Annual Stormwater Monitoring Report

Water Year 2017

Developed by the

Tahoe Resource Conservation District

for the

Implementers' Monitoring Program

component of the

Regional Stormwater Monitoring Program

Submitted to the

Lahontan Regional Water Quality Control Board and the

Nevada Division of Environmental Protection

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Implementers' Montoring Program (IMP), component of the Regional Stormwater Monitoring Program (RSWMP)

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Submitted by the Tahoe Resource Conservation District in cooperation with:

California	Nevada
City of South Lake Tahoe	Douglas County
El Dorado County	Washoe County
Placer County	Nevada Department of Transportation
	Nevada Tahoe Conservation District

TABLE OF CONTENTS

List of Acronyms

AC	Autosampler Composite Sample
Autosamplers	ISCO brand automated samplers
BMP	Best Management Practice
CEC	Characteristic Effluent Concentration
cf	cubic feet
cfs	cubic feet per second
CI	Contech MFS Inflow
CICU	Commercial, Industrial, Communications, Utilities
CMP	Corrugated Metal Pipe
CPP	Corrugated Plastic Pipe
CO	Contech MFS Outflow
CPC	Characteristic Pollutant Concentration
CRC	Characteristic Runoff Concentration
DMS	Data Management System
EMC	Event Mean Concentration
FB	Field Blank
FIG	Framework and Implementation Guidance document for RSWMP
FSP	Fine Sediment Particles
GS	Grab Sample
IMP	Implementers' Monitoring Program
JI	Jellyfish Inflow
JO	Jellyfish Outflow
Lahontan	Lahontan Regional Water Quality Control Board
LS	Lakeshore
MS	Manual Sample
NDEP	Nevada Division of Environmental Protection
NDOT	Nevada Department of Transportation
NPDES	National Pollutant Discharge Elimination System
NTU	Nephlometric Turbidity Units
PD	Pasadena
PI	Pasadena Inflow
PO	Pasadena Outflow
PLRM	Pollutant Load Reduction Model
PSD	Particle Size Distribution
QAPP	Quality Assurance Project Plan
QAQC	Quality Assurance, Quality Control
ROW	Right-of-Way
RSWMP	Regional Stormwater Monitoring Program
SAP	Sampling and Analysis Protocol
SB	Speedboat
SR	State Route 431
TA	Tahoma
Tahoe RCD	Tahoe Resource Conservation District
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids

TV	Tahoe Valley
USDA	United States Department of Agriculture
UT	Upper Truckee
WY	Water Year

1. Monitoring Purpose

The Regional Stormwater Monitoring Program (RSWMP) was developed by the Tahoe Resource Conservation District (Tahoe RCD) in partnership with the Implementers' Monitoring Program (IMP) in 2015 to collectively fulfill California National Pollutant Discharge Elimination System (NPDES) Permit requirements and Nevada Interlocal Agreement commitments. A new NPDES permit was issued on March 9, 2017 for term two and aligned all monitoring activities with the Regional Stormwater Monitoring Program (RSWMP) Framework and Implementation Guidance Document (Tahoe RCD et al 2015). The renewed Nevada Interlocal Agreements require participation in IMP.

IMP is a partnership between the California and Nevada implementing jurisdictions and was inspired by permit language that encouraged jurisdictions to comply collaboratively with regulatory requirements to promote cost savings through economies of scale. IMP is a partnership between the City of South Lake Tahoe, El Dorado County, Placer County, Douglas County, Washoe County, and the Nevada Department of Transportation (NDOT). Regulations require that California and Nevada jurisdictions in the Lake Tahoe Basin take measures to decrease pollutant loading from stormwater runoff in urbanized areas by implementing pollutant controls to decrease fine sediment particles (FSP, particles less than 16 microns) and nutrient inputs to Lake Tahoe. In the second permit term (water years 2017-2021), jurisdictions are collectively required to monitor urban catchment outfalls at a minimum of six sites and Best Management Practices (BMPs) at a minimum of two sites for flow volumes and pollutant loads. Monitoring provides empirical data that will be used to (1) assess nutrient and sediment loading at chosen catchments (2) evaluate BMP effectiveness at chosen BMPs, and (3) refine characteristic effluent concentrations (CECs) used by the Pollutant Load Reduction Model (PLRM) to calculate load reductions from chosen treatment BMPs. PLRM is the standard tool developed specifically for the Tahoe Basin to calculate pollutant loads and load reductions from water quality improvement projects.

All data has been collected in a manner consistent with RSWMP monitoring protocols outlined in the RSWMP Framework and Implementation Guidance document (FIG) designed to provide consistent data collection, management, analysis, and reporting approaches so that results can easily align with RSWMP objectives (Tahoe RCD et al 2015). Data collected as part of the Implementers' Monitoring Program (a component of RSWMP) satisfies the objectives and requirements of the jurisdictions' permits and ILAs. Long-term data will be useful in identifying status and trends in the watershed and verifying PLRM estimates.

2. Study Design

During Water Year 2017 (WY17), seven catchments (monitoring sites) were monitored for continuous flow and sampled for water quality at eleven monitoring stations. The monitoring stations were the outfalls of six of the seven selected catchments (six stations) and the inflows to, and outflows from, three BMPs (six stations minus one because the outflow from one of the BMPs doubles as a catchment outfall) located within two of those catchments (two BMPs are located within the same catchment). This exceeds the minimum regulatory requirement of six monitored catchments and two monitored BMPs in the second term. The catchments were chosen because of their direct hydrologic connectivity to Lake Tahoe, diversity of urban land uses, range of sizes, and a reasonably equitable distribution among the participating jurisdictions. BMP effectiveness sites were selected because of their potential efficacy in treating storm water runoff characteristic of the Lake Tahoe Basin, the broad interest in and lack of conclusive data regarding the efficiency of the selected BMPs in reducing runoff volumes and pollutant loads (especially FSP), and the importance of determining maintenance intervals required to retain effectiveness. See Figure 1 for stormwater monitoring site and meteorological station locations.

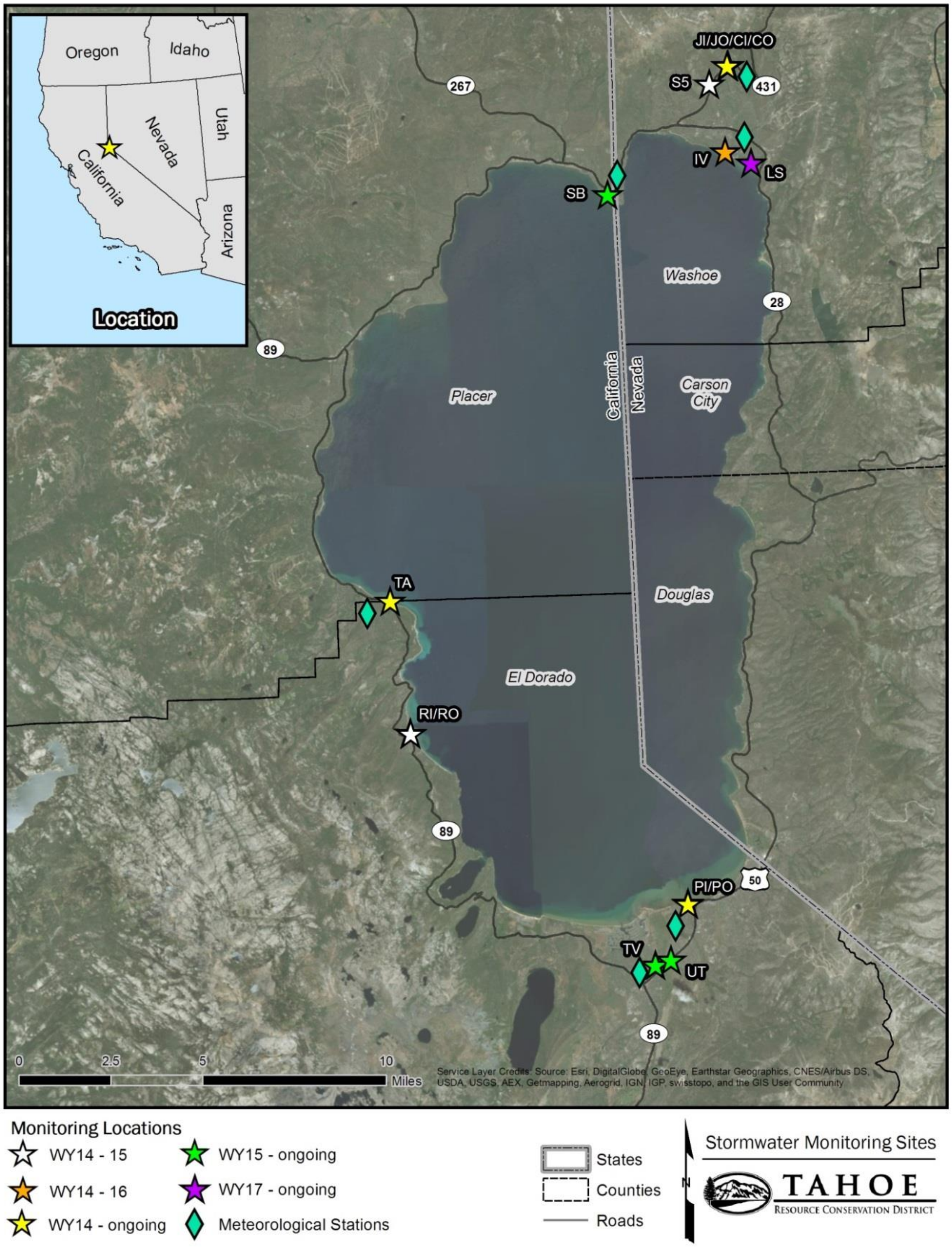

Figure 1 Past and current stormwater monitoring sites and ongoing meteorological stations. Jellyfish Inflow (JI), Jellyfish Outflow (JO), Contech MFS Inflow (CI), Contech MFS Outflow (CO), SR431 outfall (S5), Incline Village (IV), Lakeshore (LS), Speedboat (SB), Tahoma (TA), Rubicon Inflow (RI), Rubicon Outflow (RO), Tahoe Valley (TV), and Upper Truckee (UT), Pasadena Inflow (PI), and Pasadena Outflow (PO).

Table 1 summarizes the selected catchments and their corresponding designation as a catchment outfall monitoring site and/or BMP effectiveness monitoring site. Also included are the number of monitoring stations in the catchment, jurisdiction, total catchment area, percent impervious area, and dominant land uses in each catchment.

Table 1 Monitoring site specifics. Dominant urban land use is highlighted in dark pink, second most dominant in medium pink, and third most dominant in light pink. The vegetated class was not considered in this ranking. SR431 has two checkmarks under BMP because there are two different cartridge filters at this site.

Catchment Name	Outfall	BMP	# Monitoring Stations	Jurisdiction	Total Acres	Impervious Area	Landuse: Single Family Residential	Multi-Family Residential	CICU*	Primary Roads	Secondary Roads	Vegetated
SR431	√	√√	4	NDOT	14	89%	0%	0%	0%	89%	0%	11%
Pasadena	√	√	2	CSLT	78.8	39%	52%	13%	5%	0%	16%	14%
Lakeshore	√		1	Washoe	97.8	41%	2%	43%	31%	1%	10%	13%
Speedboat	√		1	Placer	29.0	30%	49%	3%	9%	4%	10%	25%
Tahoma	√		1	Placer, El Dorado, Caltrans	49.5	30%	41%	4%	12%	3%	15%	25%
Tahoe Valley	√		1	CSLT, Caltrans	338.4	39%	19%	12%	20%	2%	13%	34%
Upper Truckee	√		1	CSLT, Caltrans	10.5	72%	14%	7%	39%	14%	18%	8%

*Commercial, Industrial, Communications, Utilities

2.1 SR431 Catchment Description

The SR431 monitoring site is located on State Route 431 in Washoe County above Incline Village, Nevada. The 1.4 acre catchment encompasses NDOT right-of-way (ROW) of which approximately 89% is impervious. During winter months, when snow blocks stormwater infrastructure (like drop inlets) this catchment area may be larger, though this is difficult to verify. This is the smallest catchment monitored and outfall discharges directly into a perennial stream called Deer Creek which connects with Incline Creek and discharges into Lake Tahoe, giving this site the distinction of being directly connected to the lake despite being 2.5 miles away. SR431 is monitored as a catchment outfall site and for evaluating and comparing the effectiveness of two adjacent stormwater cartridge filter vaults, the Contech MFS and the Jellyfish, containing different types of cartridge filters. There are four monitoring stations at SR431: the inflow and outflow to the Contech MFS vault (CI, CO), and the inflow and outflow to the Jellyfish vault (JI, JO). Though located in a rural area with moderate highway traffic density, SR431 is the only site that isolates runoff from primary roads and can therefore be used to characterize runoff from one land-use type. In addition, SR431 is the only site currently available where a true side-by-side comparison of stormwater cartridge filter types can be performed.

2.2 Pasadena Catchment Description

The Pasadena monitoring site is located at the northernmost end of Pasadena Ave. in the City of South Lake Tahoe. It is monitored as a catchment outfall and BMP effectiveness site. A 36-inch outfall CMP emerging from the side of the steep slope at the end of Pasadena Avenue conveys runoff directly to Lake Tahoe. The pipe is the terminus of a 78.8 acre catchment designated the "G12" urban planning catchment by the City of South Lake Tahoe. The dominant land uses are moderate density single and multi-family residential and secondary roads. Thirty-nine percent of the catchment is impervious. In addition to the upstream permeable and porous road shoulders and perforated storm drain pipes, a pre-treatment Vortechnics storm vault and two Contech Stormfilter cartridge filter vaults were installed in parallel at the end of the catchment before discharge to the lake through the 36-inch CMP. Prior to WY14 monitoring, one of the Contech Stormfilters was not receiving any flow due to a missing orifice plate and the filter cartridges were therefore clean. The cartridges in the other Contech Stormfilter were replaced at the same time the missing orifice plate was installed (September 30, 2013). No further maintenance has been done on this system since September 2013. Pasadena Inflow (PI) is a monitoring station located at the inflow to the pre-treatment Vortechnics vault and two Stormfilter cartridge filter vaults (below the in-situ infiltration BMPs), and Pasadena Outflow (PO) is located in the 36-inch outfall CMP, the outflow from the pre-treatment vault and two Stormfilter cartridge filter vaults.

2.3 Lakeshore Catchment Description

The Lakeshore monitoring site is located in the road-side channel on the northern side of Lakeshore Blvd., near Third Creek, replacing the old Incline Village site, which was terminated after infiltration improvements upstream led to insufficient flow for sampling. It is monitored as a catchment outfall at one monitoring station (LS). At 97.8 acres, this is the second largest catchment monitored and it includes runoff from Washoe County and NDOT jurisdictions. The catchment drains a relatively steep, highly urbanized area of Incline Village with dominant urban land-uses consisting of moderate to high density residential, commercial, and secondary roads. Forty-one percent of the catchment area is impervious and there is a lack of any intervening natural dispersion and infiltration areas due to steep slopes and high-density development. Runoff discharges into Third Creek and then to Lake Tahoe via a rock-lined channel.

As part of the Central Incline Village Phase II Water Quality Improvement Project, constructed during the summer of 2015, substantial improvements were made in the catchment upstream of the monitoring site. New infiltration features that reduce roadway runoff in the catchment include: (1) a series of three upstream infiltration basins that receives 1.8 cfs of low flow from the pipe network, (2) two small roadside infiltration pools, and (3) 450 linear feet of roadside infiltration channels. A flow split routes a portion of the catchment flows through a jellyfish filter and then to the old Incline Village monitoring site; the remainder of the flows route through the road side channel to the new Lakeshore monitoring site. The drainage area for this outfall is similar to the old Incline Village catchment but receives additional flow from Lakeshore Blvd. east of Village Blvd as well as some overland flow originating upslope of Lakeshore Blvd.

2.4 Speedboat Catchment Description

The Speedboat monitoring site is located midway along the western side of Speedboat Avenue just south of Dip Street in Kings Beach, California. The 29.0 acre catchment is monitored as a catchment outfall at a single monitoring station (SB). It receives co-mingled runoff from Placer County and Caltrans jurisdictions delivered by a 12 inch CMP. The catchment is comprised of thirty percent impervious surfaces and drains a steep area that is characterized predominately by single family residences, vegetation, and secondary roads. After passing through a Palmer-Bowlus flume at the monitoring station, runoff from the catchment drains untreated through a series of CMPs along a pedestrian footpath at the intersection of Lake Street and Harbor Avenue directly to Lake Tahoe.

This site was monitored from 2003 to 2012 by the University of California, Davis, Tahoe Environmental Research Center (UCD TERC) and the Desert Research Institute (DRI). Data collected from this site was included in the initial Total Maximum Daily Load (TMDL) study that ultimately populated the PLRM used to estimate pollutant loading from urban catchments.

2.5 Tahoma Catchment Description

Tahoma is monitored as a catchment outfall at one monitoring station (TA). The 49.5 acre catchment straddles the Placer County/El Dorado County border and comingles waters from both jurisdictions, plus waters from the Caltrans maintained Highway 89. The land-uses in this catchment are primarily moderate density residential and secondary roads in the Tahoe Cedars subdivision, but also include some commercial/industrial/communications/utilities (CICU) and primary roads. Thirty percent of the catchment area is impervious. The runoff from this catchment discharges directly into Lake Tahoe via a 36-inch oval “squashed” CMP at the bottom of the Water’s Edge North condominium complex driveway without infiltration or treatment. Because of the high direct connectivity between the catchment and Lake Tahoe, this storm drain system has great potential to deliver high FSP loads to the lake.

A water quality improvement project completed in the fall of 2014 installed nine sediment traps to decrease flow rates and capture coarse sediment, one new drop inlet to more effectively capture and route flow, and more than 80 feet of perforated infiltration pipe to decrease runoff volumes to the catchment outflow.

