Plum Creek Watershed Monitoring Report

Data Collection and Analysis

April 2012 – March 2013

Developed for:

Colorado Water Conservation Board

In Accordance with the Healthy Rivers Fund Grant
Issued to the Town of Castle Rock as fiscal agent to the Chatfield Watershed Authority
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TETRA TECH

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1.0 INTRODUCTION

Monthly water quality monitoring was conducted April 2012 – March 2013 at nine locations to characterize and identify pollutant sources in the Plum Creek watershed, located upstream of Chatfield Reservoir (Figure 1). Funding for the monitoring was provided by a $20,000 grant to the Town of Castle Rock, CO, as fiscal agent for the Chatfield Watershed Authority (Authority), from the Colorado Water Conservation Board. This grant award, coupled with a cash match commitment totaling $5,000 from the Authority and over $30,000 of in-kind services that included labor from Authority members, laboratory analytical services from Plum Creek Water Reclamation Authority (PCWRA) and Centennial Water and Sanitation District (CWSD), and environmental engineering services from consultant, Tetra Tech, Inc.

The Water Quality Control Commission (WQCC) Control Regulation No.73 for Chatfield Reservoir limits the pounds of phosphorus allowable to the reservoir, as well as concentrations of total phosphorus (TP) and chlorophyll-a (chl-a) to promote protection of drinking water supplies, recreation, fisheries, and other beneficial uses. Point sources of phosphorus in the watershed are well documented in accordance with wastewater treatment facility's CDPS permit requirements and comprise about 20% of the TP load to the reservoir. However, other pollutant sources, known as nonpoint source (NPS) pollution, comes from many diffuse sources that are not well understood. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, and ground water (EPA, 2013).

The Authority has collected water quality and flow data for 29 years at three stations; (1) the South Platte River below Strontia Springs Reservoir at Waterton Canyon, (2) Plum Creek near the confluence with Chatfield Reservoir at Titan Road, and (3) Chatfield Reservoir itself. The data indicate approximately 70% or more of the inflow to Chatfield Reservoir is from the South Platte River with the remaining inflow primarily from Plum Creek. However, while only 30% of the flow comes from Plum Creek, approximately 80% of the phosphorus load to the reservoir is from the Plum Creek watershed. Data suggest the nutrient and sediment loading from Plum Creek need to be more thoughtfully managed to address water quality in Chatfield Reservoir.

Water quality characterization in the Plum Creek watershed and identification of nonpoint source pollutant sources are not well understood. Previous water quality assessments have identified several general categories of NPS pollution sources. Pollution categories include agriculture, wildfire burn areas, stream degradation and stream bank erosion, urban and construction runoff, aged Individual Sewage Disposal Systems (ISDS) and groundwater loading, and natural sources. While additional water quality monitoring and watershed characterization is needed to facilitate understanding of specific NPS sources and priority areas to target improvement, data collected suggests the primary NPS water quality problems along Plum Creek are nutrients, sedimentation, and bacteria.

In order to better understand pollutants and sources, the following objectives of the Plum Creek water quality monitoring program were established:

- Characterize water quality in the Plum Creek watershed,

- Identify potential nutrient pollutant sources to reduce pollutant loading to Chatfield Reservoir, and
- Provide data important for watershed and reservoir modeling.

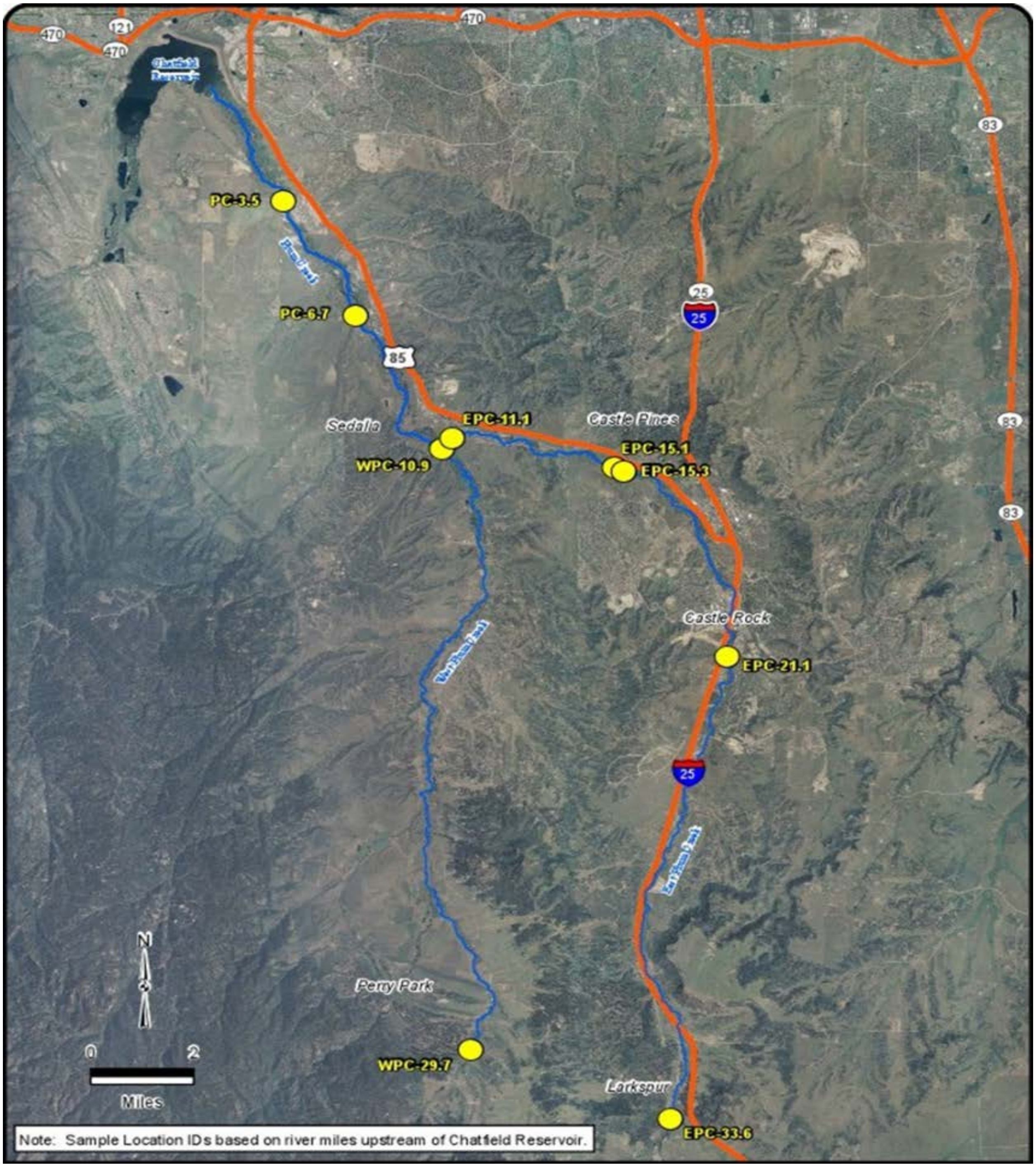

Figure 1: Location of Nine Plum Creek sampling sites upstream of Chatfield Reservoir

2.0 PLUM CREEK WATERSHED SAMPLING PROGRAM

A Sampling and Analysis Plan (SAP) (Tetra Tech, 2012) was developed for the monitoring program along West Plum Creek, East Plum Creek, and the Plum Creek mainstem. Tetra Tech staff and watershed volunteers from Town of Castle Rock and PCWRA implemented surface water sampling at nine sites along West Plum Creek, East Plum Creek and the Plum Creek mainstem, as depicted in Figure 1.

