviewed for each calendar year, as summarized in **Figures 11 to 23**. Years 2007 and 2009 precede the implementation of the comprehensive canal cleaning project, while 2013, 2014 and 2015 were concurrent with this activity. Review of available data indicates that it may be difficult to assess the water quality benefits resulting from the comprehensive canal cleaning project. There are many factors such as evaluating the effects of hydrologic conditions on TP concentration and load, and the need for better defined baseline conditions for reference. Additional monitoring may be necessary to capture the long-term effects of the improved capabilities that the project provided.

Among the information that can be gleaned for the data, however, is that the majority of TP is TDP, which may not be substantially affected by the cleaning of accumulated canal sediments and vegetation. Nevertheless, review of available data for individual stations and years suggest generally lower TPP concentrations in 2015 than in previous years.

Table 4: Canal Cleaning Dates and Percent Cleaned

Station Name	Laterals Represented	Canal Cleaning Start Date	Canal Cleaning End Date	Percent Cleaned	Total Percent Cleaned
EBWCD3	Lat. 3-1S	8/12/13	8/30/13	62.59	63
EBWCD4	Lat. 3-2S, Lat. 3-2S-1E, Lat. 3-2S-2E	10/10/13	10/21/13	27.55	50
	Lat. 3-4S, Lat. 3-4S-4E, Lat. 3-4S-5E	6/23/14	6/23/14	22.79	
EBWCD6	Lat. 3-1S	8/12/13	8/30/13	8.56	44
	Lat. 3-1S, Lat. 3-2S(A), Canal C-3	9/3/13	9/30/13	7.67	
	Canal C-3	10/1/13	10/30/13	3.11	
	Lat. 3-2S, Lat. 3-2S-1E, Lat. 3-2S-2E	10/10/13	10/21/13	9.26	
	Lat. 3-1N	11/5/13	11/8/13	3.87	
	Lat. 3-4S, Lat. 3-4S-4E, Lat. 3-4S-5E, Lat. 3-4S-1E	6/23/14	6/23/14	11.47	
EBWCD9	Lat. 3-1S	8/12/13	8/30/13	9.96	37
	Lat. 3-1S, Canal C-3	9/3/13	9/10/13	4.55	
	Canal C-3	10/23/13	10/30/13	2.19	
	Canal C-2	10/31/13	11/4/13	3.15	
	Lat. 3-1N	11/5/13	11/8/13	4.51	
	Canal C-2	1/1/15	1/1/15	12.19	
EBWCD10	Lat. 3-1S	8/12/13	8/30/13	8.155	42
	Lat. 3-1S, Lat. 3-2S(A), Canal C-3	9/3/13	9/30/13	7.315	
	Canal C-3	10/1/13	10/30/13	2.96	
	Lat. 3-2S, Lat. 3-2S-1E, Lat. 3-2S-2E	10/10/13	10/21/13	8.820	

DATA SUMMARY AND EVALUATION

Station Name	Laterals Represented	Canal Cleaning Start Date	Canal Cleaning End Date	Percent Cleaned	Total Percent Cleaned
	Lat. 3-1N	11/5/13	11/8/13	3.693	
	Lat. 3-4S, Lat. 3-4S-4E, Lat. 3-4S-5E, Lat. 3-4S-1E	6/23/14	6/23/14	10.943	
EBWCD12	Lat. 3-1S	8/12/13	8/30/13	5.54	41
	Lat. 3-1S, Lat. 3-2S(A), Canal C-3	9/3/13	9/30/13	4.97	
	Canal C-3	10/1/13	10/30/13	2.01	
	Lat. 3-2S, Lat. 3-2S-1E, Lat. 3-2S-2E	10/10/13	10/21/13	5.99	
	Canal C-2	10/31/13	11/4/13	1.76	
	Lat. 3-1N	11/5/13	11/8/13	2.51	
	Lat. 3-4S, Lat. 3-4S-4E, Lat. 3-4S-5E, Lat. 3-4S-1E	6/23/14	6/23/14	7.43	
	Lat. 4-1N	12/19/14	12/19/14	2.24	
	Canal C-2, Canal C-4	1/1/15	1/1/15	8.98	
EBWCD13	Lat. 4-1N	12/19/14	12/19/14	100	100
EBWCD14	Lat. 3-1S	8/12/13	8/30/13	5.35	41
	Lat. 3-1S, Lat. 3-2S(A), Canal C-3	9/3/13	9/30/13	4.81	
	Canal C-3	10/1/13	10/30/13	1.94	
	Lat. 3-2S, Lat. 3-2S-1E, Lat. 3-2S-2E	10/10/13	10/21/13	5.78	
	Canal C-2	10/31/13	11/4/13	1.70	
	Lat. 3-1N	11/5/13	11/8/13	2.42	
	Lat. 3-4S, Lat. 3-4S-4E, Lat. 3-4S-5E, Lat. 3-4S-1E	6/23/14	6/23/14	7.18	
	Lat. 4-1N, Canal C-4	12/19/14	12/19/14	2.94	
	Canal C-2, Canal C-4	1/1/15	1/1/15	8.67	