2.6 Tahoe Valley Catchment Description

The Tahoe Valley monitoring site is located on the eastern side of Tahoe Keys Boulevard just south of the intersection with Sky Meadows Court in South Lake Tahoe, California near the entrance to the Sky Meadows Condominium Complex. With an area of 338.4 acres, this is the largest catchment monitored. It is a relatively flat, highly urbanized catchment consisting primarily of CICU, single family residences, secondary roads, and vegetation. Thirty-nine percent of the catchment is impervious. This site is monitored as a catchment outfall at a single monitoring site (TV). Runoff to the site is delivered by a 36 inch "squashed" CMP from the City of South Lake Tahoe jurisdiction. After passing by the TV monitoring station, runoff is conveyed through a vegetated swale along the northwest edge of the Sky Meadows Condominium Complex directly to the Upper Truckee River and eventually to Lake Tahoe.

Many water quality improvement projects have been implemented in this catchment in the last 25+ years. The existing Helen Basin and almost 3,200 linear feet of vegetated swales were built as part of the Tahoe Valley Erosion Control Project (ECP) in 1989 to increase stormwater infiltration upstream of the current monitoring site. This area was maintained under a contract with the California Conservation Corps in 2014 and included removing sediment that was blocking pipes, excess vegetation in the basin and swales, drug paraphernalia, empty liquor bottles, and human waste. Additionally, Caltrans completed the $12 Million US Highway 50 water quality improvement project in 2012 which included curb, gutter, rock-lined swales, infiltration chambers and basins along Highways 50 and 89 to address highway runoff in the catchment. Lastly, to ensure high infiltration rates, the City of South Lake Tahoe removed accumulated sediment, excess vegetation, and trash in the Caltrans swales upstream of Tahoe Keys Boulevard near Council Rock Road and behind the storage units on Eloise in May and June of 2015, also under a contract with the California Conservation Corps. Nearby homeless camps littered with trash, human waste, empty liquor bottles, and used needles were also removed.

2.7 Upper Truckee Catchment Description

The Upper Truckee monitoring site is located on the eastern bank of the Upper Truckee River at the intersection of Highway 50 and River Drive a short distance upstream of the bridge on Highway 50 that crosses the Upper Truckee River in the City of South Lake Tahoe, California. The 10.5 acre catchment drains a highly urbanized area which is primarily composed of CICU, primary and secondary roads, and single family residences. This is the second smallest catchment monitored, but with a high percentage of impervious coverage (72%) it receives relatively high volumes of co-mingled runoff from the City of South Lake Tahoe and Caltrans jurisdictions through an 18 inch Corrugated Plastic Pipe (CPP). After exiting the CPP, runoff is discharged to an 80 inch x 48 inch x 24 inch trash collection device lined with filter fabric and then to a 15 foot rock lined slope that leads directly into the Upper Truckee River and eventually to Lake Tahoe. The site is monitored as a catchment outfall site at a single location (UT). Improvements were made in this catchment by the City of South Lake Tahoe in the summer of 2015 that included an 8,100 cubic foot infiltration gallery, 394 linear feet of perforated pipe and infiltration trenches, seven sediment traps/dry wells, and 3,340 linear feet of stabilized road shoulders. However, since the majority of runoff in this catchment originates from Highway 50, under Caltrans' jurisdiction, volume and pollutant reductions at this monitoring site have been hard to detect. Caltrans has plans for further improvements in the summer of 2018. This site provides an opportunity to assess the effectiveness of these improvements with pre- and post-implementation data.

3. Data Collection Methods, Sampling Protocols, Analytic Methods

Continuous hydrology and stormwater samples are collected using ISCO brand automated samplers (autosamplers) per RSWMP protocols (RSWMP FIG 2015 section 10.2.1, Tahoe RCD et al 2015) at all eleven monitoring stations in WY17 to support seasonal [fall/winter (October 1-February 28), spring (March 1-May 31), and summer (June 1-September 30)] volume and load reporting. Autosamplers were installed and sites maintained according to protocols outlined in the RSWMP FIG sections 10.1.2.2 and 10.2.1.3 respectively. Continuous turbidity was collected at all sites with an FTS DTS-12 turbidimeter. Turbidimeters were installed and maintained as outlined in the RSWMP FIG sections 10.2.2.1 and 10.2.2.2. Equations that relate turbidity to FSP concentration have been developed specifically for the Tahoe Basin and were applied to estimate FSP loads (2NDNATURE et al 2014). Continuous meteorological data is recorded using a Davis Instruments Vantage

Pro weather station installed at six locations in the vicinity of the seven monitored catchments and maintained following recommendations in the RSWMP FIG sections 10.2.3.1 and 10.2.3.2. Meteorological data is used to calculate seasonal and annual precipitation totals (RSWMP FIG section 10.2.3.5) and to estimate the amount of flow that can be expected in a particular catchment for a particular amount of precipitation to aid with autosampler programming for event based sampling (RSWMP FIG section 10.2.1.4).

Continuous data (flow, turbidity, and meteorology) are logged at a constant time interval, generally every 5 minutes. Flow and turbidity data are QAQC'd with frequent stage and turbidity field measurements to ensure that no drift has occurred in the readings and sensors are performing optimally (RSWMP FIG sections 10.2.1.7 and 10.2.2.5). Visual observations are used to confirm when a flume or pipe is dry and stage and turbidity should read zero. Visual observations are also used to determine if ice in the flume or pipe is causing stage errors that need to be adjusted to zero. Visual observations and field measurements are made every two weeks at a minimum but more often during precipitation events. Recalibration of stage measuring equipment is done by adjusting the level measurement on the autosampler. Turbidimeter accuracy was verified on all in-situ turbidimeters with a solution of known turbidity in late September/early October 2016, and June 2017. In-situ turbidimeter verification occurs regularly prior to the beginning of each water year as well as during the sampling season. Turbidimeters requiring servicing are sent back to the manufacturer for recalibration.

Weather is monitored closely and autosamplers are programmed to sample at the beginning of each runoff event in accordance with RSWMP FIG sections 10.2.1.4 and 10.2.1.5. Single samples are combined into flow-weighted composites (RSWMP FIG section 10.2.1.10) based on their occurrence in the hydrograph. Full event composites and quality control samples are analyzed for total nitrogen (TN) concentration, total phosphorus (TP) concentration, total suspended solid (TSS) concentration, turbidity, and particle size distribution (PSD) to determine fine sediment particle (FSP) concentration at the UC Davis Tahoe Environmental Research Center Laboratory in Incline Village, NV, the UC Davis Laboratory in Davis, CA, or the High Sierra Water Laboratory, Inc. in Tahoe City, CA. Table 2 summarizes the sample type acronyms and their meaning. Table 3 summarizes the analytical methods and detection limits for all analyses. Raw analytical data for all samples is presented in Appendix A.

Table 2 Sample types and acronyms.

Sample Acronym	Sample Type
AC	**A**uto-sampler **C**omposite, flow-weighted composite of whole or part of hydrograph
FB	**F**ield **B**lank (QA/QC)
GS	**G**rab **S**ample single (QA/QC)
MS	**M**anually triggered auto-**S**ampler single (QA/QC)

Table 3 Analytical methods and detection limits.

Analyte	Methods	Description	Detection Limit	Target Reporting Limit
Total Phosphorus as P	TERC Low Level Method	Colorimetric, Total Phosphorus, Persulfate digestion, low level	2 ug/L	10 ug/L
Total Kjeldahl Nitrogen	EPA 3511; or EPA 3512	Colorimetric, block digestion, phenate	40 ug/L	100 ug/L
Nitrate + Nitrite	TERC Low Level Method	Colorimetric, NO3 + NO2 Hydrazine Method, low level	2 ug/L	10 ug/L
Total Nitrogen as N	N/A	Total Kjeldahl Nitrogen + Nitrate + Nitrite	40 ug/L	100 ug/L
Total Suspended Solids	EPA 160.2 or SM 2540-D	Gravimetric	0.4 mg/L	1mg/L
Turbidity	EPA 180.1or SM 2130-B	Nephelometric	0.05 NTU	0.1NTU
Particle Size Distribution	SM 2560 or RSWMP addendum SOP	Laser backscattering	0.5 mg/L	1mg/L

Sample handling and processing includes proper labeling of samples in the field, transporting samples to a laboratory immediately after collection in a cooler with ice, compositing single samples on a flow-weighted basis, taking turbidity measurements with a calibrated instrument, shipping to an analytical laboratory with proper chain-of-custody procedures, and filtering samples within a 24-hour period. A minimum of 10% of all samples analyzed were QAQC samples to identify problems related to field sampling and sample processing (RSWMP FIG section 10.2.1.6). Analytical data for all QAQC samples is presented in Appendix B.

4. Data Management Procedure

Continuous data series and sample dates and times are collected through the RSWMP Data Management System (DMS) at the time samples are collected, maintenance is required, or every two weeks during dry periods. All data are input into Excel workbooks for storing continuous parameters and sample dates and times. Any other field measurements and observations are recorded in a field notebook and transcribed into the same Excel workbooks. Samples are transported to a processing lab immediately after collection. The DMS automatically calculates the recipe for compositing single samples into an event composite for each monitoring station. All samples are measured for turbidity and values are recorded on standard data sheets in the laboratory and entered into an Excel workbook for storing nutrient and sediment data. All samples are sent to proper laboratories within appropriate holding times for TN, TP, TSS, and PSD analysis. For a complete description of holding times for sampled parameters, see the RSWMP Quality Assurance Project Plan (QAPP) (DRI et al 2011a). Results from analytical laboratories are entered into the same Excel workbook for storing nutrient and sediment data. All Excel workbooks are housed on one central server (with backup device) and managed by Tahoe RCD staff. All data management procedures described above follow protocols outlined in the RSWMP FIG section 10.2.1.

5. Data Analysis

The raw hydrologic data set includes stage, velocity (at select sites), flow (determined by an equation relating stage in a weir, flume or pipe, or stage and velocity in a smooth walled pipe to flow), and turbidity recorded every 5 or 10 minutes (depending on the site) throughout the water year. Data gaps were short and rare. Erroneous readings are corrected and data gaps are filled following protocols outlined in the RSWMP FIG sections 10.2.1.7 for flow and 10.2.2.5 for turbidity.

Seasonal and annual volumes are calculated by the DMS in accordance with RSWMP FIG sections 10.2.1.8 and 10.2.1.9. Results from lab analysis are used by the DMS to calculate a flow-weighted event mean concentration (EMC) as outlined in section 10.2.1.10 of the RSWMP FIG. The DMS groups EMCs by season and calculates a seasonal characteristic pollutant concentration for each site; the DMS then applies these concentrations to each hydrologic measurement for that season. The DMS calculates loads by summing concentrations multiplied by runoff volumes over time as outlined in section 10.1.2.11 of the RSWMP FIG. Turbidity is converted to FSP concentration (in both mass per liter and number of particles per liter) using equations relating turbidity to FSP (2NDNATURE et al 2014) and integrated over time to calculate seasonal and annual load estimates in pounds and number of particles (RSWMP FIG sections 10.2.2.6 and 10.2.2.7).

Raw meteorological data include a precipitation and a temperature reading every 5 or 10 minutes (depending on the station) throughout the water year. Precipitation occurring as snow is converted to inches of water by a heated tipping bucket at the meteorological station that melts falling snow upon contact with the device. Data is QAQC'd by comparing event, seasonal and annual totals to the closest neighboring meteorological station. Data gaps were rare, but were filled with data from a neighboring station when they occurred (RSWMP FIG section 10.2.3.4). The DMS calculates seasonal and annual precipitation totals for reporting purposes.

6. Catchment Outfall Monitoring

6.1 Summary Data for All Monitoring Sites

A meteorological station at the Tahoe City Dam located in the northwest corner of the lake at an elevation of 6,235 feet is maintained under the Truckee River Operating Agreement (TROA). Per RSWMP protocols, this station is to be used as a reference station to determine if a particular water year is wet, average, or dry (assuming that a wet, average, or dry season in Tahoe City will be the same around the lake). Using an 85-year precipitation record (water years 1933-2017) from this station, WY17, at **69.8 total inches**, constitutes the maximum for this period of record and is therefore designated a very wet year (Table 4, Figure 2).

Table 4 Annual precipitation statistics from the Tahoe City meteorological reference station, water years 1933-2017.

WY 1933-2017	Annual Precipitation (in)	Designation
1st quartile	8.9 - 219	very dry
2nd quartile	22.0 - 29.0	dry
Median	29.0	average
3rd quartile	29.1- 39.5	wet
4th quartile	39.6 - 69.8	very wet

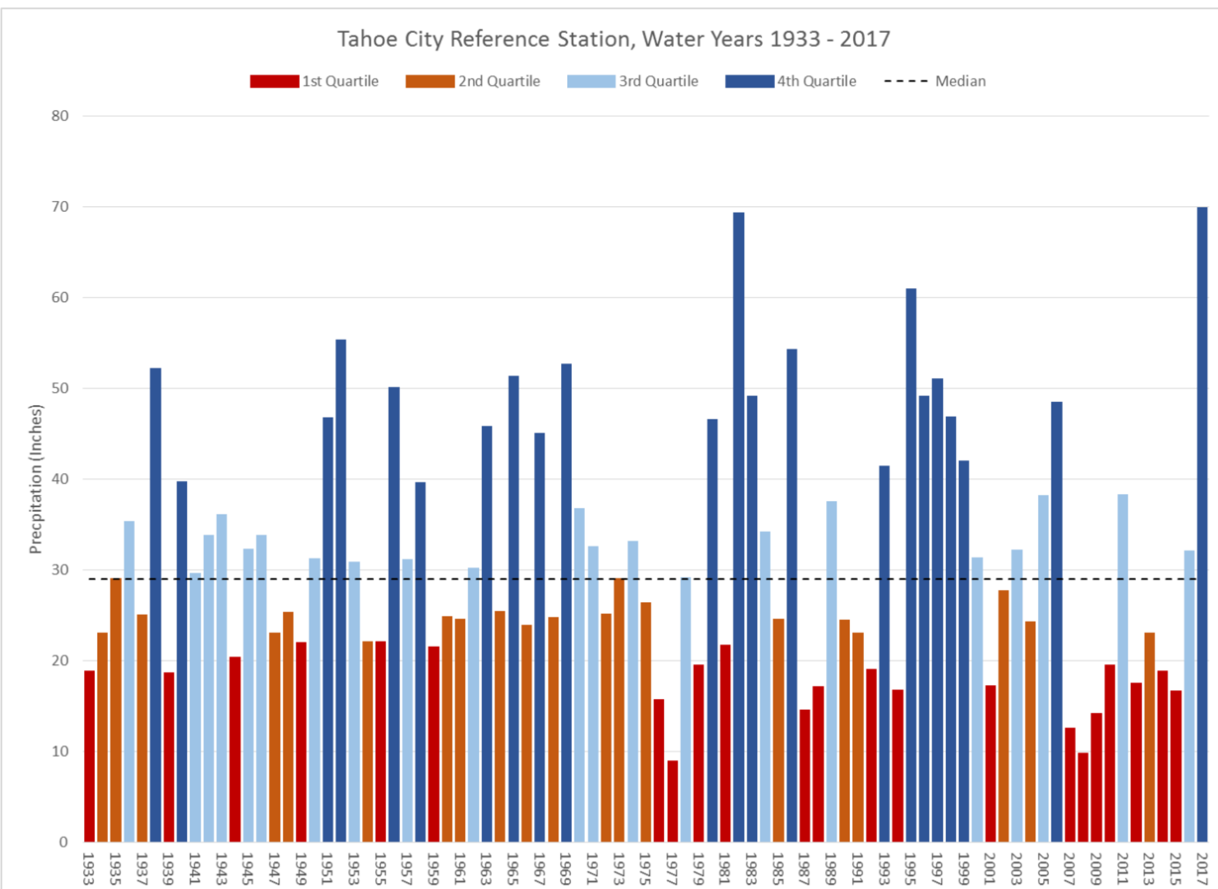

Figure 2 Long-term precipitation record at the Tahoe City meteorological station, water years 1933-2017.

Three primary “seasons” are defined by the NPDES permit; fall/winter (October 1 - February 28), spring (March 1 - May 31), and summer (June 1 - September 30). The seasons are defined as such to better fit with precipitation patterns and storm event types that occur in the Tahoe Basin. The primary event types in the fall/winter are frontal rain storms, rain on snow, mixed rain/snow, or event snowmelt. An event snowmelt occurs during and shortly after a snow event when enough snow melts (generally on the roads from the heat generated by automobile traffic) to produce runoff at a given monitoring site. Spring event types include the fall/winter event types plus non-event snowmelts. A non-event snowmelt event generally occurs in the spring when temperatures are greater than 50 degrees Fahrenheit and accumulated snowpack melts. Most monitoring sites do not receive sufficient spring non-event snowmelt to sample. Summer events are primarily thunderstorms and frontal rain storms.

Summary data for all sites are presented in Table 5. Figure 3 - Figure 10 illustrate Table 5 in graphical form. FSP loads are calculated from continuous turbidity, and TN and TP loads are calculated from event sampling. As not every runoff event was sampled during the year; the seasonal and annual TN and TP loads represent an average (volume weighted) load estimation for the respective period based on the events that were sampled in that period. In Figure 3 - Figure 10, SR431 is represented by its four sites: Contech MFS Inflow (CI), Contech MFS Outflow (CO), Jellyfish Inflow (JI), and Jellyfish Outflow (JO); Pasadena is represented by its two sites: Pasadena Inflow (PI) and Pasadena Outflow (PO); Lakeshore is LS, Speedboat is SB, Tahoma is TA, Tahoe Valley is TV, and Upper Truckee is UT.

Table 5 Summary statistics for all catchments for WY17. Top table shows seasonal precipitation, seasonal volumes, and FSP data, bottom table shows seasonal volumes and nutrient data.