2.1 Constituents and Sampling Frequency

Surface water samples were collected the 4^{th} week of every month April 2012 through March 2013 and analyzed for the parameters summarized in Table 1. Parameters were selected to maximize the use of available financial resources while meeting the objectives of the program. Analytical laboratory services were provided as in-kind service from Authority member laboratories at CWSD (nitrate-nitrite and ammonia) and PCWRA (E. coli, TSS, alkalinity, specific conductance, dissolved oxygen, temperature, pH). The Authority contracted with GEI Consultants, Inc. to provide analytical laboratory service for the TP and ortho-P analyses with a Method Detection Limit (MDL) of 2µg/L.

Table 1: Analyte List, Methods, and Analytical Labs for Surface Water Samples

	Constituent	*U.S. EPA Method Number*	*Sample Preservation and Treatment*	*Holding Times*	*Analytical Lab*
Field Parameters	pH	----	Measure In-Situ	Immediately	Tetra Tech - In Situ PCWRA in situ
	Specific Conductance	----		Immediately	Tetra Tech - In Situ PCWRA in Lab
	Temperature	----		Immediately	Tetra Tech - In Situ PCWRA in situ
	Streamflow	----		Immediately	Tetra Tech - In Situ
	Dissolved Oxygen	----		Immediately	Tetra Tech - In Situ PCWRA in situ
Bacteriological	E. coli	SM 9223-B Enzyme Substrate	Chill to 4 degrees C	8 hours	PCWRA
Wet Chemistry	Alkalinity	SM2320-B - Titration	Chill to 4 degrees C	14 days	PCWRA
	Total Phosphorus	M365.1 Auto Ascorbic Acid	Chill to 4 degrees C	48 hours	GEI
	Ortho-Phosphorus	M365.1 Auto Ascorbic Acid	Chill to 4 degrees C	48 hours	GEI
	Nitrate-nitrite	SM 4500-NO3-I FIA	H_2SO_4 to pH<2, Chill to 4 degrees C	28 days	CWSD
	Ammonia	SM 4500-NH3-H FIA	H_2SO_4 to pH<2, Chill to 4 degrees C	28 days	CWSD
	Total Suspended Solids (TSS)	160.2 Gravimetric	Chill to 4 degrees C	7 days	PCWRA

2.2 Basis for Analyses

Because the regulatory basis in Control Regulation 73 is minimizing TP loads and maintaining TP and chl-a standards in the reservoir to protect beneficial uses, nutrient analyses, including TP, ortho-P, nitrate-nitrite, and ammonia, are critical to the monitoring program. Streams and lakes with high nutrient levels can promote excessive plant and algal growth. Nutrient management is a critical objective of the Authority's long-term watershed and reservoir management program.

Bacteriological and sediment analyses are also a significant indicator of NPS pollutants in the watershed which impact nutrient loading and affect watershed health.

2.2.1 Nutrient Analyses

Analyses of nutrient species (i.e., phosphorous and nitrogen species) were necessary to assess the relative contributions of NPS to the watershed and reservoir from various nutrient sources such as fertilizers, animal and human waste. Sediments in the watershed also have a high mass loading of phosphorus per cubic yard of material, allowing it to enter waterways through sediment runoff and increase TP concentrations.

2.2.2 Bacteriological Analysis

E. coli is often used as an indicator that waters are polluted with animal or human waste. In agricultural portions of the Plum Creek basin, sources of E. coli include failed septic systems, livestock manure, and wildlife.

2.2.3 Sediment Analysis

When sediment enters Plum Creek, it smothers valuable aquatic habitat, damages riparian areas, fills in stream channels, increases the chance of flooding, contributes to the erosion of stream banks, reduces the storage volume and life of Chatfield Reservoir, and increases phosphorus loading from TP that absorbs to soil particles.

2.3 Surface Water Monitoring Locations

The monthly Plum Creek Watershed monitoring program included 9 locations; five sample locations on East Plum Creek, two sample locations on West Plum Creek, and two sample locations on Plum Creek (Figure 1). Table 2 provides a description of each sampling location, and the potential NPS influences that were anticipated based on land uses.

Table 2: Plum Creek Sampling Locations

Sample Identification*	Location	Reasoning for Sample Location	Potential NPS Influences
WPC-29.7	West Plum Creek, Near Perry Park	Background water quality condition of W. Plum Creek; in reach of native fishery	Sedimentation, stream bank erosion
WPC-10.9	West Plum Creek, Above Confluence with Plum Creek	Water chemistry contributions from rural land use/primarily agricultural zoning	Runoff from agricultural lands
EPC-33.6	East Plum Creek, Near Larkspur	Background water quality condition	Sedimentation, stream bank erosion
EPC-21.1	East Plum Creek, in Castle Rock	Urbanized area	Stormwater runoff
EPC-15.3	East Plum Creek, Upstream of PCWRA	Upgradient of WWTF discharge	Stormwater runoff from urban and non-urban areas
EPC-15.1	East Plum Creek, Downstream of PCWRA	Downgradient of WWTF	Stormwater and stream bank erosion
EPC-11.1	Near Sedalia, above confluence	Near Sedalia	Aged ISDS
PC-6.7	Plum Creek Near Louviers, CO	Downstream of Louviers	Urban and anthropogenic impacts, runoff from rural lands
PC-3.5	Plum Creek At Titan Road	Near Titan Road Industrial Park, at USGS gaging station, near Chatfield Reservoir	ISDS, stream bank erosion, agricultural runoff from stables.

*Sample identification reflects initials of waterbody sampled and approximate number of river miles upstream from Chatfield Reservoir; therefore, WPC-29.7 is West Plum Creek, sampled approximately 29.7 miles upstream of Chatfield Reservoir.

3.0 DATA RESULTS

Streamflow and water quality results are summarized graphically for key constituents of concern. All data is summarized in Appendix A.

3.1 Streamflow

Plum Creek streamflow during the 2012/2013 study period was lower than average conditions (Figure 2). US Geological Survey (USGS) data collected for the past 28 years upstream of Chatfield Reservoir (Plum Creek at Titan Road, near Louviers, CO) indicate flows considerably lower than the median daily statistic, depicted as a gold line on the hydrograph. The largest storm event of the season was observed in early June 2012, and streamflow measurements exceeded 200 cfs.