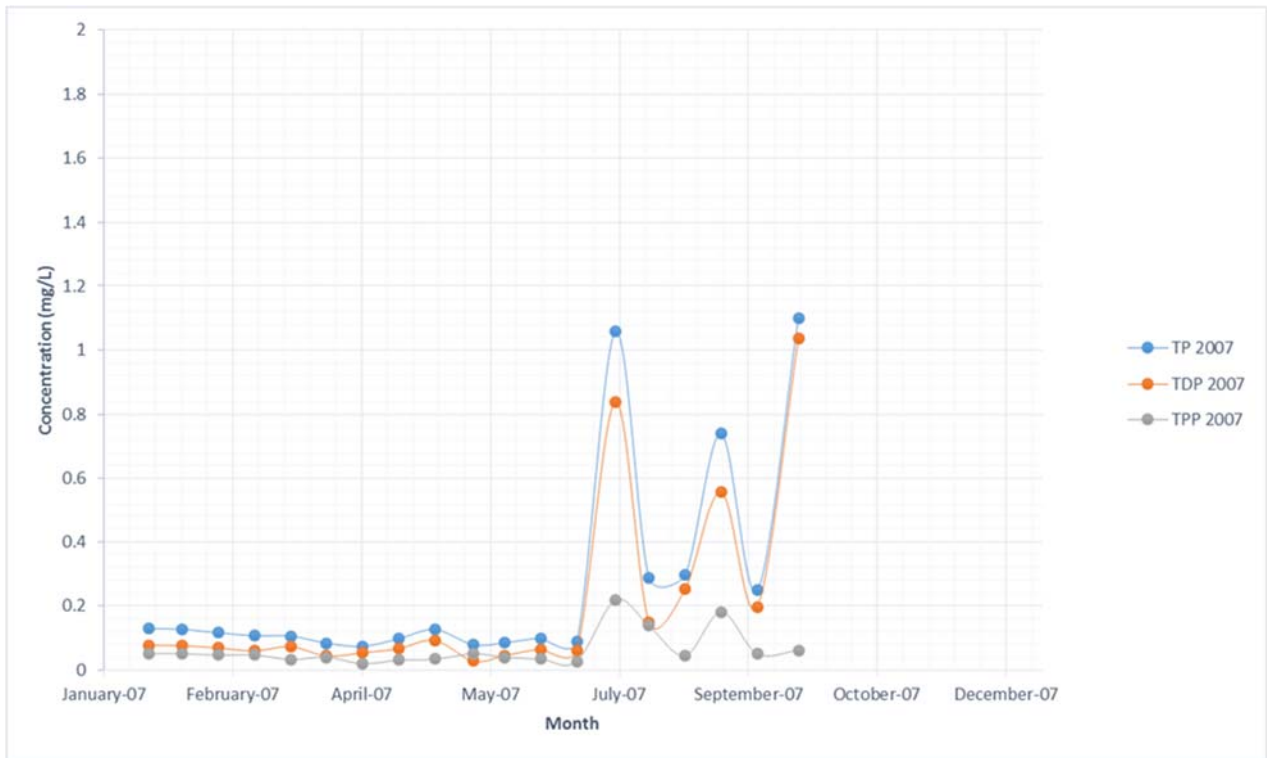


Figure 11a: TP, TDP and TPP Concentrations at EBWCD3 during 2007

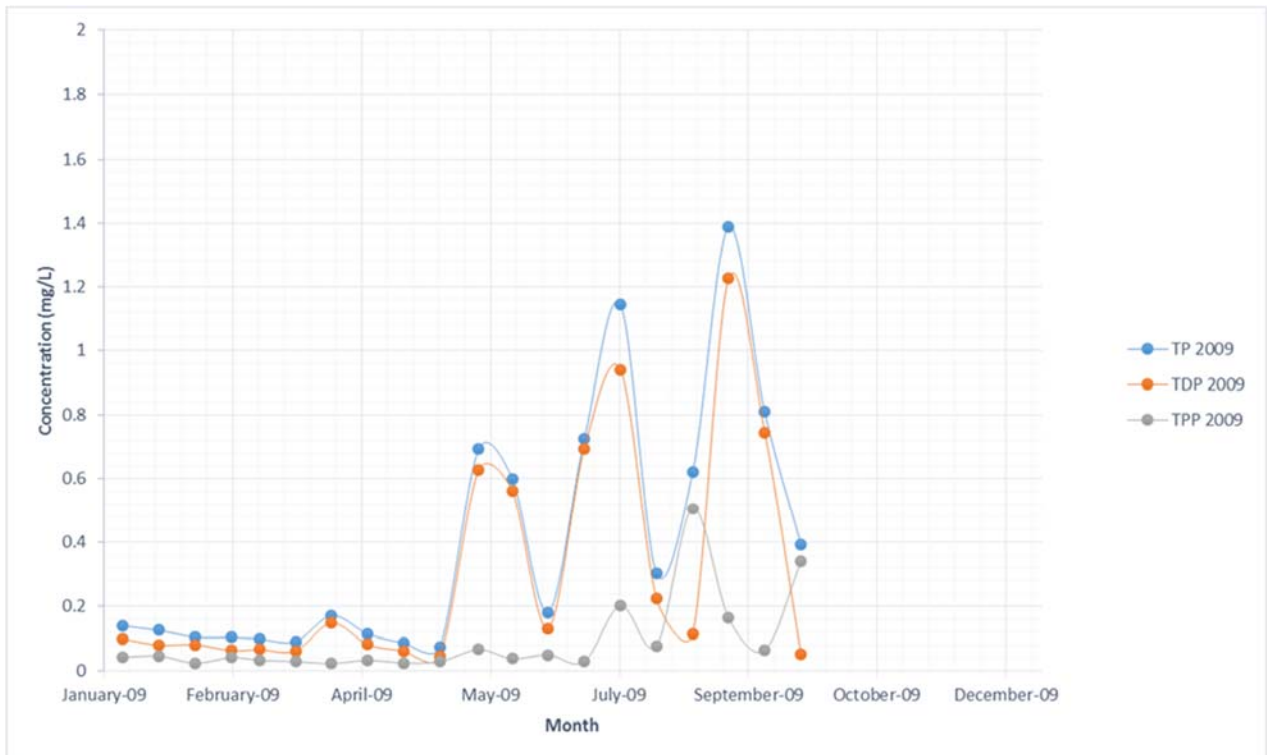


Figure 11b: TP, TDP and TPP Concentrations at EBWCD3 during 2009

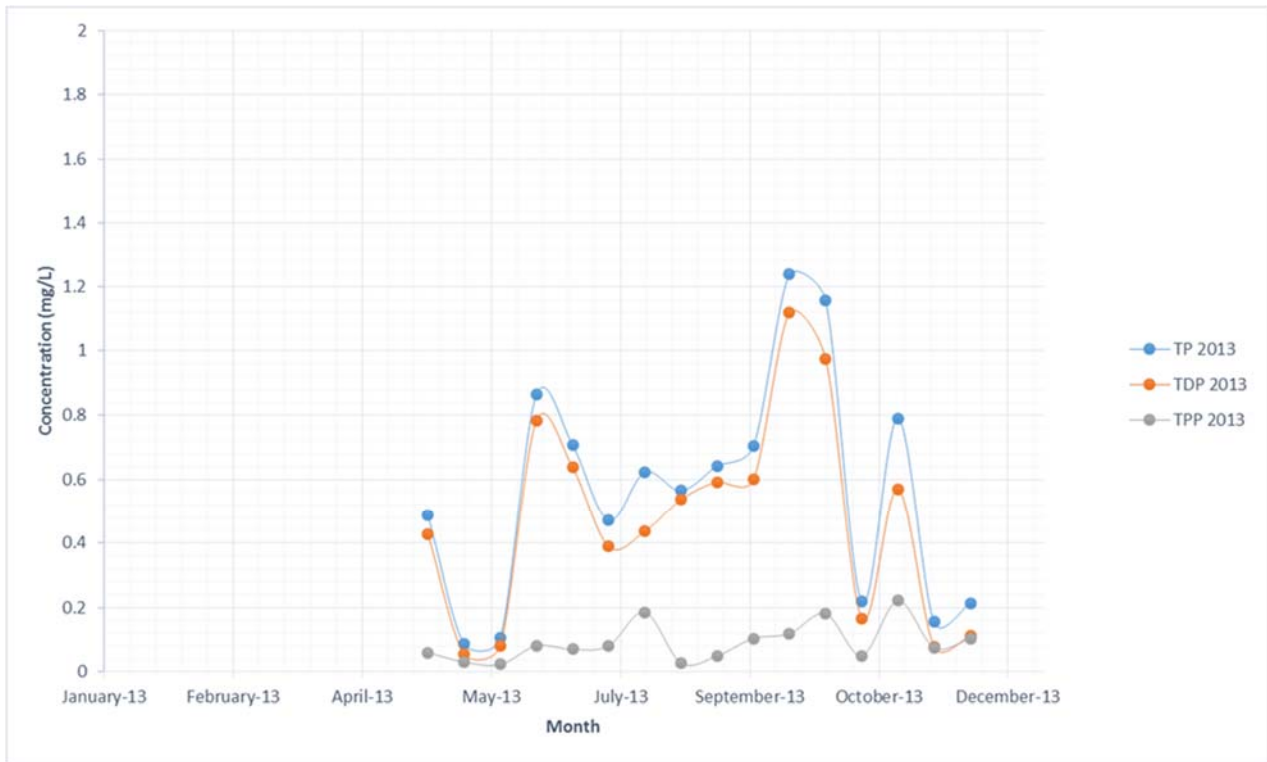


Figure 11c: TP, TDP and TPP Concentrations at EBWCD3 during 2013



Figure 11d: TP, TDP and TPP Concentrations at EBWCD3 during 2014

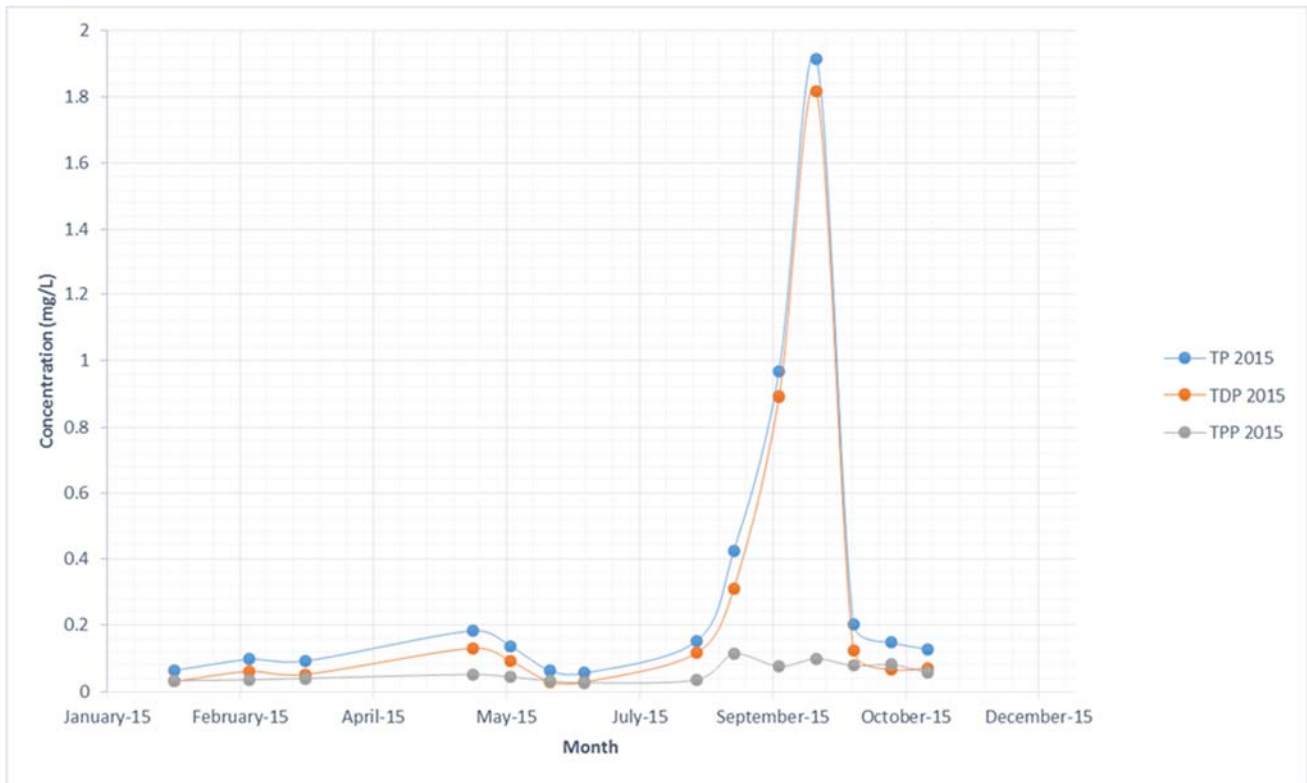


Figure 11e: TP, TDP and TPP Concentrations at EBWCD3 during 2015

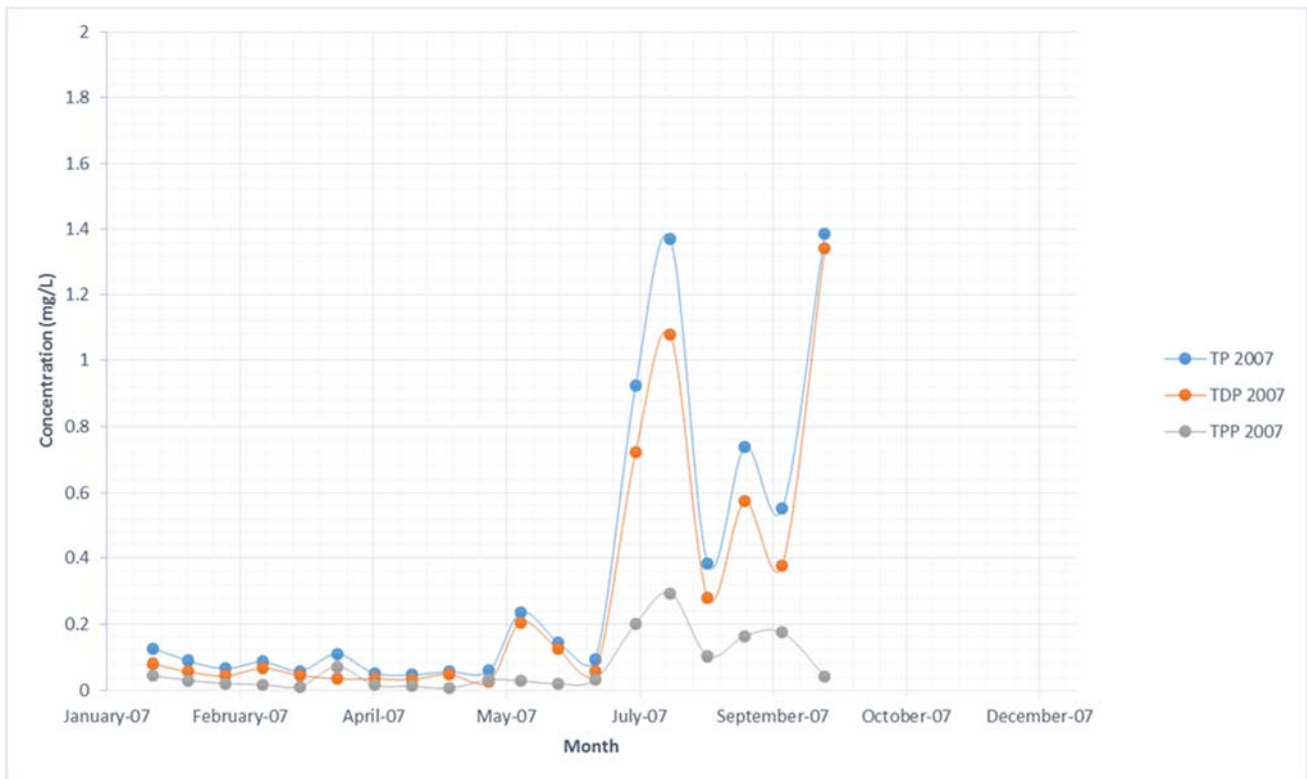


Figure 12a: TP, TDP and TPP Concentrations at EBWCD4 during 2007

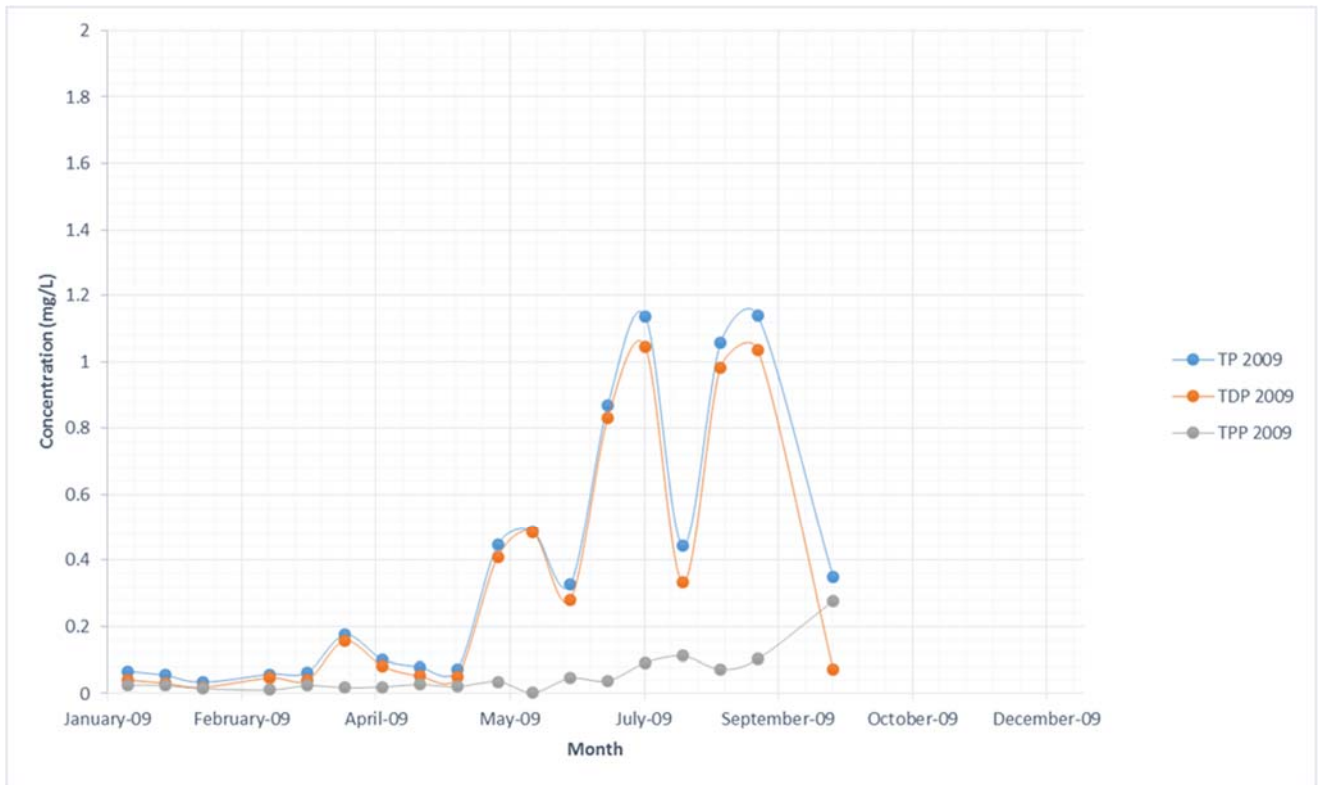


Figure 12b: TP, TDP and TPP Concentrations at EBWCD4 during 2009

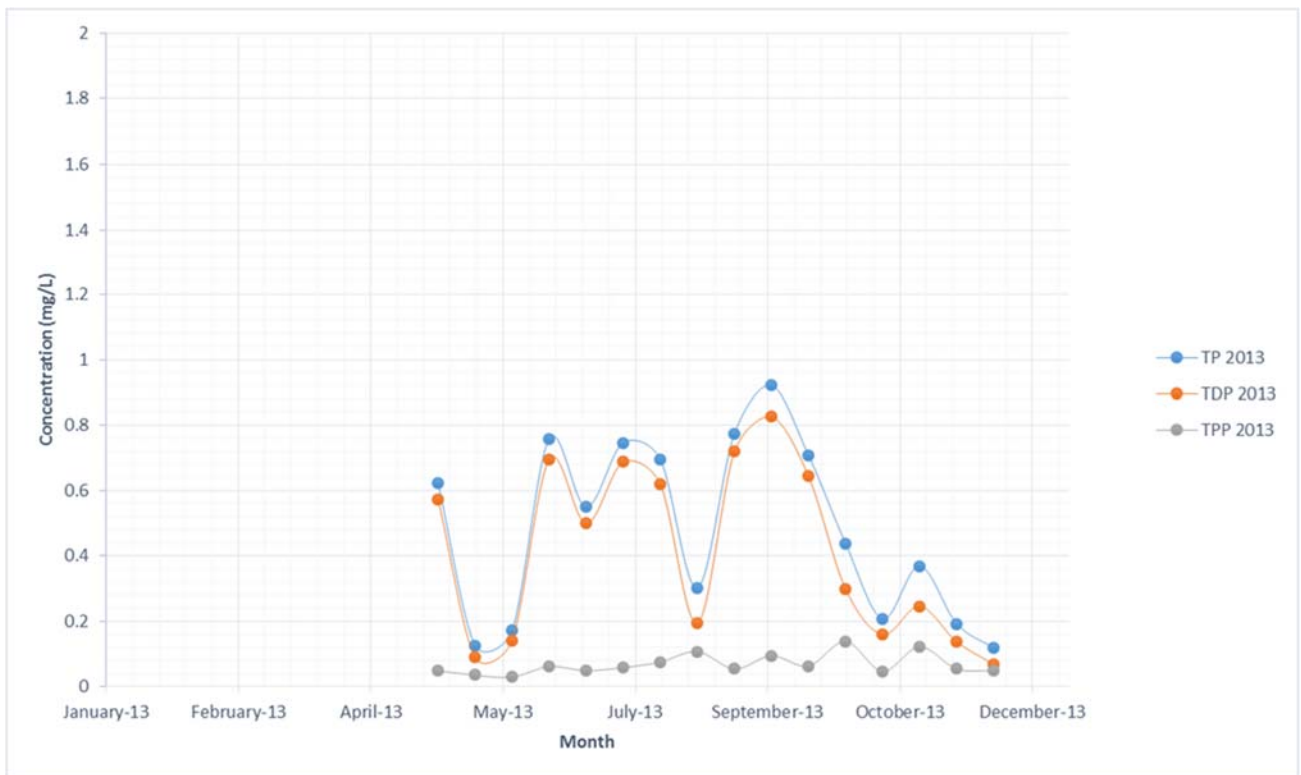


Figure 12c: TP, TDP and TPP Concentrations at EBWCD4 during 2013

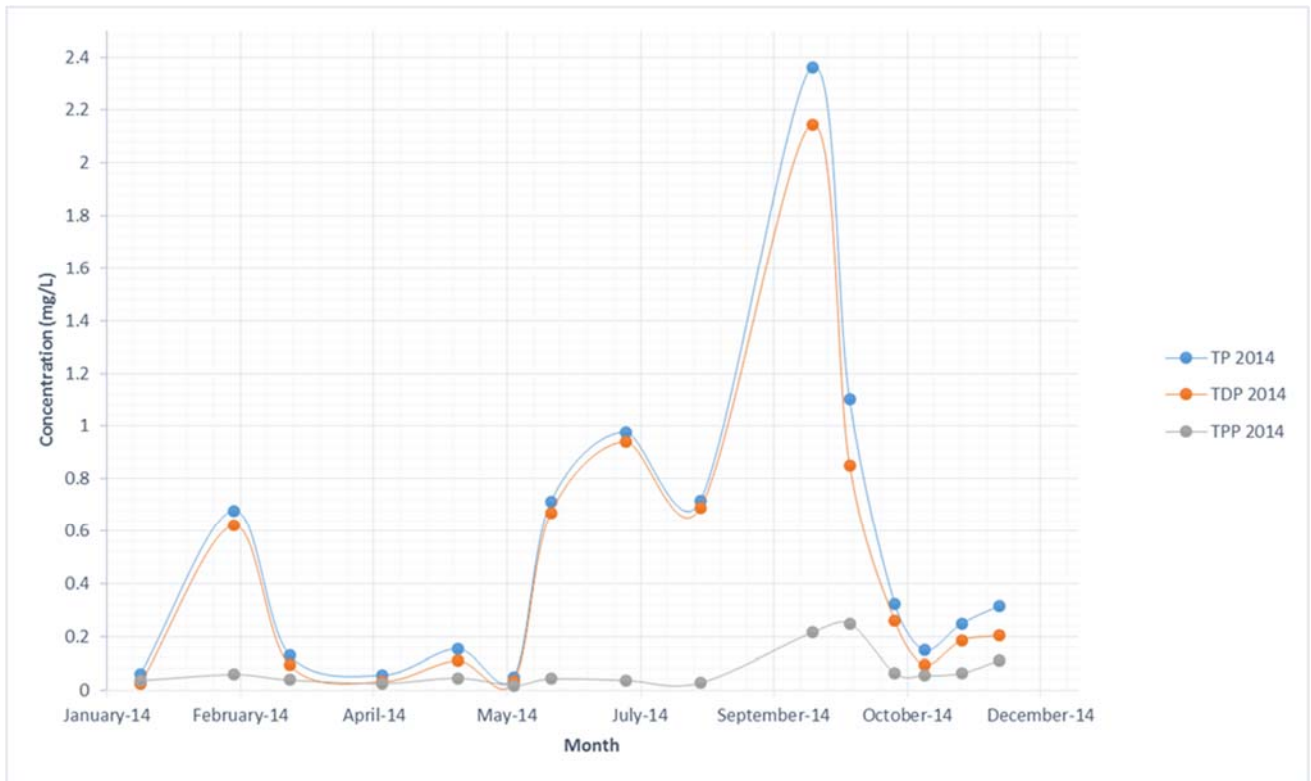


Figure 13d: TP, TDP and TPP Concentrations at EBWCD4 during 2014

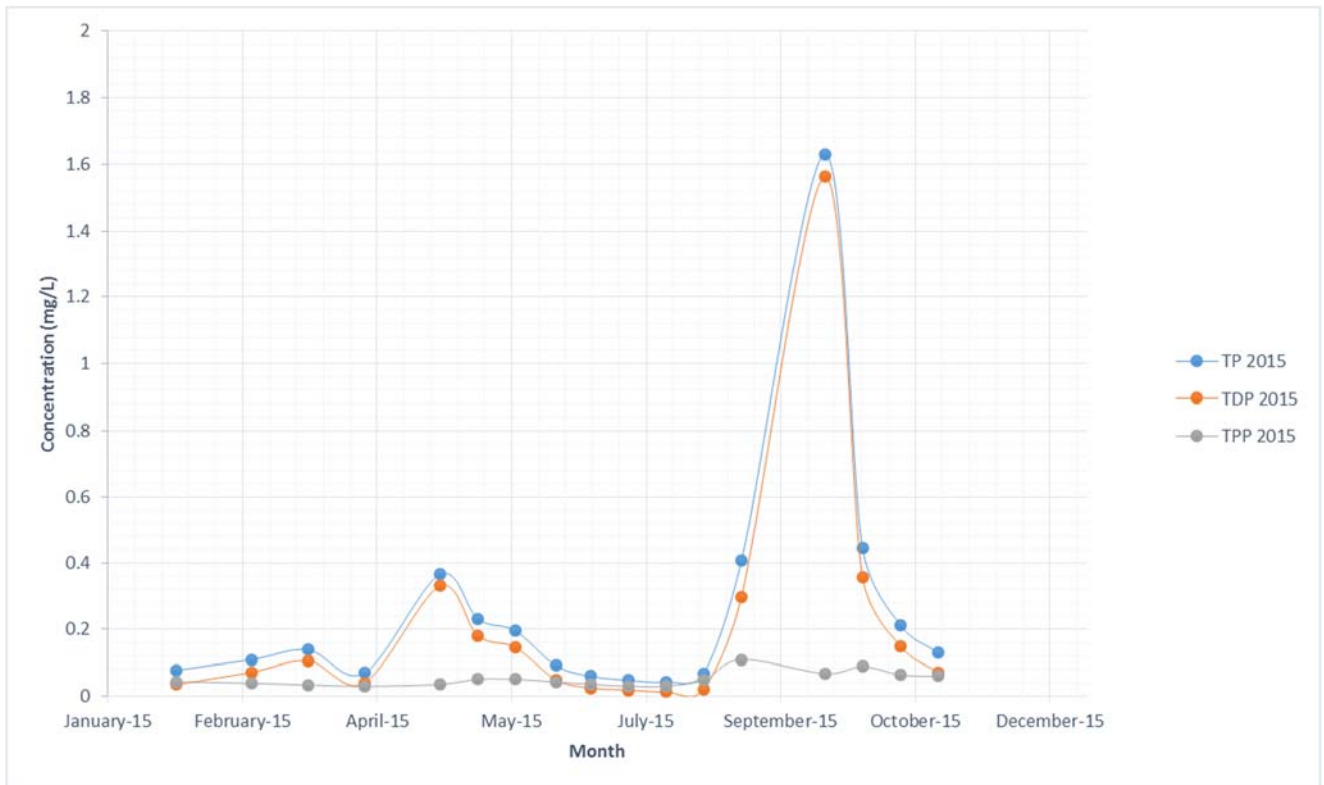


Figure 13e: TP, TDP and TPP Concentrations at EBWCD4 during 2015

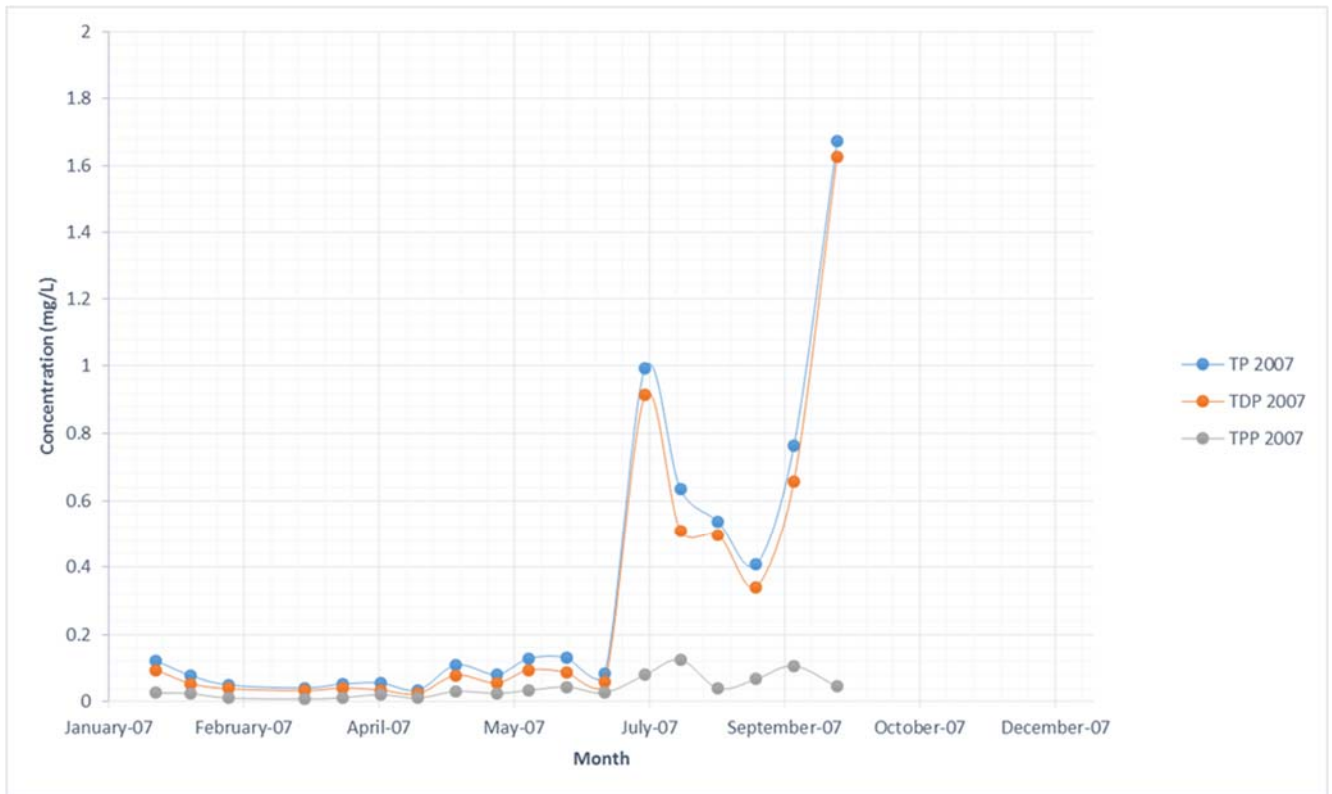


Figure 14a: TP, TDP and TPP Concentrations at EBWCD6 during 2007

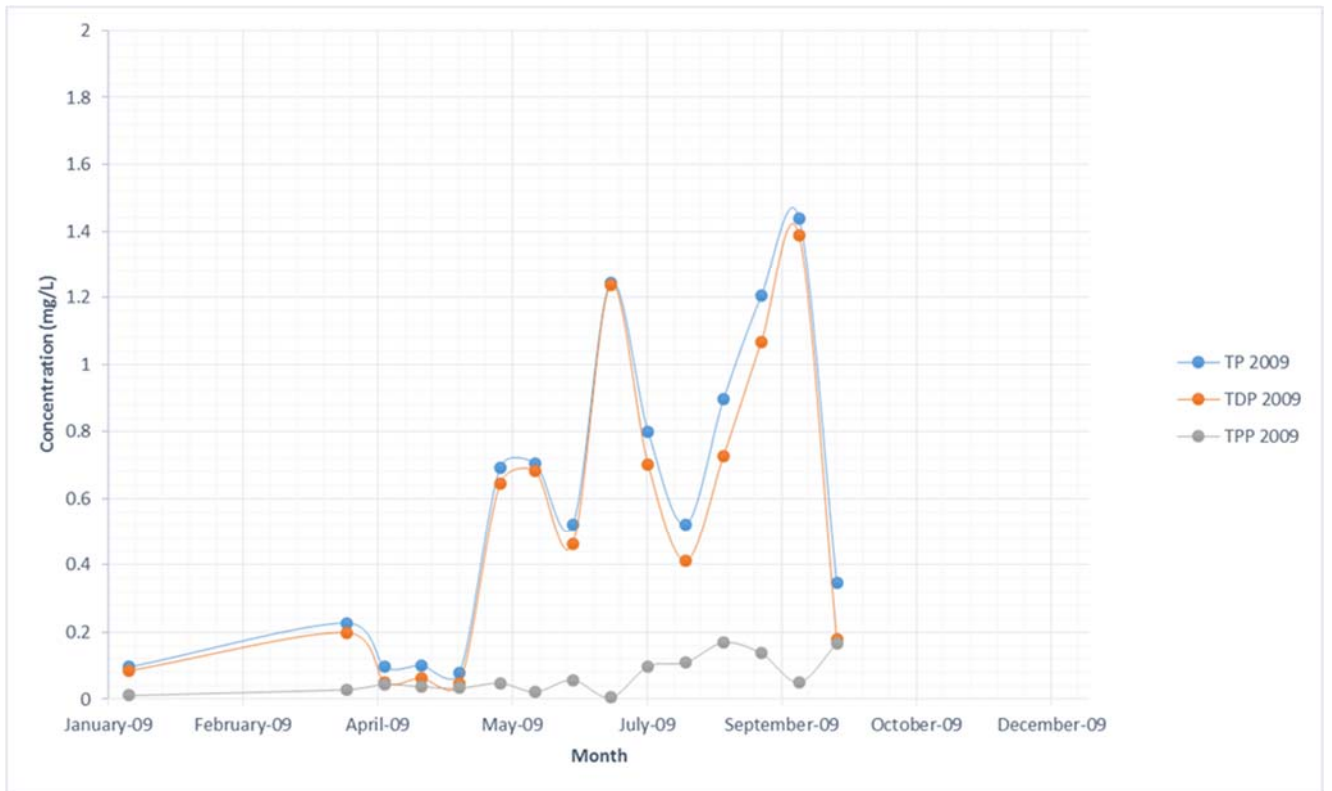


Figure 14b: TP, TDP and TPP Concentrations at EBWCD6 during 2009

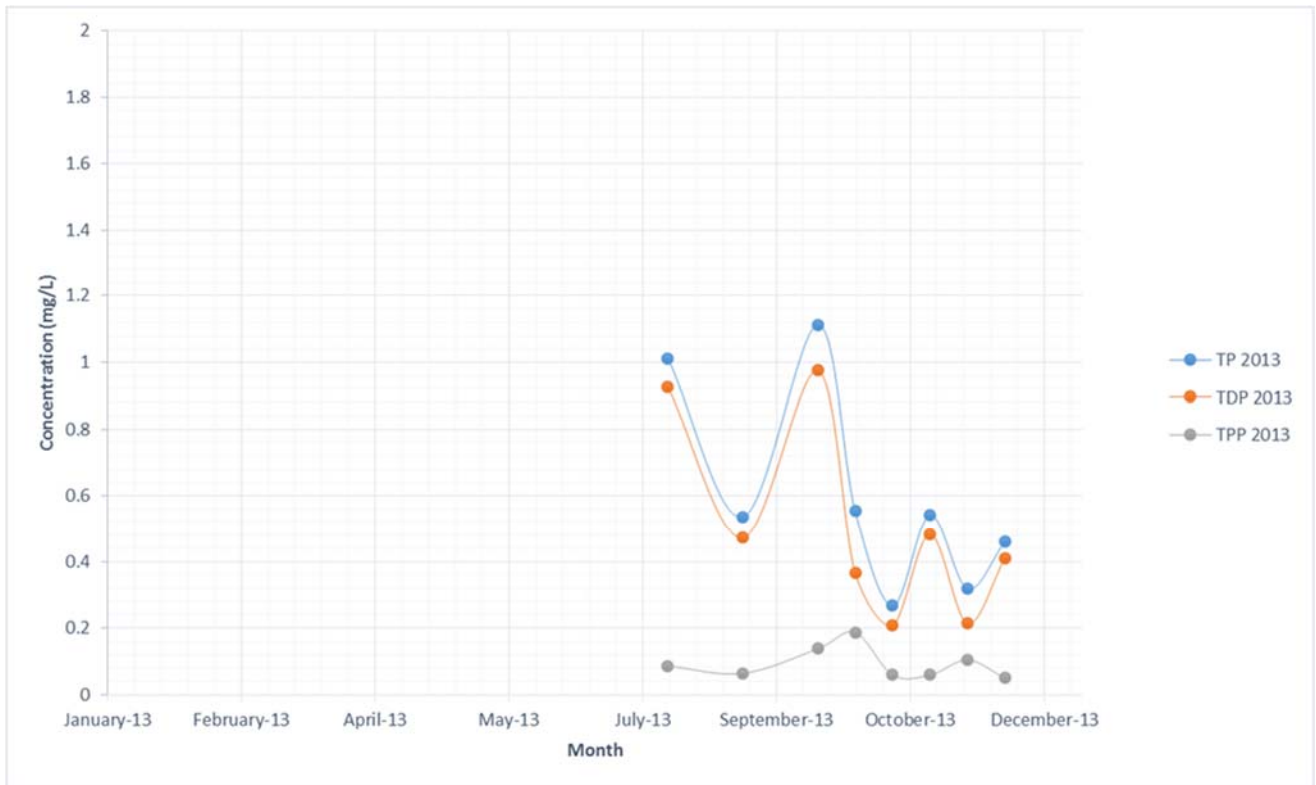


Figure 14c: TP, TDP and TPP Concentrations at EBWCD6 during 2013



Figure 14d: TP, TDP and TPP Concentrations at EBWCD6 during 2014

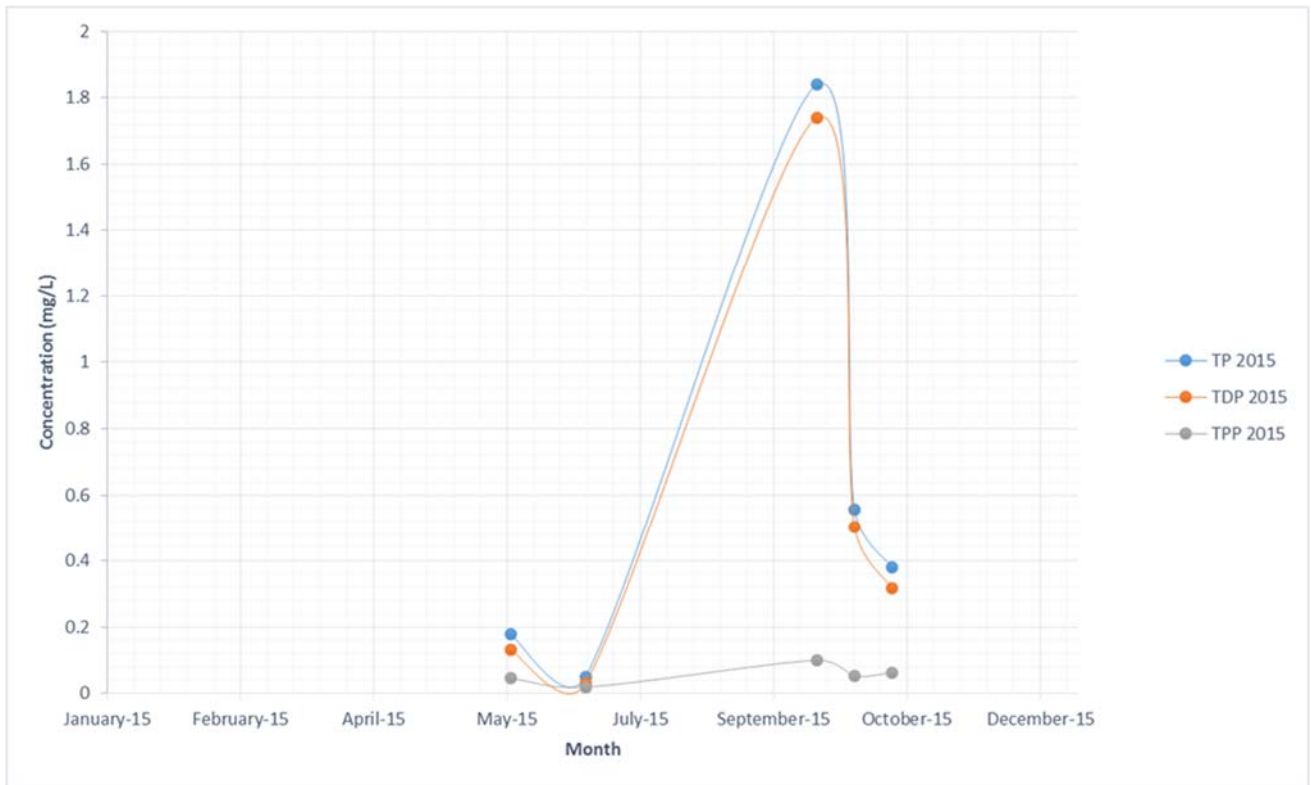


Figure 14e: TP, TDP and TPP Concentrations at EBWCD6 during 2015

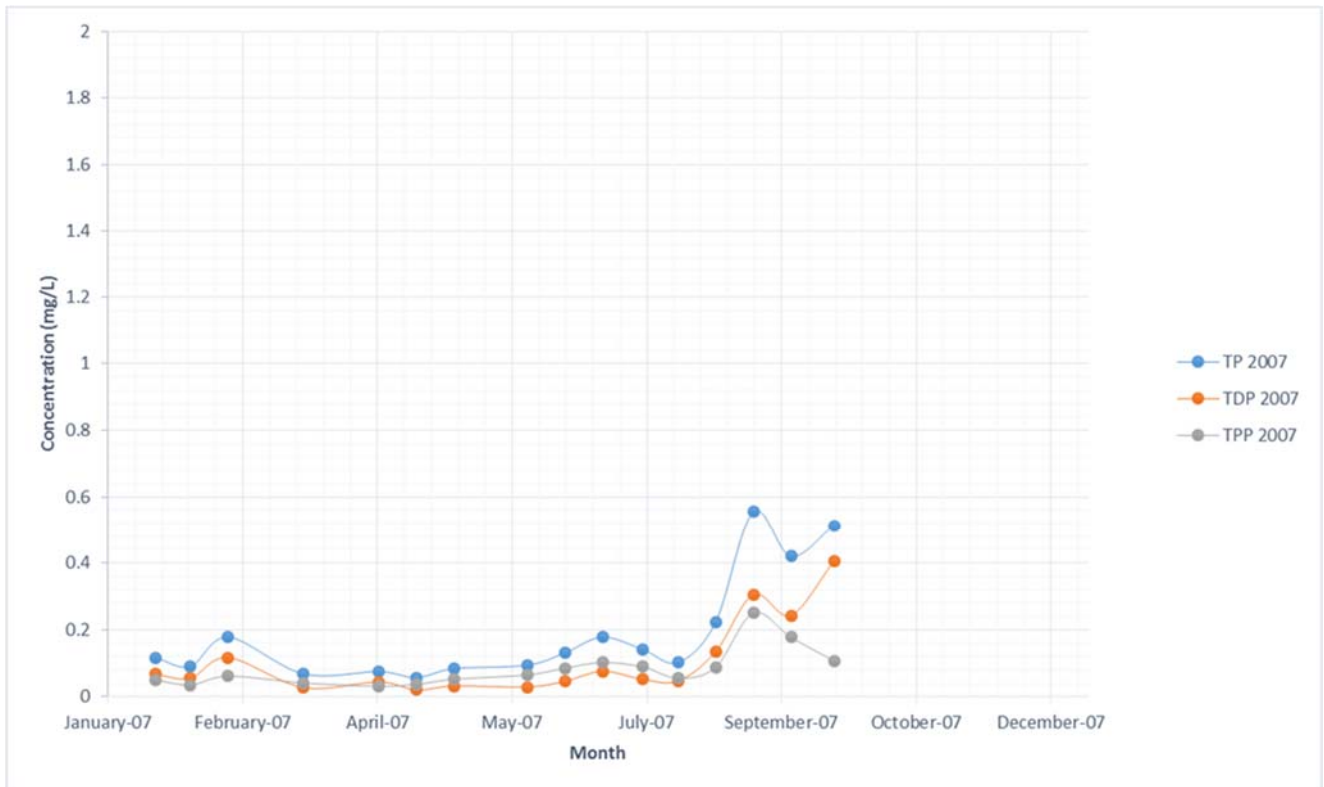


Figure 15a: TP, TDP and TPP Concentrations at EBWCD9 during 2007

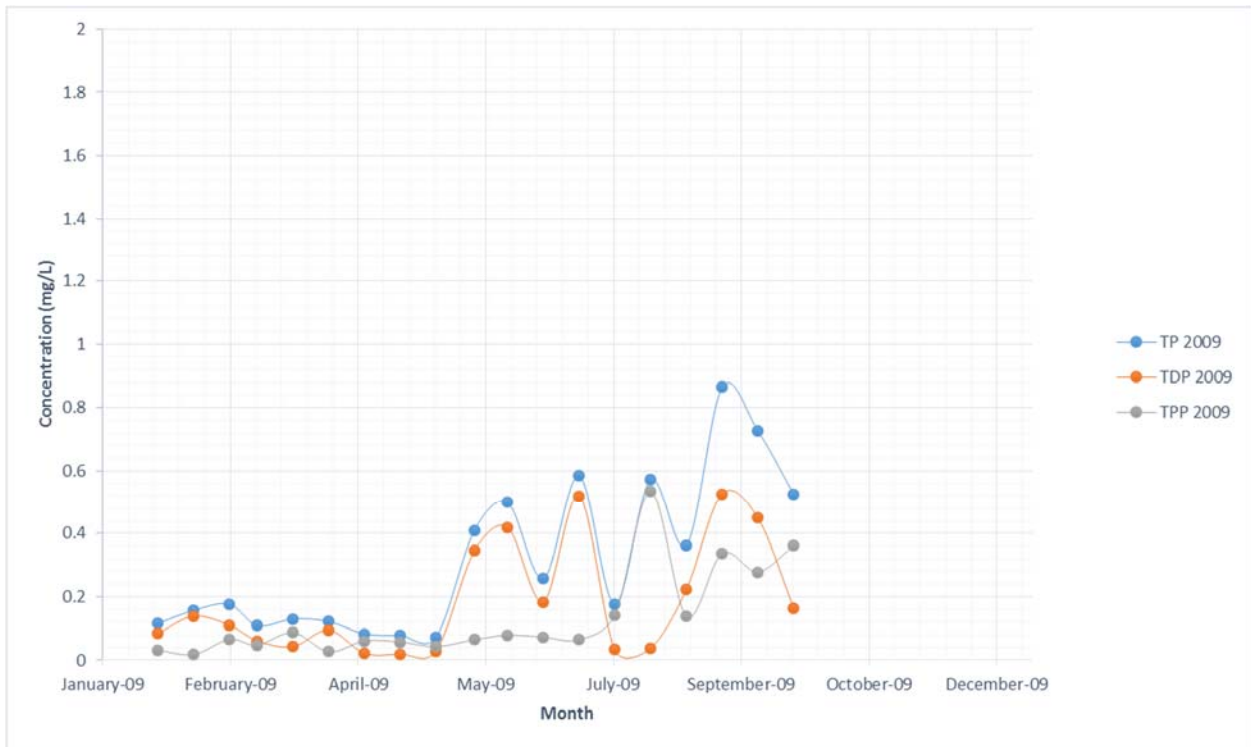


Figure 15b: TP, TDP and TPP Concentrations at EBWCD9 during 2009

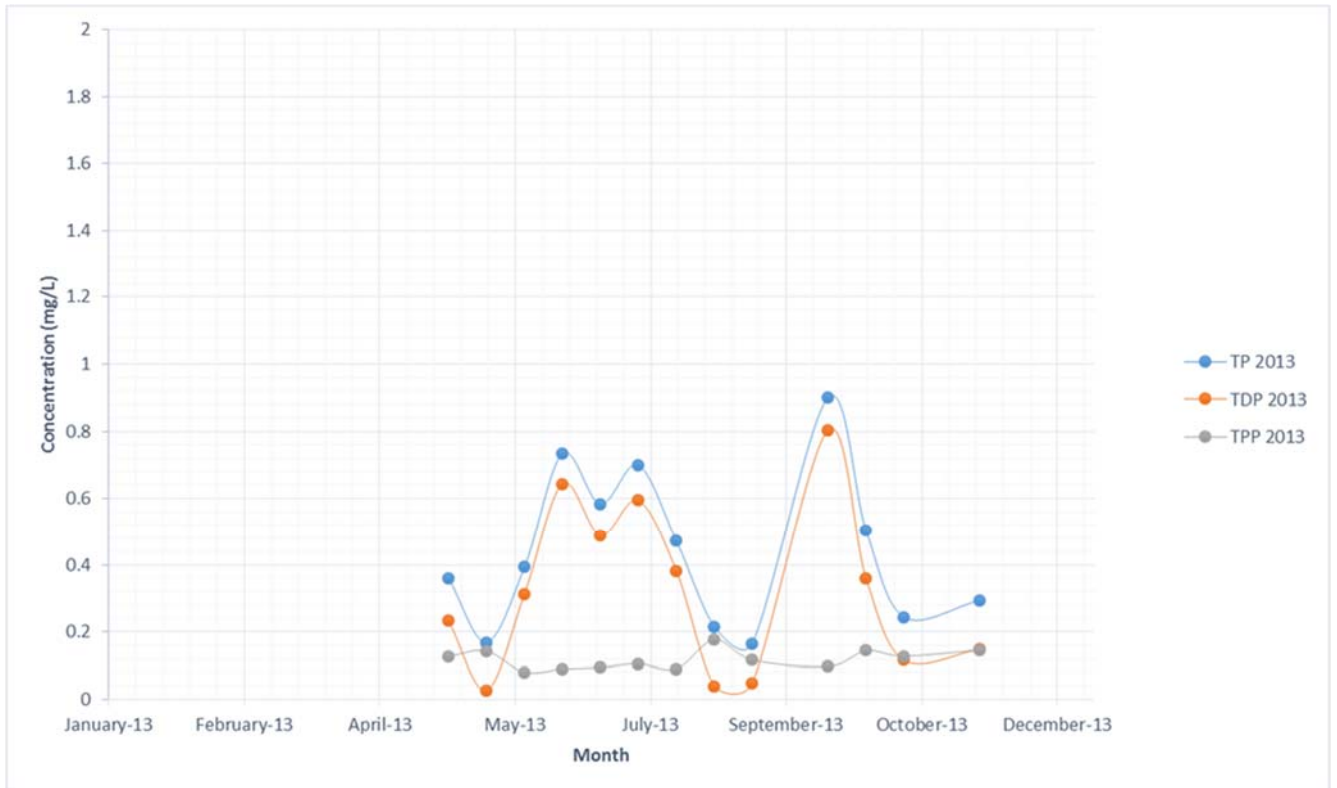


Figure 15c: TP, TDP and TPP Concentrations at EBWCD9 during 2013

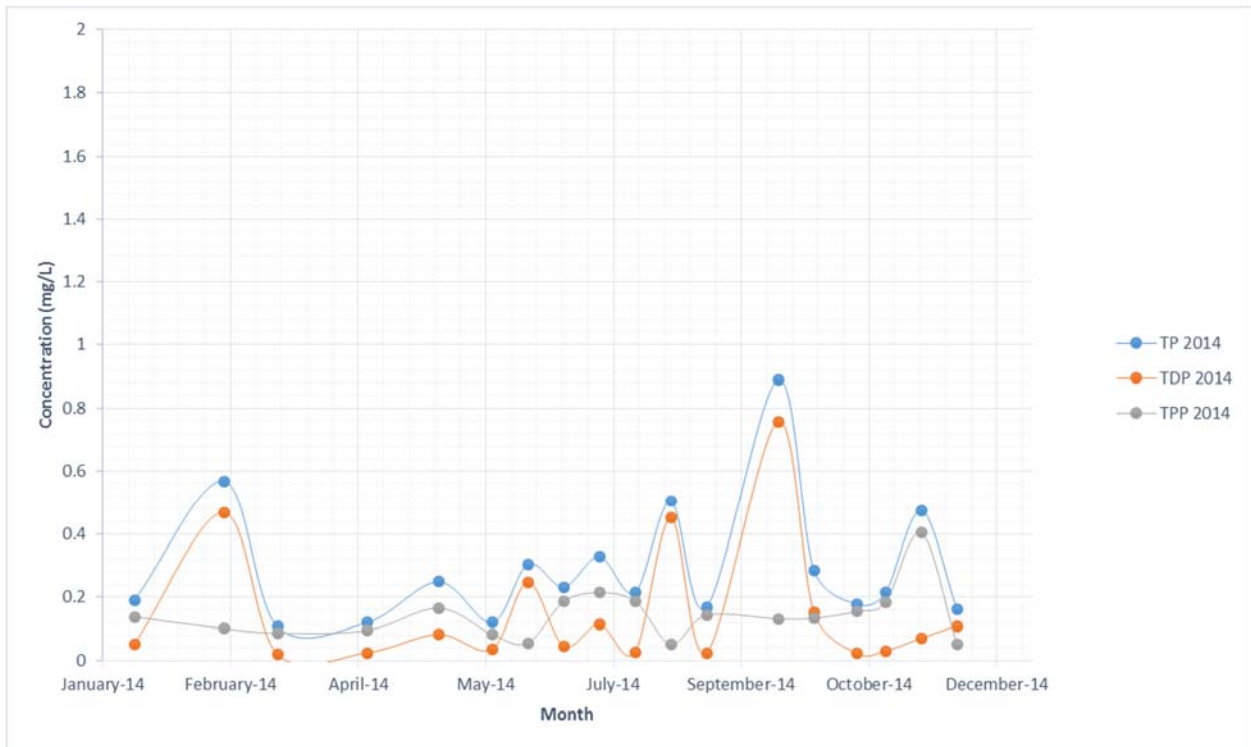


Figure 15d: TP, TDP and TPP Concentrations at EBWCD9 during 2014

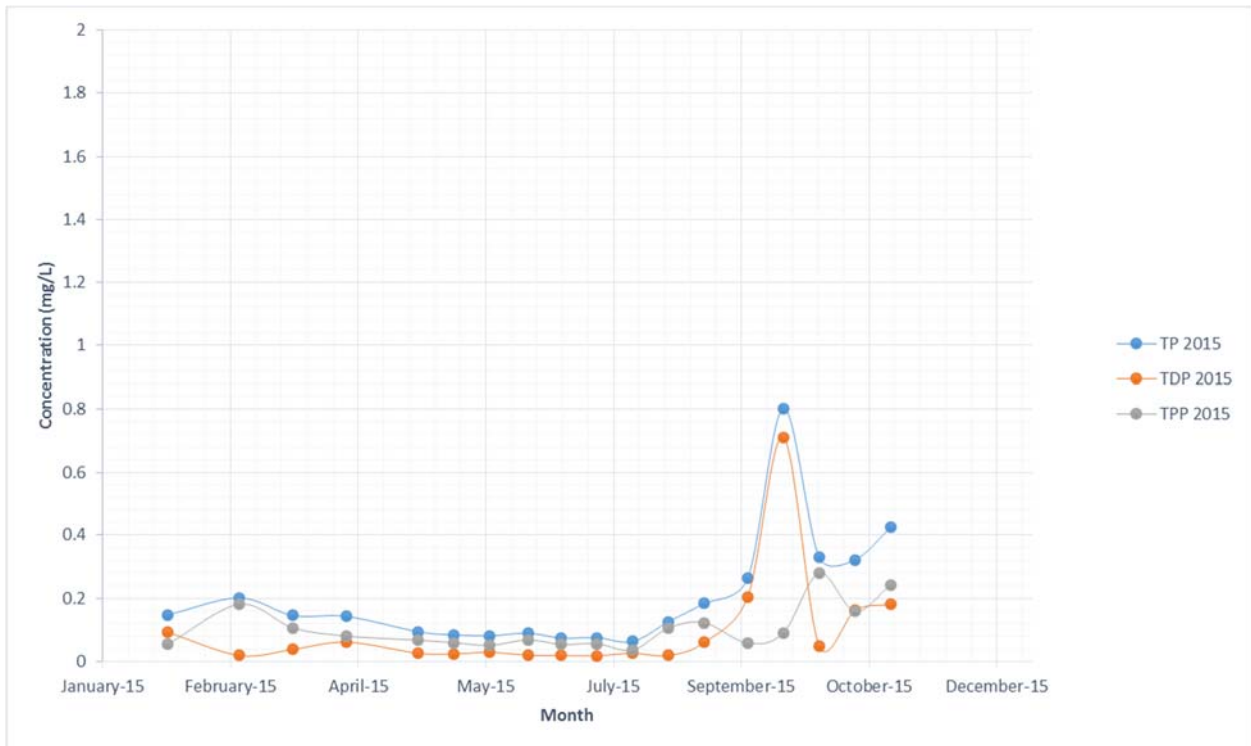


Figure 15e: TP, TDP and TPP Concentrations at EBWCD9 during 2015

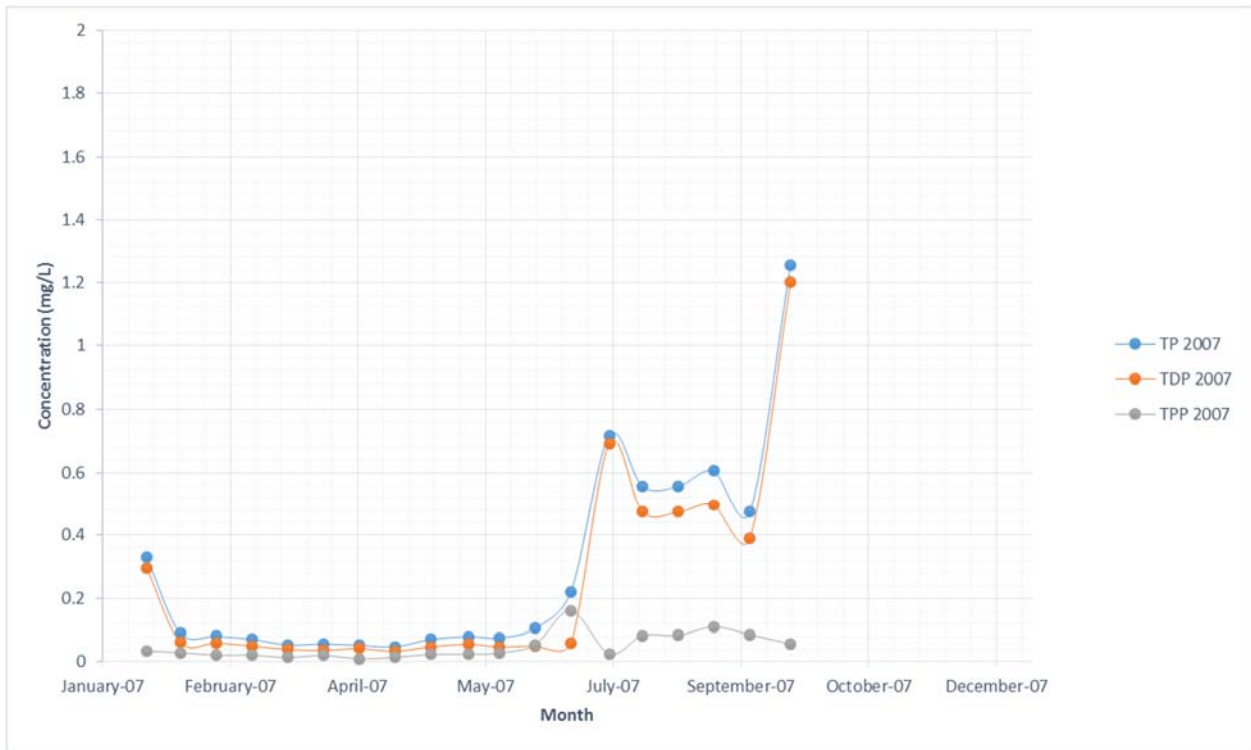


Figure 16a: TP, TDP and TPP Concentrations at EBWCD10 during 2007