Water Year 2017 (October 1, 2016 - September 30, 2017)			Seasonal Precipitation (in)			Total Annual Precip (in)	Seasonal Runoff Volumes (cf)			Total Annual Runoff Volumes (cf)	Average Seasonal FSP Concentrations (mg/L)			Average Estimated Annual FSP Concen-trations (mg/L)	Seasonal FSP Loads (lbs)			Total Annual Estimated FSP Loads (lbs)	Seasonal FSP Loads (#particles)			Total Annual Estimated FSP Loads (#particles)
Catchment Name	Station Name	Station Acronym	Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)	
SR431	Contech In	CI	38.03	8.67	2.31	49.01	31,621	63,942	2,786	98,349	129	76	124	94	254	303	22	578	2.67E+16	3.11E+16	1.71E+15	5.95E+16
	Contech Out	CO	38.03	8.67	2.31	49.01	29,932	63,897	1,937	95,767	78	63	115	69	147	250	14	411	1.48E+16	2.44E+16	1.09E+15	4.03E+16
	Jellyfish In	JI	38.03	8.67	2.31	49.01	32,905	48,357	2,456	83,718	130	63	106	91	267	190	16	474	2.82E+16	1.90E+16	1.28E+15	4.85E+16
	Jellyfish Out	JO	38.03	8.67	2.31	49.01	32,859	47,409	2,123	82,391	90	66	98	76	184	196	13	393	1.94E+16	1.98E+16	9.77E+14	4.02E+16
Pasadena	Pasadena In	PI	28.04	5.45	2.19	35.68	324,604	22,288	12,687	359,579	20	62	136	27	402	86	108	596	3.37E+16	6.91E+15	7.99E+15	4.86E+16
	Pasadena Out	PO	28.04	5.45	2.19	35.68	305,159	15,560	6,901	327,620	16	58	109	20	308	56	47	411	2.51E+16	4.64E+15	3.39E+15	3.31E+16
Lakeshore	Lakeshore	LS	36.15	6.00	0.94	43.09	387,635	158,812	0	546,447	25	85	0	42	597	844	0	1,441	5.40E+16	8.79E+16	0.00E+00	1.42E+17
Speedboat	Speedboat	SB	36.47	6.72	1.80	44.99	953,925	360,501	5,089	1,319,514	118	121	512	120	6,368	2,682	168	9,218	6.66E+17	2.64E+17	1.41E+16	9.44E+17
Tahoma	Tahoma	TA	51.54	10.34	2.40	64.28	1,558,247	917,270	8,248	2,483,765	18	9	33	15	1,740	518	17	2,275	1.60E+17	4.31E+16	1.46E+15	2.05E+17
Tahoe Valley	Tahoe Valley	TV	28.04	7.66	1.76	37.46	8,802,817	10,929,685	574,238	20,306,740	23	23	27	23	12,650	15,535	959	29,143	1.20E+18	1.05E+18	3.43E+16	2.28E+18
Upper Truckee	Upper Truckee	UT	28.04	7.66	1.76	37.46	364,120	108,393	24,177	496,690	129	124	84	126	2,939	836	126	3,902	3.08E+17	7.65E+16	1.09E+16	3.96E+17

Water Year 2017 (October 1, 2016 - September 30, 2017)			Seasonal Runoff Volumes (cf)			Total Annual Runoff Volumes (cf)	Average Seasonal TN Concentrations (ug/L)			Average Annual TN Concen-trations (ug/L)	Seasonal TN Loads (lbs)			Total Annual TN Loads (lbs)	Average Seasonal TP Concentrations (ug/L)			Average Annual TP Concen-trations (ug/L)	Seasonal TP Loads (lbs)			Total Annual TP Loads (lbs)
Catchment Name	Station Name	Station Acronym	Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)	
SR431	Contech In	CI	31,621	63,942	2,786	98,349	2,395	930	472	1,388	4.7	3.7	0.08	8.5	864	1,045	329	967	1.7	4.2	0.06	5.9
	Contech Out	CO	29,932	63,897	1,937	95,767	892	761	569	798	1.7	3.0	0.07	4.8	582	753	218	689	1.1	3.0	0.03	4.1
	Jellyfish In	JI	32,905	48,357	2,456	83,718	1,240	1,294	662	1,254	2.5	3.9	0.10	6.6	847	1,437	348	1,173	1.7	4.3	0.05	6.1
	Jellyfish Out	JO	32,859	47,409	2,123	82,391	1,110	1,184	431	1,135	2.3	3.5	0.06	5.8	710	921	164	818	1.5	2.7	0.02	4.2
Pasadena	Pasadena In	PI	324,604	22,288	12,687	359,579	1,057	1,262	9,222	1,357	21	1.8	7.3	30	436	399	2,023	490	8.8	0.56	1.6	11
	Pasadena Out	PO	305,159	15,560	6,901	327,620	1,041	1,543	7,895	1,209	20	1.5	3.4	25	408	399	1,693	435	7.8	0.39	0.73	8.9
Lakeshore	Lakeshore	LS	387,635	158,812	0	546,447	626	341	0	543	15	3.4	0	19	208	114	0	180	5.0	1.1	0	6.2
Speedboat	Speedboat	SB	953,925	360,501	5,089	1,319,514	881	1,313	4,472	1,012	53	30	1.4	84	399	329	873	382	24	7.4	0.28	32
Tahoma	Tahoma	TA	1,558,247	917,270	8,248	2,483,765	686	277	na	534	67	16	na	83	211	64	na	157	21	3.7	na	24
Tahoe Valley	Tahoe Valley	TV	8,802,817	10,929,685	574,238	20,306,740	907	571	4,538	829	498	389	163	1,050	233	100	824	178	128	68	30	225
Upper Truckee	Upper Truckee	UT	364,120	108,393	24,177	496,690	1,234	3,200	7,094	1,948	28	22	11	60	714	302	1,748	674	16	2.0	2.6	21

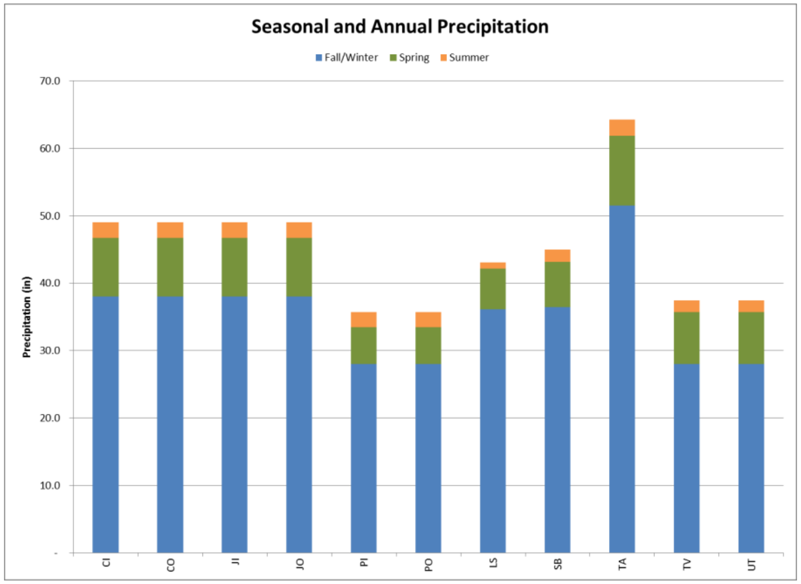

Figure 3 Precipitation totals at each monitoring station, WY17.

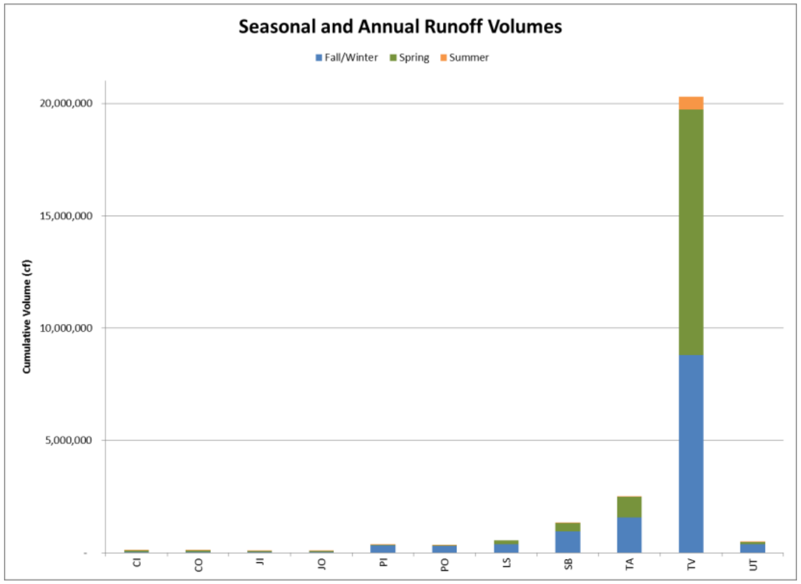

Figure 4 Runoff volumes at each monitoring station, WY17.

Precipitation

- The west shore of the lake received the most precipitation, the south shore received the least, and the north shore fell in between (there are no stations on the east shore).
- All regions of the lake received the greatest amount of precipitation during the fall/winter season and least during the summer.

Runoff Volumes

- Catchment size influences runoff volume. Tahoe Valley is the largest catchment and had the greatest runoff volume. SR431 is the smallest catchment and had the least runoff.
- Infiltration features influence runoff volume. Though Tahoma is approximately half the size of Lakeshore, it had approximately 5 times the runoff volume. A large EIP project was completed in the Lakeshore catchment in 2016. One is planned in the Tahoma catchment in 2018.
- Impervious area influences runoff volume. SR431 is 13% of the size of Upper Truckee, but has 40% of the runoff volume. SR431 is 89% impervious and Upper Truckee is 72% impervious.
- Precipitation totals influence runoff volumes. Most catchments had the most runoff in the fall/winter season. All catchments had the least runoff in the summer.
- Snow accumulation and snowmelt may influence spring runoff volumes. SR431 and Tahoe Valley had the most runoff in the spring.

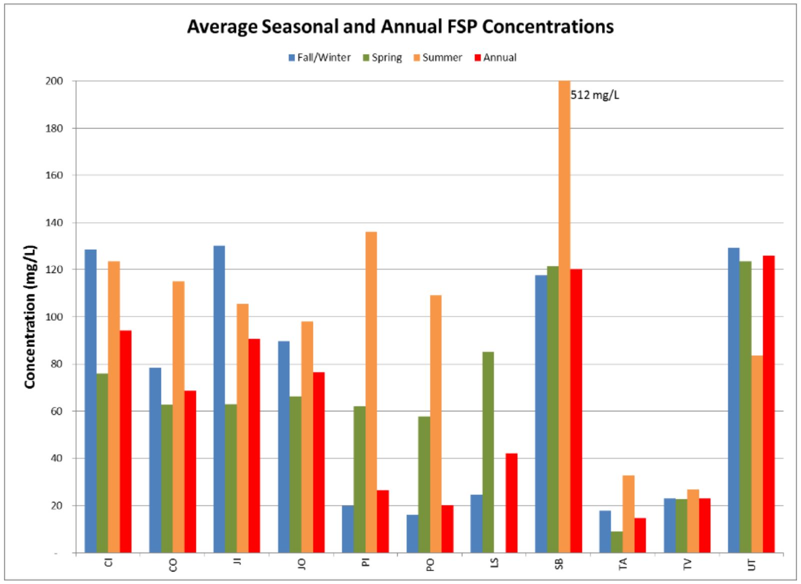

Figure 5 FSP concentrations at each monitoring station, WY17.

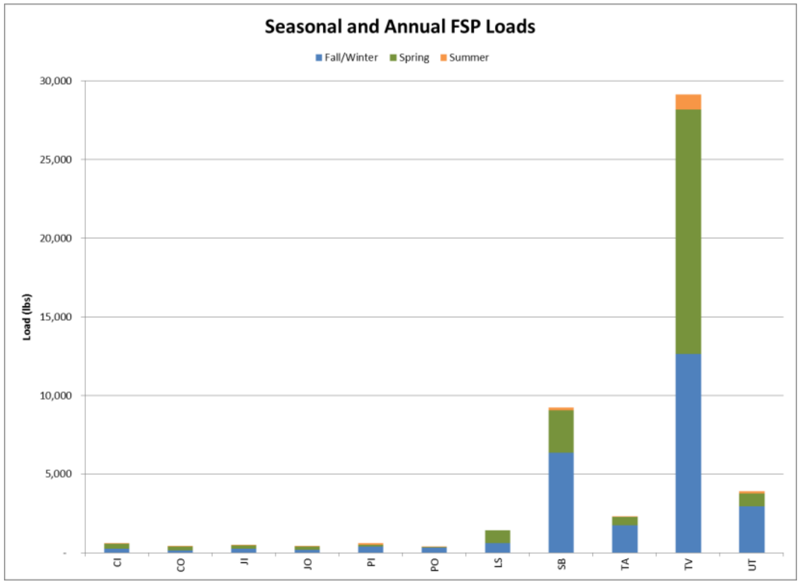

Figure 6 FSP loads at each monitoring station, WY17.

FSP Concentrations

- FSP concentrations tend to be the highest in the fall/winter or summer, depending on catchment.
- Average annual FSP concentrations were highest at Speedboat and Upper Truckee and lowest at Pasadena, Tahoma, and Tahoe Valley.
- Of all of the sites, the highest average seasonal FSP concentration was observed during the summer season at Speedboat.

FSP Loads

- Runoff volume has the largest influence on loads. Tahoe Valley contributed significantly more FSP to the lake than any other site, yet it had one of the lowest average seasonal FSP concentrations in all seasons.
- Concentrations influence loads. Upper Truckee had relatively low runoff volumes, relatively high FSP concentrations, and relatively high FSP loads.

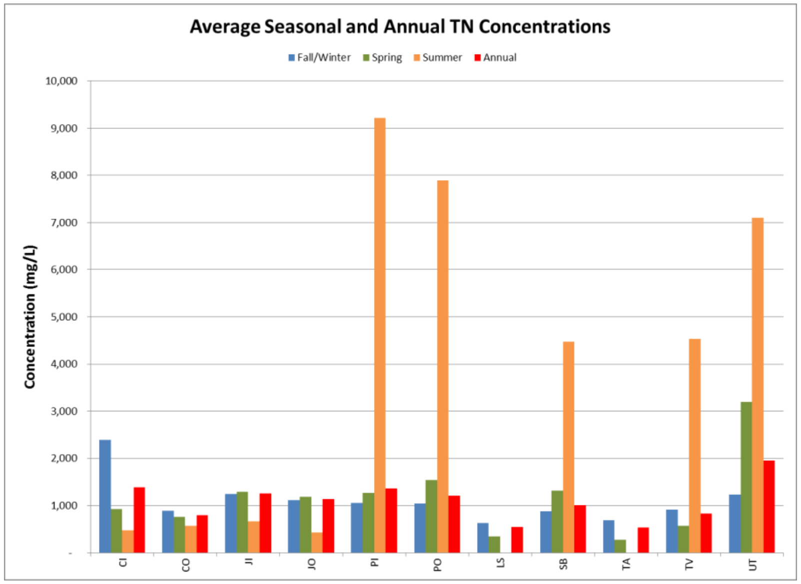

Figure 7 TN concentrations at each monitoring station, WY17.

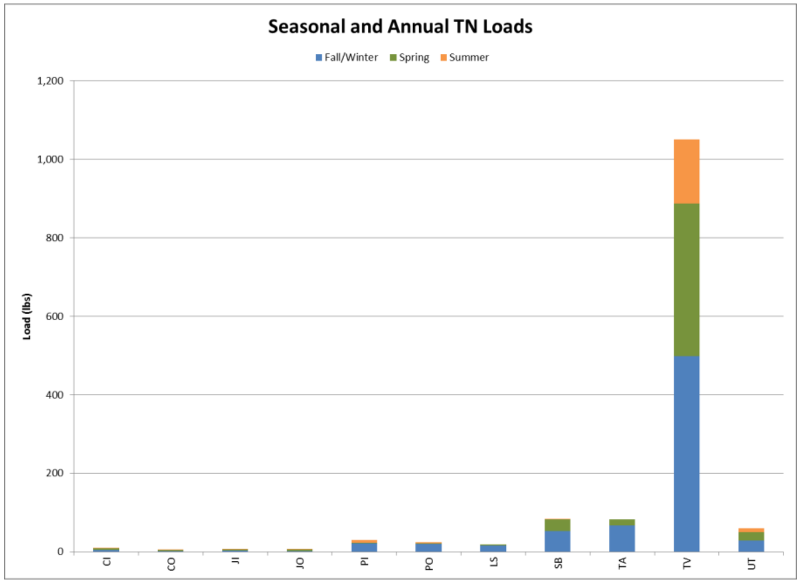

Figure 8 TN loads at each monitoring station, WY17.

TN Concentrations

- With the exception of SR431, average seasonal TN concentrations were substantially higher in the summer than any other season at all sites. (There was no measured flow at Lakeshore in the summer and high lake levels prohibited flow measurements at Tahoma in the summer.) Pasadena Inflow had the highest TN concentration of all sites during the summer season.
- At SR431 average seasonal TN concentrations were lowest in the summer.
- TN concentrations at the SR431 inflow sites should have been similar to each other in all seasons, but the winter concentration is much higher at the Contech MFS than the Jellyfish in the winter. Average seasonal concentration for the winter is based on three events, one of which had a TN event mean concentration (EMC) three times higher at the Contech MFS than the Jellyfish. It is unknown why this occurred, but it likely skewed the data.
- Average seasonal TN concentrations are generally similar in the fall/winter and spring seasons.

TN Loads

- Runoff volume has the largest influence on loads. Tahoe Valley contributed significantly more TN to the lake than any other site, yet it had one of the lowest average seasonal TN concentrations in all seasons.
- Concentrations influence loads. Though runoff volumes were universally low in the summer, high average seasonal TN concentrations resulted in proportionally higher summer TN loads.