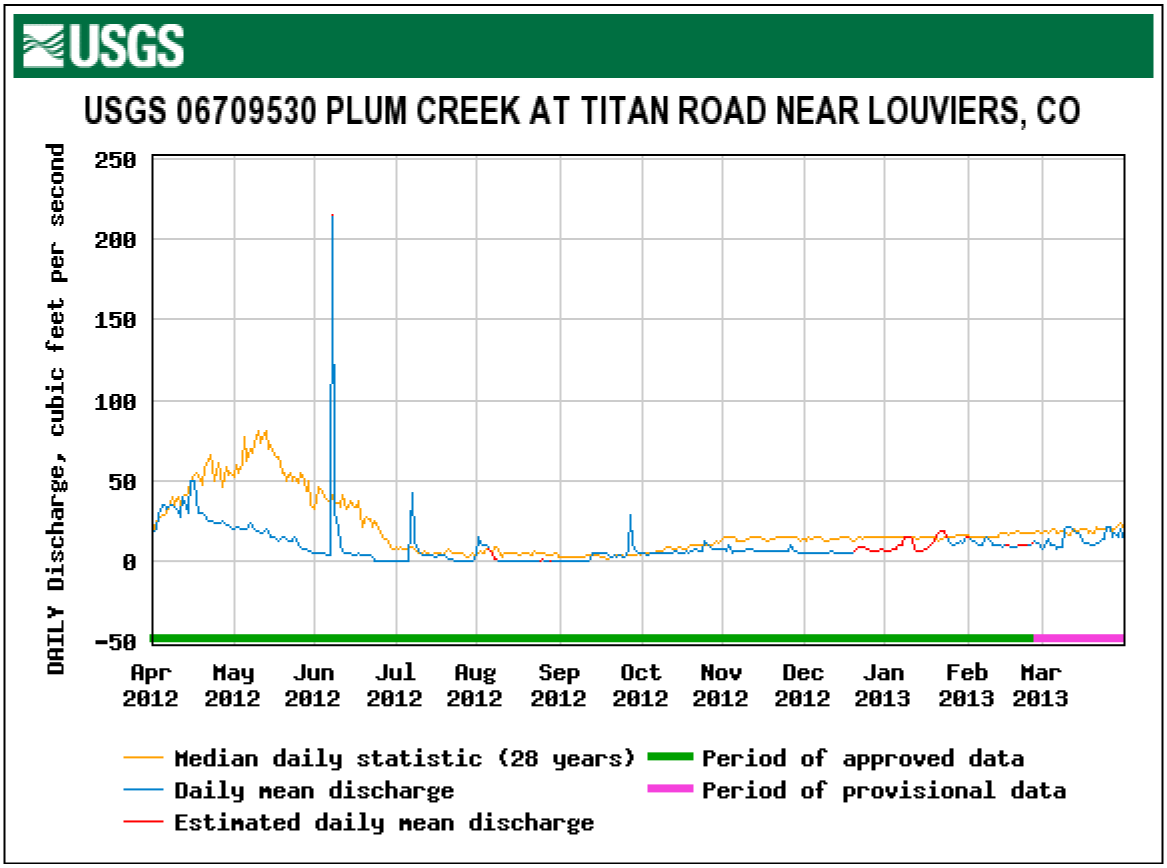

Figure 2: Plum Cr Flows Measured at USGS Gaging Station at Titan Road (Apr 2012 – Mar 2013)

Baseflow and low flow conditions were observed July 1, 2012 through March 31, 2013 (Figure 3), where flows averaged 7 cfs. Episodic storm events increased flows to approximately 40 cfs in July and 30 cfs in September.

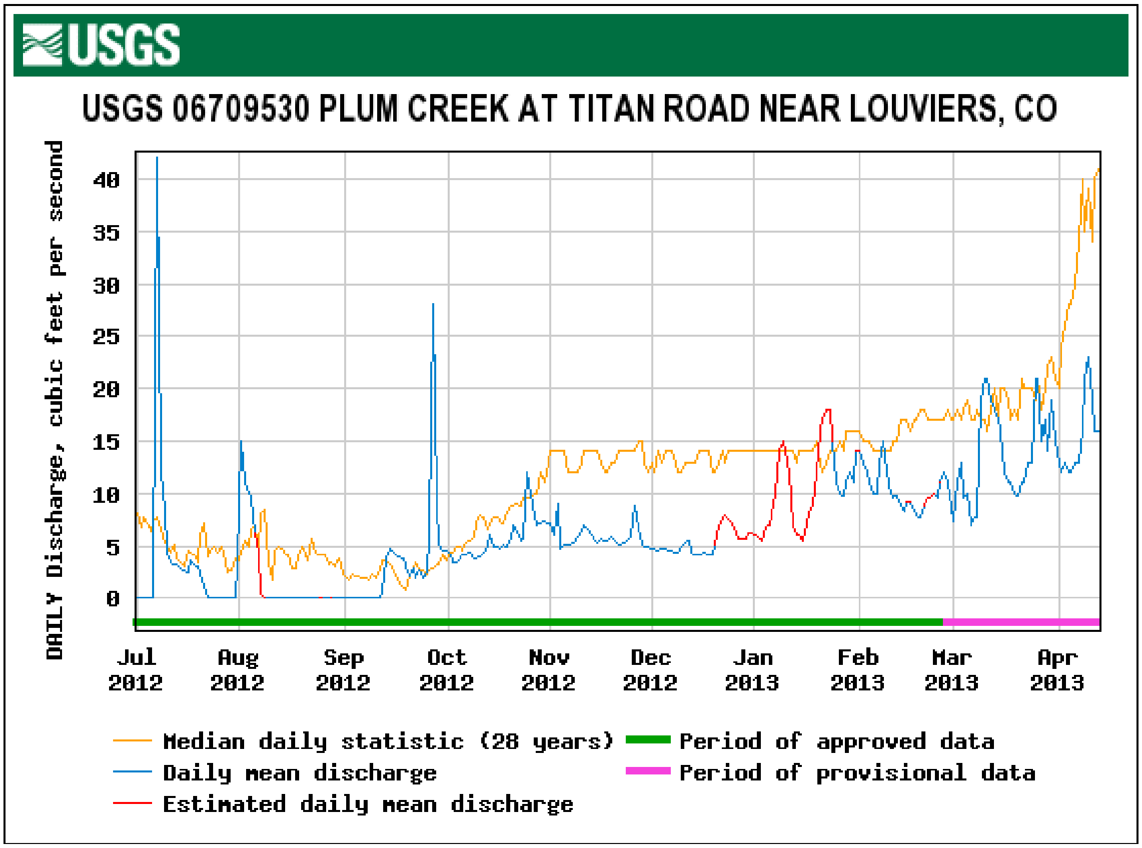

Figure 3: Low Streamflow Conditions Measured at USGS Station, Plum Cr at Titan Rd (Jul 2012 - Apr 2013)

Tetra Tech performed manual streamflow measurements at each monitoring station within the Basin on a monthly basis (9 sites). Box and whiskers plots depict the streamflow measurements taken at each Plum Creek sampling station (Figure 4) during monthly sampling events, from upstream to downstream locations. The box and whiskers plots depict the maximum measurement (top of whisker), 85^{th} percentile (top of rectangle), median value (cross symbol), 15^{th} percentile (bottom of rectangle), and minimum value (bottom whisker). Monthly streamflow measurements were used to calculate pollutant loads, with the exception of USGS continuous streamflow data which was utilized for loading calculations at PC-3.5 (Plum Creek at Titan Road).