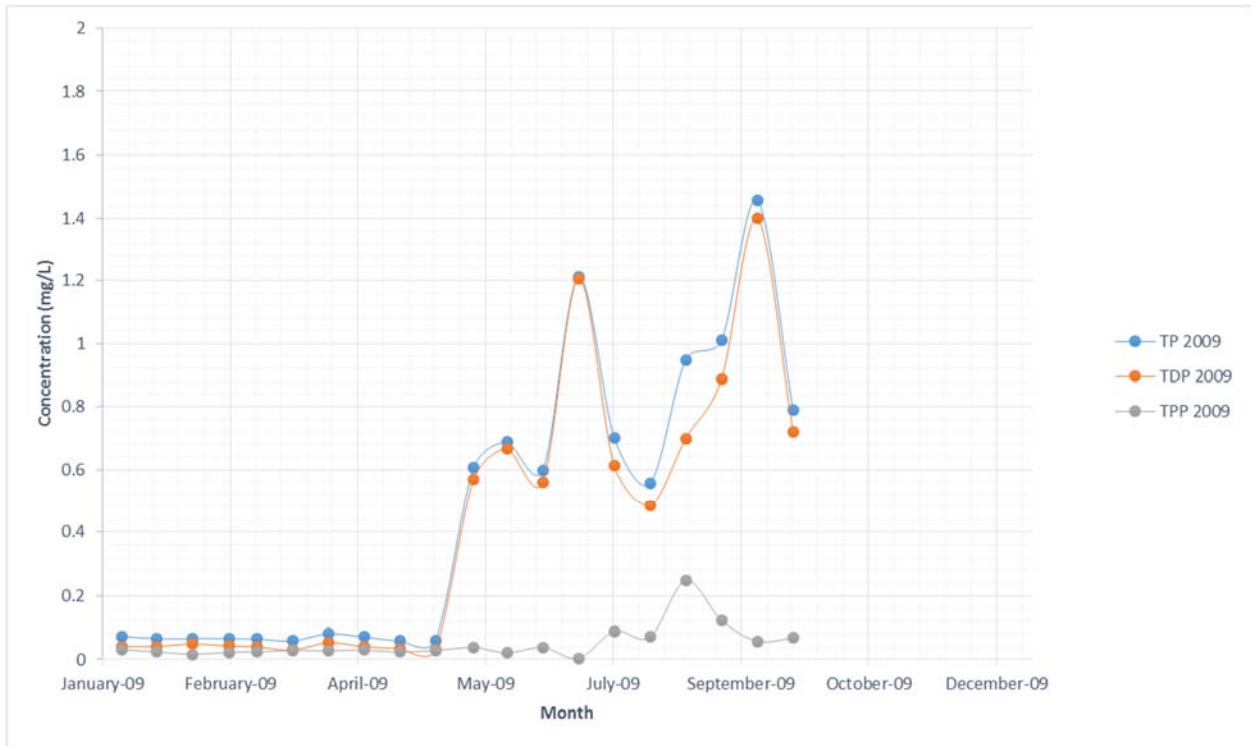


Figure 16b: TP, TDP and TPP Concentrations at EBWCD10 during 2009

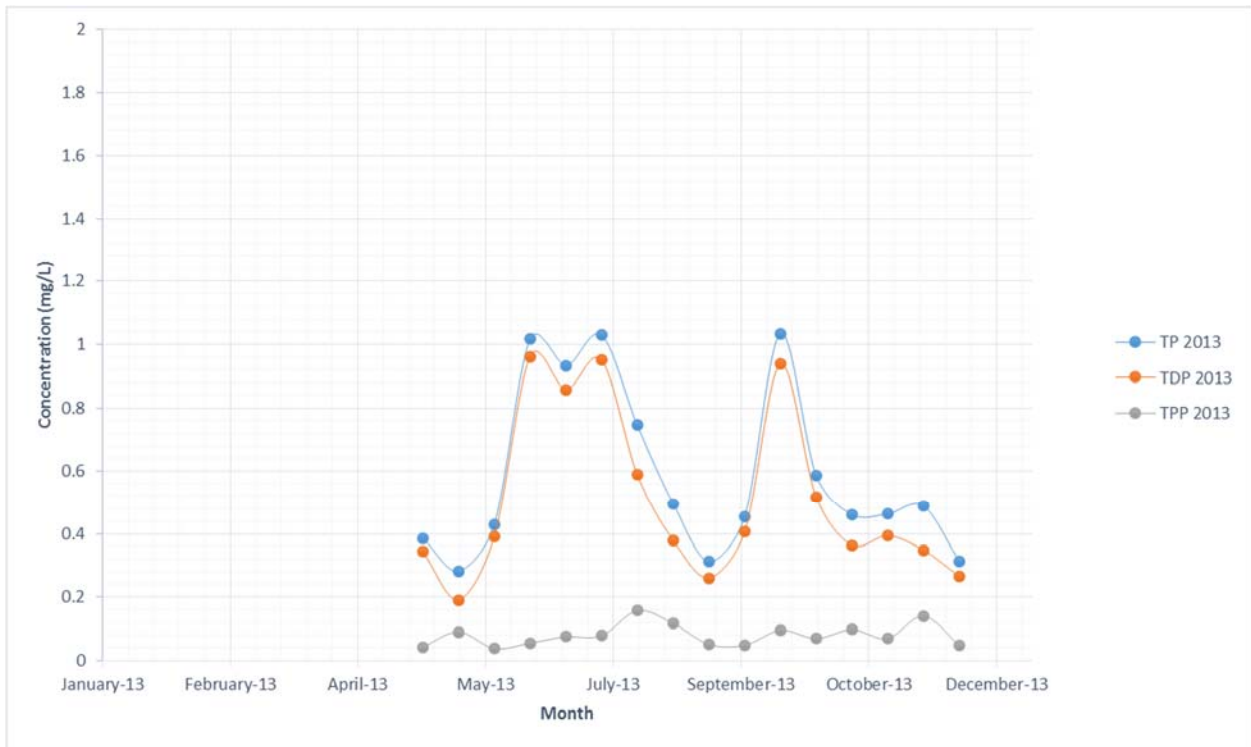


Figure 16c: TP, TDP and TPP Concentrations at EBWCD10 during 2013

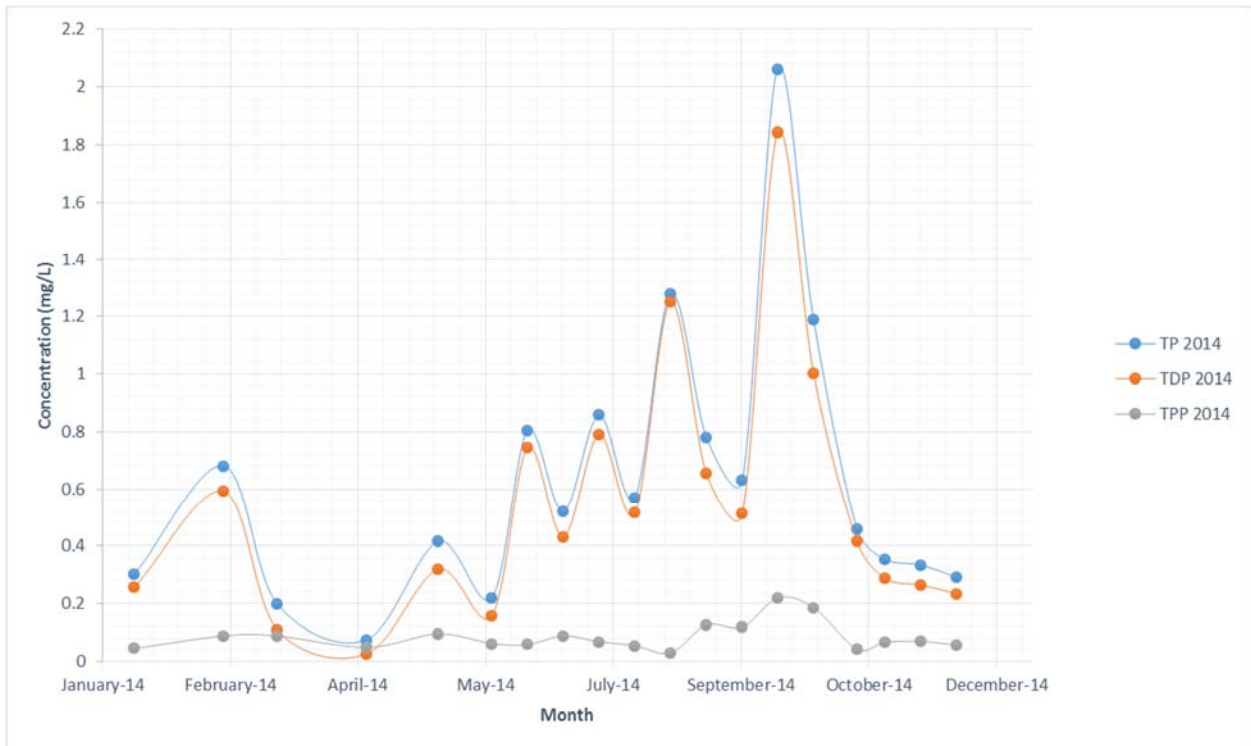


Figure 16d: TP, TDP and TPP Concentrations at EBWCD10 during 2014

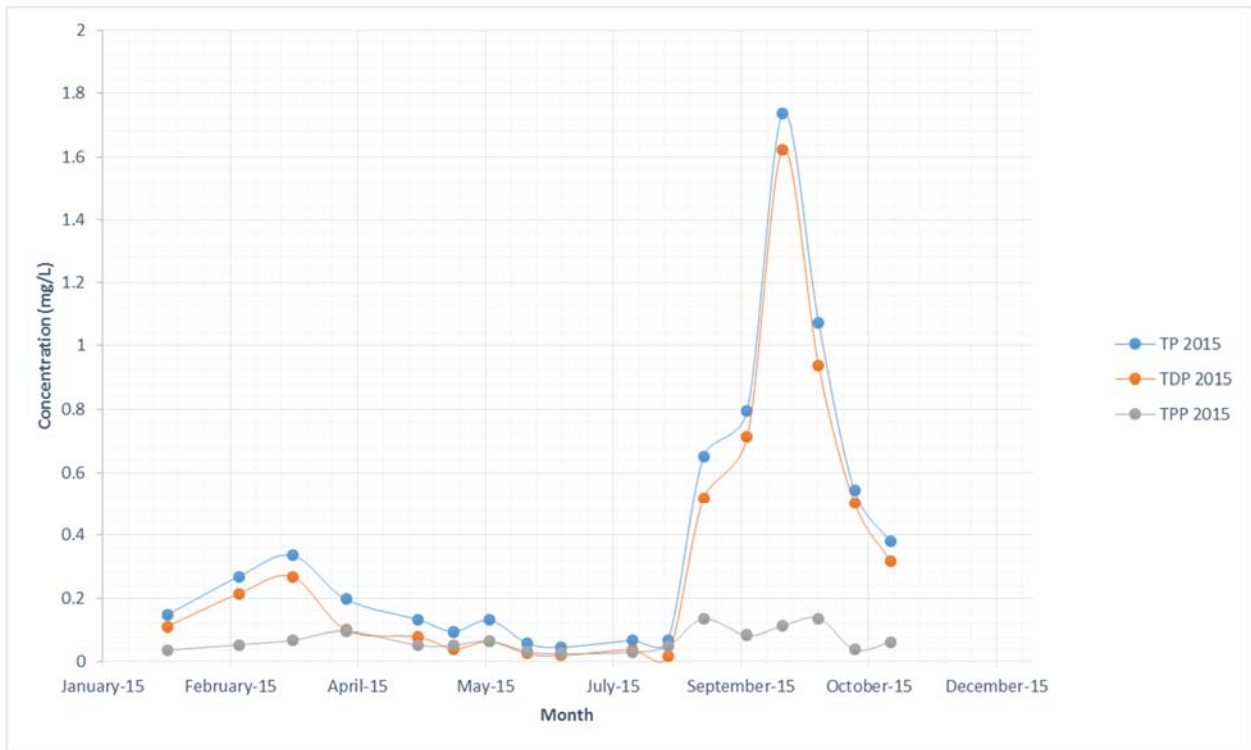


Figure 16e: TP, TDP and TPP Concentrations at EBWCD10 during 2015

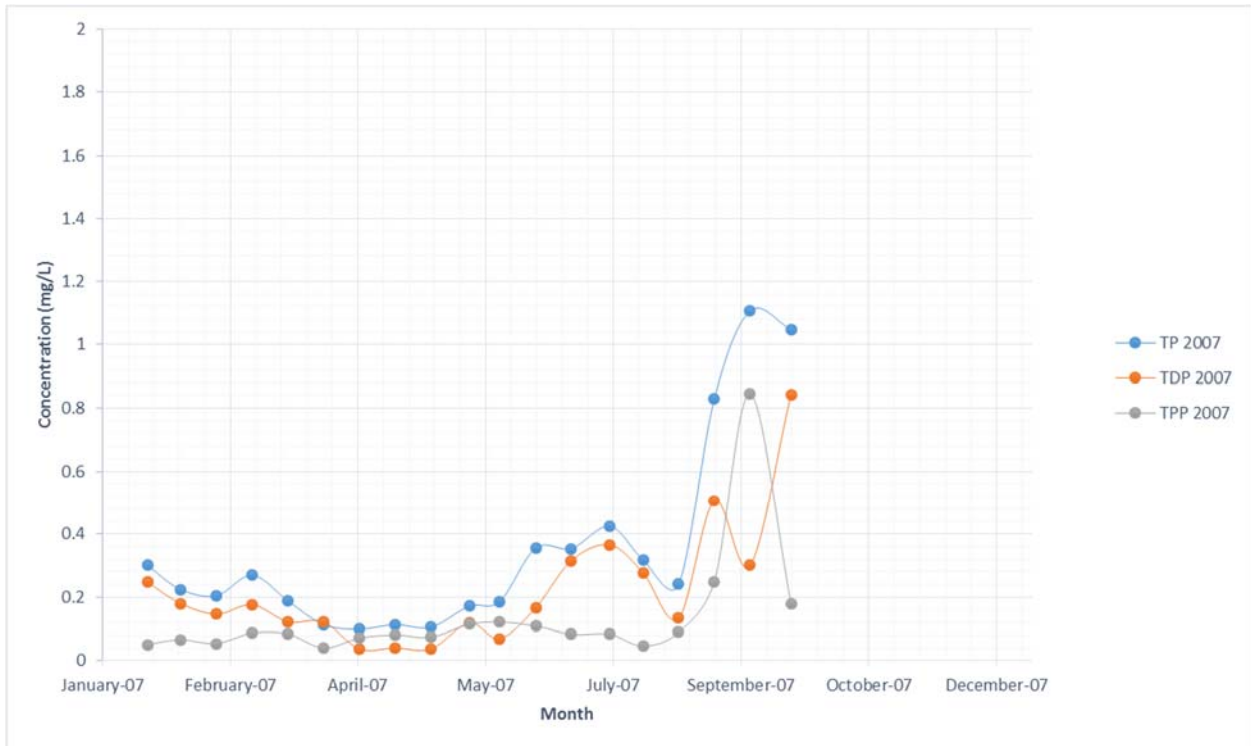


Figure 17a: TP, TDP and TPP Concentrations at EBWCD12 during 2007

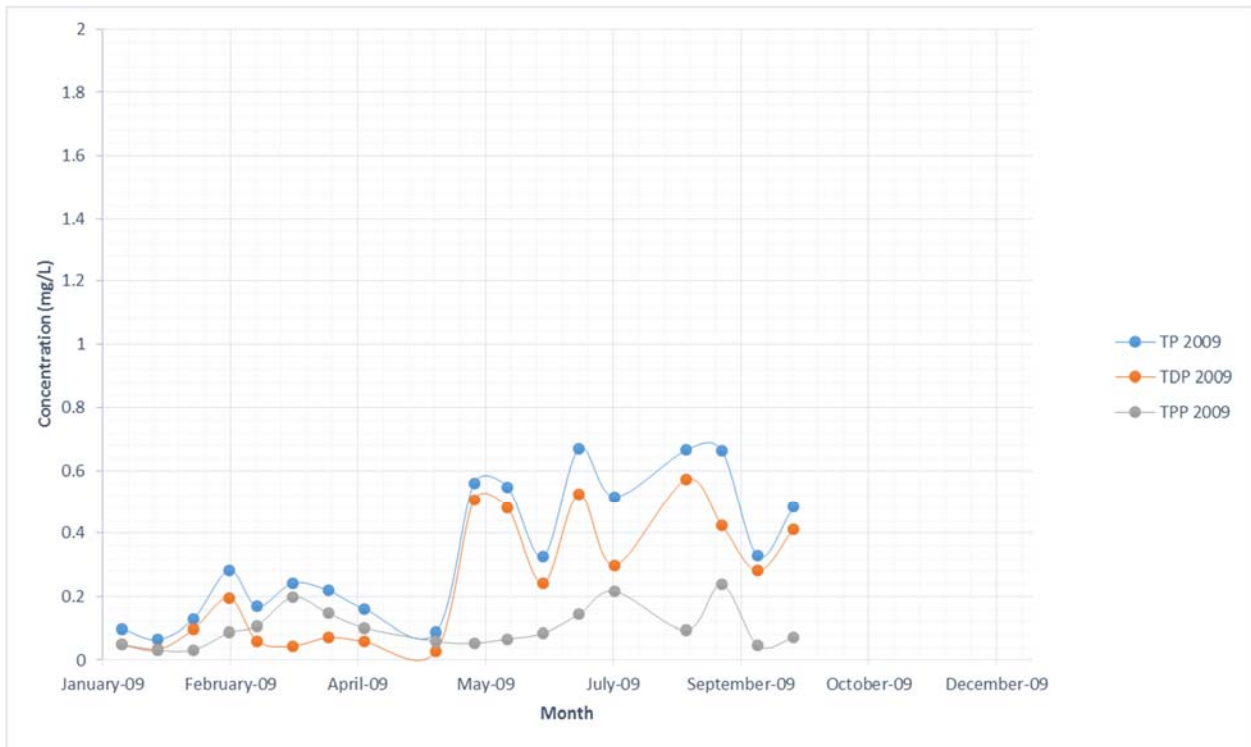


Figure 17b: TP, TDP and TPP Concentrations at EBWCD12 during 2009



Figure 17c: TP, TDP and TPP Concentrations at EBWCD12 during 2013

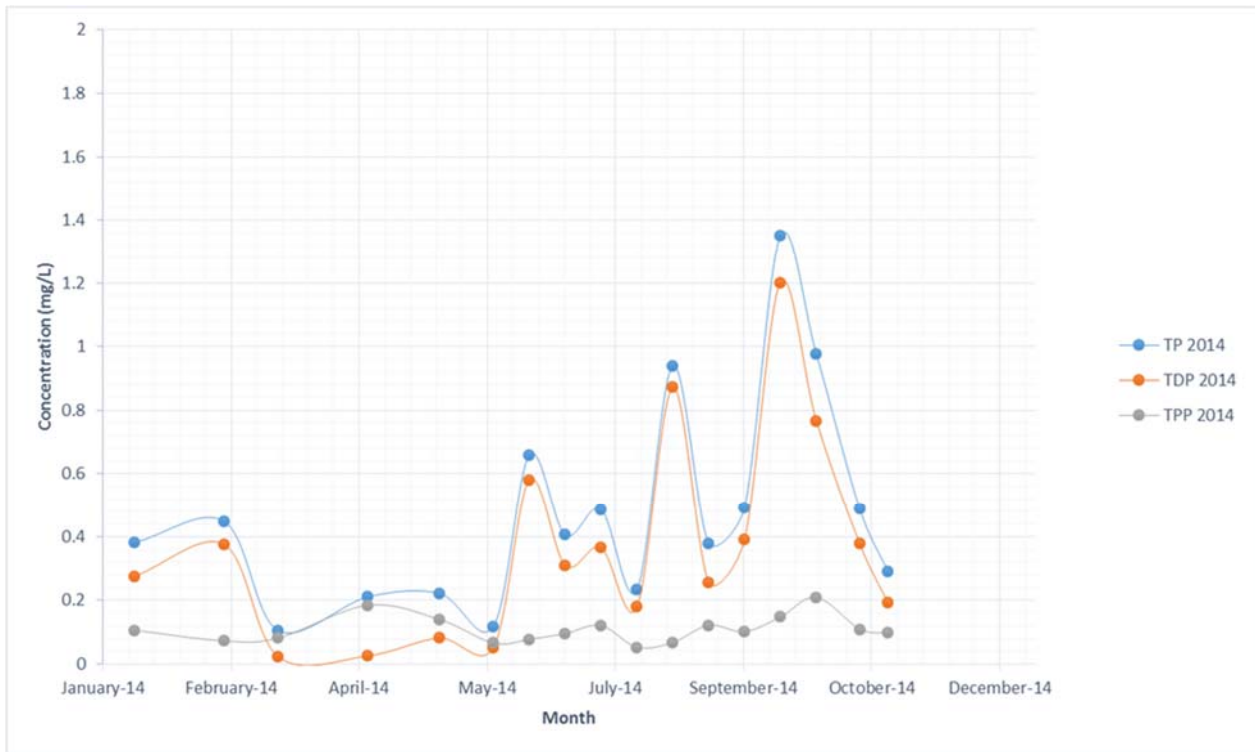


Figure 17d: TP, TDP and TPP Concentrations at EBWCD12 during 2014

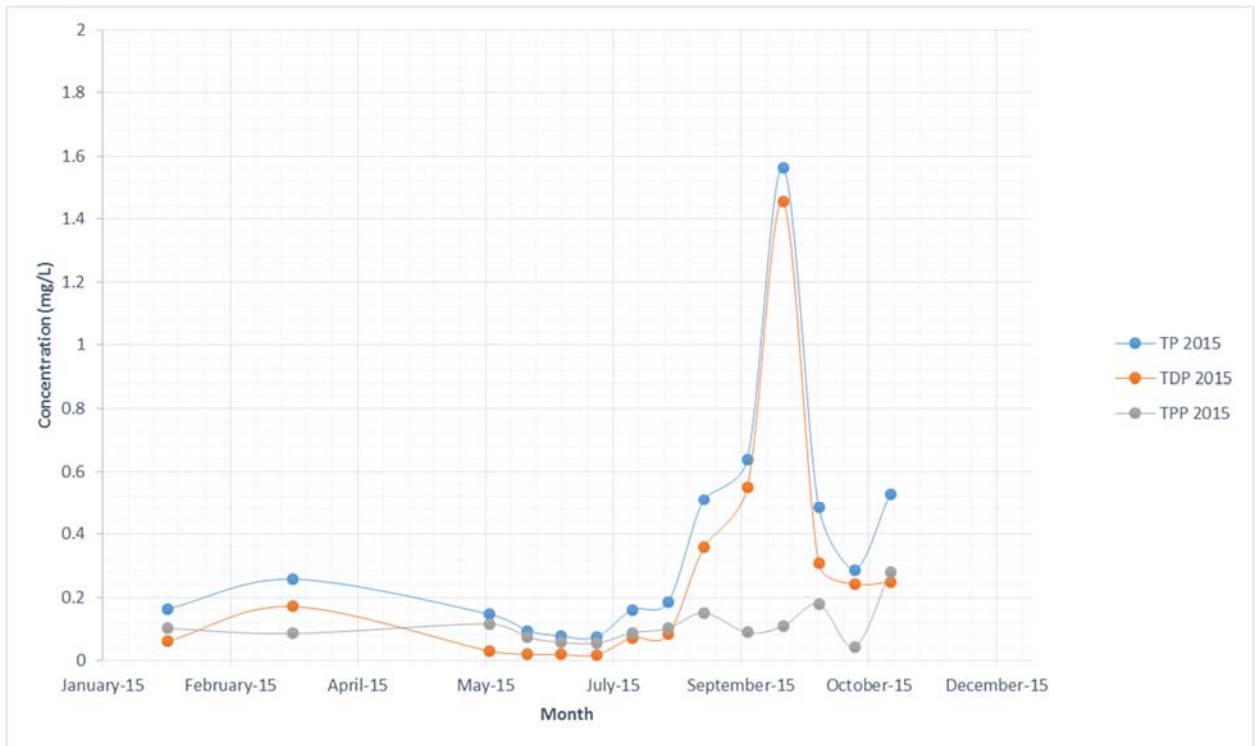


Figure 17e: TP, TDP and TPP Concentrations at EBWCD12 during 2015

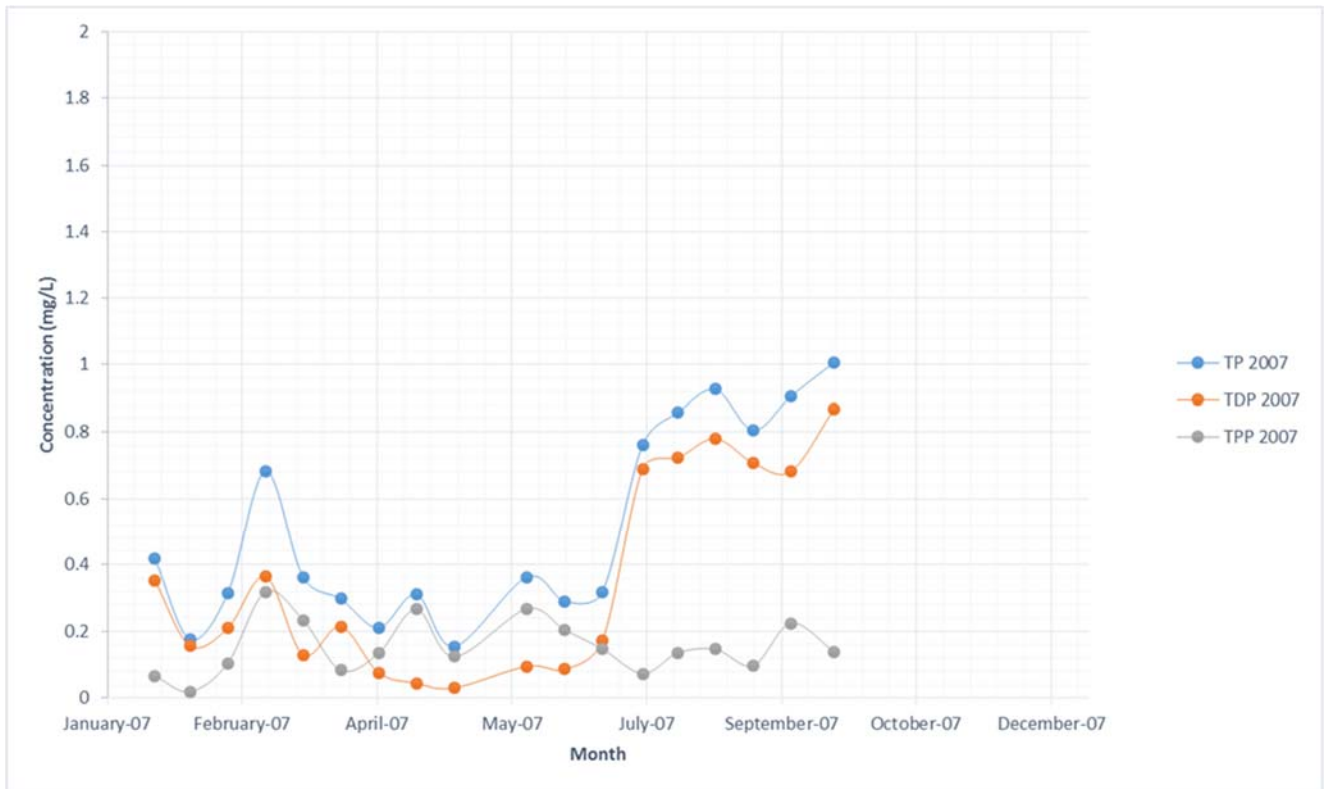


Figure 18a: TP, TDP and TPP Concentrations at EBWCD13 during 2007



Figure 18b: TP, TDP and TPP Concentrations at EBWCD13 during 2009

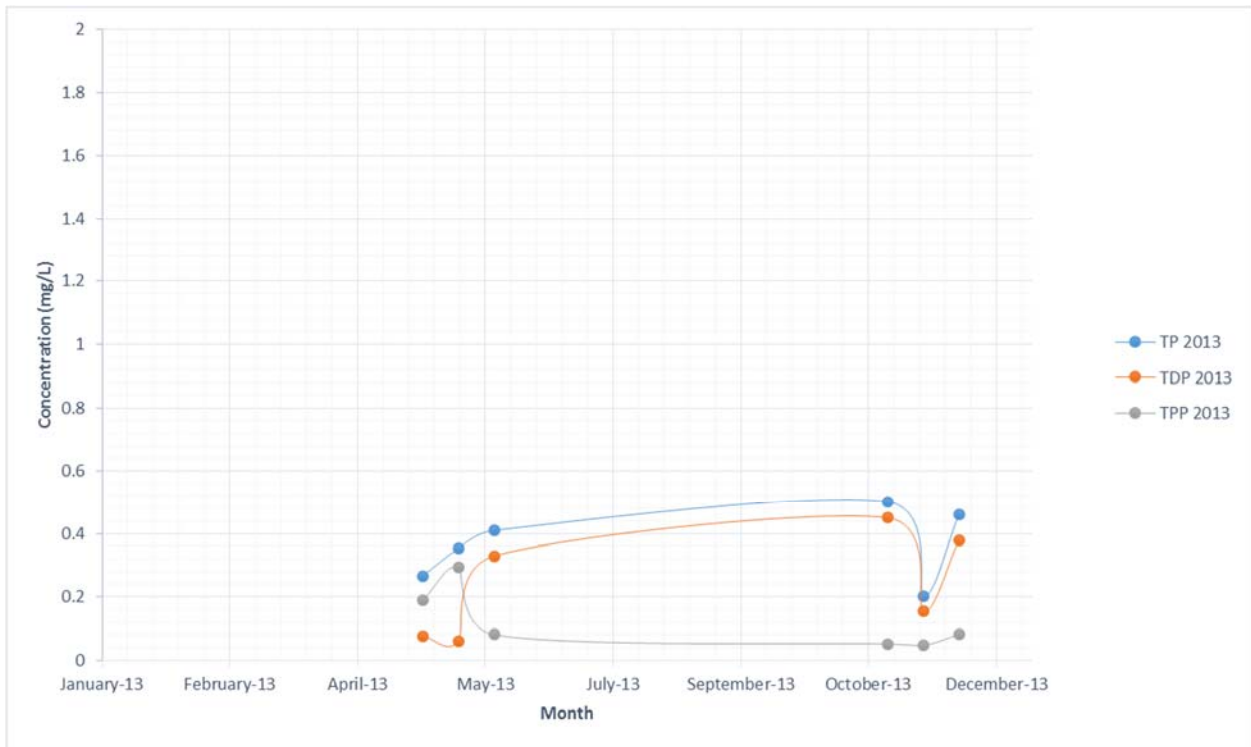


Figure 18c: TP, TDP and TPP Concentrations at EBWCD13 during 2013



Figure 18d: TP, TDP and TPP Concentrations at EBWCD13 during 2014

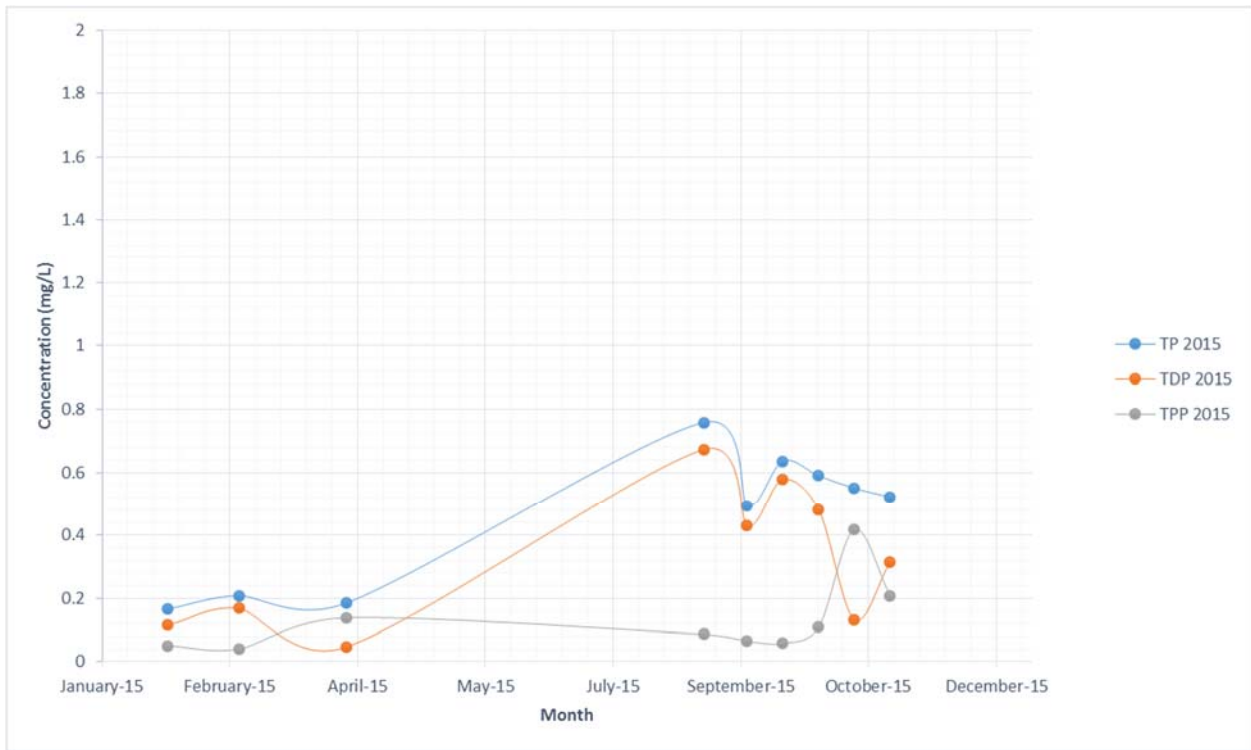


Figure 18e: TP, TDP and TPP Concentrations at EBWCD13 during 2015

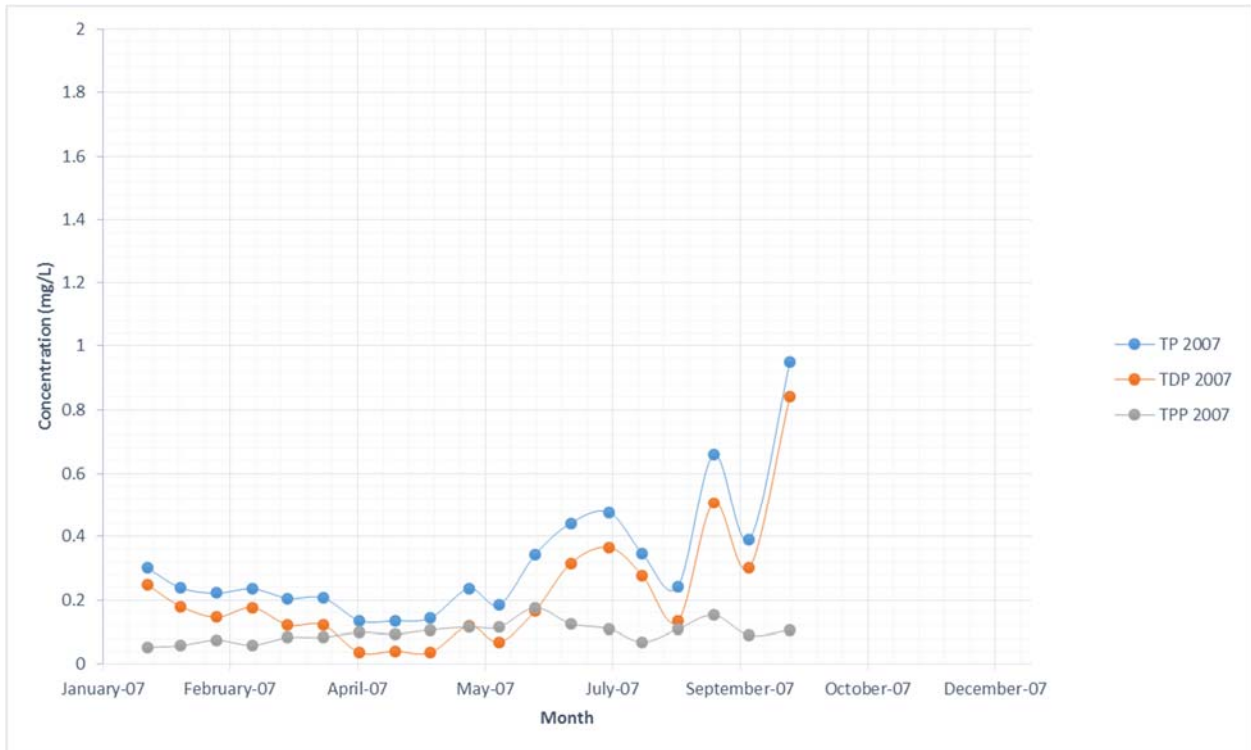


Figure 19a: TP, TDP and TPP Concentrations at EBWCD14 during 2007

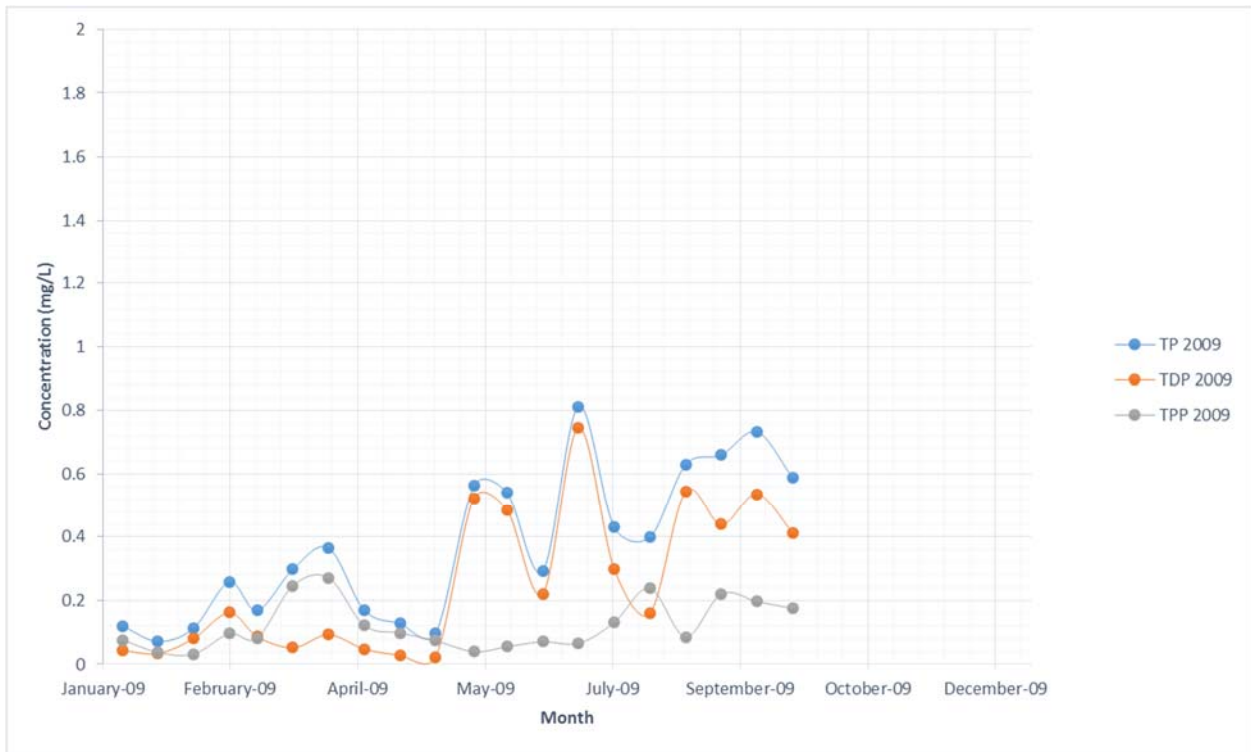


Figure 19b: TP, TDP and TPP Concentrations at EBWCD14 during 2009

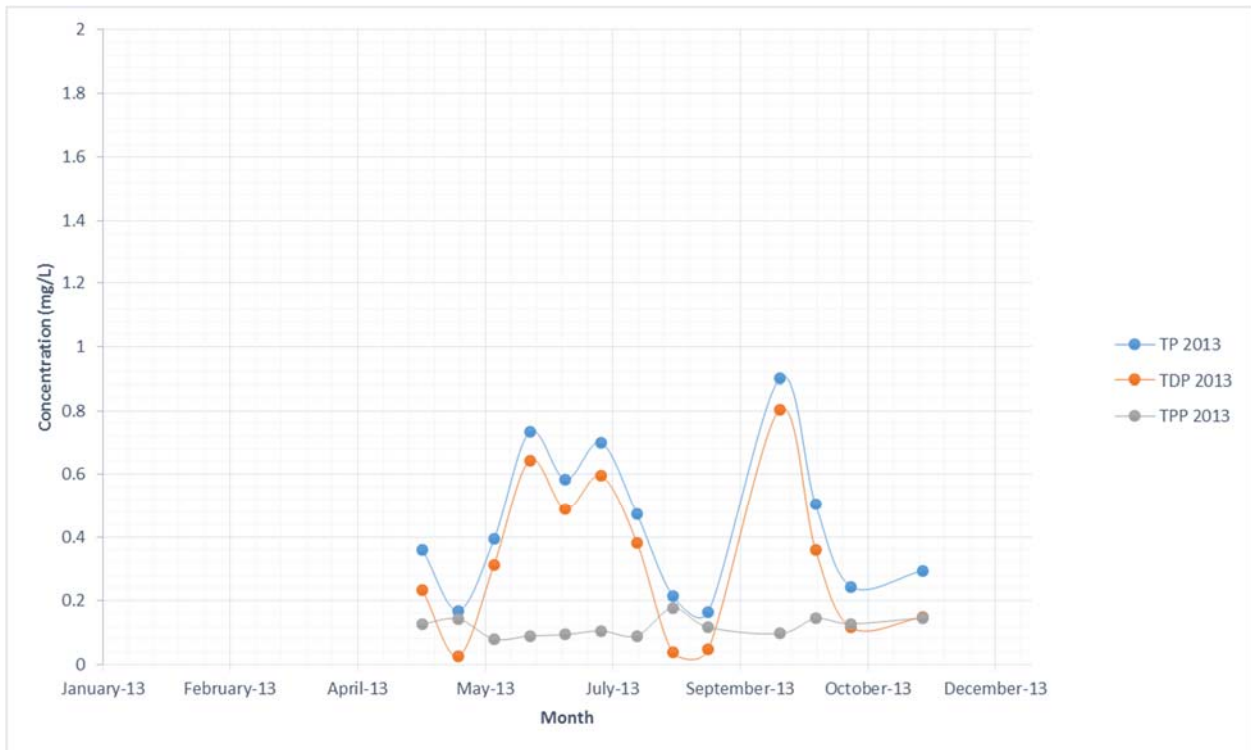


Figure 19c: TP, TDP and TPP Concentrations at EBWCD14 during 2013

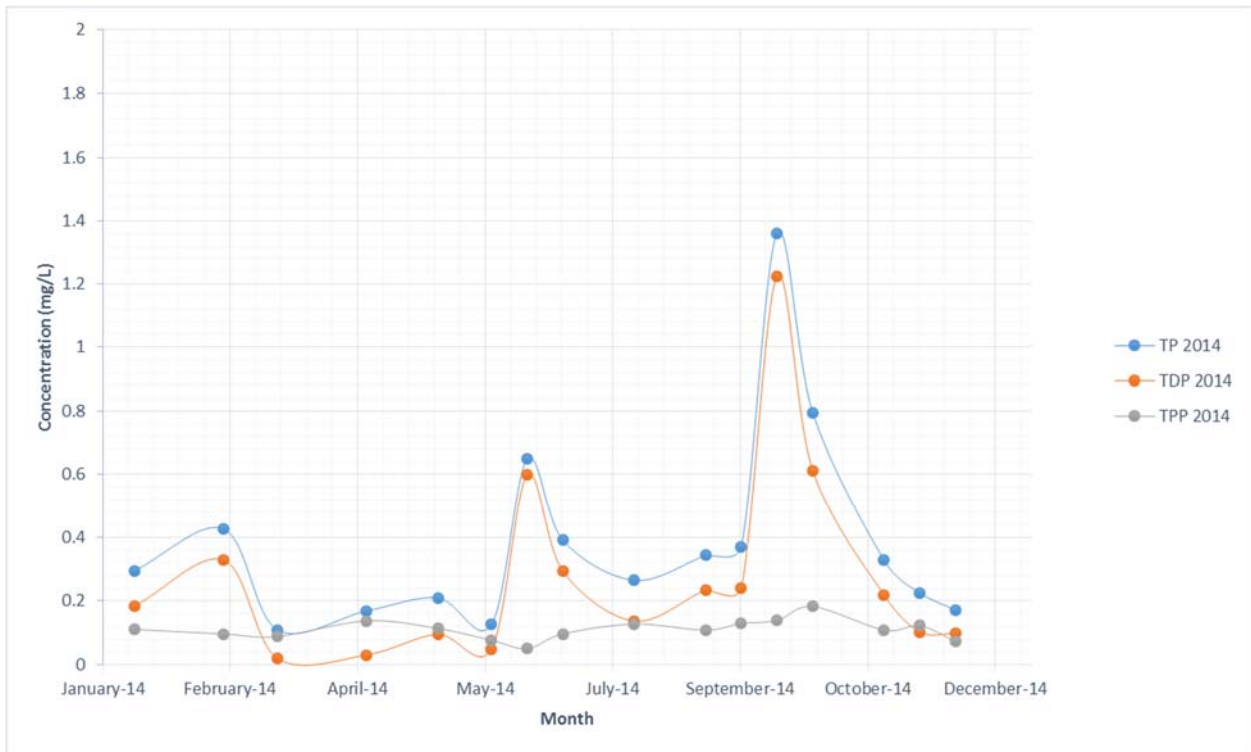


Figure 19d: TP, TDP and TPP Concentrations at EBWCD14 during 2014

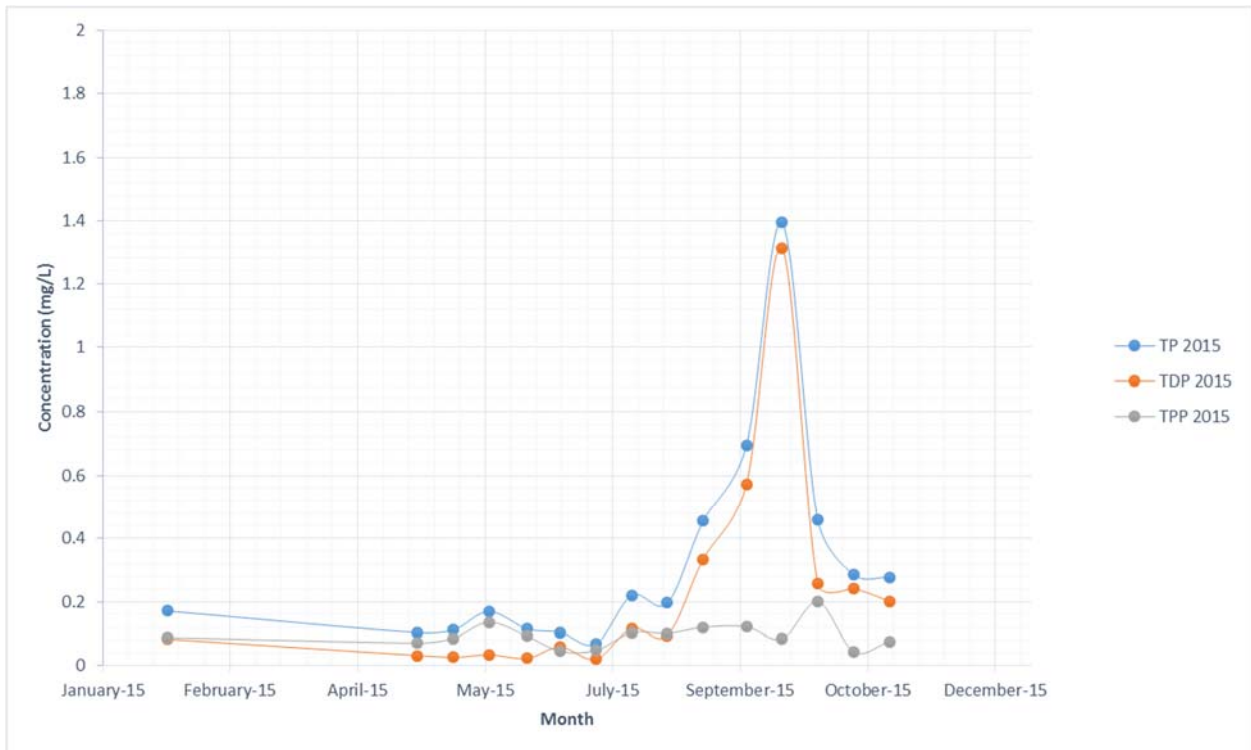


Figure 19e: TP, TDP and TPP Concentrations at EBWCD14 during 2015