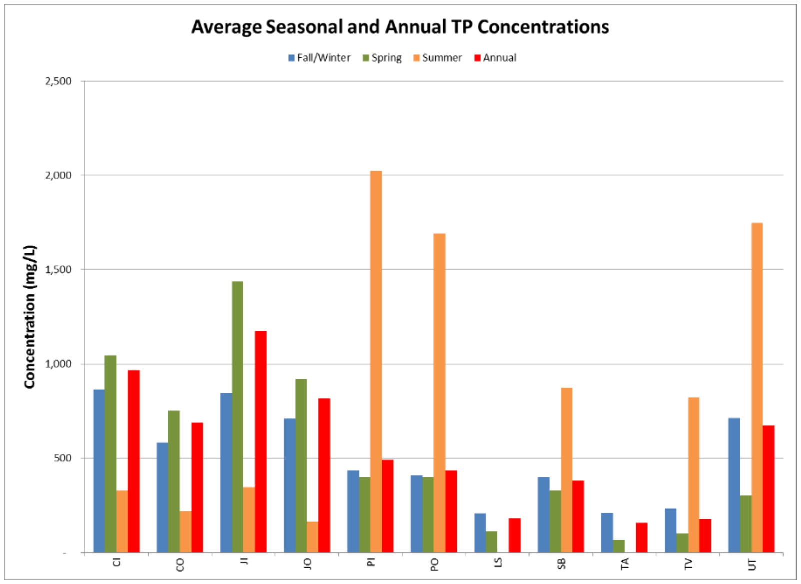

Figure 9 TP concentrations at each monitoring station, WY17.

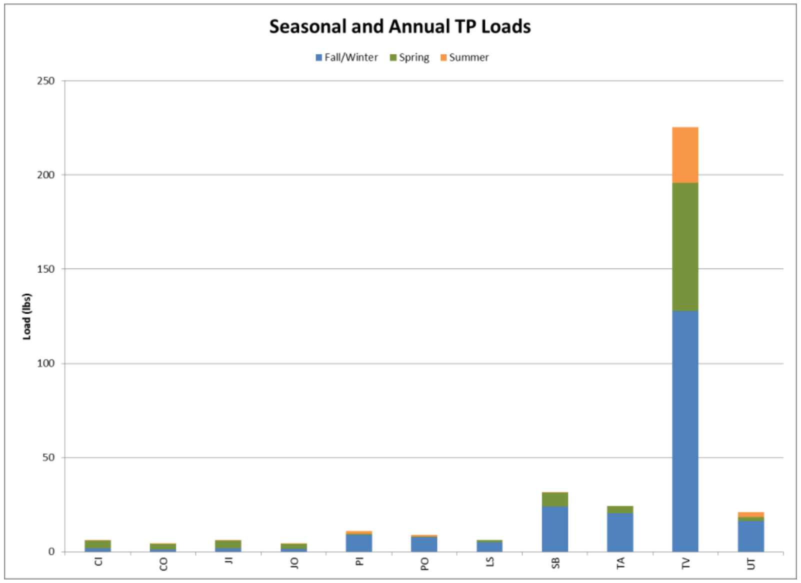

Figure 10 TP loads at each monitoring station, WY17.

TP Concentrations

- TP concentrations are lower than TN concentrations in all seasons, but generally follow a very similar pattern. Pasadena Inflow had the highest TP concentration of all sites during the summer season.
- With the exception of SR431, average seasonal TP concentrations were substantially higher in the summer than any other season at all sites and lowest in the spring.
- At SR431 average seasonal TP concentrations were lowest in the summer and highest in the spring.

TP Loads

- Runoff volume has the largest influence on loads. Tahoe Valley contributed substantially more TP to the lake than any other site, yet it had one of the lowest average seasonal TP concentrations in all seasons.
- Concentrations influence loads. Though runoff volumes were universally low in the summer, high average seasonal TP concentrations resulted in proportionally higher summer TP loads.

6.2 Summary Data for Individual Catchments

6.2.1 SR431

Figure 11 shows the average daily inflow and cumulative precipitation for WY17 at the SR431 treatment vaults. Inflow to the Contech MFS and Jellyfish vaults should be roughly equal. However, inflows to the Contech MFS were about 16% higher than inflows to the Jellyfish. It is believed that sediment build up in the vault that splits the flows routed more flow to the Contech MFS than the Jellyfish. The treatment vaults are not designed to reduce flows so outflows are roughly equal to inflows.

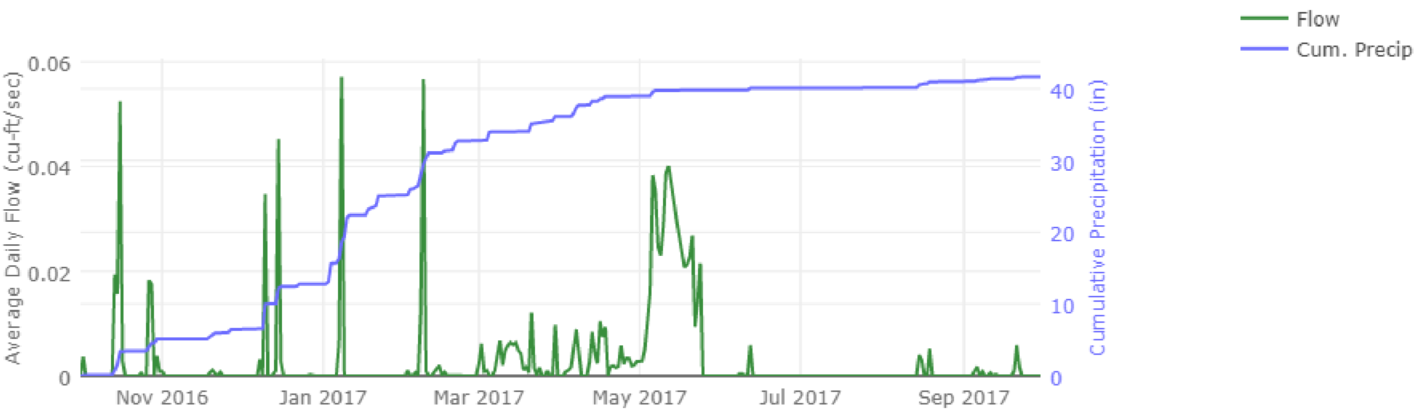

Figure 11 Average daily inflow and cumulative precipitation at the SR431 treatment vaults, WY17.

- 49.02 inches of total precipitation (38.03 in the fall/winter, 8.67 in the spring, and 2.31 in the summer) recorded at the NDOT weather station.
- 49 precipitation events (21 fall/winter events, 15 spring events, 13 summer events).
- Two very large storms, each with over 7 inches of precipitation, occurred between January 7th and 12th, 2017 and January 31st and February 10th, 2017.
- 57% of storms were less than half an inch.
- Highest average daily flows occurred in the fall/winter season (October – February).
- 49 days of continuous and intermittent snowmelt occurred in the spring and early summer seasons (March – June).
- Ten thunderstorms occurred from mid-August through September.
- The highest instantaneous peak precipitation was 0.07 inches in 5 minutes during a rain on snow event on February 5, 2017.
- The highest instantaneous peak flow was 0.38 cfs during a rain-on-snow event on February 8,, 2017.

Contech MFS

Daily flow and FSP EMC summaries for the Contech MFS inflow and outflow are presented in Figure 12 and Figure 13, respectively. Table 6 presents this data in tabular form. Table 6 also presents the load data referenced in some bullet points below.

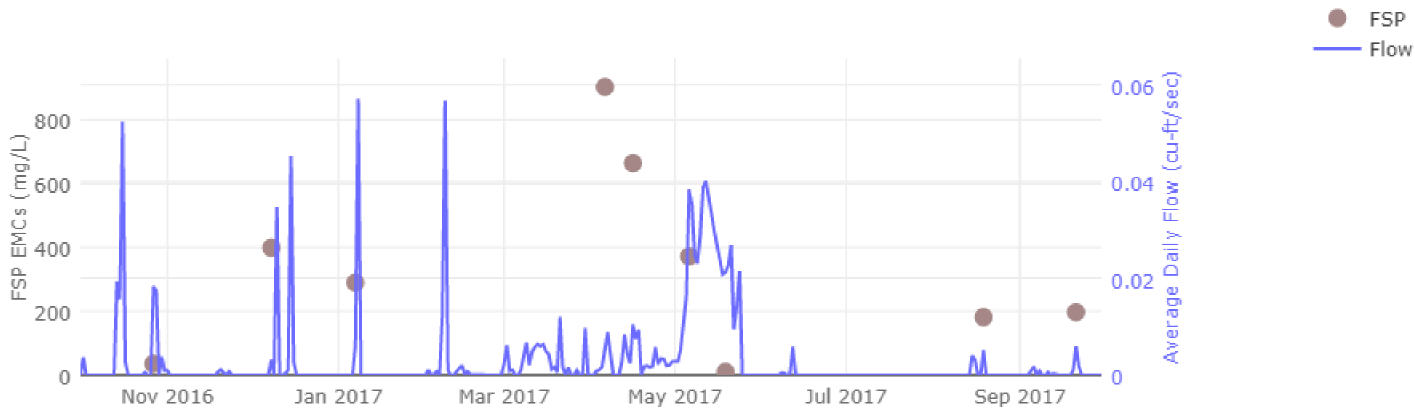

Figure 12 Daily inflow and FSP EMC summary at the Contech MFS, WY17.

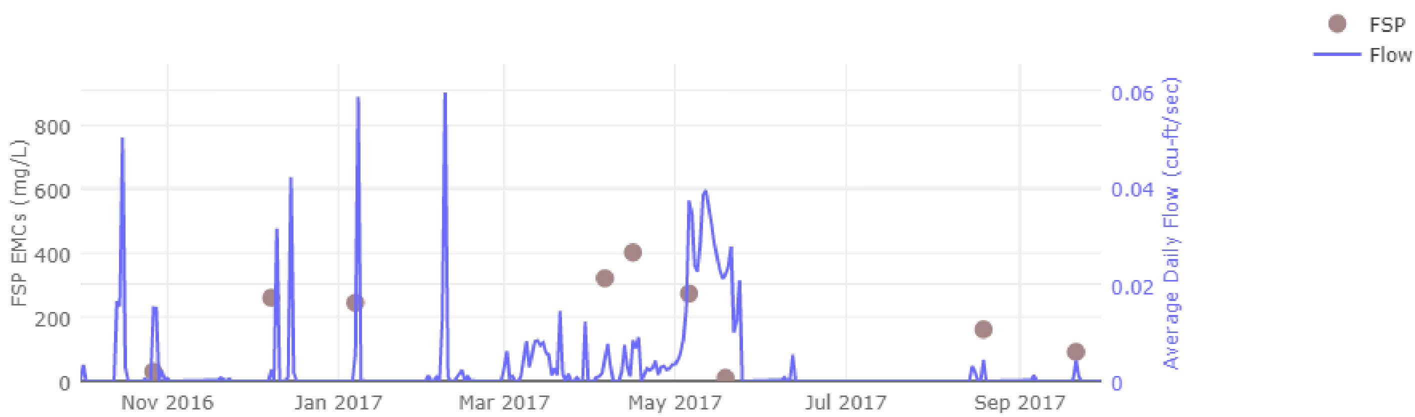

Figure 13 Daily outflow and FSP EMC summary at the Contech MFS, WY17.

- Nine events sampled for FSP (three in the fall/winter, four in the spring, two in the summer)
- In general FSP EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech MFS vault.
- The highest FSP EMCs occurred during two rain on snow events in the spring (April).
- The highest FSP loads occurred during the rain on snow event from January 7th to 9th, 2017 (refer to Table 6).
- The lowest FSP EMCs occurred during a non-event snowmelt at the end of May.
- The lowest FSP loads occurred during the thunderstorm event on September 21, 2017 (refer to Table 6).

Daily flow and TN EMC summaries for the Contech MFS inflow and outflow are presented in Figure 14 and Figure 15, respectively. Table 6 presents this data in tabular form. Table 6 also presents the load data referenced in some bullet points below.

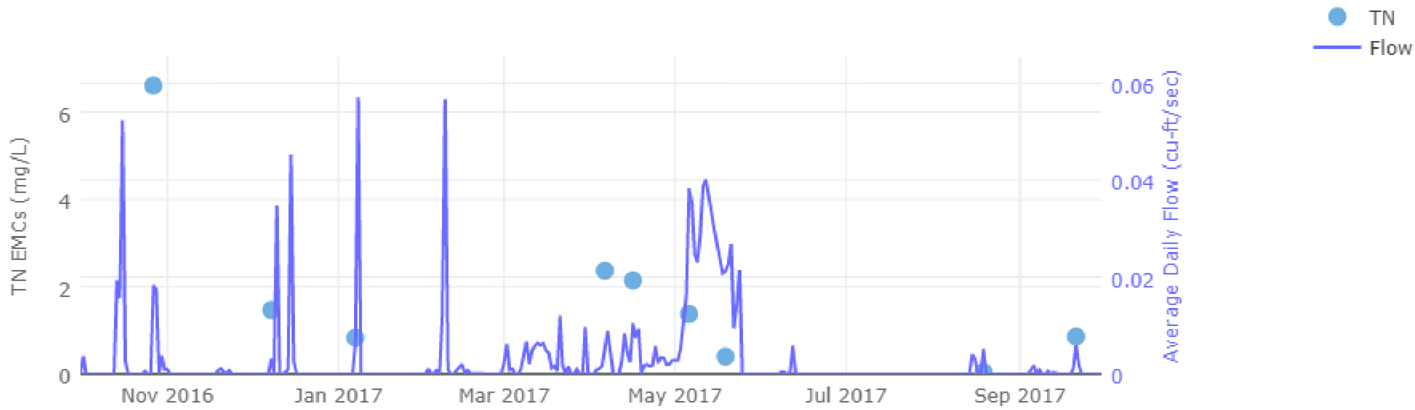

Figure 14 Daily inflow and TN EMC summary at the Contech MFS, WY17.

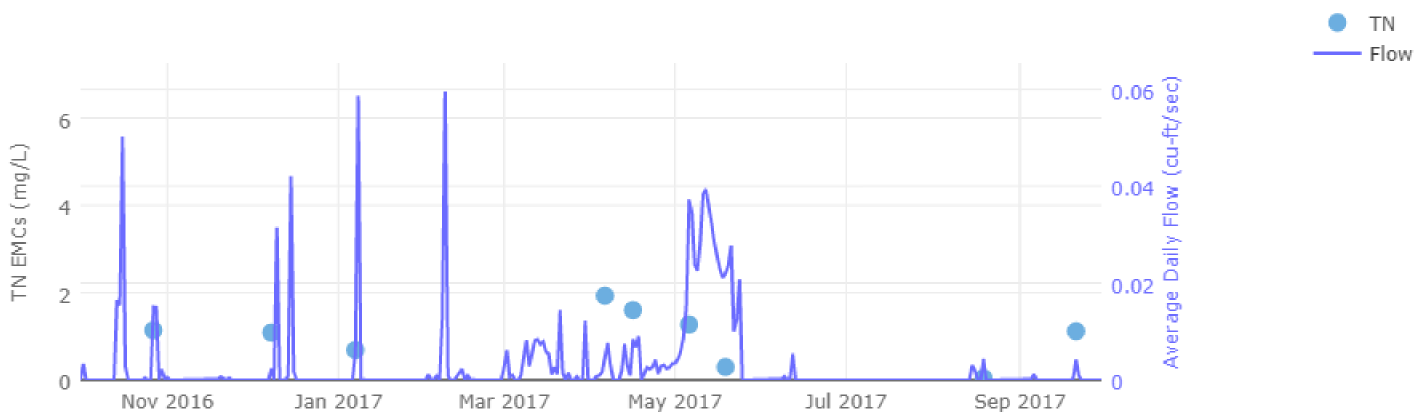

Figure 15 Daily outflow and TN EMC summary at the Contech MFS, WY17.

- Eight events sampled for TN (three in the fall/winter, four in the spring, one in the summer – the August 19, 2017 event was not sampled for TN – the doors to the sampler were jammed and nutrient analyses holding times were exceeded before doors were fixed).
- In general TN EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech MFS.
- The highest TN EMC at the Contech MFS inflow occurred during the rain event in October, though the excessively high value may be due to contamination. The TN EMC at the inflows to the Contech MFS and Jellyfish should be approximately equal; however the value at the Contech MFS is about three times higher. The reason for this discrepancy is unknown.
- The next highest TN EMCs at both sites occurred during two rain on snow events in the spring (April).
- The highest TN load at the inflow occurred during the rain event in October, although this may be skewed by the excessively high TN EMC for this event. The next highest TN loads at both sites occurred during the rain on snow event from May 6th to 7th, 2017 (refer to Table 6).
- The lowest TN EMCs occurred during a non-event snowmelt at the end of May.
- The lowest TN loads occurred during the thunderstorm event on September 21, 2017 (refer to Table 6).

Daily flow and TP EMC summaries for the Contech MFS inflow and outflow are presented in Figure 16 and Figure 17, respectively. Table 6 presents this data in tabular form. Table 6 also presents the load data referenced in some bullet points below.

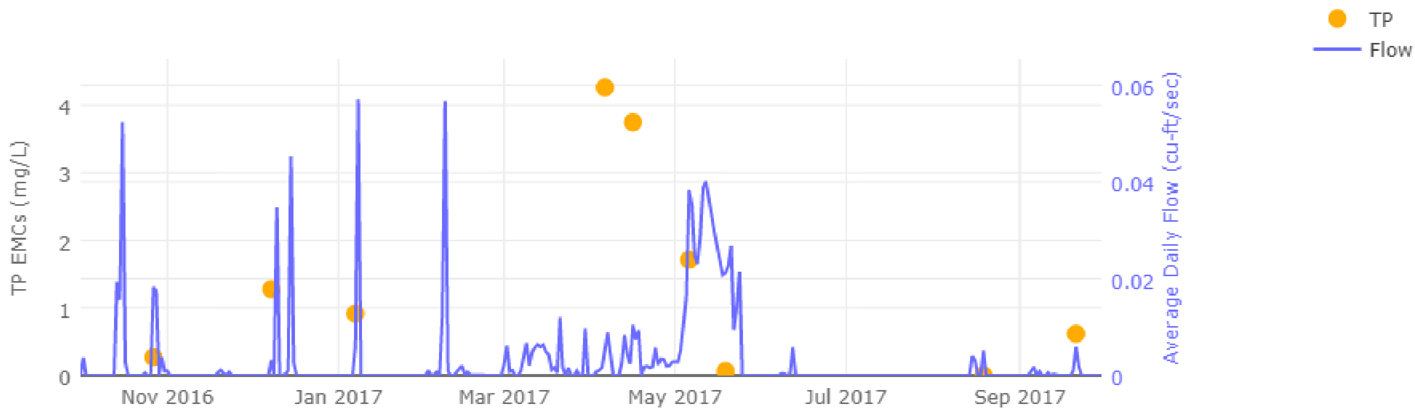

Figure 16 Daily inflow and TP EMC summary at the Contech MFS, WY17.