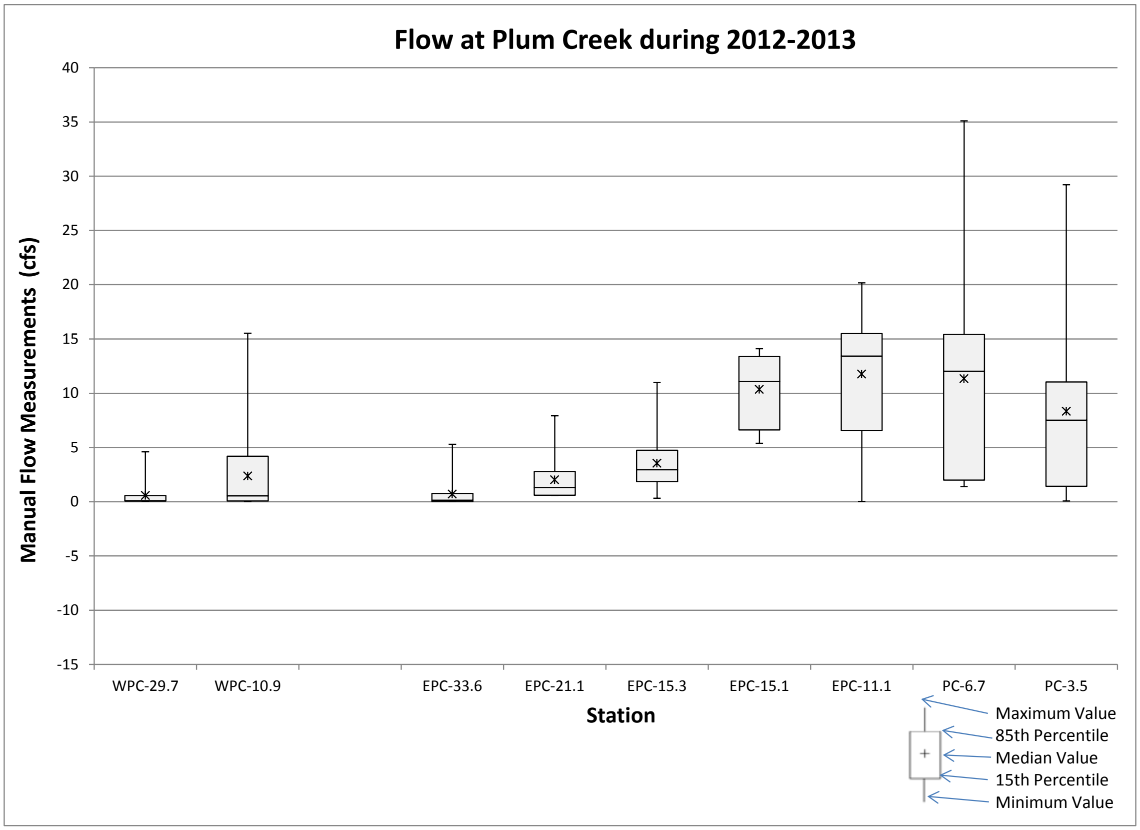

Figure 4: Summary of Monthly Streamflow at Plum Cr Monitoring Locations (Apr 2012 – Mar 2013)

3.2 Water Quality

Monthly water quality samples were analyzed for constituents in Table 1. Nutrient concentrations are shown in Figures 5 – 8. The TP concentrations at the nine sampling sites are provided in Figure 5. The two highest TP concentrations, approximately 300 ug/L) were measured in October 2012 and February 2013 at EPC-15.1 (downstream of PCWA) and WPC-29.7 (headwaters of West Plum Creek), respectively. These maximum concentrations occurred during average streamflow conditions. The 85th percentile TP concentration at PC-3.5 (Upstream of Chatfield Reservoir, at Titan Road) was 115 ug/L. Ortho-P concentration variability at each sampling site, depicted on Figure 6, was highest at EPC-15.1 (85th percentile of 75 ug/L); upstream of Chatfield Reservoir the 85th percentile ortho-P was 37 ug/L).

Ammonia concentrations are depicted in Figure 7. The MDL at the lab was 0.1 mg/L. As anticipated, ammonia concentrations were highest downstream of PCWRA (EPC-15.1), with the 85th percentile measured at 0.35 mg/L. PCWRA's permit limit for ammonia is 30 mg N/L as a daily maximum. In addition PCWRA has a 30 day average ammonia limit, which ranges from 4.3 to 8.3 mg N/L depending on the month. The stream data indicates successful operation of the biological nutrient removal facility, which is removing ammonia to levels far below permitted limits. The maximum ammonia concentration during the study period, 1.3 mg/L, was measured in the headwaters of East Plum Creek (EPC-33.6) in December 2012 when temperatures were lower, approximately 4^{o}C.

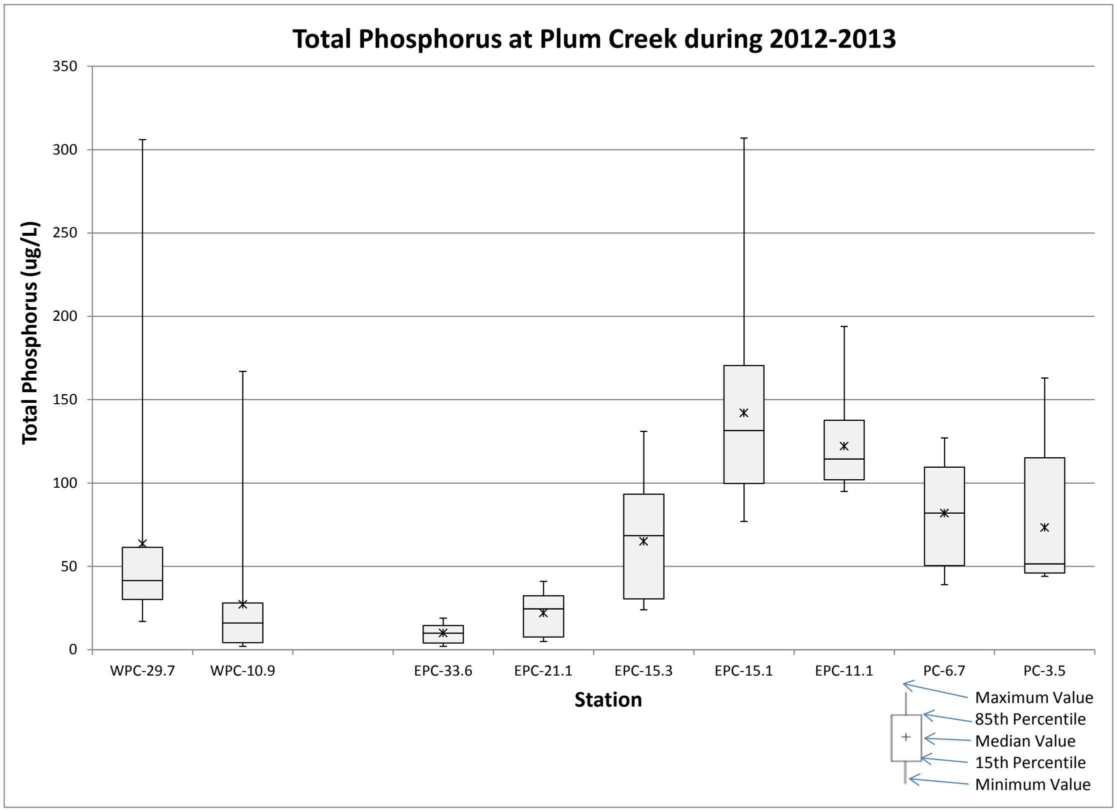

Figure 5: TP Concentrations in Plum Creek Watershed (Apr 2012 – Mar 2013)