Water quality data at the upstream monitoring stations and at EBWCD offsite pump station EBPS3 during calendar year 2015 were compared to glean potential relationships. Calendar year 2015 was selected as it was the period that offered the more robust dataset for all stations and represented relatively recent data. For reference, a flow schematic among the upstream stations and EBPS3 is depicted in **Figure 20** depicts a. As shown in the figure, while there are surface water runoff tributaries in-between the stations, EBWCD14 is located at the headwaters of the EBWCD outfall canal and there are no inflows to this canal downstream of that location.

As a start, available grab TP concentrations collected at EBPS3 and EBWCD14 were compared as shown in **Figure 21a**. TP concentrations at both stations behaved similarly and levels at EBPS3 were lower than at EBWCD14 for periods when grab data were available. This was particularly noticeable during a higher TP concentration measurement in September 2015. TP concentration data were not available for EBWCD14 during some dry season months.

Grab TDP data at EBWCD14 were also reviewed side by side with grab OPO4 data at EBPS3. These different constituents were compared because OPO4 data were not collected at EBWCD14, and TDP data were not collected at EBPS3 during 2015. While both constituents are not the same, OPO4 generally represents a substantial fraction of TDP in runoff. TDP at EBWCD14 and OPO4 at EBPS3 behaved similarly as TP during 2015 (see **Figure 21b**). Accordingly, TPP data at EBWCD14 were plotted side by side with non-OPO4 data at EBPS3 and the scale of the concentration axis was increased to observe potential relationships (**Figure 21c**). While there appears to be potential attenuation of TP and TDP/OPO4 between EBWCD14 and EBPS3, additional water quality monitoring data for TDP and OPO4 may shed light on sub-regional project opportunities for better attenuating TPP and TP in the outfall canal.

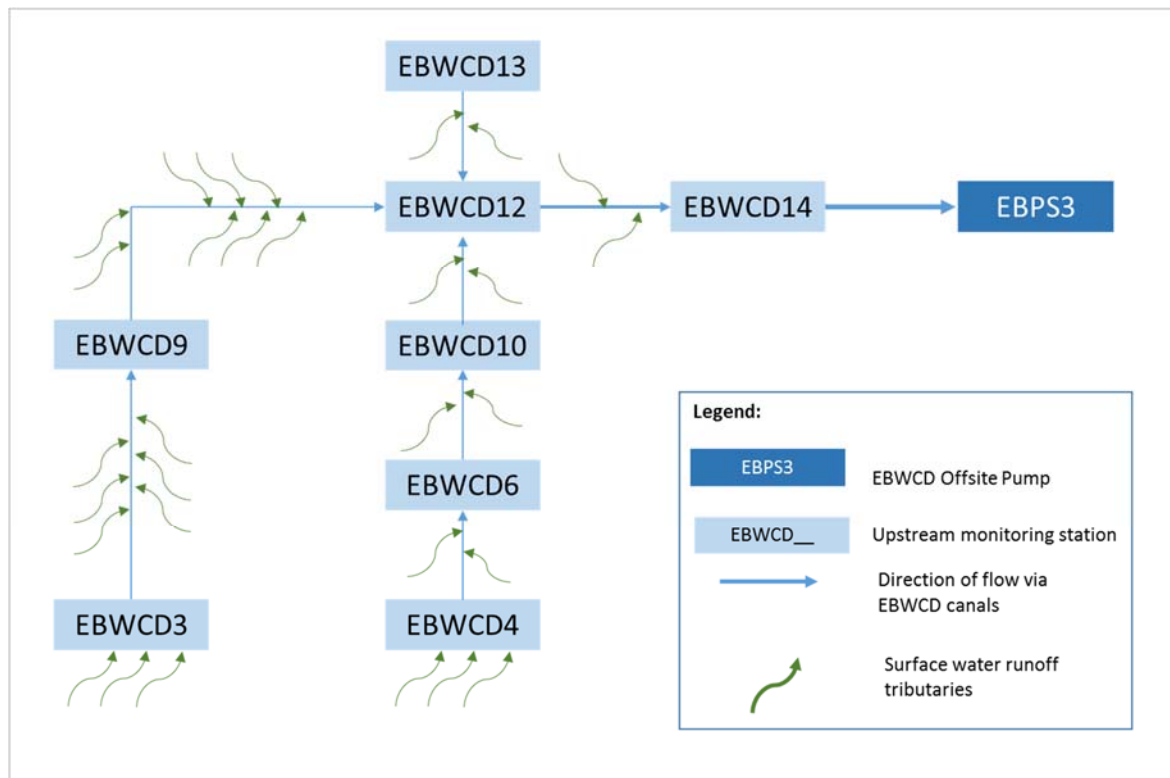


Figure 20a: EBWCD Flow Schematic



Figure 21a: TP Grab Samples at EBPS3 and EBWCD14

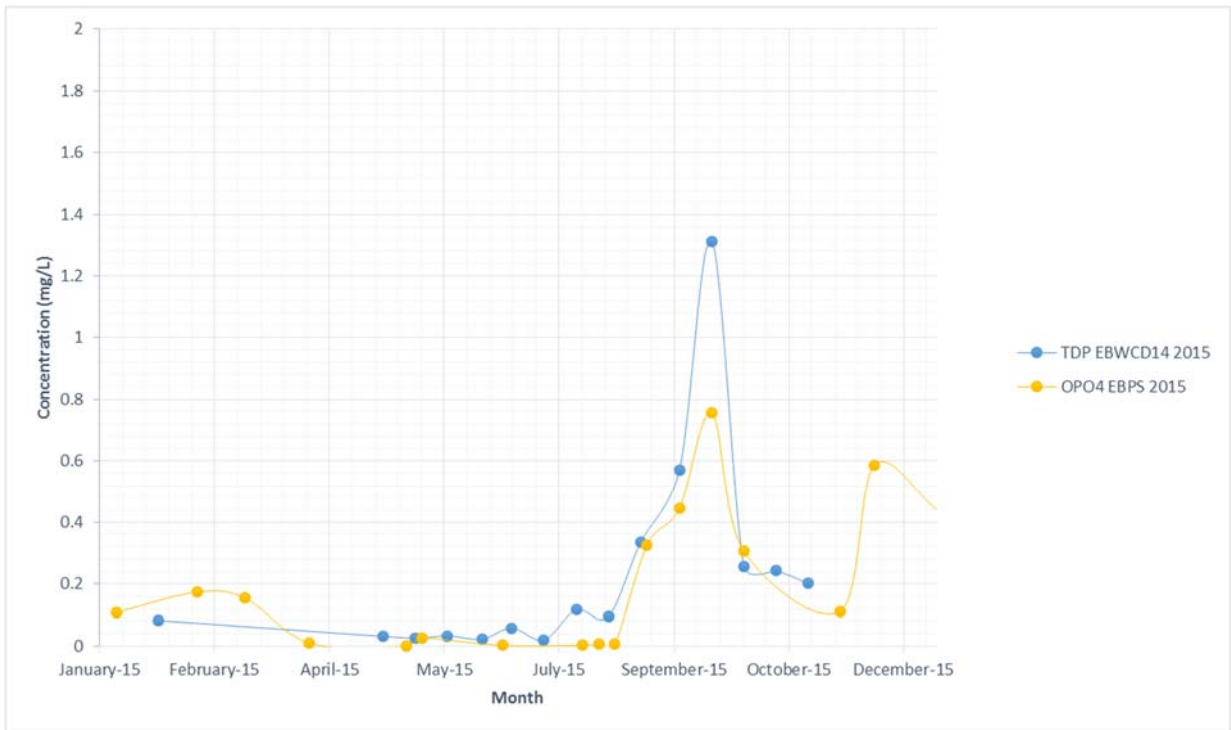


Figure 21b: OPO4 Grab Samples at EBPS3 and TDP Grab Samples at EBWCD14



Figure 21c: Non-OPO4 at EBPS3 and TPP at EBWCD14