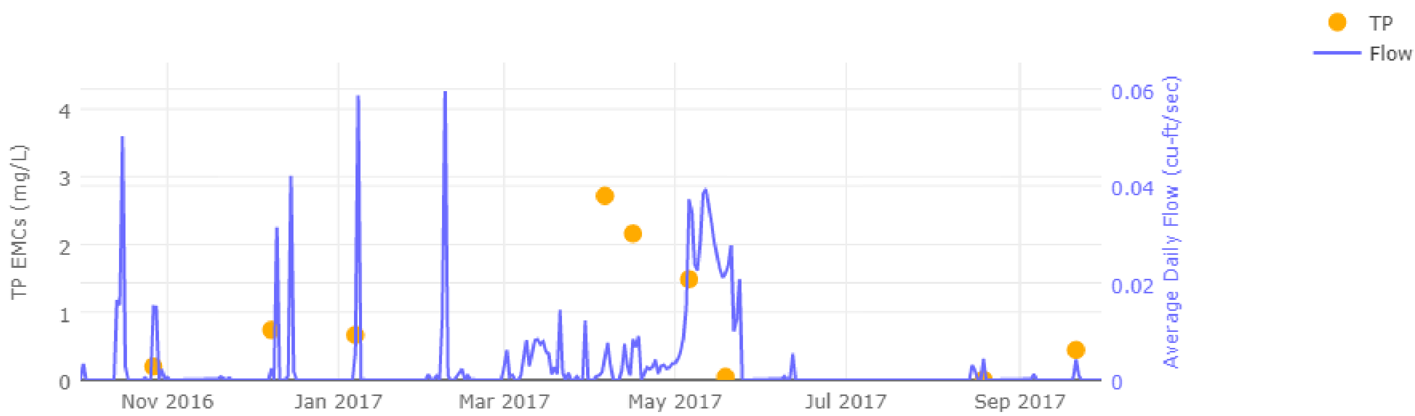

Figure 17 Daily outflow and TP EMC summary at the Contech MFS, WY17.

- Eight events sampled for TP (three in the fall/winter, four in the spring, one in the summer – the August 19, 2017 event was not sampled for TP - the doors to the sampler were jammed and nutrient analyses holding times were exceeded before doors were fixed)
- In general TP EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech MFS.
- The highest TP EMCs occurred during three rain on snow events in the spring (April and early May).
- The highest TP loads occurred during the rain on snow event from May 6th to 7th, 2017 (refer to Table 6).
- The lowest TP EMCs occurred during a non-event snowmelt at the end of May.
- The lowest TP loads occurred during the thunderstorm event on September 21, 2017 (refer to Table 6).

Seasonal load as a fraction of the water year load for the Contech MFS inflow and outflow are presented in Figure 18 and Figure 19, respectively. Event loads are presented in tabular form in Table 6.

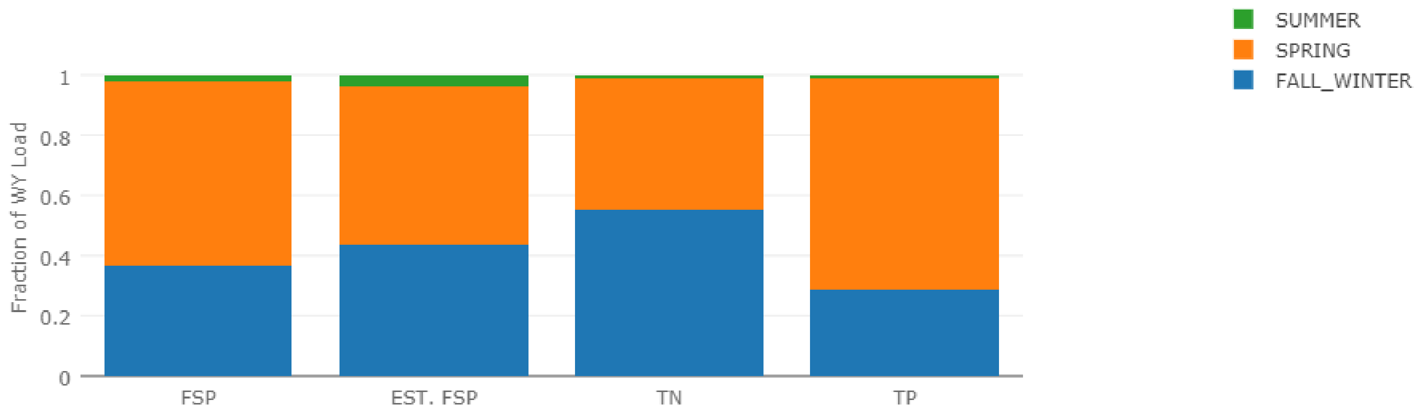

Figure 18 Seasonal load as a fraction of the water year load at the Contech MFS inflow, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

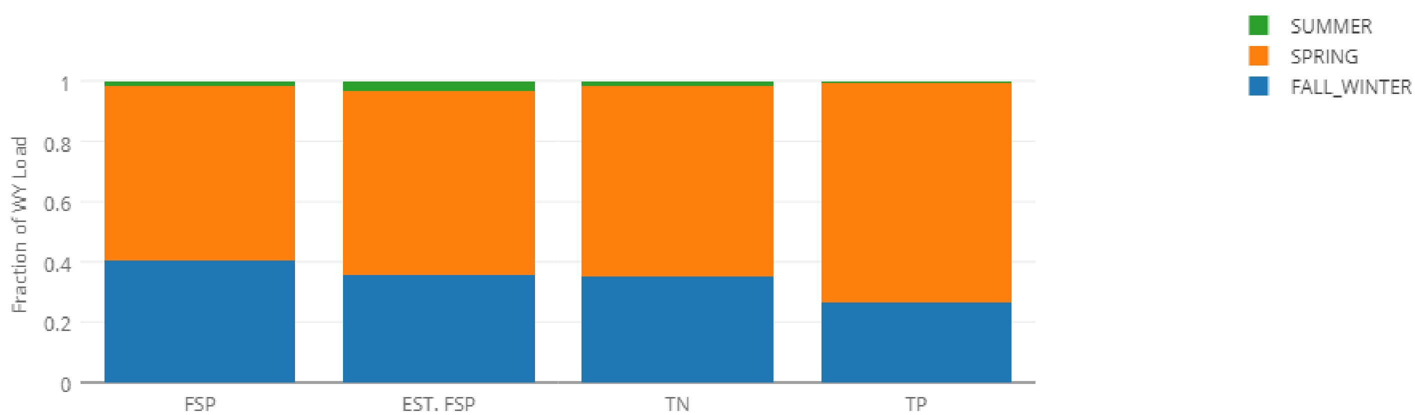

Figure 19 Seasonal load as a fraction of the water year load at the Contech MFS outflow, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads were generated in the spring at both the inflow and outflow to the Contech MFS.
- The largest fraction of TN loads at the inflow was generated in the fall/winter, but the largest fraction of TN loads at the outflow was generated in the spring. This skew may be due to the excessively high TN EMC value from the October 2016 rain event.
- The largest fraction of TP loads at the inflow and outflow was generated in spring.
- Summer produces a very small fraction of the overall load for all three pollutants.

Jellyfish

Daily flow and FSP EMC summaries for the Jellyfish inflow and outflow are presented in Figure 20 and Figure 21, respectively. Table 7 presents this data in tabular form. Table 7 also presents the load data referenced in some bullet points below.

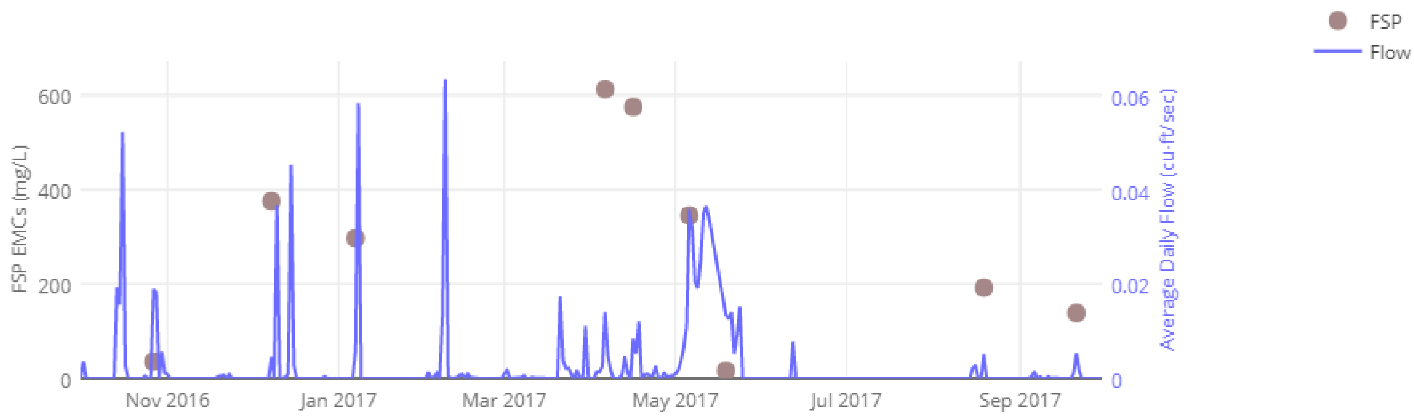

Figure 20 Daily inflow and FSP EMC summary at the Jellyfish, WY17.

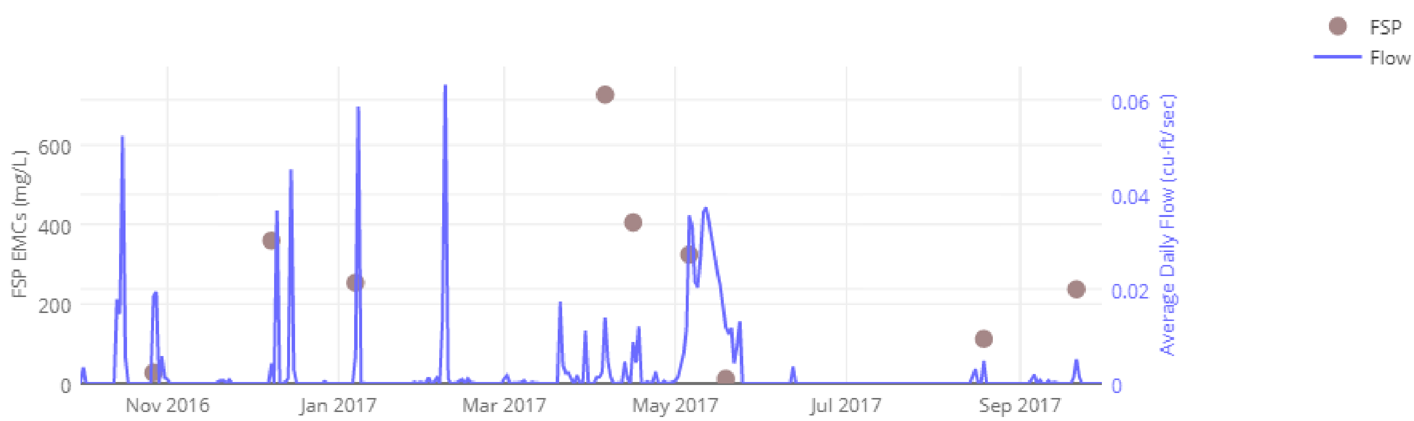

Figure 21 Daily outflow and FSP EMC summary at the Jellyfish, WY17.

- Nine events sampled for FSP (three in the fall/winter, four in the spring, two in the summer)
- In general FSP EMCs were similar at the inflow and outflow indicating minimal treatment occurred in the Jellyfish vault. Events occurring on April 6, 2017 and September 21, 2017 saw higher outflow FSP EMCs than inflow FSP EMCs indicating a need for maintenance.
- The highest FSP EMCs occurred during two rain on snow events in the spring (April).
- The highest FSP loads occurred during the rain on snow event from January 7th to 9th, 2017 (refer to Table 7).
- The lowest FSP EMCs and loads occurred during a non-event snowmelt at the end of May (refer to Table 7).

Daily flow and TN EMC summaries for the Jellyfish inflow and outflow are presented in Figure 22 and Figure 23, respectively. Table 7 presents this data in tabular form. Table 7 also presents the load data referenced in some bullet points below.

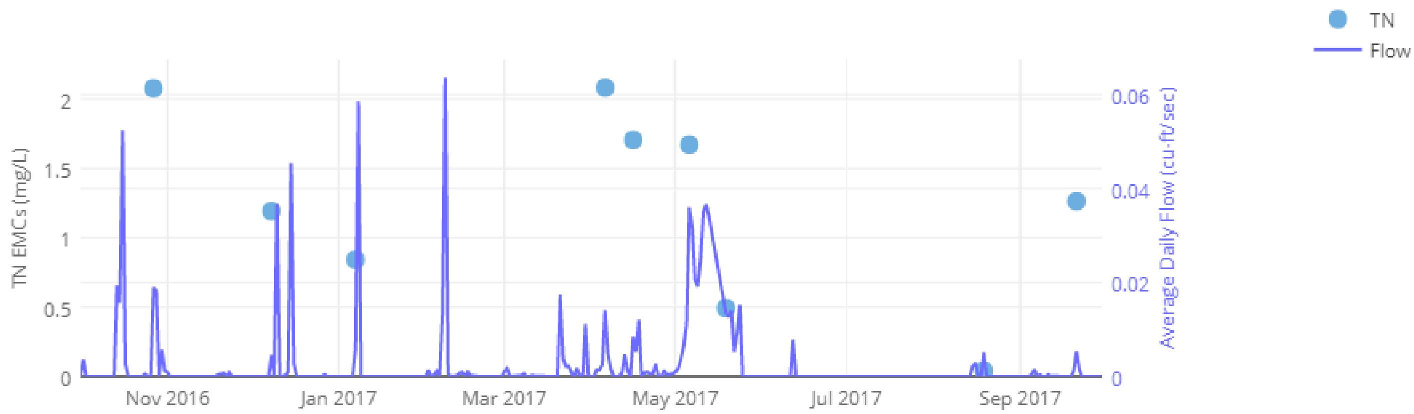

Figure 22 Daily inflow and TN EMC summary at the Jellyfish, WY17.

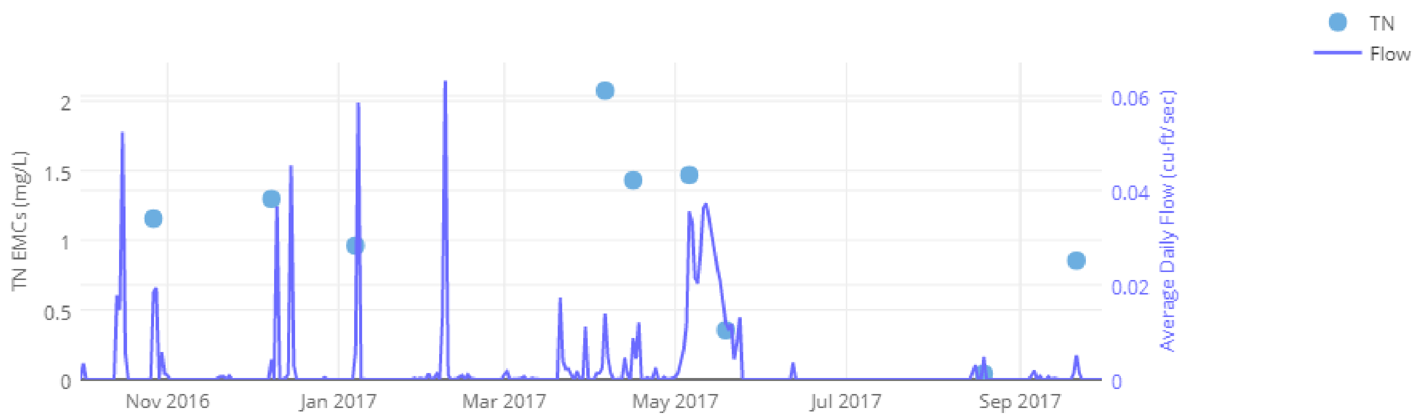

Figure 23 Daily outflow and TN EMC summary at the Jellyfish, WY17.

- Eight events sampled for TN (three in the fall/winter, four in the spring, one in the summer – the August 19, 2017 event was not sampled for TN - the doors to the sampler were jammed and nutrient analyses holding times were exceeded before doors were fixed).
- In general TN EMCs were similar at the inflow and outflow indicating minimal treatment occurred in the Jellyfish.
- The highest TN EMC at the inflow occurred during a rain event in October. The next highest TN EMCs at both sites occurred during three rain on snow events in the spring (April and early May).
- The highest TN loads occurred during the rain on snow event from May 6th to 7th, 2017 (refer to Table 7).
- The lowest TN EMCs occurred during a non-event snowmelt at the end of May.
- The lowest TN loads occurred during a rain storm on September 21, 2017 (refer to Table 7).

Daily flow and TP EMC summaries for the Jellyfish inflow and outflow are presented in Figure 24 and Figure 25, respectively. Table 7 presents this data in tabular form. Table 7 also presents the load data referenced in some bullet points below.