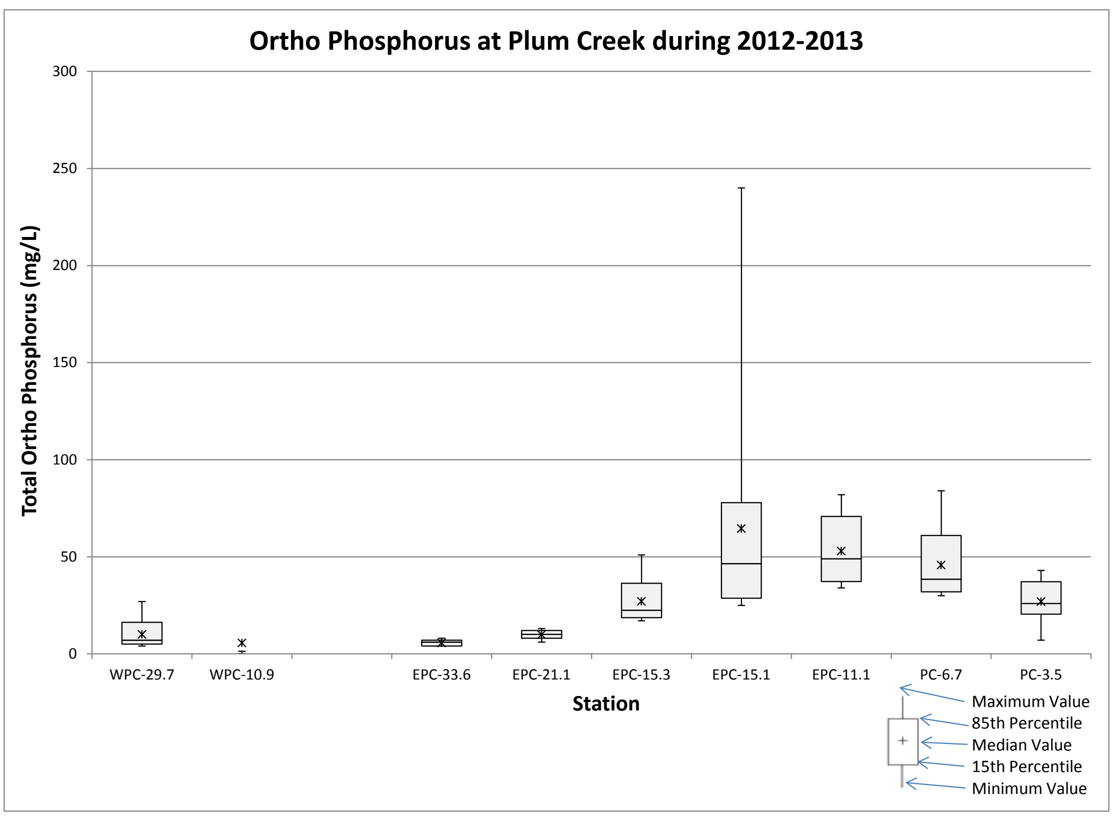

Figure 6: Ortho-P Concentrations in Plum Cr Watershed (Apr 2012 – Mar 2013)

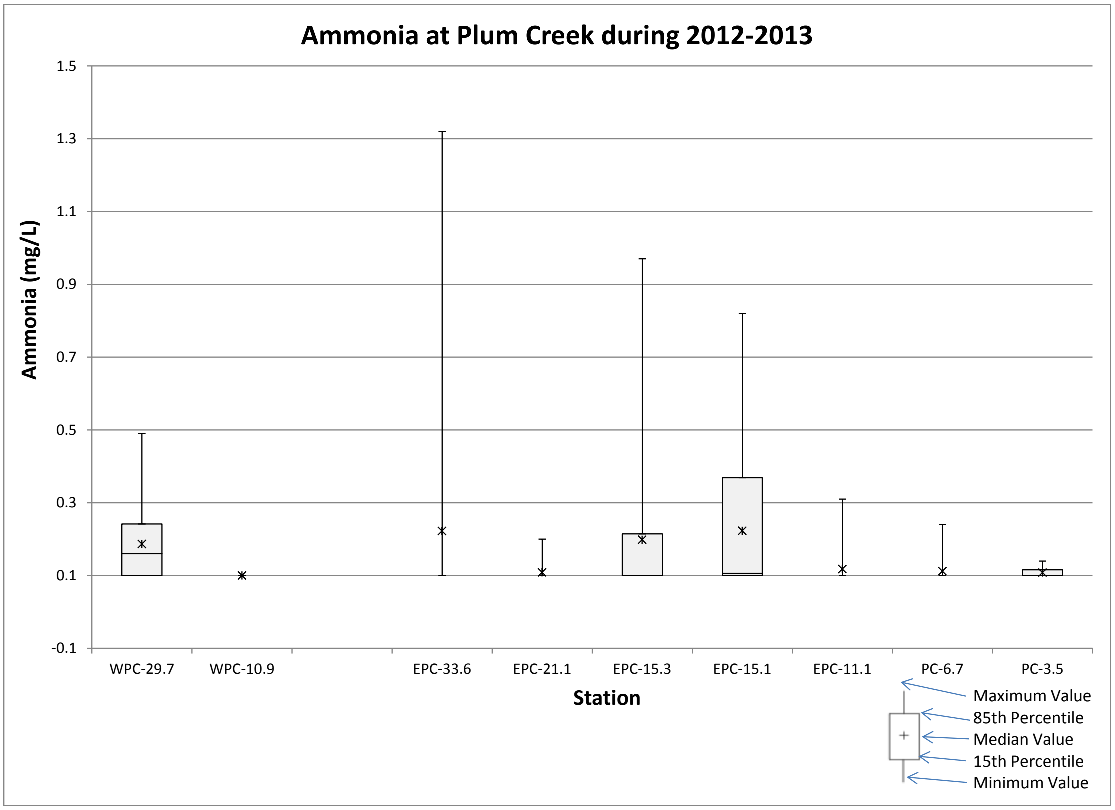

Figure 7: Ammonia Concentrations* in Plum Cr Watershed (Apr 2012 – Mar 2013)
*** MDL = 0.1 mg/L**

E. coli measurements are shown in Figure 8. The recreational water quality criteria protective of human health is 126 colonies/mL. E. coli measurements were highest at EPC-11.1 (East Plum Creek near Sedalia) where the 85th percentile was 178 colonies/mL. The other standard exceedance was at EPC-21.1, downstream of Castle Rock, where the 85th percentile was 151 colonies/mL. The highest E. coli counts were measured in April 2012 at EPC-11.1, when flows in East Plum Creek were approximately 20 cfs.