To glean the potential effects of upstream stations on EBWCD discharges, TP concentrations collected via grab sampling at upstream synoptic monitoring stations were plotted together with TP load discharged offsite during flow events at EBPS3. TP load at EBPS3 was based on weekly-composite autosampler TP concentrations. In reviewing these data, we must consider that TP grab concentrations at upstream stations may not capture all conditions resulting in discharge events at EBPS3. This is because grab sample collection is based on a weekly collection regime that provides a snapshot of TP concentration, while flow-triggered autosampler provides representative TP concentration (and load) during a discharge period. For example, **Figure 22** compares grab TP concentrations at EBPS3 against autosampler-based data collection at the same location.

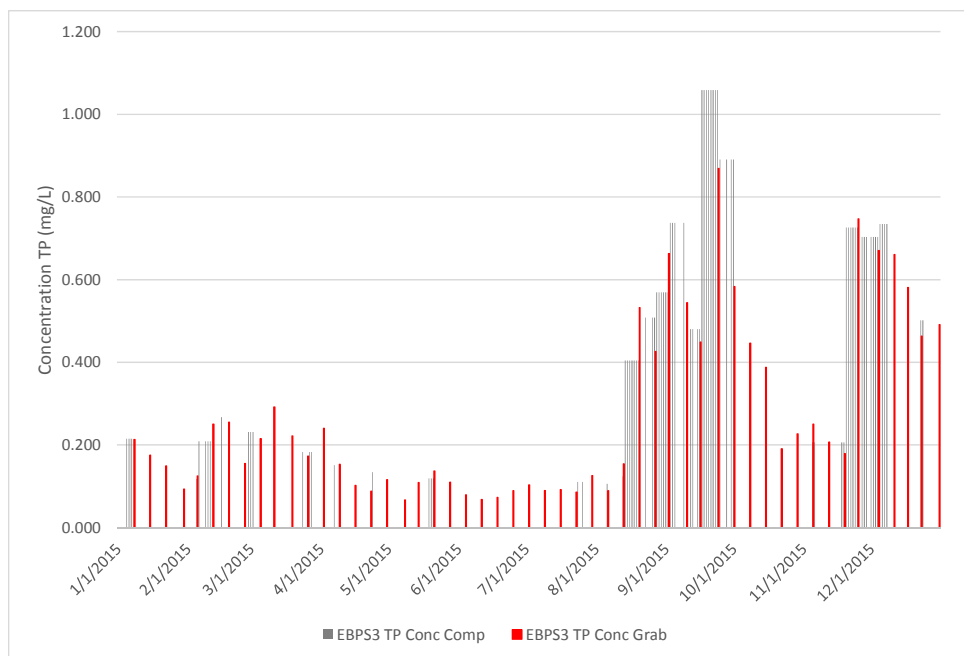


Figure 22: Grab and Autosampler TP data at EBPS3

Except for December 2015, for which upstream station data are not available, **Figures 23a to 23h** depict that the highest TP concentrations at upstream stations were concurrent with months when the majority of TP load at EBPS3 was observed. However, when TP concentration data are contrasted among the stations, those having the highest TP concentrations concurrent with the highest TP load from EBPS3 are EBWCD14 (**Figure 23a**), EBWCD12 (**Figure 23b**), and EBWCD10 (**Figure 23c**). EBWCD13 (**Figure 23d**) and EBDWCD9 (**Figure 23e**) show relatively lower TP concentrations. EBWCD06 (**Figure 23f**) is characterized by having less TP concentration events reported, although elevated TP concentrations were also observed during the peak TP load discharge event at EBPS3. Regarding EBWCD03 (**Figure 23g**) and EBWCD04 (**Figure 23h**), which also reported relatively higher TP concentrations, they may not have the same effect on EBPS3 load as other stations: EBWCD03 is upstream of EBWCD09 which showed relatively lower concentrations, and EBWCD04 which is upstream of station EBWCD06. Some attenuation may be provided within the EBWCD canal system. Continuing water quality and flow monitoring at upstream monitoring locations within EBWCD, as well as sub-basin hydrologic delineation would provide insight on transport mechanisms and priority areas for subregional projects.