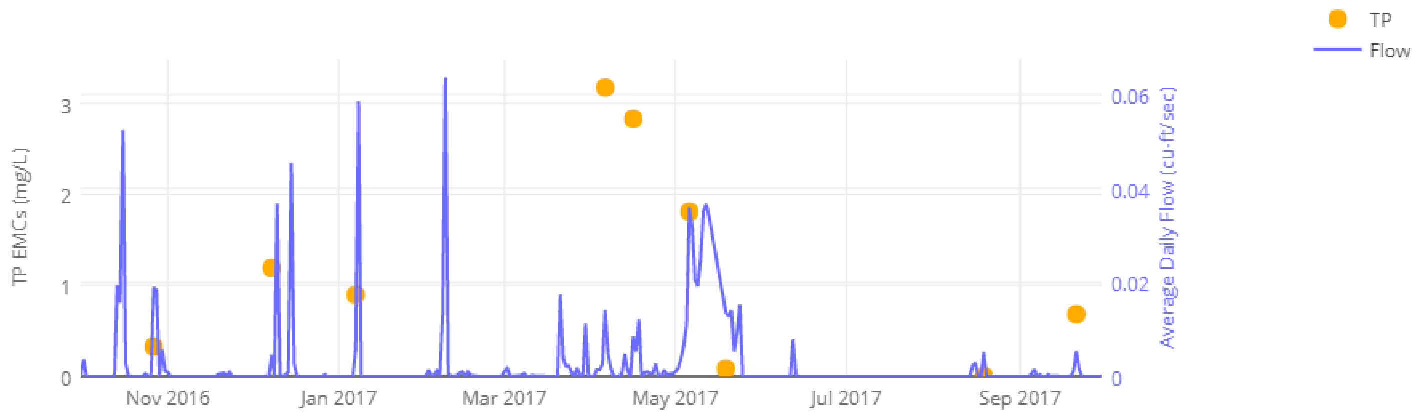

Figure 24 Daily inflow and TP EMC summary at the Jellyfish, WY17.

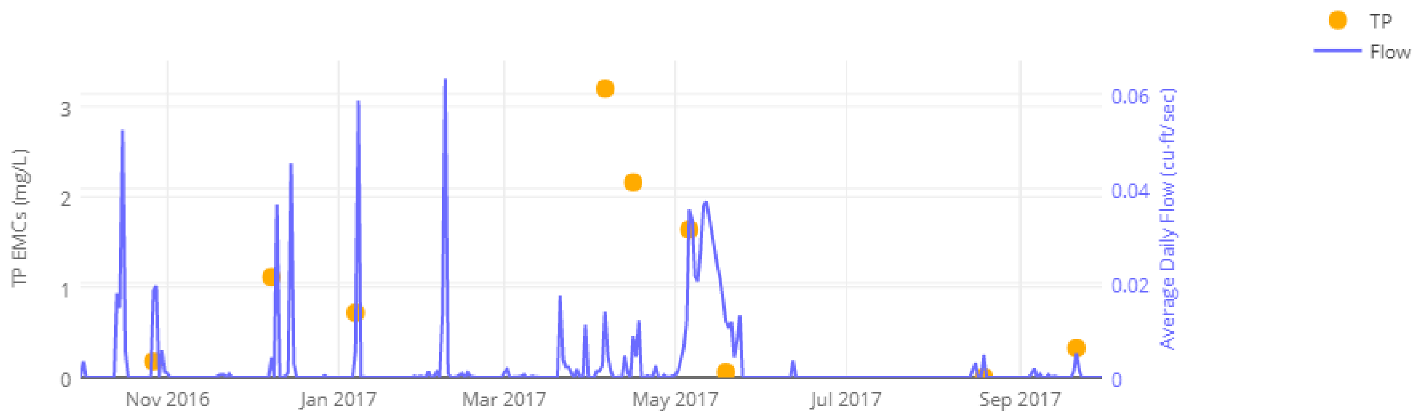

Figure 25 Daily outflow and TP EMC summary at the Jellyfish, WY17.

- Eight events sampled for TP (three in the fall/winter, four in the spring, and one in the summer – the August 19, 2017 event was not sampled for TP - the doors to the sampler were jammed and nutrient analyses holding times were exceeded before doors were fixed).
- In general TP EMCs were similar at the inflow and outflow indicating minimal treatment occurred in the Jellyfish.
- The highest TP EMCs occurred during three rain on snow events in the spring (April and early May).
- The highest TN loads occurred during the rain on snow event from May 6th to 7th, 2017 (refer to Table 7).
- The lowest TN EMCs occurred during a non-event snowmelt at the end of May.
- The lowest TN loads occurred during a rain event on September 21, 2017 (refer to Table 7).

Seasonal load as a fraction of the water year load for the Jellyfish inflow and outflow are presented in Figure 26 and Figure 27, respectively. Event loads are presented in tabular form in Table 7.

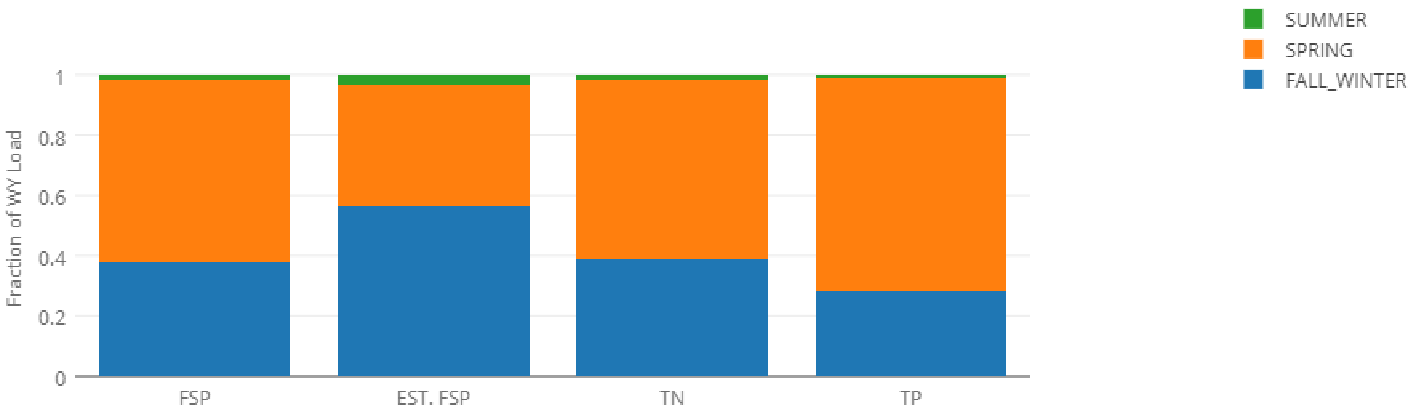

Figure 26 Seasonal load as a fraction of the water year load at the Jellyfish inflow, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

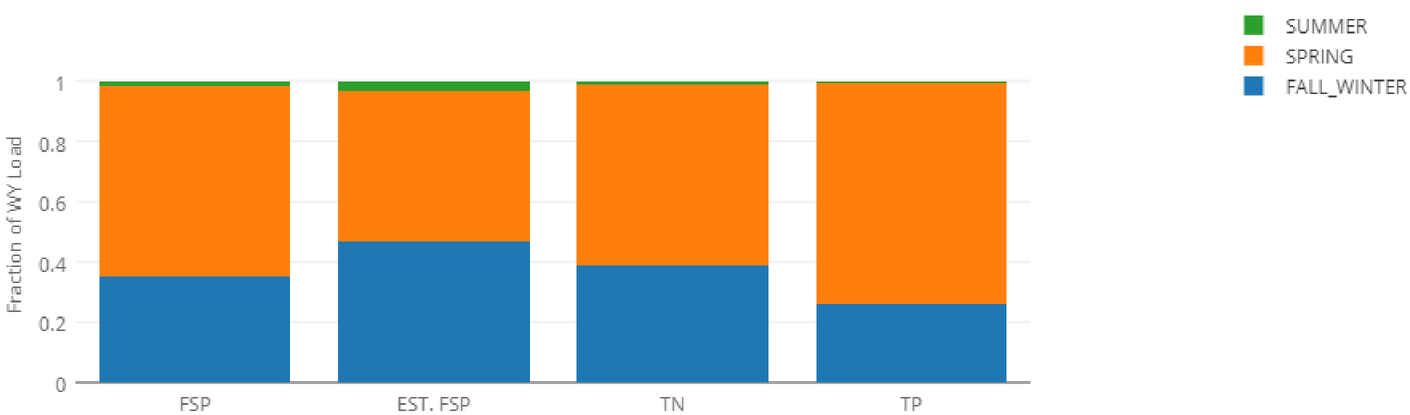

Figure 27 Seasonal load as a fraction of the water year load at the Jellyfish outflow, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads were generated in the spring at both the inflow and outflow to the Jellyfish, with the exception of the FSP load estimated from continuous turbidity for Jellyfish inflow (Figure 26 – EST. FSP column), which estimated the largest FSP fractional load occurred in the winter.
- The FSP loads are calculated using the EMCs from runoff events (not all events are sampled), and the EST. FSP loads are based on continuous turbidity data collected throughout the water year, therefore differences are to be expected.
- The largest fraction of TN loads at the inflow and outflow to the Jellyfish were generated in the spring.
- The largest fraction of TP loads were generated in the spring at both the inflow and outflow to the Jellyfish.
- Summer produces a very small fraction of the overall load for all three pollutants.

Nine events were sampled at SR431 in WY17. Event summary data for the Contech MFS and Jellyfish treatment vaults is presented in Table 6 and Table 7 respectively.

Table 6 Event summary data at the Contech MFS treatment vault, WY17

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
CI	Fall/Winter	10/27/2016 9:45	10/28/2016 7:50	22:05	2,759	0.15	159	1.37	rain	100%	35	6	6,608	1.14	271	0.05
CO	Fall/Winter	10/27/2016 9:50	10/28/2016 7:50	22:00	2,349	0.15	73	1.37	rain	100%	29	4	1,140	0.17	197	0.03
CI	Fall/Winter	12/8/2016 6:45	12/10/2016 22:05	63:20	3,279	0.20	318	3.91	rain on snow	100%	399	82	1,465	0.30	1,277	0.26
CO	Fall/Winter	12/8/2016 7:00	12/10/2016 22:00	63:00	2,918	0.20	731	3.91	rain on snow	100%	260	47	1,086	0.20	738	0.13
CI	Fall/Winter	1/7/2017 14:00	1/9/2017 0:15	34:15	5,474	0.20	1,857	7.02	rain on snow	100%	289	99	830	0.28	916	0.31
CO	Fall/Winter	1/7/2017 14:10	1/9/2017 0:35	34:25	5,575	0.21	1,334	7.02	rain on snow	100%	245	85	686	0.24	663	0.23
CI	Spring	4/6/2017 14:40	4/6/2017 23:50	9:10	377	0.07	1,511	1.78	rain on snow	55%	902	21	2,367	0.06	4,263	0.10
CO	Spring	4/6/2017 15:05	4/7/2017 4:20	13:15	298	0.04	1,244	1.78	rain on snow	50%	321	6	1,928	0.04	2,717	0.05
CI	Spring	4/16/2017 16:00	4/17/2017 3:20	11:20	828	0.06	3,994	0.93	rain on snow	75%	664	34	2,142	0.11	3,749	0.19
CO	Spring	4/16/2017 16:00	4/17/2017 4:00	12:00	801	0.07	939	0.93	rain on snow	100%	402	20	1,599	0.08	2,160	0.11
CI	Spring	5/6/2017 12:10	5/7/2017 8:40	20:30	4,036	0.17	254	0.88	rain on snow	100%	372	94	1,374	0.35	1,714	0.43
CO	Spring	5/6/2017 12:35	5/7/2017 8:40	20:05	3,978	0.17	291	0.88	rain on snow	100%	274	68	1,270	0.32	1,486	0.37
CI	Spring	5/19/2017 6:00	5/22/2017 6:00	72:00	6,265	0.03	10	na	non-event snowmelt	80%	10	4	397	0.16	65	0.03
CO	Spring	5/19/2017 6:00	5/22/2017 6:00	72:00	6,516	0.03	17	na	non-event snowmelt	90%	9	4	295	0.12	43	0.02
CI	Summer	8/19/2017 15:10	8/19/2017 17:25	2:15	369	0.22	336	0.27	thunderstorm	90%	181	4	na	na	na	na
CO	Summer	8/19/2017 15:30	8/19/2017 17:40	2:10	372	0.14	372	0.27	thunderstorm	90%	161	4	na	na	na	na
CI	Summer	9/21/2017 10:00	9/21/2017 16:30	6:30	539	0.14	431	0.44	rain	100%	197	7	855	0.03	618	0.02
CO	Summer	9/21/2017 10:00	9/21/2017 17:10	7:10	390	0.07	394	0.44	rain	100%	91	2	1,118	0.03	442	0.01

Table 7 Event summary data at the Jellyfish treatment vault, WY17

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
JI	Fall/Winter	10/27/2016 9:45	10/28/2016 7:55	22:10	2,786	0.16	188	1.37	rain	100%	35	6	2,077	0.36	326	0.06
JO	Fall/Winter	10/27/2016 10:20	10/28/2016 8:00	21:40	2,889	0.16	15	1.37	rain	100%	27	5	1,155	0.21	178	0.03
JI	Fall/Winter	12/8/2016 6:45	12/10/2016 22:00	63:15	3,558	0.21	575	3.91	rain on snow	100%	374	83	1,192	0.26	1,191	0.26
JO	Fall/Winter	12/8/2016 6:50	12/10/2016 22:15	63:25	3,760	0.21	150	3.91	rain on snow	90%	360	84	1,297	0.30	1,111	0.26
JI	Fall/Winter	1/7/2017 13:55	1/9/2017 0:15	34:20	5,588	0.21	1,980	7.02	rain on snow	100%	296	103	842	0.29	895	0.31
JO	Fall/Winter	1/7/2017 13:55	1/9/2017 0:15	34:20	5,570	0.20	1,192	7.02	rain on snow	100%	253	88	961	0.33	716	0.25
JI	Spring	4/6/2017 13:00	4/7/2017 4:50	15:50	1,234	0.11	2,312	1.78	rain on snow	75%	610	47	2,082	0.16	3,175	0.24
JO	Spring	4/6/2017 13:35	4/6/2017 23:25	9:50	1,278	0.11	1,252	1.78	rain on snow	25%	727	58	2,074	0.17	3,198	0.26
JI	Spring	4/16/2017 16:05	4/17/2017 4:15	12:10	794	0.08	2,605	0.93	rain on snow	100%	572	28	1,706	0.08	2,831	0.14
JO	Spring	4/16/2017 16:10	4/17/2017 1:10	9:00	804	0.08	384	0.93	rain on snow	100%	405	20	1,431	0.07	2,160	0.11
JI	Spring	5/6/2017 12:10	5/7/2017 8:40	20:30	3,927	0.17	228	0.88	rain on snow	100%	344	84	1,671	0.41	1,809	0.44
JO	Spring	5/6/2017 12:10	5/7/2017 8:40	20:30	3,750	0.18	9	0.88	rain on snow	100%	324	76	1,469	0.34	1,638	0.38
JI	Spring	5/19/2017 6:00	5/22/2017 6:00	72:00	3,448	0.02	10	na	non-event snowmelt	90%	16	3	492	0.11	83	0.02
JO	Spring	5/19/2017 6:00	5/22/2017 6:05	72:05	2,897	0.02	12	na	non-event snowmelt	90%	12	2	354	0.06	56	0.01
JI	Summer	8/19/2017 15:15	8/19/2017 17:20	2:05	369	0.24	1,639	0.27	thunderstorm	90%	191	4	na	na	na	na
JO	Summer	8/19/2017 15:15	8/19/2017 17:40	2:25	410	0.20	207	0.27	thunderstorm	90%	112	3	na	na	na	na
JI	Summer	9/21/2017 10:00	9/21/2017 16:30	6:30	328	0.17	467	0.44	rain	100%	138	3	1,263	0.03	681	0.01
JO	Summer	9/21/2017 10:00	9/21/2017 16:40	6:40	419	0.11	209	0.44	rain	100%	237	6	854	0.02	325	0.01

6.2.2 Pasadena

Figure 28 shows the average daily inflow and cumulative precipitation for WY17 at the Pasadena treatment vault. The treatment vault is not designed to reduce flows so outflows are roughly equal to inflows.

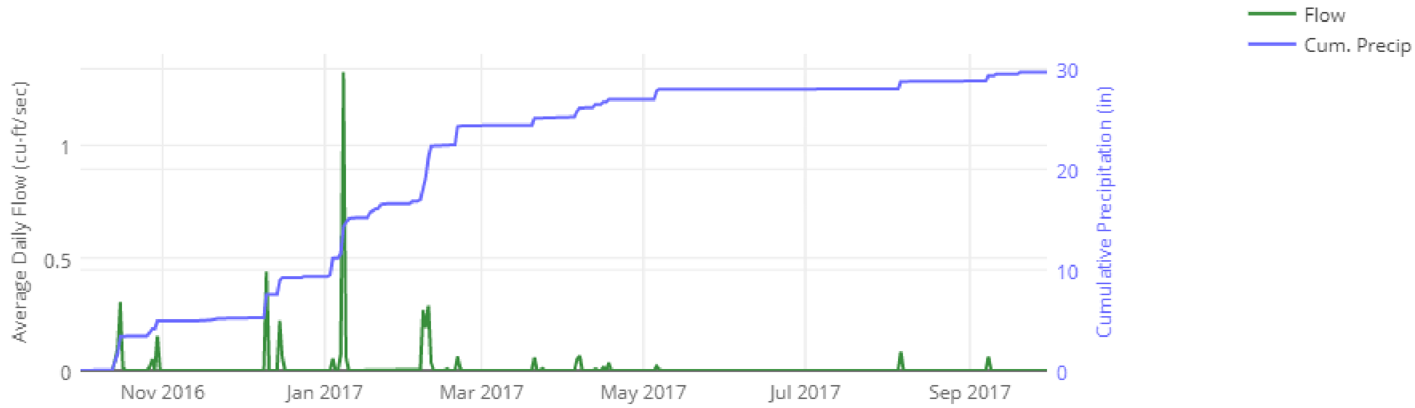

Figure 28 Average daily inflow and cumulative precipitation at the Pasadena treatment vault, WY17.