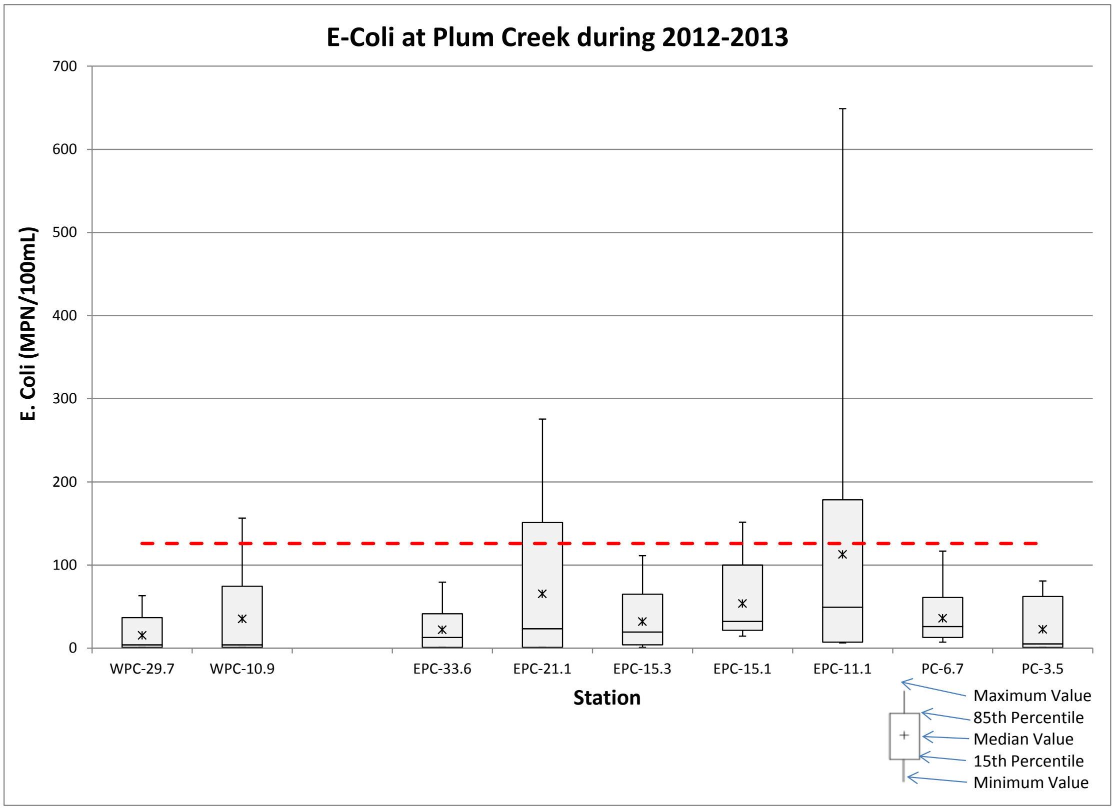

Figure 8: E. Coli (# colonies/100mL) along Plum Cr (Apr 2012 – Mar 2013); Water Quality Standard in Red (126 colonies/mL)

Higher TSS concentrations are an indicator of soil erosion, high velocity flow, and land disturbance. Figure 9 summarizes TSS measurements. Higher TSS concentrations, above 55 mg/L, were generally measured from EPC-15.3 downstream to PC-3.5, with higher measurements at EPC-11.1, near Sedalia.

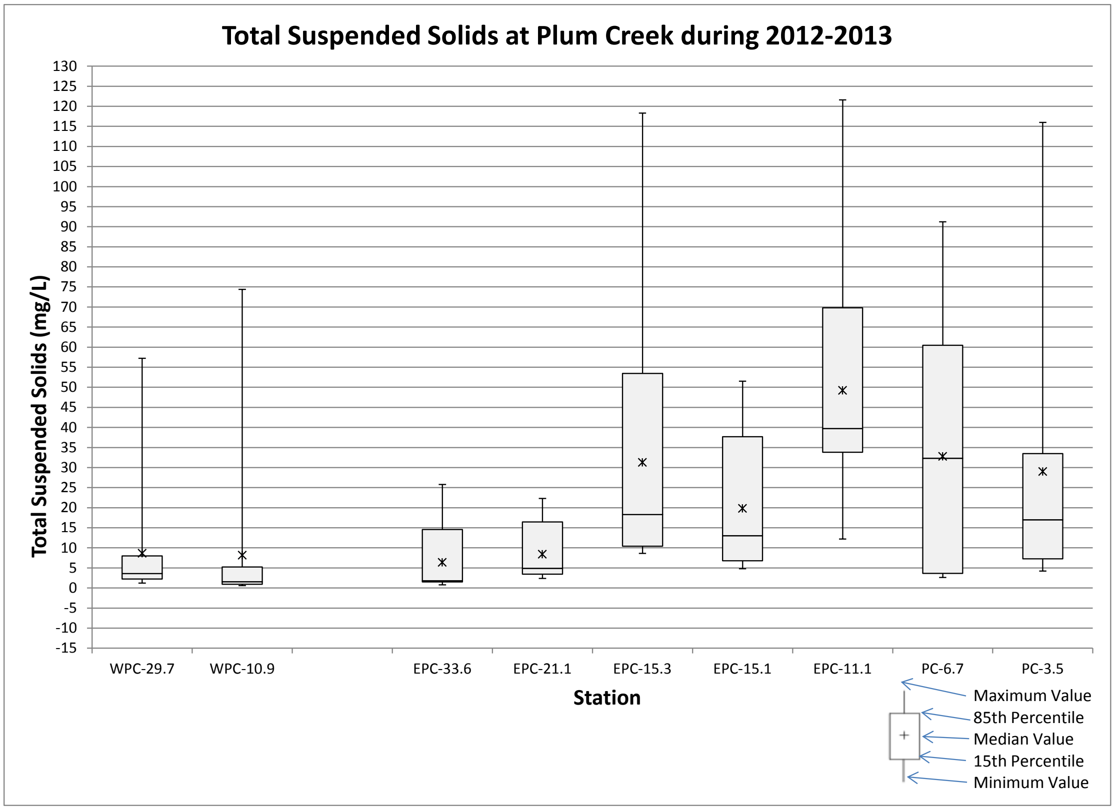

Figure 9: TSS Concentrations in Plum Cr Watershed (Apr 2012 – Mar 2013)

3.2.1 Potential Sources

Based on the limited data collected (12 data points at each station) the potential sources appear to be from urban runoff (elevated TP downstream of urbanized areas), runoff from agricultural lands (higher TP and E. coli downgradient of agricultural land uses), streambank erosion (higher TSS and TP near degraded areas (Figures 10 and 11), wastewater treatment facilities (higher TP, ortho-P and ammonia downstream of PCWA) and ISDS (higher E.coli near Sedalia, where aged ISDS are located in the floodplain (Figure 12).

Figure 10 - Streambank Erosion on Plum Creek, Upstream of Chatfield Reservoir

Significant stream bank erosion and channel degradation has developed along riparian reaches of Plum Creek due to unmanaged storm water runoff, erosive soils, and geomorphic conditions (Figures 10 and 11). Data collected in Plum Creek demonstrate the impact of stream bank erosion, and the significant correlation between sediment and nutrient loads (i.e. total phosphorus) in Plum Creek.

Figure 11- Streambank along West Plum Creek; Aggraded stream reach; 12-foot vertical drops in select areas upstream.