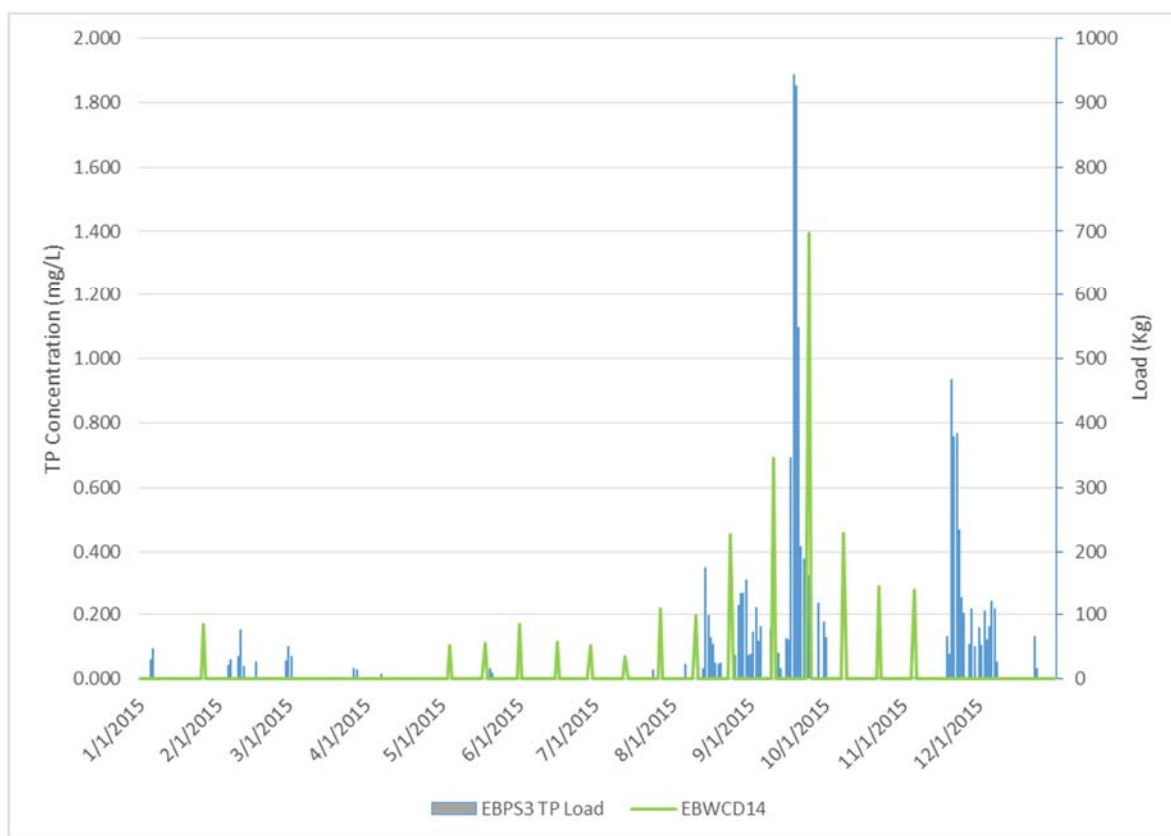


Figure 23a: EBWCD14 TP Concentration and TP Load at EBPS3

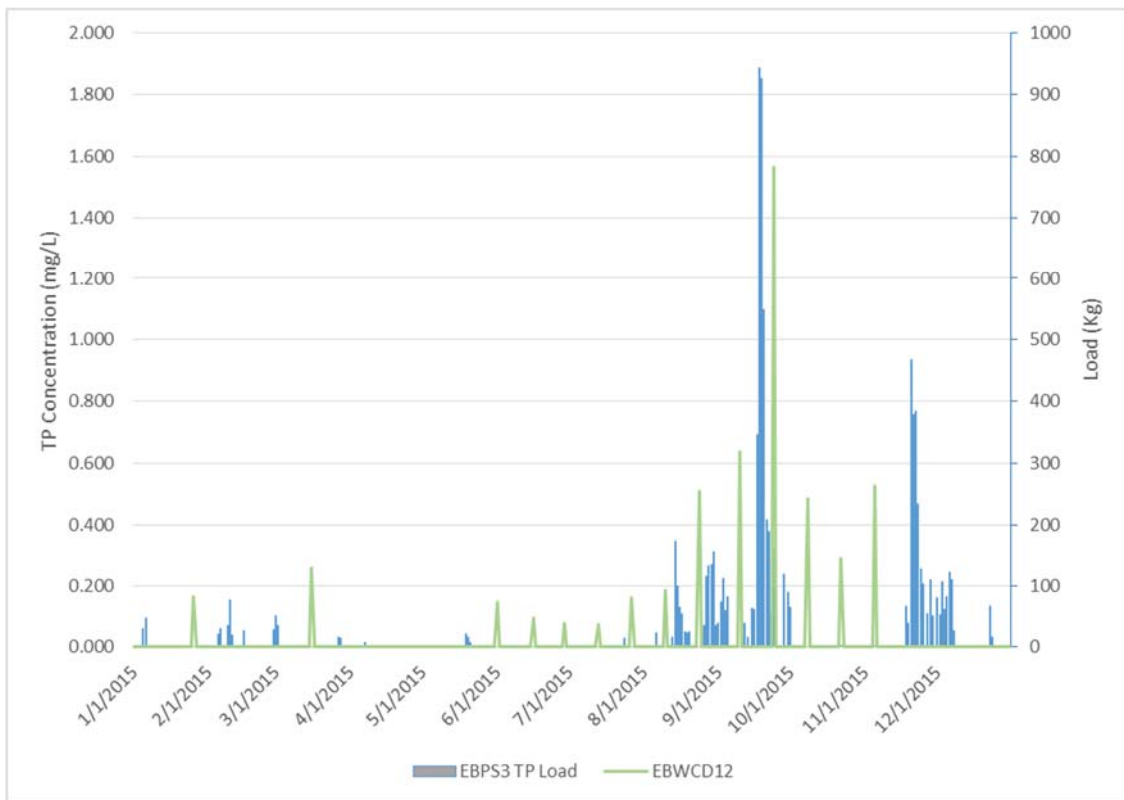


Figure 23b: EBWCD12 TP Concentration and TP Load at EBPS3

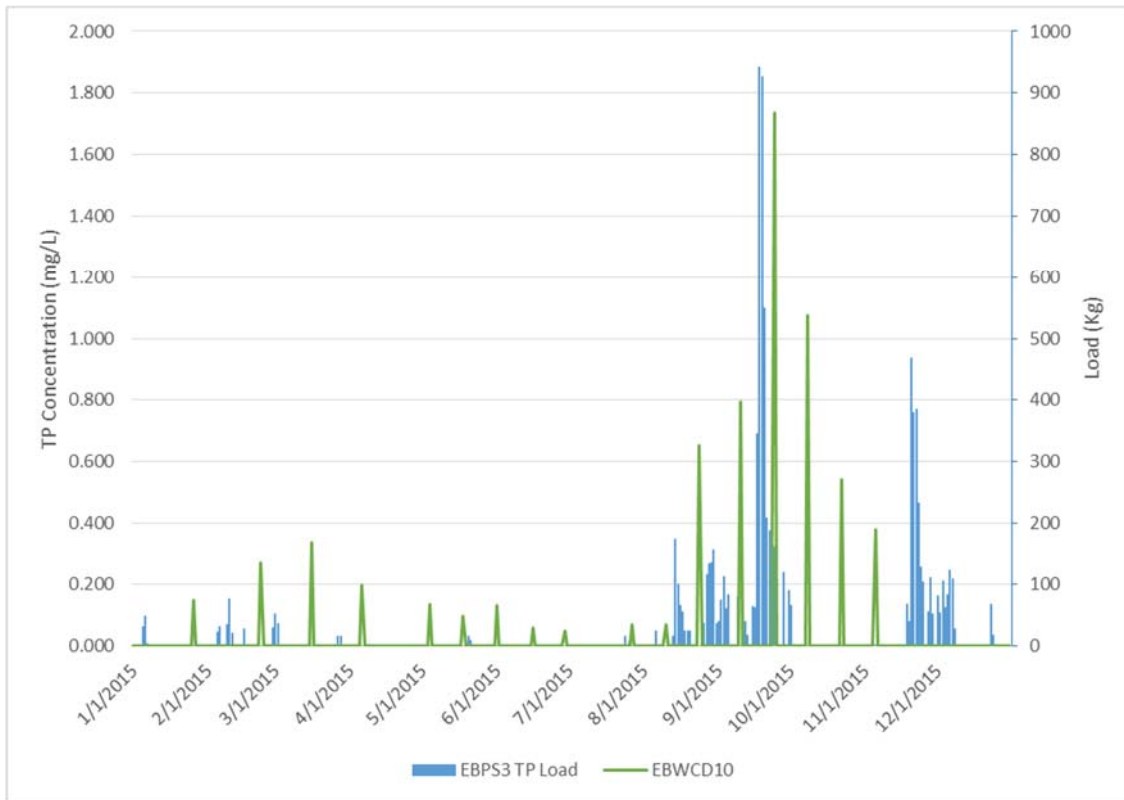


Figure 23c: EBWCD10 TP Concentration and TP Load at EBPS3

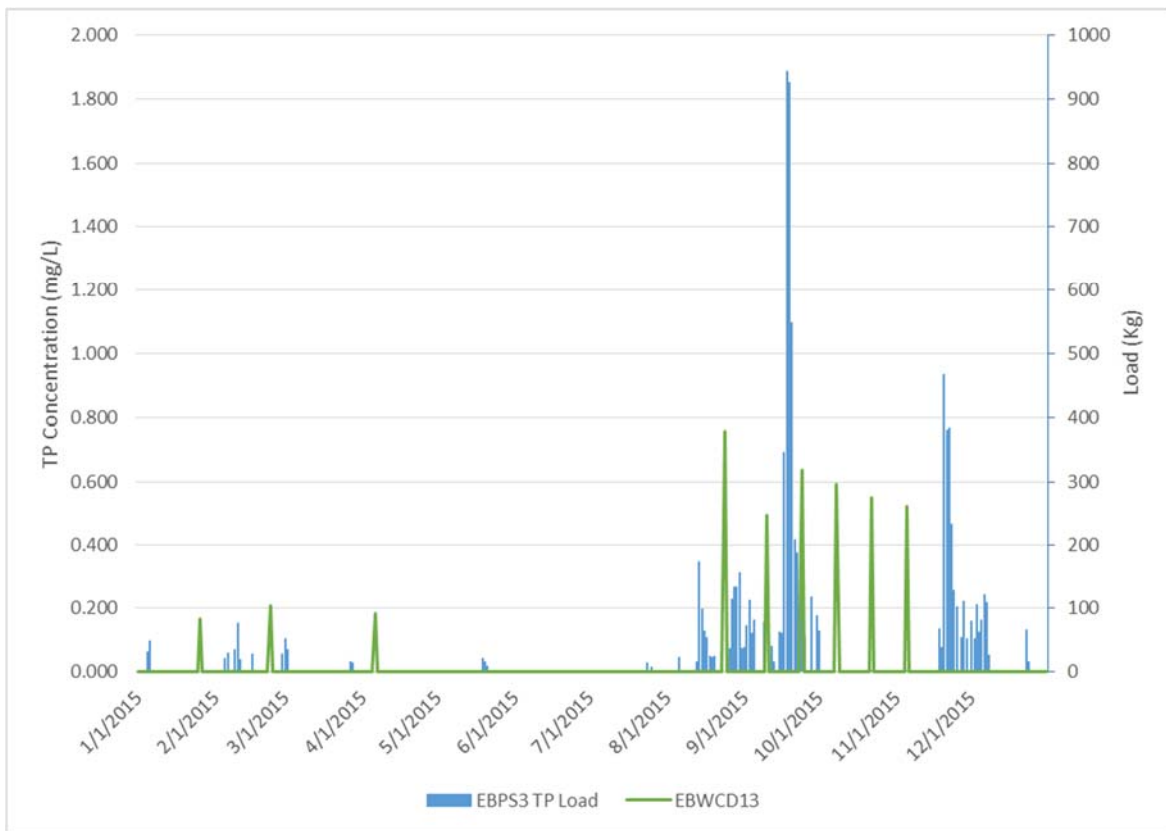


Figure 23d: EBWCD13 TP Concentration and TP Load at EBPS3

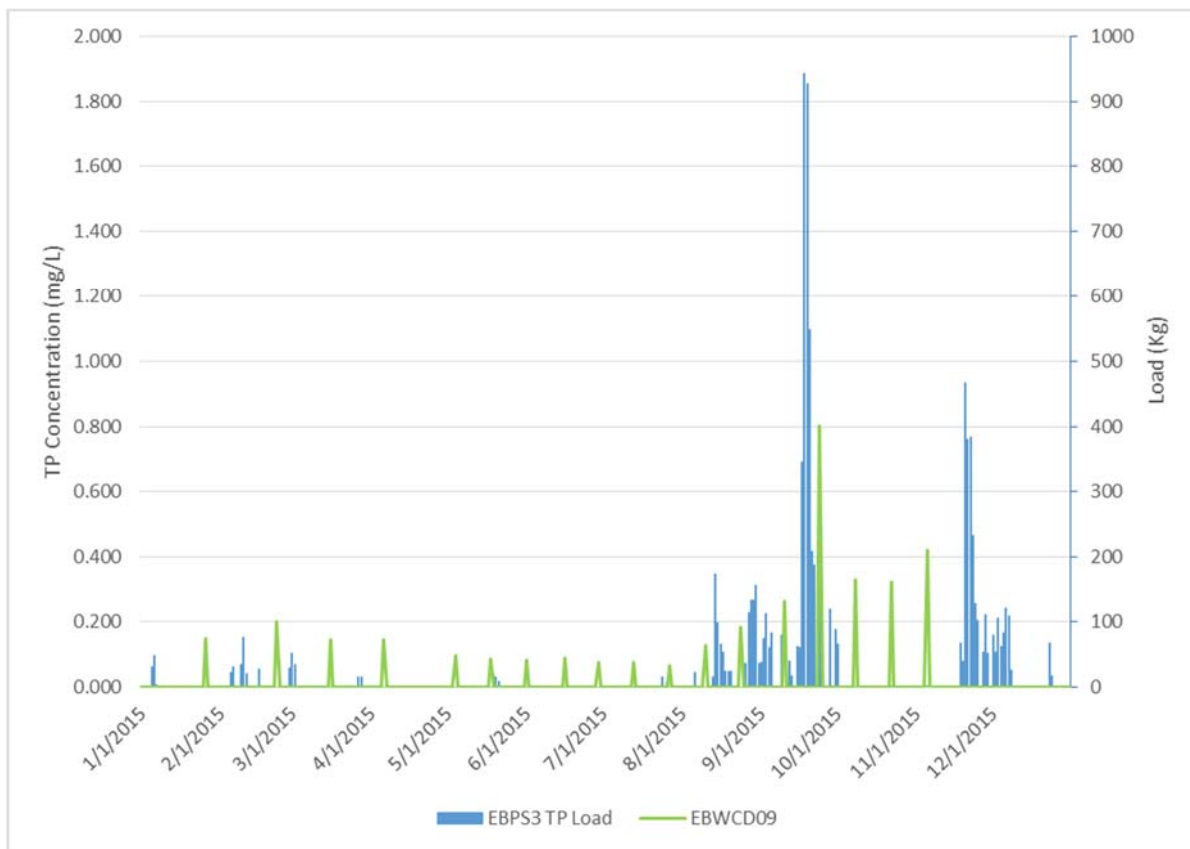


Figure 23e: EBWCD09 TP Concentration and TP Load at EBPS3

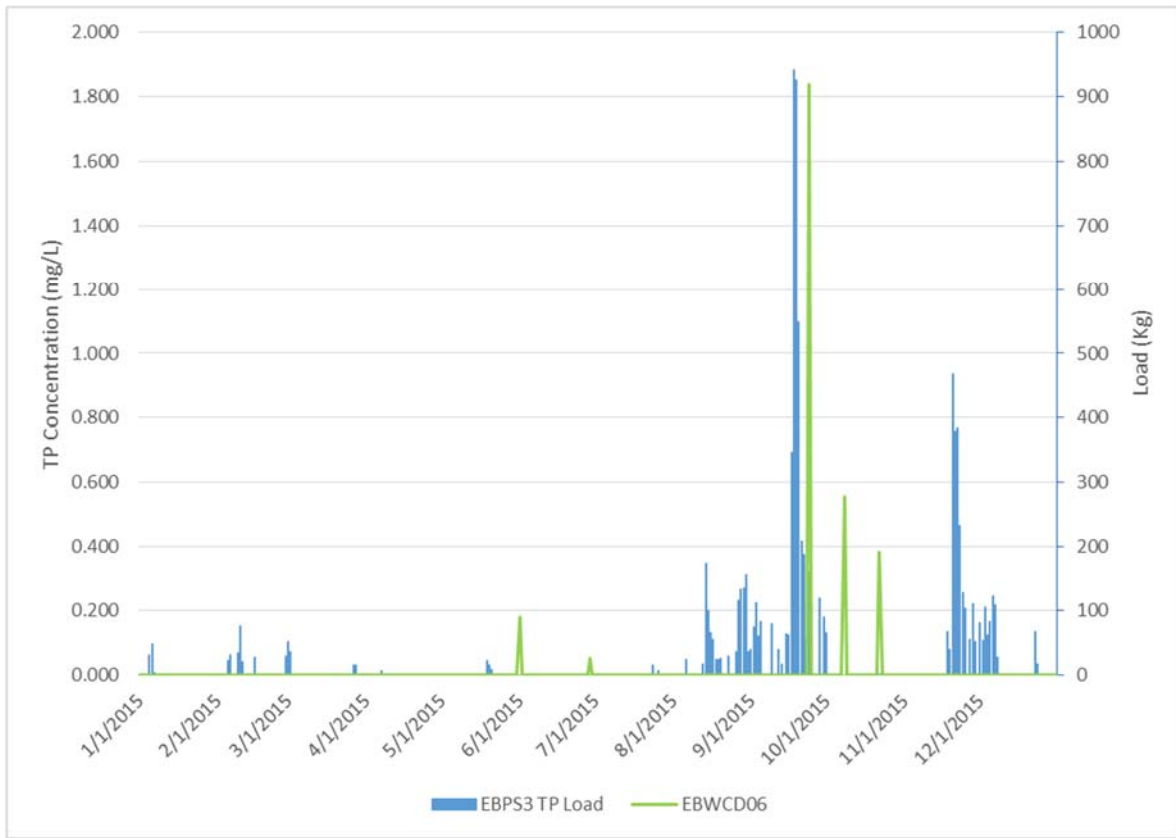


Figure 23f: EBWCD6 TP Concentration and TP Load at EBPS3

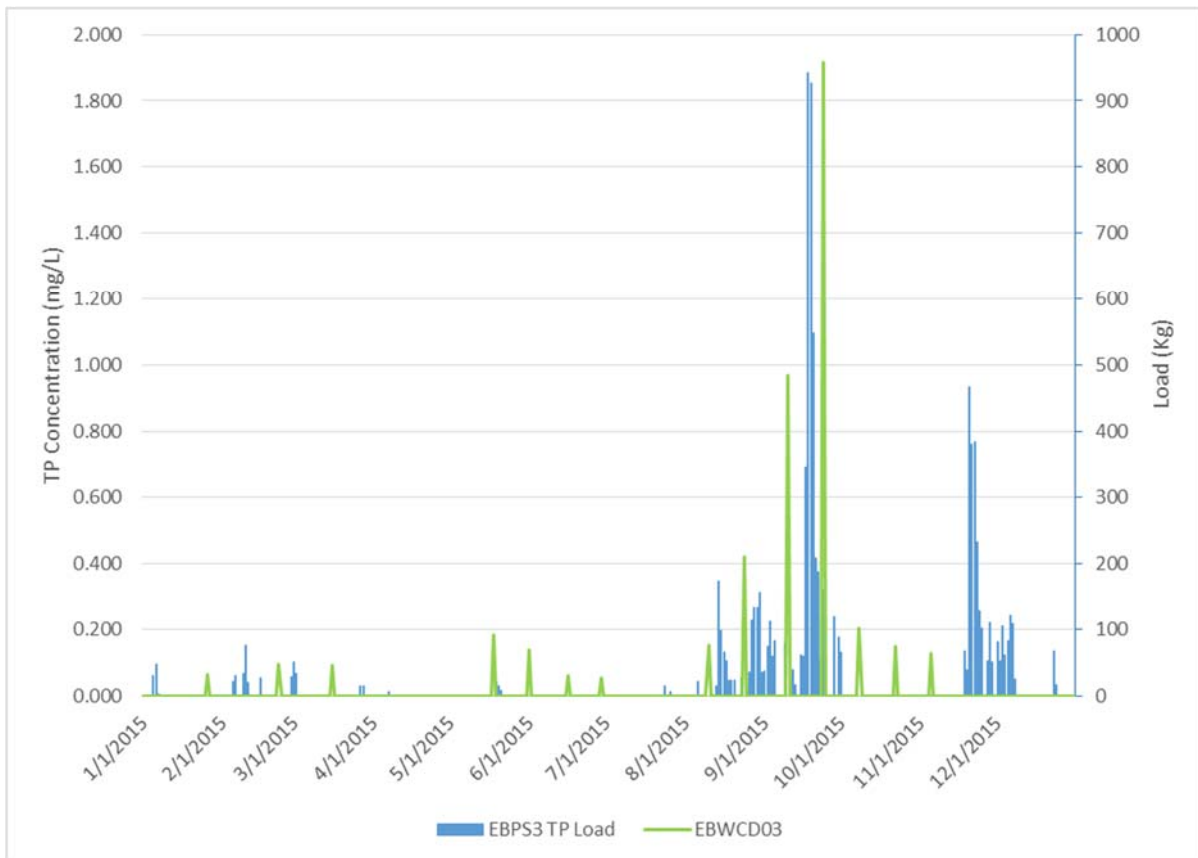


Figure 23g: EBWCD3 TP Concentration and TP Load at EBPS3

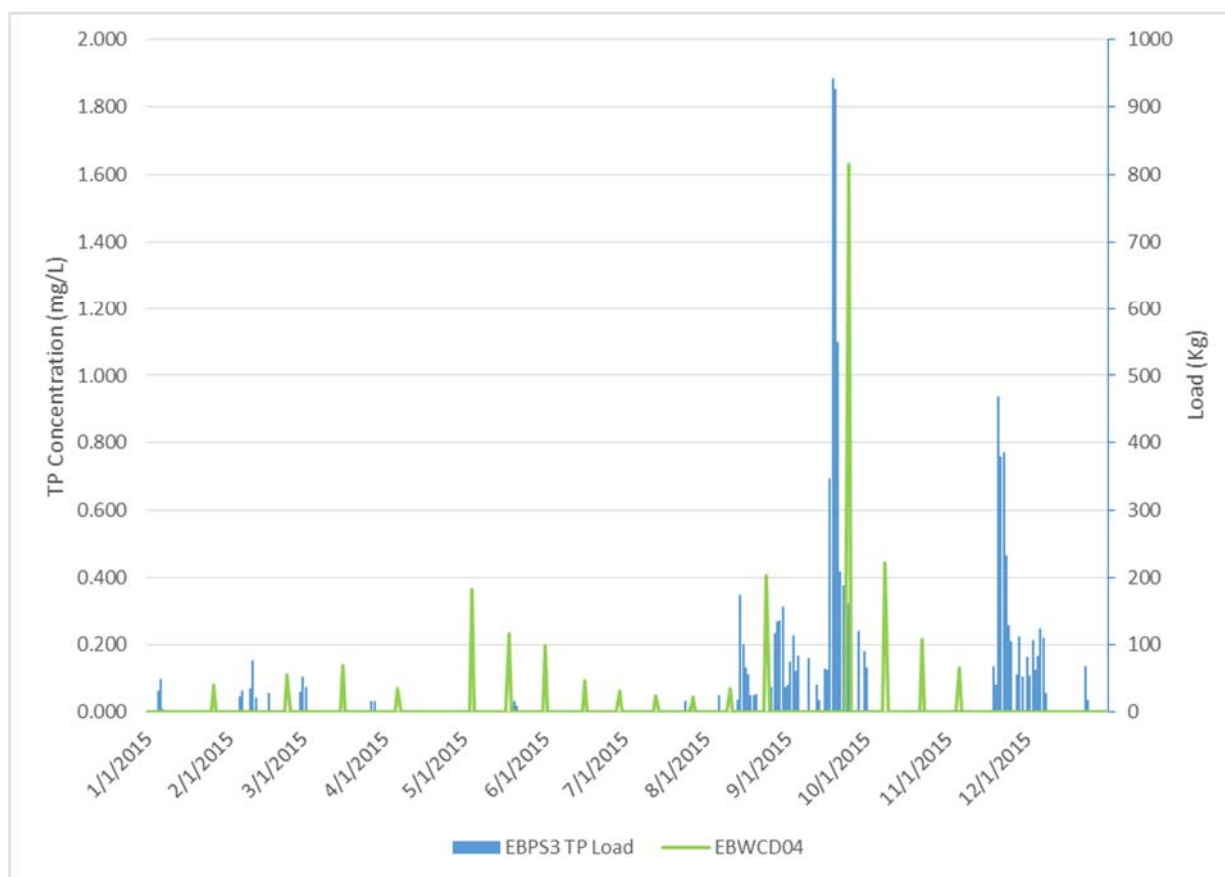


Figure 23h: EBWCD4 TP Concentration and TP Load at EBPS3

4.2 Statistical Analysis

Historic water quality data collected at eight upstream stations from January 2007 to September 2007, and from January 2009 to September 2009, were compared with the data collected from May 2013 to November 2015, concurrent with the comprehensive canal cleaning project. These data are presented in **Tables 5** through **7**. Higher levels of TDP than TPP were noted in 2007 (FAU, 2008) and continued based on the upstream station data collected in calendar years 2009, and 2013 through 2015. Additionally, there was generally an increase in TDP and TP based on the data collected in 2007 and 2009, and the data collected from 2013 through 2015. From 2013 through 2015, however, TPP stayed at or below historic levels.