- 35.7 inches of total precipitation (28.04 in the fall/winter, 5.45 in the spring, and 2.18 in the summer) recorded at the Bellevue weather station.
- 42 precipitation events (22 in the fall/winter, 13 in the spring, 7 in the summer).
- Largest storm, with over 6 inches of precipitation, occurred between February 5th and 10th, 2017.
- 60% of storms were less than half an inch.
- Highest average daily flows occurred in the fall/winter season (October – February).
- 1 day of snowmelt runoff at Pasadena Inflow and zero at Pasadena Outflow.
- Several thunderstorms occurred from mid-August through September.
- The highest instantaneous peak precipitation was 0.33 inches in 5 minutes during a thunderstorm on August 8, 2017.
- The highest instantaneous peak flow was 4.3 cfs during a rain on snow event on January 8, 2017.

Daily flow and FSP EMC summaries at the Pasadena treatment vault inflow and outflow are presented in Figure 29 and Figure 30, respectively. Table 7 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

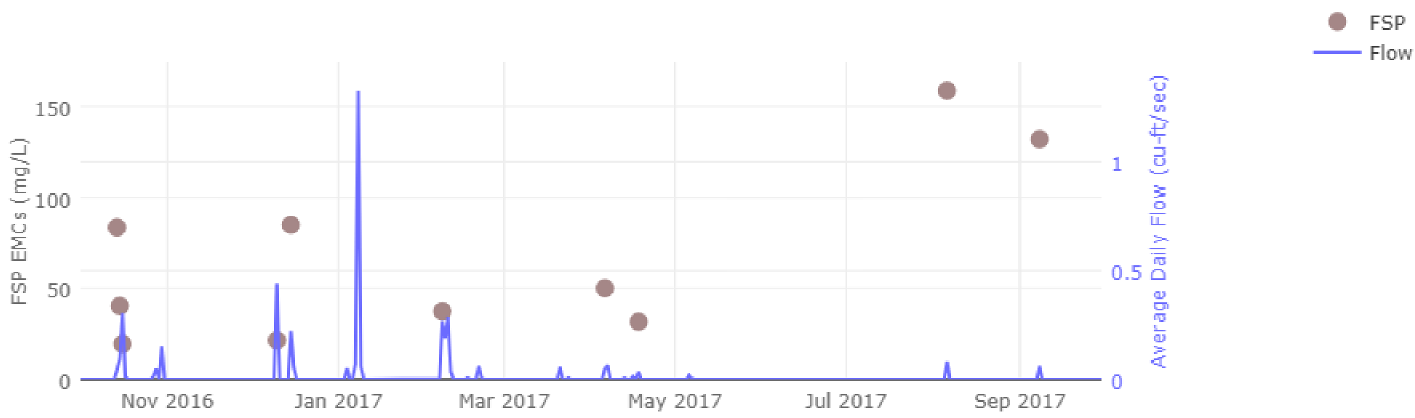

Figure 29 Daily inflow and FSP EMC summary at the Pasadena treatment vault, WY17.

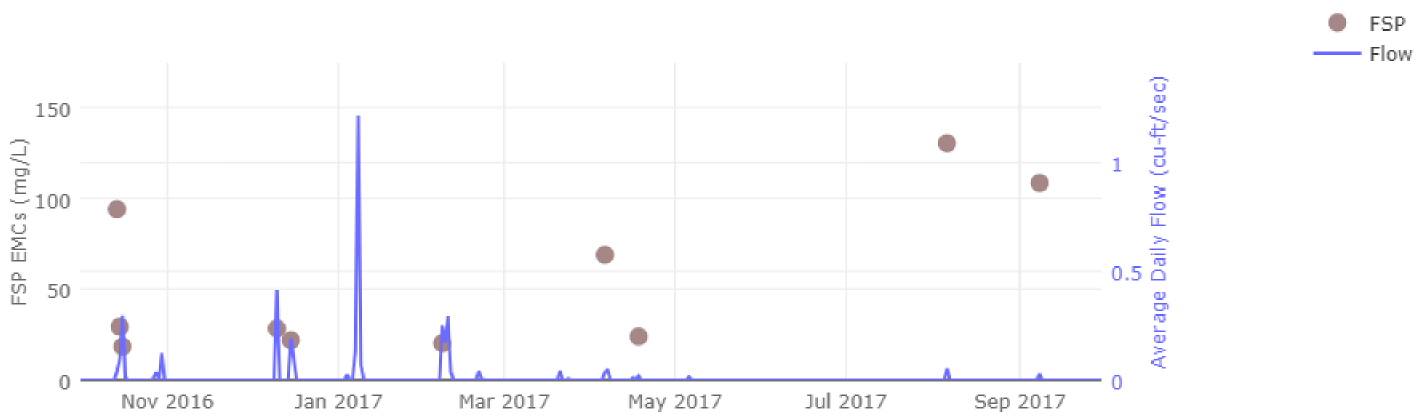

Figure 30 Daily outflow and FSP EMC summary at the Pasadena treatment vault, WY17.

- Ten events sampled for FSP (six in the fall/winter, two in the spring, two in the summer)
- In general FSP EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech Stormfilter vault.
- The highest FSP EMCs occurred during the thunderstorm on August 8, 2017.
- The highest FSP loads occurred during the rain on snow event from December 12th to 16th, 2016 (refer to Table 8).
- The lowest FSP EMCs and loads occurred during a rain event on April 18, 2017 (refer to Table 8).

Daily flow and TN EMC summaries for the Pasadena treatment vault inflow and outflow are presented in Figure 31 and Figure 32, respectively. Table 7 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

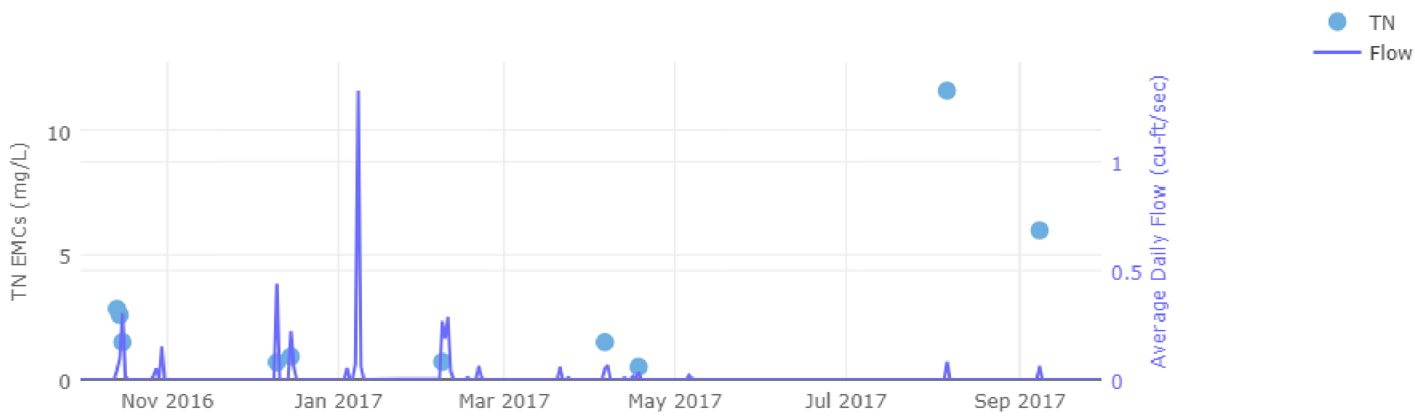

Figure 31 Daily inflow and TN EMC summary at the Pasadena treatment vault, WY17.

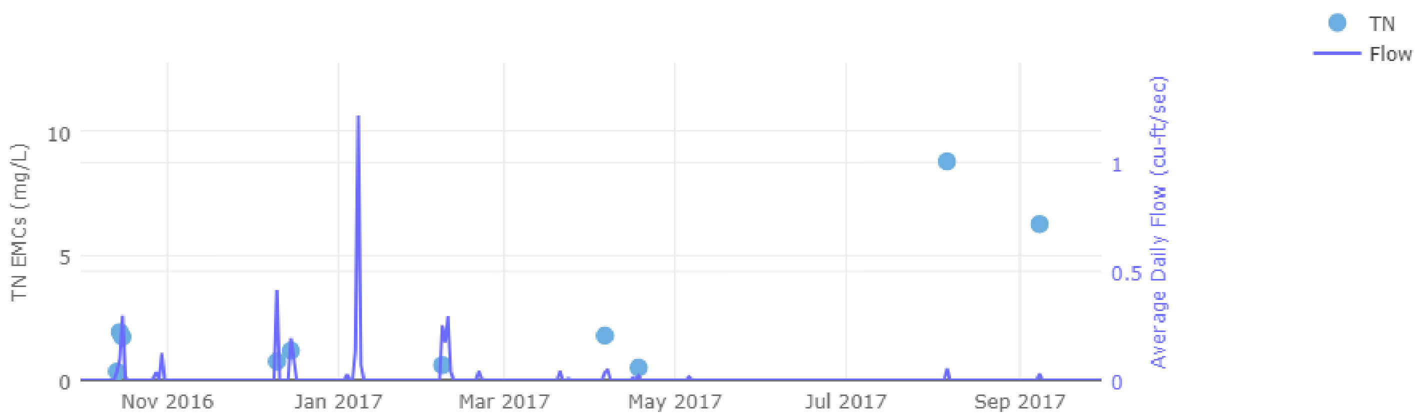

Figure 32 Daily outflow and TN EMC summary at the Pasadena treatment vault, WY17.

- Ten events sampled for TN (six in the fall/winter, two in the spring, two in the summer)
- In general TN EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech Stormfilter vault.
- The highest TN EMCs occurred during the thunderstorm on August 8, 2017.
- The highest TN loads occurred during the thunderstorm on August 8, 2017 (refer to Table 8).
- The lowest TN EMCs and loads occurred during a rain event on April 18, 2017 (refer to Table 8).

Daily flow and TP EMC summaries for the Pasadena treatment vault inflow and outflow are presented in Figure 33 and Figure 34, respectively. Table 7 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

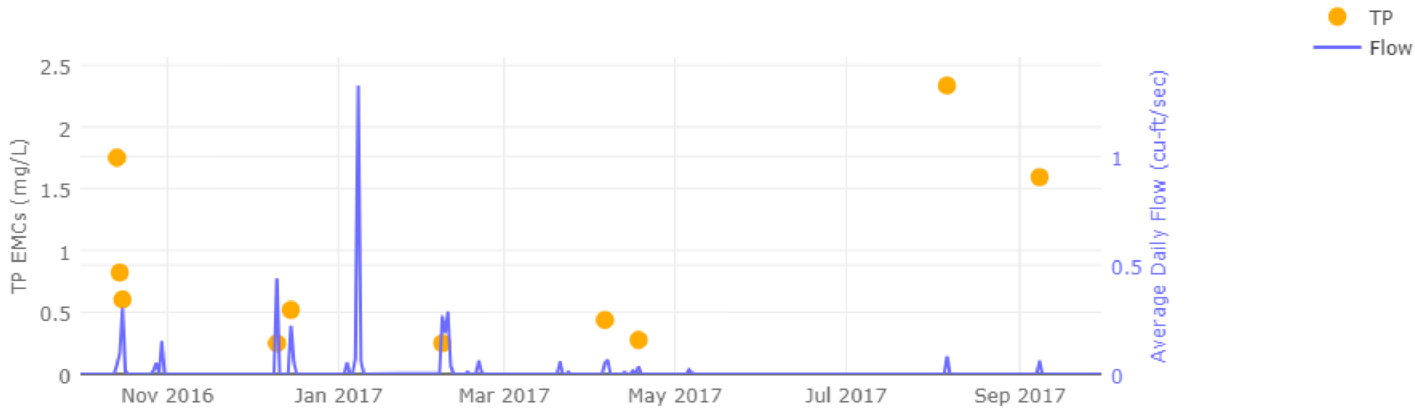

Figure 33 Daily inflow and TP EMC summary at the Pasadena treatment vault, WY17.

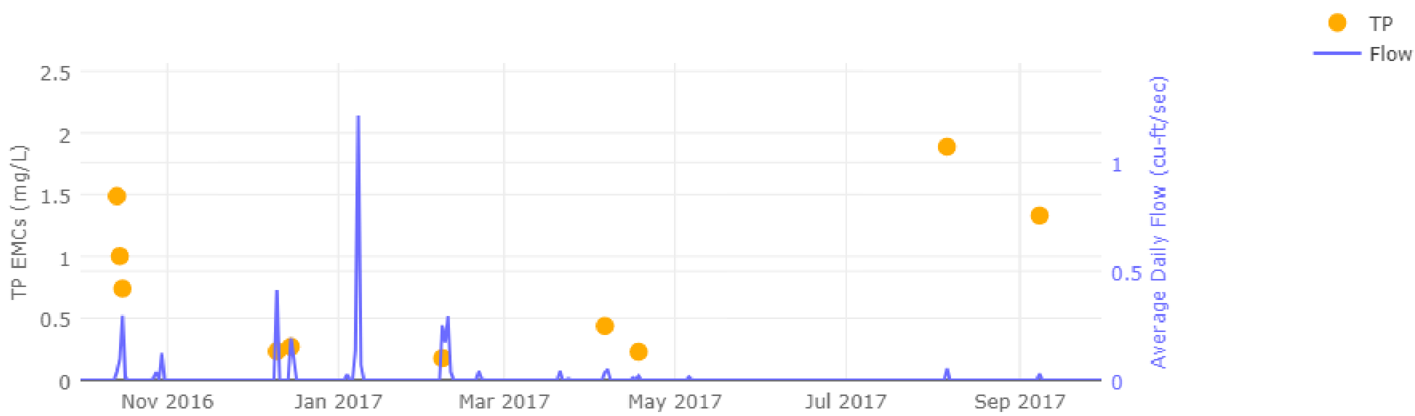

Figure 34 Daily outflow and TP EMC summary at the Pasadena treatment vault, WY17.

- Ten events sampled for TP (six in the fall/winter, two in the spring, two in the summer)
- In general TP EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech Stormfilter vault.
- The highest TP EMCs occurred during the thunderstorm on August 8, 2017.
- The highest TP loads occurred during the rain event on October 16th to 17th, 2017 (refer to Table 8).
- The lowest TP EMCs and loads occurred during a rain event on April 18, 2017 (refer to Table 8).

Seasonal load as a fraction of the water year load for the Pasadena treatment vault inflow and outflow are presented in Figure 35 and Figure 36, respectively. Event loads are presented in tabular form in Table 7.

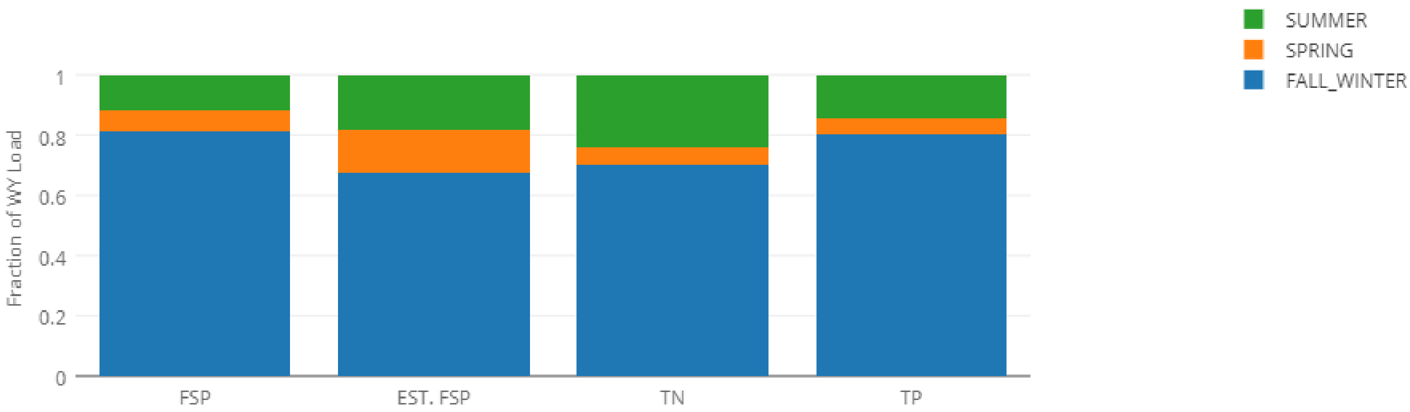

Figure 35 Seasonal load as a fraction of the water year load at the Pasadena treatment vault inflow, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

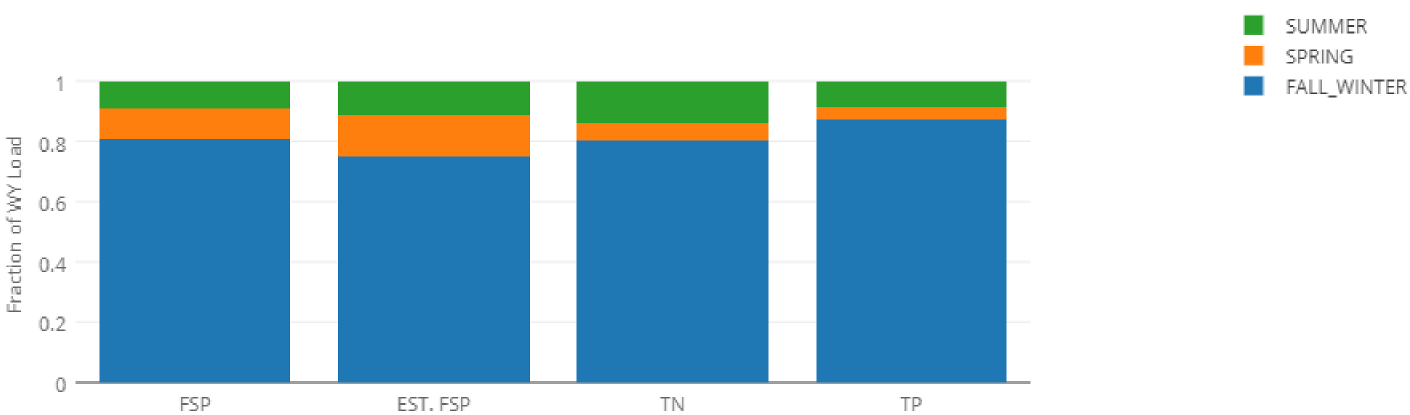

Figure 36 Seasonal load as a fraction of the water year load at the Pasadena treatment vault outflow, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- The largest fractions of FSP, TN, and TP loads were generated in the fall/winter at both the inflow and outflow.
- The smallest fraction of FSP loads was approximately evenly split between spring and summer at both the inflow and the outflow.
- The smallest fraction of TN and TP loads was generated in the spring for both inflow and outflow.