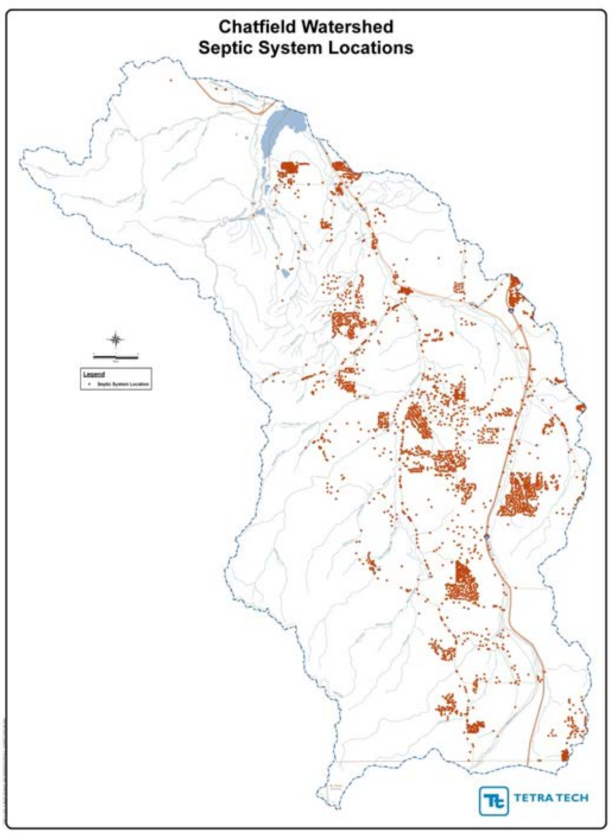

Figure 12 - ISDS Located in the Plum Cr Watershed

The higher concentrations of nutrients, bacteria, and TSS were measured at EPC-11.1, near Sedalia. This sampling location is in proximity to ISDS impacts (each business and residence has an ISDS) and agricultural land uses. Figure 13 compares monthly TSS, E.coli, and TP concentrations at this sampling site. TP concentrations at this location average 120 ug/L. The TP growing season (July – September) TP standard in Chatfield Reservoir is 30 ug/L. Future monitoring will better pinpoint pollutant sources; however, this data illustrates the need to control pollutant sources from this general area.

Significant correlations between TSS and TP suggest another potential source of TP is stream bank erosion (Figures 14 and 15). Higher coefficients of determination (R2 =0.98 and 0.90) were noted along West Plum Creek downstream of Perry Park (WPC-10.9) and Plum Creek upstream of Chatfield Reservoir at Titan Road (PC-3.5), respectively.

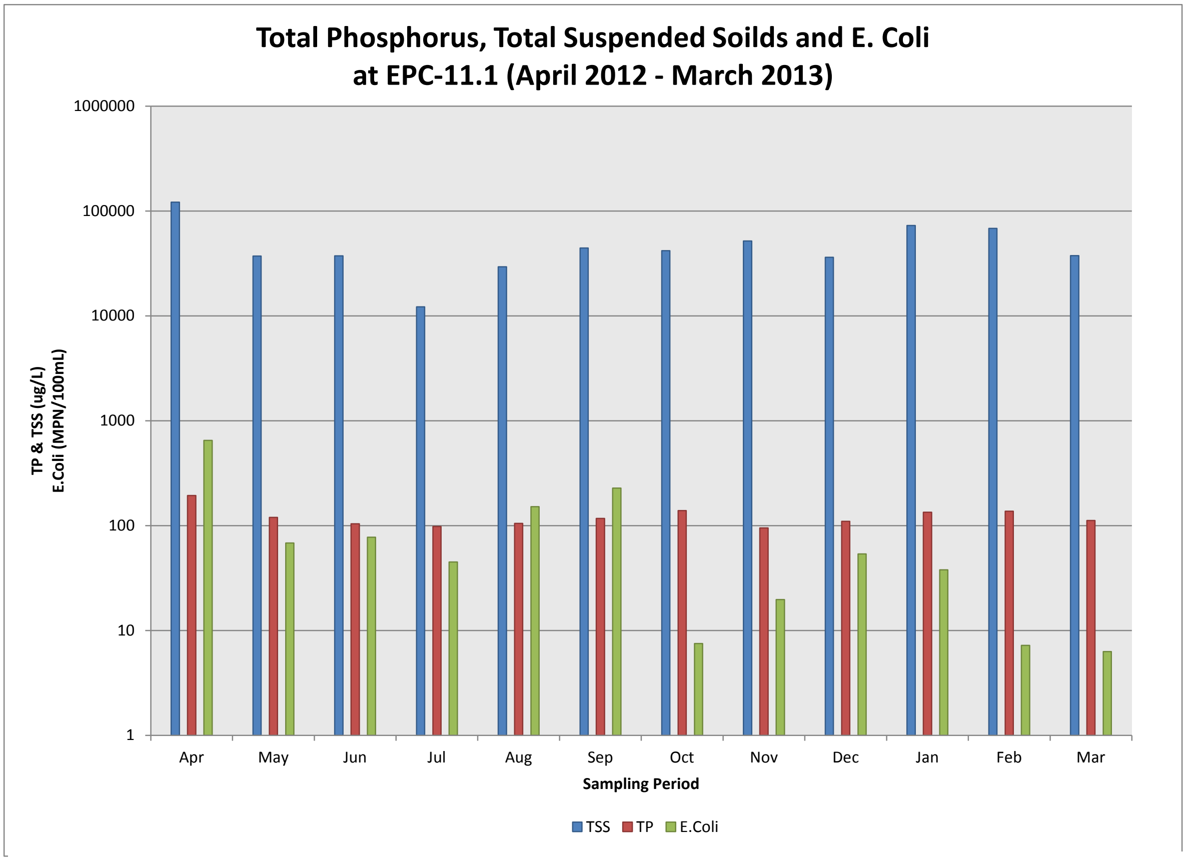

Figure 13 – TP, TSS, and E. Coli at EPC-11.1, Near Sedalia

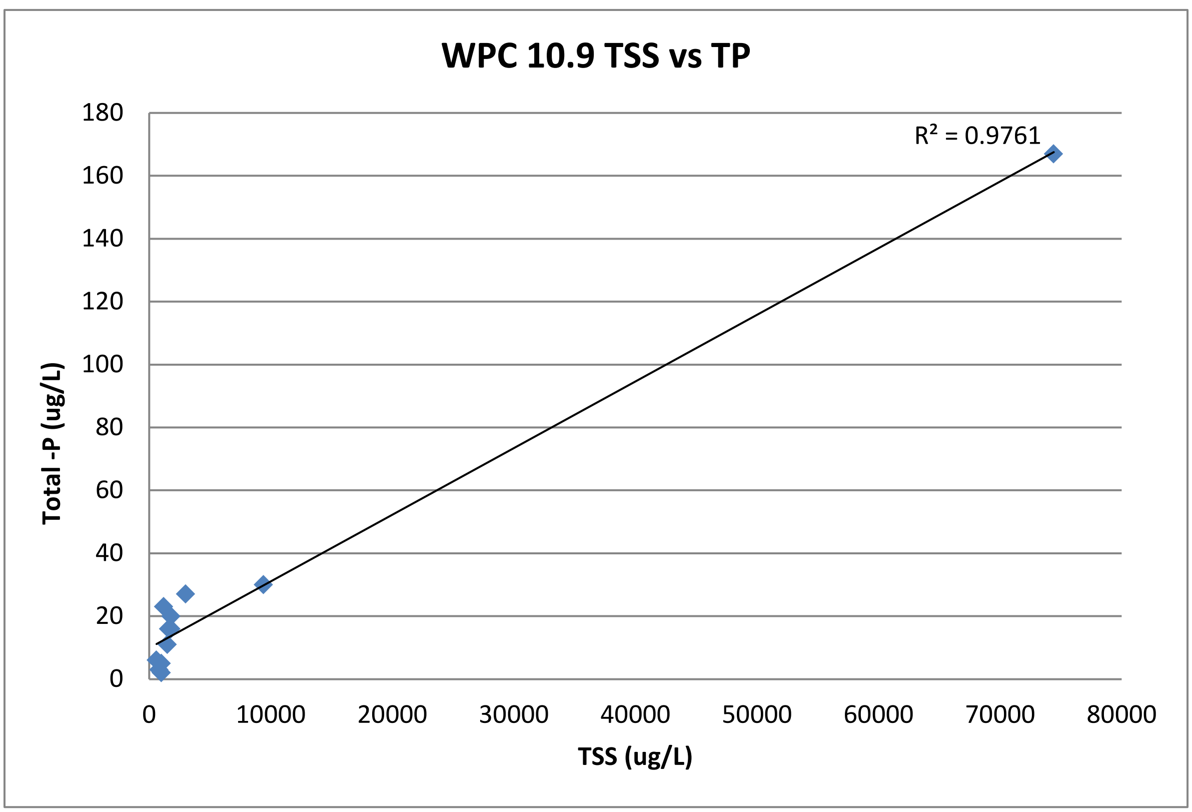

Figure 14 – TSS versus TP at WPC-10.9 (R^2=0.98)