Figures 24 through **26** are a series of box and whisker plots that illustrate the distribution of values measured for all 15 upstream synoptic monitoring stations. Box and whisker plots of the composite data from the eight stations for the wet and dry seasons of each water year are presented in **Figures 33** and **34**. The plots describe the upper and lower quartiles, the minimum and maximum values, and the median value for the data set. The box plots show higher concentrations and greater overall variability in measurements during the wet season.

The rainfall depths and flow volumes for the years being compared are presented in **Figure 35** and **36**. Except for 2014, these years were drier than the 30-year average rainfall at EBPS3. The calendar year rainfall totals for 2007, 2009, 2013, 2014, and 2015 are 41.1, 44.9, 41.1, 44.3, and 46.8 inches. **Figure 36** illustrates the average monthly flow rate at EBPS3 for these years. In general, 2007 and 2009 had less flow than 2013-2015.

Tables 8 through 13 and Figures 27 to 32 present other constituents monitored at the upstream stations. The FAU Water Quality Synoptic Survey Data Analysis for East Beach Water Control District study (FAU, 2008) indicated several co-pollutants found in the phosphorus sources located in EBWCD. They identified that landfill leachate can be characterized by enrichment with COD, TDS, ammonia, and trace metals. The study stated that agricultural runoff can be characterized by nitrogen isotopic ratios indicative of fertilizer application, and by enrichment with arsenic, pesticides, a high nitrate to ammonia ratio, and a high particulate phosphorus to dissolved phosphorus ratio. Additionally, they indicated that rock pit mining activities typically add fluoride and ammonia in the waste stream, and that wastewater sources can be characterized by their biological markers.

High measured levels of ammonia at the EBWCD13 monitoring station (see **Figure 38**) may indicate landfill leachate entering the canal from the City of Pahokee Incinerator and Ash Landfill, and the Solid Waste Authority Pahokee Landfill.

Table 5: TP Descriptive Statistics at EBWCD Upstream Stations

TP (mg/L)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	0.334	0.521	0.366	0.418	0.453	0.596	0.254	0.251	0.378	0.542	0.348	0.431	0.442	0.418	0.347	0.382
Median	0.127	0.446	0.126	0.24	0.228	0.542	0.149	0.184	0.091	0.457	0.269	0.364	0.378	0.412	0.292	0.29
Min	0.074	0.049	0.034	0.042	0.035	0.05	0.057	0.064	0.047	0.046	0.065	0.075	0.081	0.165	0.072	0.068
Max	1.389	1.915	1.386	2.362	1.672	1.839	0.864	0.89	1.457	2.062	1.106	1.564	1.007	0.759	0.95	1.396
Stand. Dev.	0.361	0.439	0.416	0.447	0.46	0.432	0.217	0.177	0.402	0.42	0.262	0.323	0.246	0.168	0.219	0.302

Table 6: TDP Descriptive Statistics at EBWCD Upstream Stations

TDP (mg/L)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	0.255	0.438	0.304	0.355	0.4	0.518	0.146	0.138	0.328	0.465	0.23	0.319	0.321	0.3	0.236	0.274
Median	0.081	0.322	0.081	0.184	0.18	0.472	0.072	0.061	0.059	0.372	0.182	0.248	0.285	0.302	0.162	0.193
Min	0.028	0.02	0.019	0.012	0.024	0.031	0.02	0.019	0.03	0.018	0.027	0.019	0.03	0.046	0.023	0.02
Max	1.225	1.816	1.342	2.146	1.627	1.739	0.527	0.758	1.399	1.842	0.868	1.455	0.868	0.673	0.844	1.313
Stand. Dev.	0.325	0.411	0.379	0.421	0.443	0.41	0.153	0.175	0.384	0.397	0.201	0.317	0.233	0.179	0.209	0.299

Table 7: TPP Descriptive Statistics at EBWCD Upstream Stations

TPP (mg/L)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	0.079	0.083	0.062	0.063	0.053	0.079	0.108	0.113	0.049	0.077	0.118	0.112	0.121	0.119	0.11	0.107
Median	0.045	0.076	0.032	0.05	0.037	0.059	0.065	0.095	0.029	0.068	0.084	0.102	0.101	0.086	0.096	0.105
Min	0.02	0.02	0.003	0.018	0.005	0.019	0.018	0.037	0.004	0.026	0.032	0.036	0.019	0.04	0.032	0.044
Max	0.506	0.221	0.293	0.25	0.169	0.191	0.534	0.404	0.248	0.22	0.845	0.28	0.318	0.418	0.272	0.2
Stand. Dev.	0.097	0.055	0.072	0.045	0.046	0.048	0.111	0.069	0.047	0.04	0.135	0.049	0.077	0.09	0.059	0.035

Table 8: Ammonia-N Descriptive Statistics at EBWCD Upstream Stations

Ammonia-N (mg/L)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	0.414	0.732	0.375	0.588	0.709	1.285	0.578	0.659	0.503	0.767	0.793	1.023	1.507	2.419	0.728	0.893
Median	0.047	0.311	0.078	0.115	0.161	0.558	0.210	0.352	0.021	0.258	0.222	0.777	0.831	1.994	0.424	0.587
Min	BDL	0.011	BDL	0.010	0.006	0.033	0.013	0.015	BDL	0.013	0.013	0.029	0.008	0.026	0.011	0.024
Max	3.722	3.791	3.515	4.199	4.543	3.619	2.540	2.687	4.022	4.456	4.262	3.416	5.733	6.985	3.193	3.476
Stand. Dev.	0.883	0.944	0.753	0.965	1.268	1.247	0.750	0.754	1.050	1.094	1.078	0.962	1.640	2.051	0.926	0.947

Table 9: Nitrate-N Descriptive Statistics at EBWCD Upstream Stations

Nitrate-N (mg/L)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	0.136	-	0.015	-	0.041	-	0.223	-	0.060	-	0.290	-	0.044	-	0.155	-
Median	0.105	-	0.004	-	0.012	-	0.029	-	0.007	-	0.025	-	0.020	-	0.106	-
Min	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Max	0.414	-	0.051	-	0.178	-	2.025	-	0.574	-	3.244	-	0.194	-	0.807	-
Stand. Dev.	0.146	-	0.019	-	0.066	-	0.552	-	0.147	-	0.824	-	0.061	-	0.203	-

Table 10: NOx Descriptive Statistics at EBWCD Upstream Stations

NOx (mg/L)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	0.094	0.134	0.043	0.093	0.029	0.110	0.153	0.100	0.049	0.171	0.304	0.166	0.331	0.055	0.259	0.176
Median	0.017	0.015	0.007	0.016	0.007	0.060	0.039	0.012	0.006	0.049	0.105	0.083	0.034	0.013	0.217	0.098
Min	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.005*	BDL	0.005*	BDL
Max	0.424	3.117	0.560	1.469	0.227	0.428	2.115	1.730	0.652	1.063	3.402	1.891	6.099	0.188	0.910	2.000
Stand. Dev.	0.123	0.490	0.105	0.232	0.053	0.134	0.371	0.311	0.136	0.244	0.657	0.316	1.064	0.068	0.249	0.323

*Minimum Detection Limit

Table 11: Sulfate Descriptive Statistics at EBWCD Upstream Stations

Sulfate (mg/L)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	84	-	79	-	92	-	177	-	89	-	242	-	210	-	261	-
Median	47	-	46	-	44	-	163	-	49	-	251	-	212	-	254	-
Min	31	-	26	-	35	-	50	-	35	-	111	-	0	-	130	-
Max	282	-	279	-	263	-	340	-	272	-	348	-	318	-	377	-
Stand. Dev.	75	-	68	-	79	-	79	-	73	-	62	-	56	-	64	-

Table 12: Turbidity Descriptive Statistics at EBWCD Upstream Stations

Turbidity (NTU)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	10.6	-	7.6	-	7.4	-	12.6	-	5.8	-	10.3	-	15.1	-	9.9	-
Median	8.7	-	5.6	-	5.2	-	7.5	-	4.5	-	8.0	-	11.8	-	8.3	-
Min	3.5	-	1.5	-	1.1	-	4.4	-	2.1	-	3.6	-	2.7	-	4.2	-
Max	28.1	-	24.3	-	33.7	-	140	-	24.7	-	45.8	-	74.6	-	38.4	-
Stand. Dev.	5.8	-	5.9	-	7.5	-	22.2	-	4.7	-	8.4	-	13.5	-	6.0	-

Table 13: Specific Conductivity Descriptive Statistics at EBWCD Upstream Stations

Specific Conductivity (uS/cm)	EBWCD3		EBWCD4		EBWCD6		EBWCD9		EBWCD10		EBWCD12		EBWCD13		EBWCD14	
	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015	2007-2009	2013-2015
Average	945	-	885	-	1023	-	2263	-	964	-	2708	-	2997	-	2701	-
Median	618	-	598	-	621	-	2047	-	651	-	2642	-	3040	-	2616	-
Min	451	-	473	-	504	-	664	-	521	-	1347	-	1063	-	1520	-
Max	2951	-	3000	-	2370	-	5281	-	2361	-	4433	-	4669	-	4037	-
Stand. Dev.	685	-	575	-	608	-	1050	-	525	-	746	-	824	-	623	-

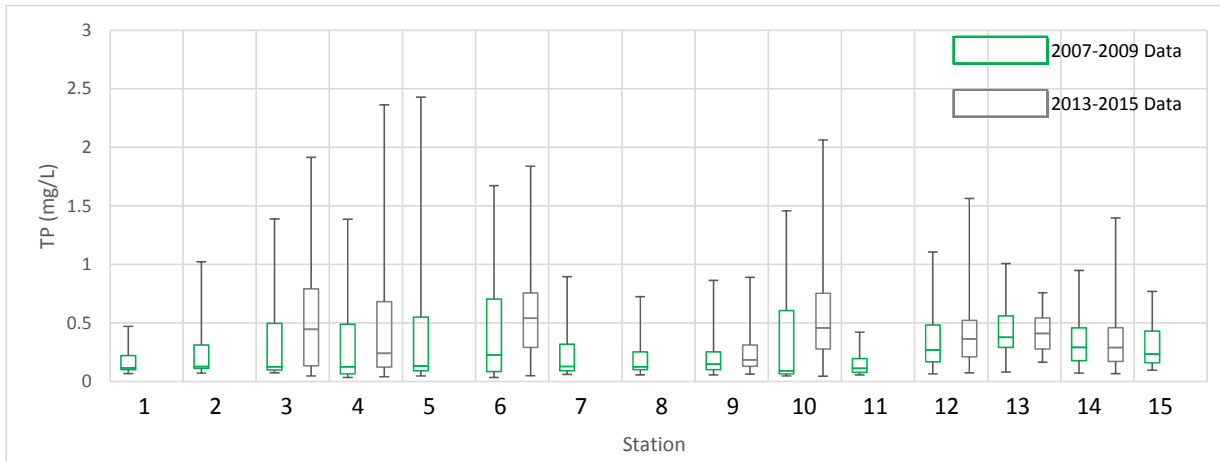


Figure 24: TP Box and Whisker Plots for EBWCD Upstream Stations

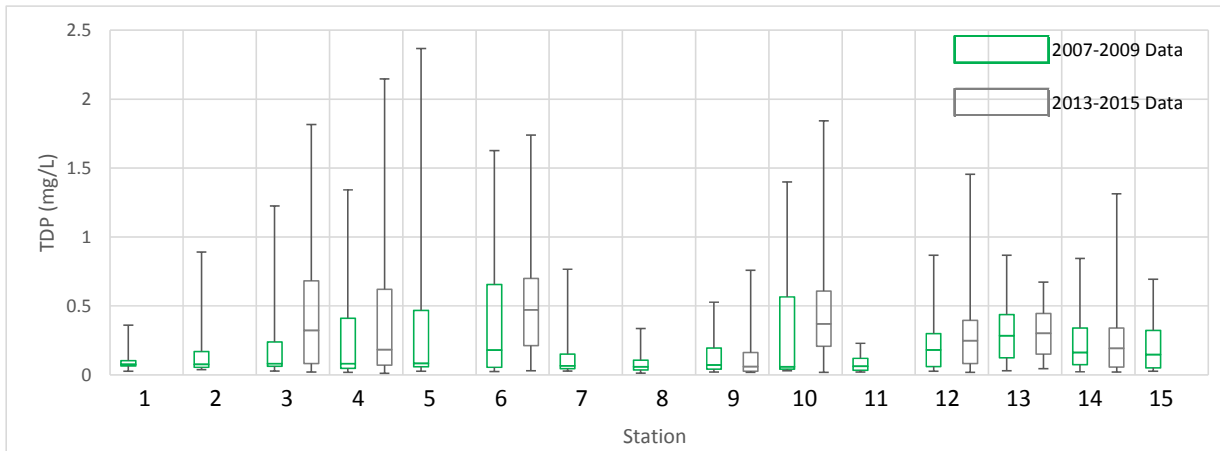


Figure 25: Dissolved P Box and Whisker Plots for EBWCD Upstream Stations

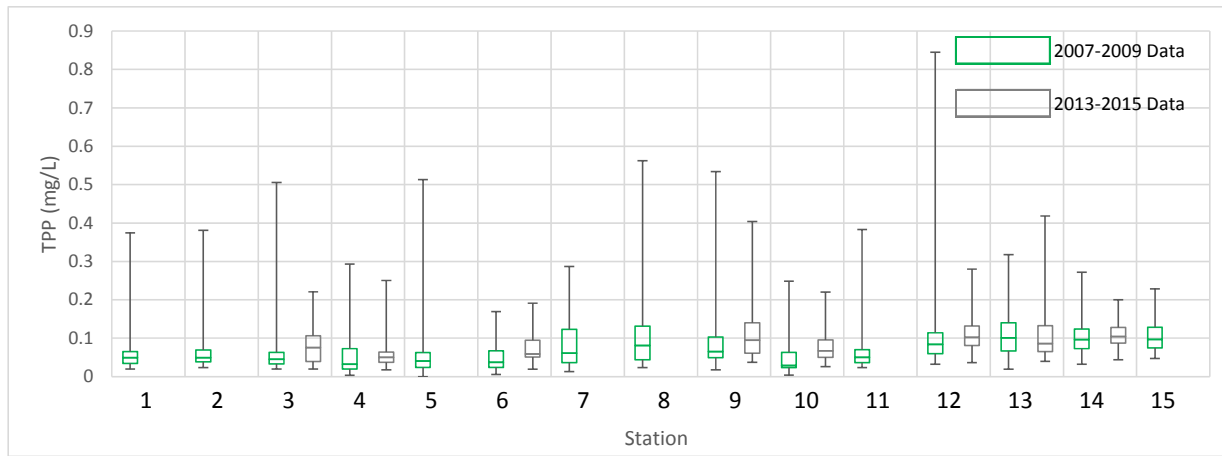


Figure 26: Particulate P Box and Whisker Plots for EBWCD Upstream Stations

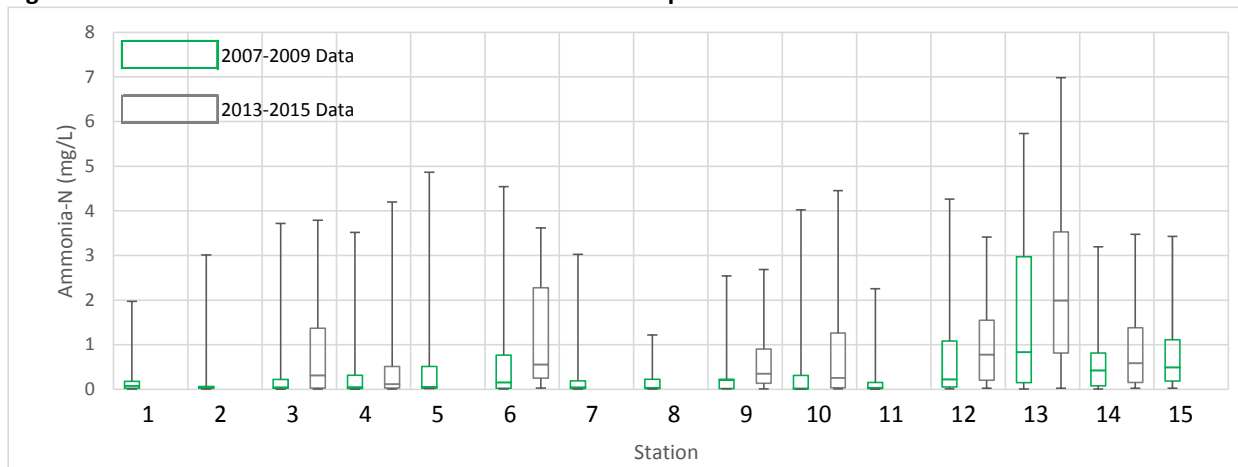


Figure 27: Ammonia-N Box and Whisker Plots for EBWCD Upstream Stations

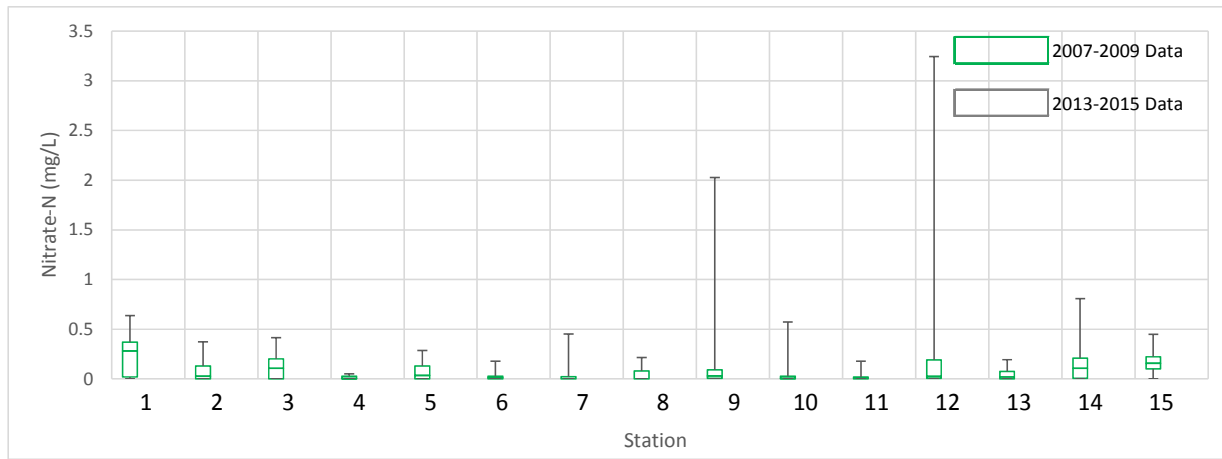


Figure 28: Nitrate-N Box and Whisker Plots for EBWCD Upstream Stations

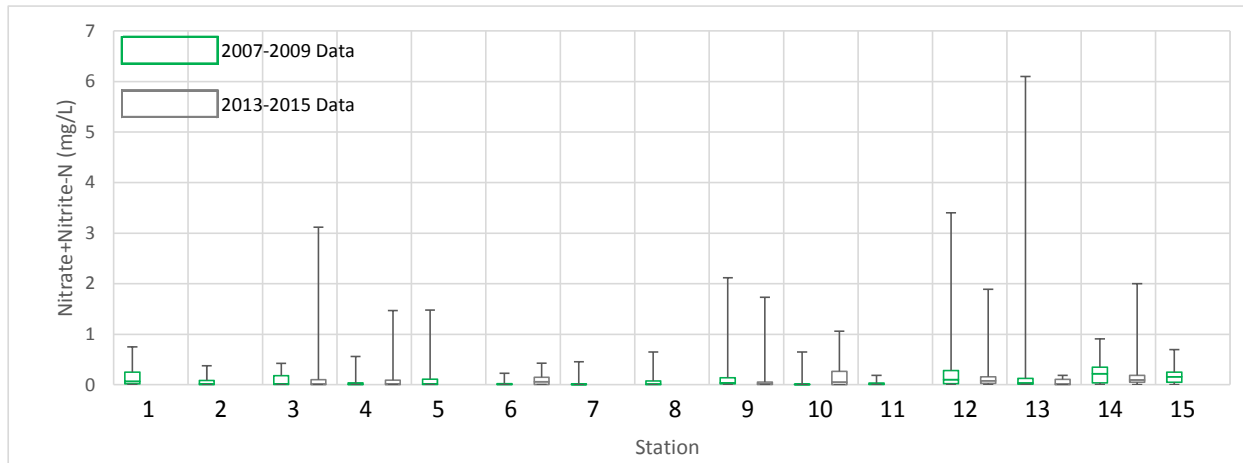


Figure 29: Nitrate/Nitrite-N Box and Whisker Plots for EBWCD Upstream Stations

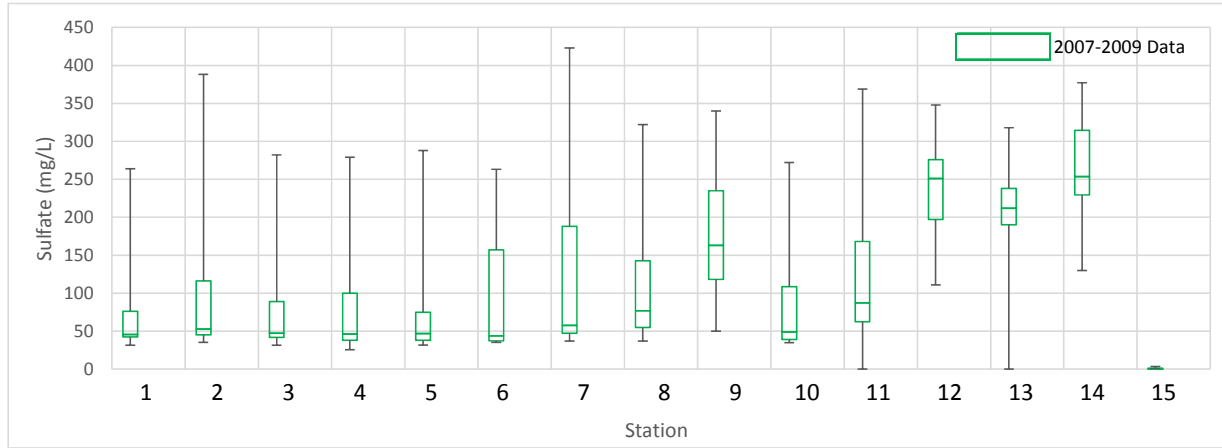


Figure 30: Sulfate Box and Whisker Plots for EBWCD Upstream Stations

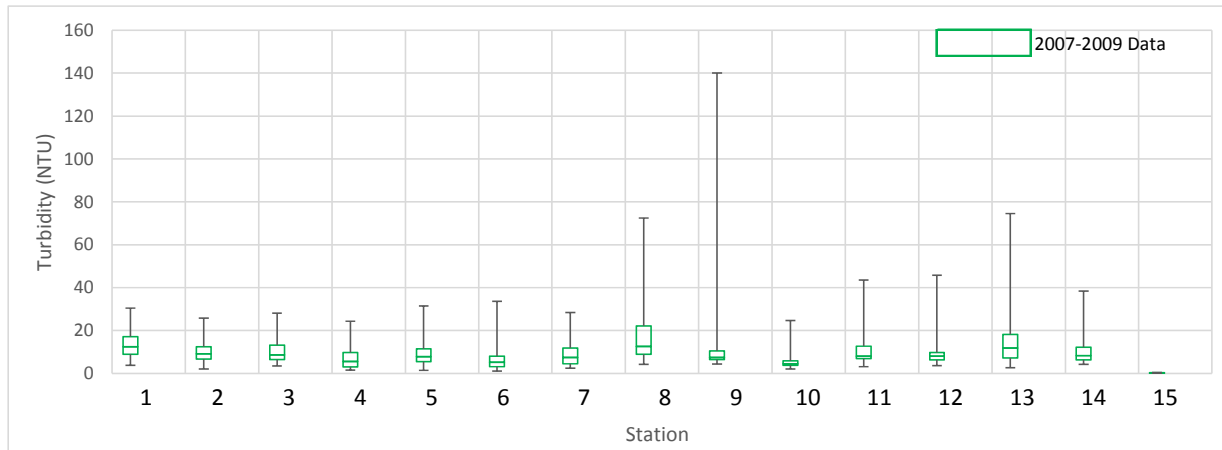


Figure 31: Turbidity Box and Whisker Plots for EBWCD Upstream Stations

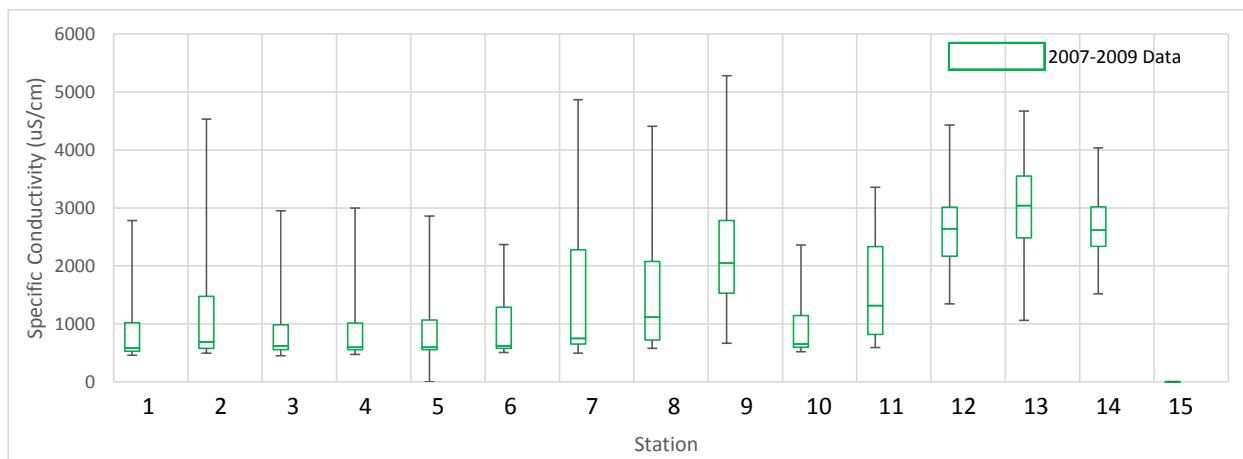


Figure 32: Specific Conductivity Box and Whisker Plots for EBWCD Upstream Stations