4.0 POLLUTANT LOADING

In order to provide a technical basis to support implementation of future water quality improvements in the basin, including identification and siting of priority projects and BMPs, a monthly evaluation of TP and TSS pollutant loads was conducted in the watershed (Tables 3 and 4, respectively). Plum Creek loading was assessed at three locations:

1. East Plum Creek
2. West Plum Creek, and
3. Plum Creek

As shown on Table 3, TP loading was greatest in April 2012, when streamflow and TP concentrations are higher. Of the total calculated annual TP load of 1534 pounds (April 2012 – March 2013), approximately 600 pounds of TP was calculated entering the reservoir during April alone. Table 4 summarizes monthly TSS loads during the same timeframe. The highest TSS loads were also calculated in April 2012, approximately 435,850 pounds. Total annual TSS loading during the study period was approximately 825,875 pounds.

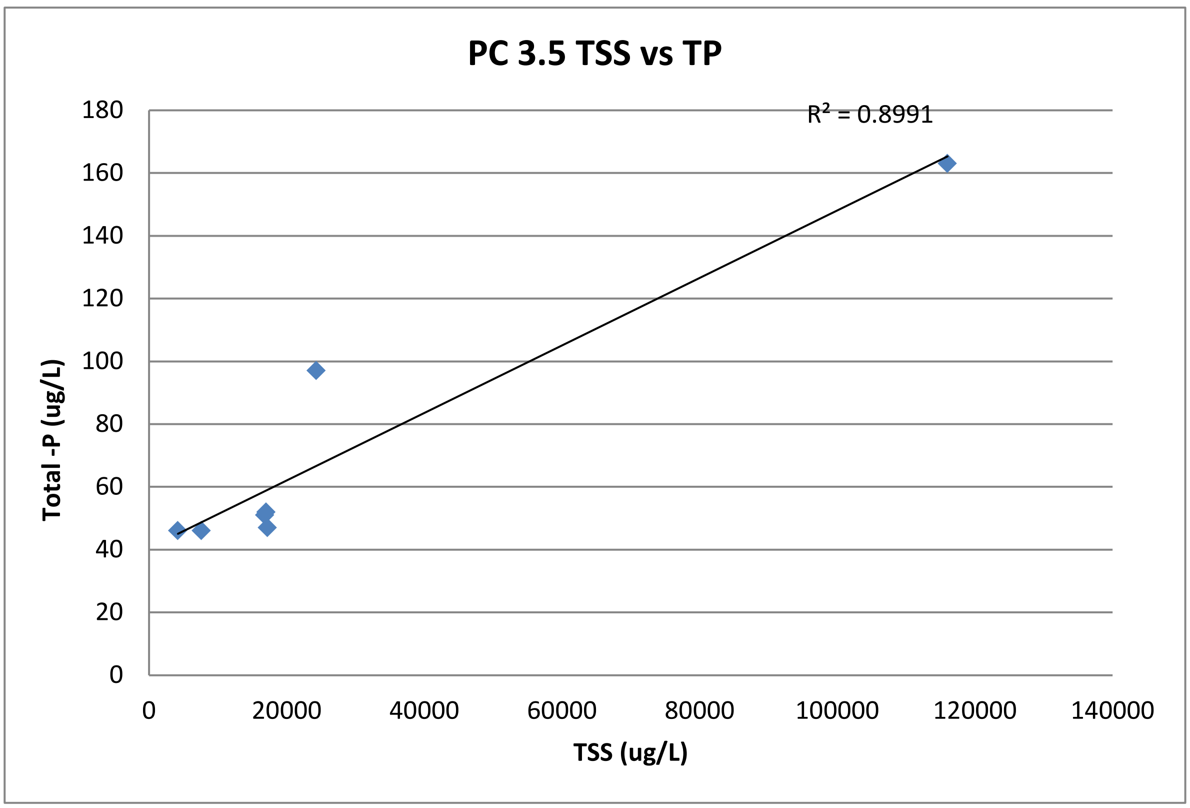

Figure 15 - TSS versus TP at PC-3.5, upstream of Chatfield Reservoir (R^2 = 0.90)

Table 3: Total Phosphorus Loading in Plum Creek Watershed (Apr 2012 – Mar 2013)

Table 3. Total Phosphorus Loading in Plum Creek Watershed (Apr 2012 - Mar 2013)

Source Category	Sampling Site	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total
East Plum Creek (lbs/day)	EPC-11.1, above confluence	21.1	9.0	3.1	0.0	4.0	5.1	9.7	6.6	9.1	10.6	11.7	8.9	
West Plum Creek (lbs/day)	WPC-10.9, above confluence	2.5	0.4	0.0	0.6	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	
Plum Creek (lbs/day)	PC-3.5, at Titan Road	19.9	4.9	2.7	1.0	0.3	1.7	1.4	1.5	1.5	9.3	2.6	3.8	
Total Load to Chatfield Reservoir (lbs/month)	PC-3.5, at Titan Road	597.4	152.2	81.6	30.0	10.4	50.0	42.8	43.9	46.2	288.7	73.3	117.8	1534.3

Table 4. Total Suspended Solids Loading in Plum Creek Watershed (Apr 2012 - Mar 2013)

Source Category	Sampling Site	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total
East Plum Creek (lbs/day)	EPC-11.1, above confluence	13,226.2	2,780.1	1,116.4	1.8	1,128.8	1,914.0	2,927.7	3,605.8	2,988.7	5,735.1	5,835.2	2,979.5	
West Plum Creek (lbs/day)	WPC-10.9, above confluence	787.2	47.2	0.5	62.2	33.1	0.1	0.6	0.4	0.5	8.4	5.7	5.1	
Plum Creek (lbs/day)	PC-3.5, at Titan Road	14,528.4	2,311.8	185.6	70.3	25.7	417.3	228.0	133.6	487.5	6,628.4	957.6	1,252.0	
Total Load to Chatfield Reservoir (lbs/month)	PC-3.5, at Titan Road	435,852.5	71,664.7	5,566.8	2,180.5	797.3	12,520.2	7,067.4	4,007.6	15,111.8	205,481.2	26,812.5	38,812.2	825,874.7

5.0 NEXT STEPS AND RECOMMENDATIONS

Data collected during the grant study period suggest the following:

- Controlling streambank erosion in the Plum Creek watershed will reduce TP and TSS concentrations.
- Pollutant sources appear to be greatest along East Plum Creek, specifically at the mouth of the creek, near Sedalia.
- Potential NPS impacts in and around the Sedalia area include aged ISDS, many located in and near the floodplain; reducing ISDS will improve water quality.
- Additional monitoring and data collection, especially under different hydrologic scenarios, will further support pollutant loading and potential sources in the watershed.

6.0 REFERENCES

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