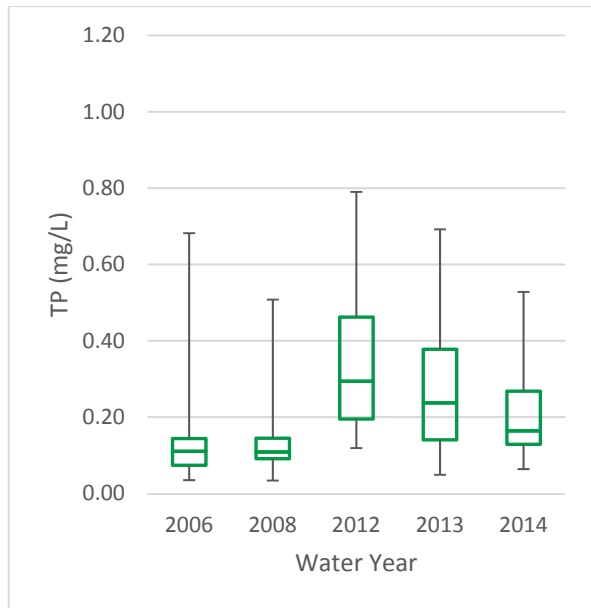


Figure 33: Dry Season Box and Whisker Plot

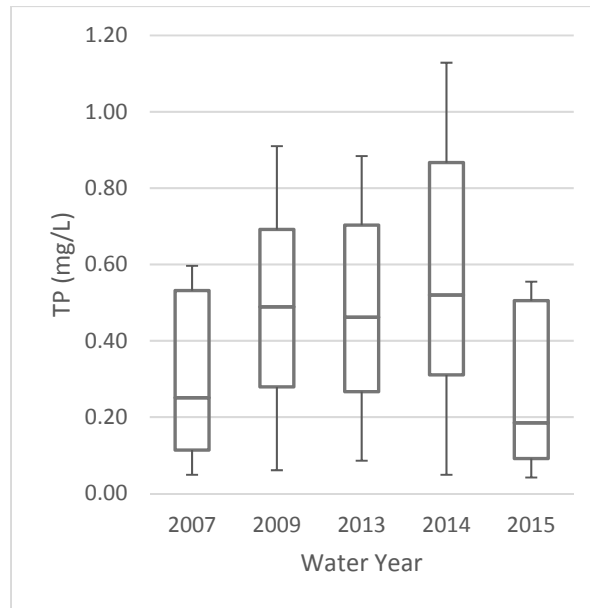


Figure 34: Wet Season Box and Whisker Plot

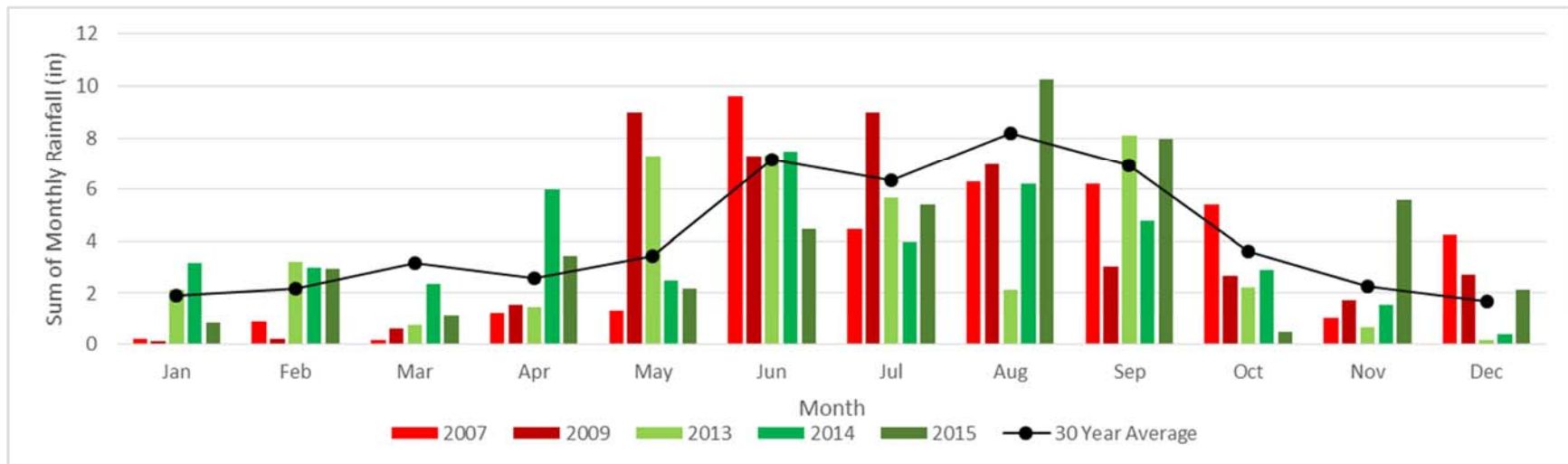


Figure 35: Rainfall Monthly Depth for 2007, 2009 2013, 2014, 2015, and 30 Year Average at EAST_BEA_R

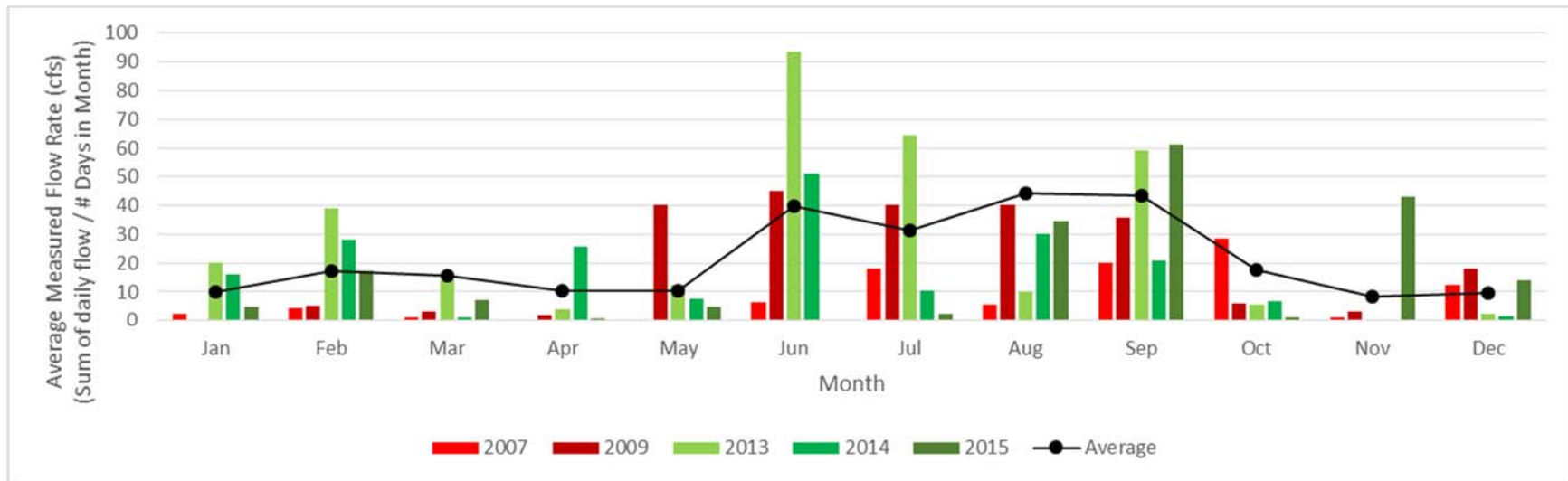


Figure 36: Average Monthly Flow for 2007, 2009 2013, 2014 and 2015 at EBEACH

4.3 Spatial Assessment

A spatial depiction of the average results was performed to determine substantial differences across the study area. The TP concentrations for each of the eight sites monitored from May 2013 to November 2015 were averaged and the percentages of dissolved and particulate P were calculated. The results of this assessment are shown in **Figure 37** as pie chart symbols with the relative P percentiles.

EBWCD9 exhibited the lowest average concentration, which is associated with lower TDP. Spatially, this site represents the highest ratio of urban to rural land uses. The northeastern sites (EBD13, EBD12, and EBD14) exhibited moderately higher percentages of TPP than the remainder of EBWCD. This area has lower topographic elevations than its surroundings, and EBD12 and EBD14 are downstream from the remaining stations, which may be associated with higher particulate and sediment transport.

EBWCD13 is near the now closed Bryant Mill, the City of Pahokee Incinerator and Ash Landfill, and the Palm Beach County LF#4 Pahokee Landfill (see **Figure 4**). While landfill leachate is not typically associated with elevated TPP, this can be a secondary effect. Leachate from the closed landfill could be a cause for unusually high Ammonia N concentrations at EBWCD13 as shown in **Figure 38**. If Total Nitrogen is high, then more plant and algae life may be present in the canal, which could create more uptake of TDP and lower ratios of TDP to TPP. This is one of many possibilities and would depend on the concentrations of Nitrogen constituents that were not tested such as NH₄ and how often the pH levels drop below 7.0, which facilitates the conversion of NH₃ to NH₄. Recorded pH levels at this site ranged from 6.8 to 7.9. Observations made at the time of sampling indicated that duckweed, algae and other floating aquatic vegetation were present at this location. Other sites, however, had similar observations. The most prevalent observation at this site is that the water was “dirty brown” in color and visibility, more so than at other sites. Though it may be possible that leachate from the landfill is occurring, considering the TP levels at EBWCD13 compared to the other sites, it does not appear to explain the TP levels at EBWCD13.

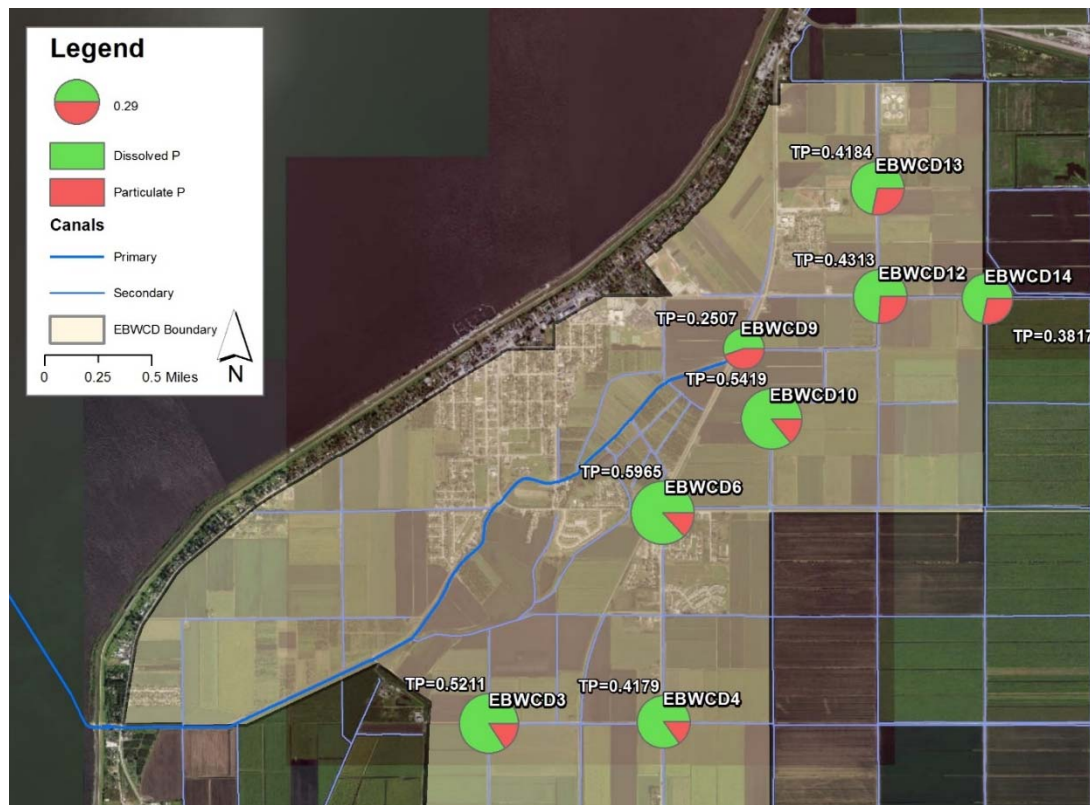


Figure 37: Averaged Dissolved and Sediment P Percentiles

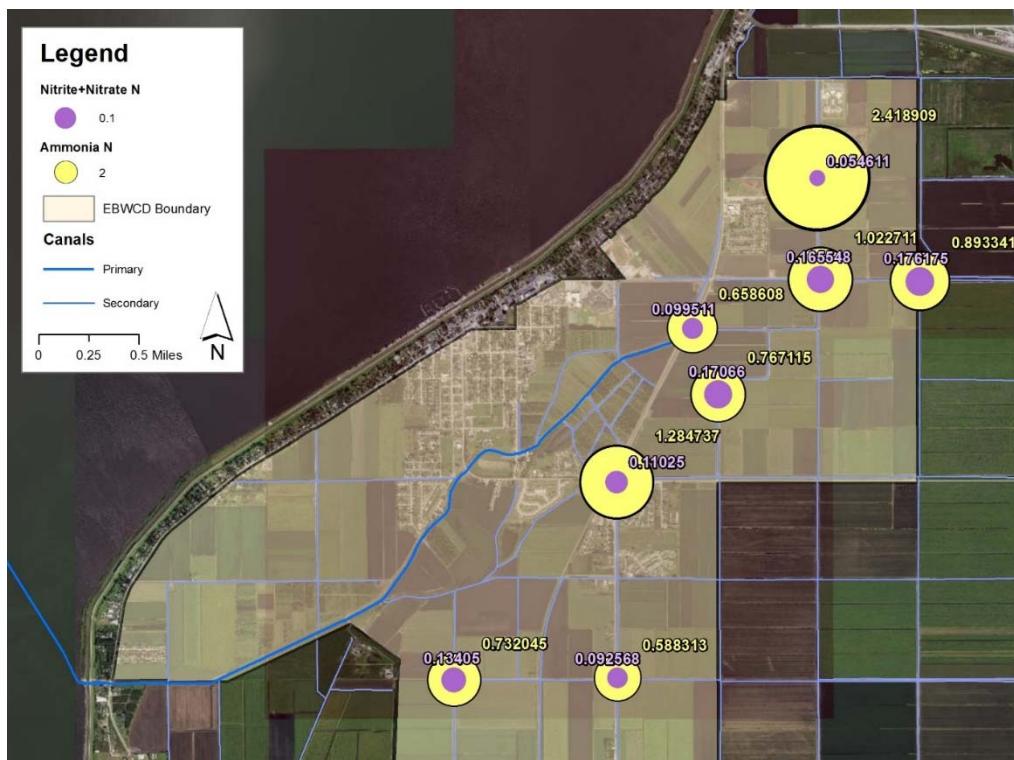


Figure 38: Averaged Ammonia N and Nitrite+Nitrate N Concentrations

5.0 Conclusions

The EBWCD is a water management district public entity established in 1945 pursuant to Chapter 298 of the Florida Statutes and is located along the southeast side of Lake Okeechobee. EBWCD discharges into the S-5A Sub-basin of the Everglades Agricultural Area (EAA), which is located east of Lake Okeechobee (Lake) and south of the L-8 Canal. Discharges from EBWCD and the S-5A Sub-basin drain primarily through the WPB Canal to the Stormwater Treatment Area 1 West (STA-1W)/STA-1E complex, 16.8 miles to the southeast of structure EBPS3. Prior to 2001, the EBWCD primarily discharged to Lake Okeechobee, however, diversion projects were implemented in response to legislative mandates aimed at improving water quality.

For more than 35 years there has been monitoring of water quality parameters occurring in the EBWCD. For over 20 years there have been various assessments and studies of the water quality data that is available for EBWCD discharges and within internal canals. These assessments have utilized a combination of monitoring and analysis to provide insight into high nutrient concentrations. Water quality data for EBWCD is periodically reviewed with permittees during Best Management Practice verification visits required by an EWOD permit issued to EBWCD pursuant to Chapter 40E-63, F.A.C. Water quality data are also reported annually in the South Florida Environmental Report.

This memorandum consolidates and updates data previously presented with respect to water quality and flow within and from EBWCD trends and recent canal cleaning project efforts. The report is a component of a contract high goal is to consolidate historic information and water quality data in the S5A Sub-basin and the EBWCD into a report that facilitates development of sub-regional source control projects to reduce phosphorus discharges in runoff from these basins.

Findings and recommendations are:

- The analysis of trends for TP indicated rising and falling rolling averages of TP concentrations in the period of record between WY1980 and 2016. In particular, the 5-year rolling average of TP concentration increased from WY1980 to WY2002, decreased until 2007 and rolled back up until 2010. Since 2010 the five-year TP concentration rolling average is within the 500-600 ppb range.
- The 5-year rolling average flow volume increased from WY1980 to 2006, decreased to WY2012, and has hovered around 12,500 and 15,000 acre-feet since then. The five-year rolling average of rainfall decreased since WY1996, and is hovering around 50 inches since WY2001.
- The combined effect of TP concentration and flow results in 5-year rolling average of TP load increasing until WY2002 and is hovering around 10 metric tons since 2006.
- Review of monthly data indicates that highest TP concentrations and loads occur during the wet season months, and higher wet season TP concentrations were observed post-diversion.
- Review of available data indicates that it may be difficult to assess the water quality benefits resulting from the comprehensive canal cleaning demonstration project that removed sediments and floating aquatic vegetation from EBWCD canals from August, 2013 to January, 2015.
- Factors confounding the evaluation include the effects of varying hydrologic conditions on TP concentration and load, and the need for a more robust baseline dataset. Nevertheless, available data for individual stations and years suggest a lesser incidence of TPP peak concentrations during the 2013 to 2015 period, and generally lower TPP concentrations in 2015 than in previous years.
- Continued water quality monitoring of TP, OPO4 and TDP at EBPS3, together with tracking of canal cleaning activities within EBWCD will be necessary to capture the long-term water quality benefits of the improved canal cleaning capabilities that the long-arm backhoe provided.
- The majority of TP in EBWCD runoff and at individual stations is TDP and OPO4. Sub-regional projects with focus on flow volume and TDP/OPO4 attenuation may prove most effective to reduce phosphorus in EBWCD discharges to the EAA West Palm Beach canal.
- Based on the TPP/TP concentration ratio for EBWCD10, EBWCD13, and EBWCD14 in comparison to the rest of the upstream stations, source controls and/or regional projects for particulate matter (e.g., through aquatic vegetation removal and use of floating barriers) and sediment controls (e.g., prevent scouring of canal bottoms and vegetated banks) may be most beneficial on the northeast portion of EBWCD.
- Comparison of 2015 water quality monitoring data at EBWCD14 and EBPS3 indicates potential attenuation of TP and TDP/OPO4 in the outfall canal between EBWCD14 and EBPS3. This was particularly noticeable during a higher TP concentration measurement in September 2015. Additional water quality monitoring data for TDP and OPO4 may shed light on sub-regional project opportunities for optimizing phosphorus attenuation in the outfall canal.
- Based on 2015 data, highest TP concentrations at upstream stations were concurrent with months when the majority of TP load at EBPS3 was observed. However, TP concentration levels among the stations varied with EBWCD14, EBWCD12, and EBWCD10 reporting the highest levels.
- EBWCD13 and EBDWCD9 showed relatively lower TP concentrations, while stations EBWCD03 and EBWCD04 may not have the same effect on EBPS3 load as they are upstream of these potentially lower TP concentration stations.
- EBWCD13 is near the now closed Bryant Mill, the City of Pahokee Incinerator and Ash Landfill, and the Palm Beach County LF#4 Pahokee Landfill, and reported highest ammonia levels among the upstream stations indicating a potential effect from these sources.

- EBWCD9 rated as the upstream station with the lowest TP and TDP levels among all stations. This location represents the highest percentage of non-agricultural areas.
- Continuing water quality and flow monitoring at upstream monitoring locations within EBWCD, as well as sub-basin hydrologic delineation to determine tributary acreage would provide insight on transport mechanisms, actual contributing TP loads and priority areas for subregional projects.

6.0 References

- Burns & McDonnell. 1994. *Everglades Construction Project, Conceptual Design*. Prepared for the South Florida Water Management District (SFWMD), West Palm Beach, Florida. February 15.
- CH2M. 2016. SFWMD Data and Documentation Summary for the Eastern Flow Path Water Quality. *Task 2.3 Final Technical Memorandum for the Review and Summary of Documentation and Previous Activities*. Prepared for the South Florida Water Management District (SFWMD), West Palm Beach, Florida. March 18.
- Everglades Agricultural Area Environmental Protection District Report on Area Performance 40E-61 Lake Discharges Permit No. 50-00001-E. July 2016. EBA Environmental Consulting & Management Services.
- Florida Atlantic University. 2008. *Water Quality Synoptic Survey Data Analysis for East Beach Water Control District*. Prepared for the SFWMD, West Palm Beach, FL. April.
- Florida Department of Environmental Protection (FDEP). 1994. 91-0705 East Beach Water Control Consent Agreement. November 14.
- Florida Department of Environmental Protection (FDEP). 2006. *Technical Memorandum –The City of Pahokee’s Wastewater Collection/Transmission System Dye Test*. January.
- Gary Goforth, Inc. 2009. *Updated Flow and Phosphorus Data Sets for the ECP Basins Covering the Period May 1,1994-April,30 2009*. Prepared for the South Florida Water Management District (SFWMD) under subcontract to Malcom Pirnie. West Palm Beach, Florida. August 14.
- Hutcheon Engineers, 2000. Pahokee Wastewater Treatment Plant 2000 Annual Report. West Palm Beach, FL.
- MacVicar Consulting, Inc. 2013a. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project July 2013 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. July,13.
- MacVicar Consulting, Inc. 2013b. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project December 2013 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. December, 23.
- MacVicar Consulting, Inc. 2014a. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project February 2014 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. February, 19.
- MacVicar Consulting, Inc. 2014b. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project March 2014 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. March, 31.
- MacVicar Consulting, Inc. 2014c. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project June 2014 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. June, 23.
- MacVicar Consulting, Inc. 2014d. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project September 2014 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. September, 29.
- MacVicar Consulting, Inc. 2014e. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project December 2014 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. December, 19.

MacVicar Consulting, Inc. 2015a. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project April 2015 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. April 1.

MacVicar Consulting, Inc. 2015b. *East Beach Water Control District (EBWCD) Sub-Regional Canal Cleaning Evaluation Project July 2015 Quarterly Report*. Prepared for the South Florida Water Management District (SFWMD). West Palm Beach, Florida. July 1.

MacVicar, Federico, and Lamb, Inc. 2001. *Technical Memorandum – 298 District/Closter Farm Phosphorus Discharges to Lake Okeechobee*. Prepared by Tony Federico for Ed Barber, EPD Technical Advisor. May 23.

Nearhoof, Frank/Florida Department of Environmental Protection (FDEP). 2006. Personal communication (e-mail) with Pam Wade/South Florida Water Management District (SFWMD) regarding Everglades Agricultural Area (EAA) Bryant Mill. February 28.

Nearhoof, Frank/Florida Department of Environmental Protection (FDEP). 2009. Personal communication (e-mail) with Pam Wade/South Florida Water Management District (SFWMD) regarding Everglades Agricultural Area (EAA) landfill near Bryant Mill. March 12.

Sarley, Steve/South Florida Water Management District (SFWMD). 2016. Personal communication (e-mail) with Carmela Bedregal/South Florida Water Management District (SFWMD) regarding East Beach Water Control District canals cleaned. July 14.

South Florida Water Management District (SFWMD). 2001. *Agreement by and among the South Florida Water Management District and East Beach Water Control District*. October 15.

South Florida Water Management District (SFWMD). 2009a. Memorandum – Year-end Status of FY2009 East Beach Water Control District Upstream Monitoring Program. Prepared by Jon Madden for Pam Wade. October 23. South Florida Water Management District (SFWMD). 2009b. L-12-CCCP 2006-2007-2008_Summary_6-12-2009. South Florida Water Management District, West Palm Beach, FL. October 23.

South Florida Water Management District (SFWMD). 2012. Restoration Strategies Regional Water Quality Plan. South Florida Water Management District, West Palm Beach, FL. April 27.

South Florida Water Management District (SFWMD). 2015. Work Order No 4600003014-WO07, PO No 9500006545, Statement of Work: Data and Documentation Summary for the Eastern Flow Path Water Quality. South Florida Water Management District, West Palm Beach, FL. October 1, 2015.