Ten events were sampled at Pasadena in WY17. Event summary data for the Pasadena treatment vault is presented in Table 8.

Table 8 Event summary data at the Pasadena treatment vault, WY17

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
PI	Fall/Winter	10/14/2016 16:30	10/14/2016 18:50	2:20	3,706	1.34	813	0.91	rain	100%	84	19	2,831	0.65	1,751	0.40
PO	Fall/Winter	10/14/2016 16:50	10/14/2016 18:40	1:50	2,897	1.26	259	0.91	rain	100%	94	17	335	0.06	1,488	0.27
PI	Fall/Winter	10/15/2016 16:50	10/15/2016 22:30	5:40	8,219	0.84	640	0.89	rain	100%	40	21	2,586	1.33	821	0.42
PO	Fall/Winter	10/15/2016 17:10	10/15/2016 22:00	4:50	7,181	0.85	122	0.89	rain	100%	29	13	1,922	0.86	1,002	0.45
PI	Fall/Winter	10/16/2016 9:30	10/17/2016 2:10	16:40	27,479	1.23	1,024	1.82	rain	100%	20	34	1,497	2.57	602	1.03
PO	Fall/Winter	10/16/2016 9:50	10/17/2016 1:10	15:20	22,985	1.15	78	1.82	rain	90%	18	26	1,729	2.48	739	1.06
PI	Fall/Winter	12/10/2016 2:30	12/10/2016 20:50	18:20	37,949	1.85	126	2.29	event snowmelt	100%	21	51	689	1.63	248	0.59
PO	Fall/Winter	12/10/2016 2:45	12/10/2016 20:50	18:05	28,500	1.67	121	2.29	event snowmelt	100%	28	50	743	1.32	232	0.41
PI	Fall/Winter	12/15/2016 14:30	12/16/2016 4:40	14:10	24,092	1.09	148	1.68	rain on snow	100%	85	128	917	1.38	519	0.78
PO	Fall/Winter	12/15/2016 14:30	12/16/2016 6:15	15:45	19,274	0.76	130	1.68	rain on snow	100%	22	26	1,175	1.41	269	0.32
PI	Fall/Winter	2/7/2017 1:10	2/8/2017 20:00	42:50	39,526	0.95	198	6.38	rain on snow	100%	37	92	706	1.74	249	0.61
PO	Fall/Winter	2/7/2017 1:25	2/8/2017 23:30	46:05	31,621	0.89	176	6.38	rain on snow	75%	20	40	593	1.17	176	0.35
PI	Spring	4/6/2017 18:50	4/7/2017 6:30	11:40	9,771	1.04	776	1.25	rain on snow	100%	50	31	1,494	0.91	437	0.27
PO	Spring	4/6/2017 19:25	4/7/2017 8:00	12:35	7,170	0.78	324	1.25	rain on snow	100%	69	31	1,778	0.80	437	0.20
PI	Spring	4/18/2017 2:00	4/18/2017 9:30	7:30	2,961	0.27	521	0.86	rain	90%	32	6	502	0.09	275	0.05
PO	Spring	4/18/2017 2:25	4/18/2017 10:25	8:00	1,599	0.17	117	0.86	rain	100%	24	2	491	0.05	227	0.02
PI	Summer	8/6/2017 13:00	8/6/2017 15:20	2:20	7,139	2.79	717	0.75	thunderstorm	100%	159	71	11,584	5.16	2,335	1.04
PO	Summer	8/6/2017 13:15	8/6/2017 14:50	1:35	4,480	1.68	453	0.75	thunderstorm	100%	130	36	8,779	2.46	1,888	0.53
PI	Summer	9/8/2017 13:00	9/8/2017 16:40	3:40	5,203	1.03	334	0.53	thunderstorm	100%	132	43	5,981	1.94	1,594	0.52
PO	Summer	9/8/2017 13:25	9/8/2017 15:55	2:30	2,421	0.68	268	0.53	thunderstorm	100%	108	16	6,260	0.95	1,331	0.20

6.2.3 Lakeshore

Figure 37 shows the average daily flow and cumulative precipitation for WY17 at the Lakeshore catchment outfall.

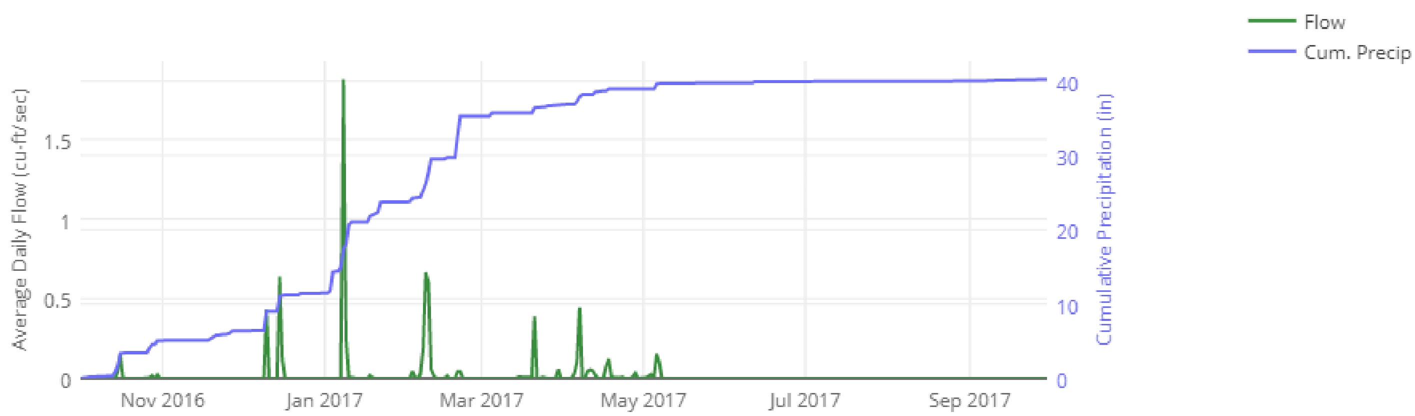

Figure 37 Average daily flow and cumulative precipitation at the Lakeshore catchment outfall, WY17.

- 43.09 inches of total precipitation (36.15 in the fall/winter, 6.00 in the spring, and 0.94 in the summer) recorded at the TERC weather station.
- 43 precipitation events (22 fall/winter events, 12 spring events, 9 summer events).
- One very large storm, with over 7 inches of precipitation, occurred between January 7th and 12th, 2017.
- A second very large storm, with close to 6 inches of precipitation occurred between February 5th and 10th, 2017.
- 58% of storms were less than half an inch.
- Highest average daily flows occurred in the fall/winter season (October – February).
- 28 days of intermittent snowmelt occurred in the spring (March – May).
- Several thunderstorms occurred from mid-August through September but produced no flow. No flow was measured at this site in the summer season.
- The highest instantaneous peak precipitation was 0.07 inches in 5 minutes during a frontal rain storm on December 10, 2016.
- The highest instantaneous peak flow was 2.64 cfs during a rain on snow event on December 15, 2016.

Daily flow and the FSP EMC summary at Lakeshore are presented in Figure 38. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

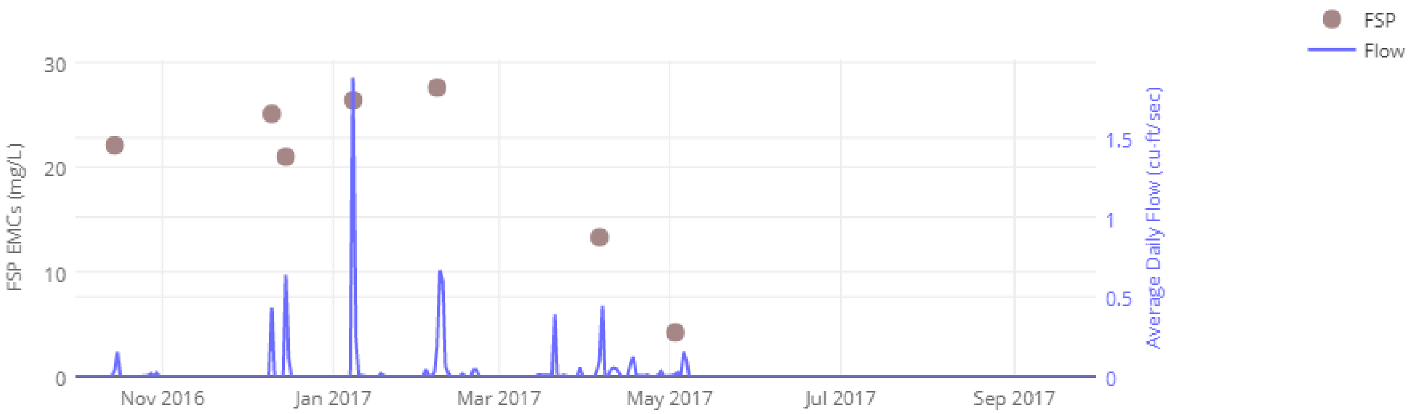

Figure 38 Daily flow and FSP EMC summary at the Lakeshore catchment outfall, WY17.

- Seven events sampled for FSP (five in the fall/winter, two in the spring, zero in the summer).
- The highest FSP EMCs occurred during the two largest rain on snow events from January 8th to 9th, 2017 and February 7th to 9th, 2017.
- The highest FSP load occurred during the rain on snow event from January 8th to 9th, 2017 (refer to Table 9).
- The lowest FSP EMC and load occurred during the non-event snowmelt at the end of May (refer to Table 9).

Daily flow and the TN EMC summary at Lakeshore are presented in Figure 39. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

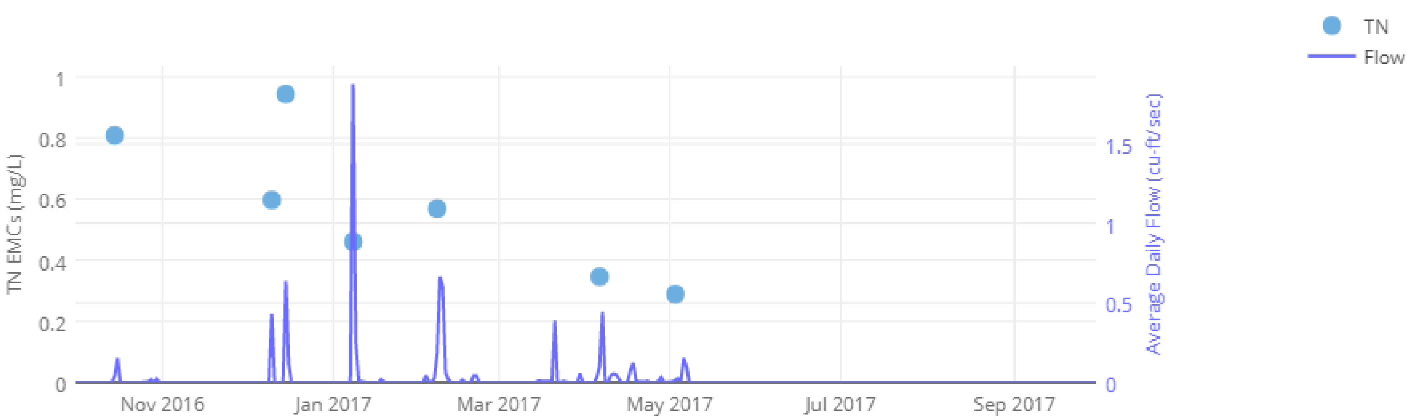

Figure 39 Daily flow and TN EMC summary at the Lakeshore catchment outfall, WY17.

- Seven events sampled for TN (five in the fall/winter, two in the spring, zero in the summer).
- The highest TN EMC occurred during the rain on snow event from December 15th to 16th, 2016.
- The highest TN load occurred during the rain on snow event from December 15th to 16th, 2016 (refer to Table 9).
- The lowest TN EMC and load occurred during the non-event snowmelt at the end of May (refer to Table 9).

Daily flow and the TP EMC summary at Lakeshore are presented in Figure 40. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

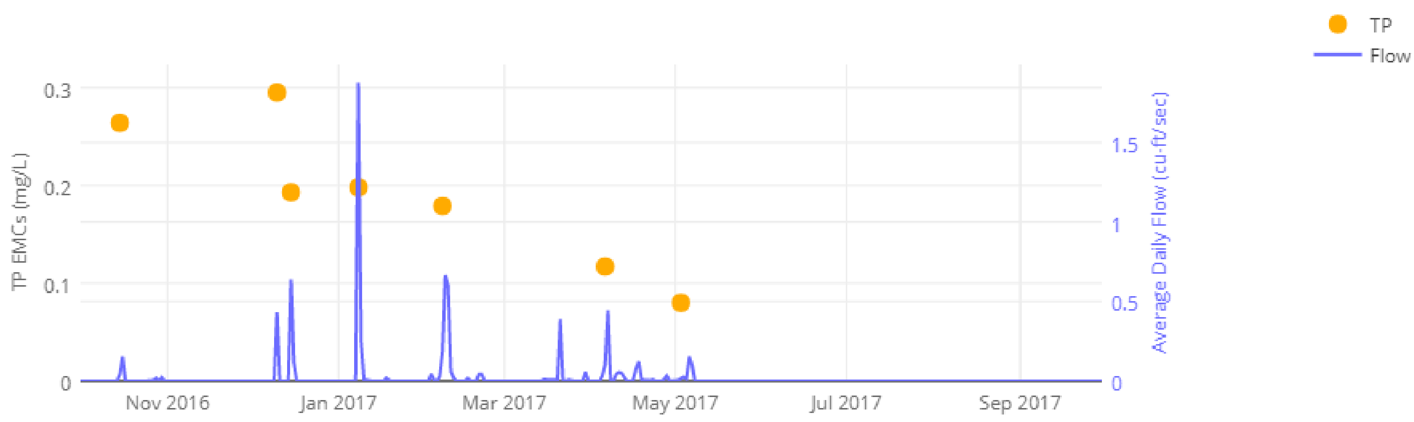

Figure 40 Daily flow and TP EMC summary at the Lakeshore catchment outfall, WY17.

- Seven events sampled for TP (five in the fall/winter, two in the spring, zero in the summer).
- The highest TP EMC occurred during the rain on snow event on December 10, 2016.
- The highest TP load occurred during the rain on snow event from January 8th to 9th, 2017 (refer to Table 9).
- The lowest TP EMC and load occurred during the non-event snowmelt at the end of May (refer to Table 9).

Seasonal load as a fraction of the water year load at Lakeshore is presented in Figure 41. Event loads are presented in tabular form in Table 9.

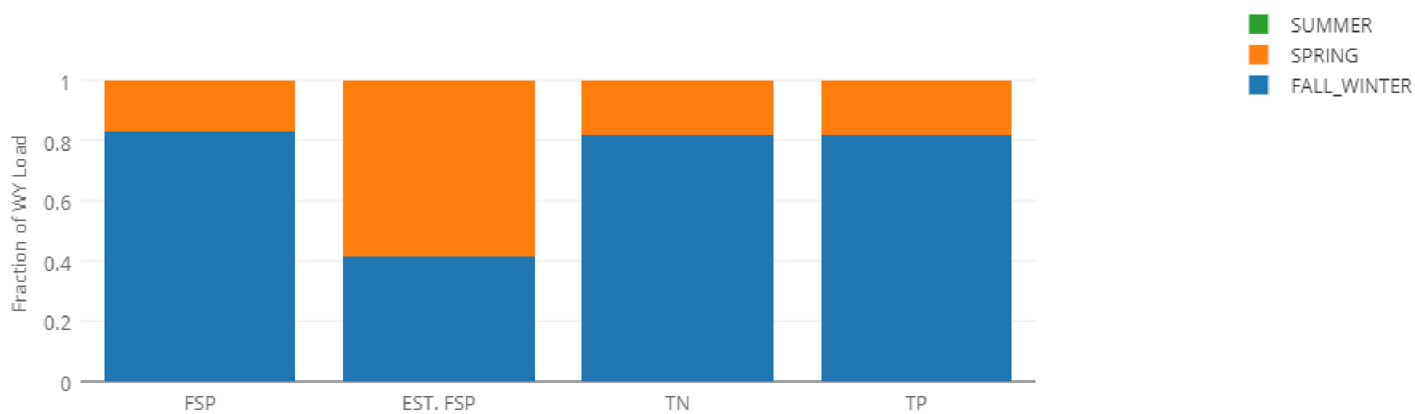

Figure 41 Seasonal load as a fraction of the water year load at the Lakeshore catchment outfall, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- For FSP calculated with the EMCs (Figure 41 – column 1), the largest fraction of FSP load was generated in the fall/winter. For the turbidity estimated FSP load (Figure 41 – column 2), the largest load was generated in the spring. The EMC FSP loads (Figure 41– column 1) are calculated using EMCs from runoff events (not all events are sampled), and the turbidity estimated FSP load (Figure 41 – column 2) is based on continuous turbidity data collected throughout the water year, therefore differences are to be expected.
- The largest fraction of TN loads was generated in the fall/winter.
- The largest fraction of TP loads was generated in the fall/winter.
- Summer produced no load for all three pollutants (because there was no runoff).

Seven events were sampled at Lakeshore in WY17. Event summary data is presented in Table 9.

Table 9 Event summary data at the Lakeshore catchment outfall, WY17

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
LS	Fall/Winter	10/15/2016 17:30	10/17/2016 6:25	36:55	17,102	0.74	1,740	3.22	rain	90%	22	24	809	0.86	264	0.28
LS	Fall/Winter	12/10/2016 3:25	12/10/2016 21:55	18:30	37,420	1.38	517	2.52	rain on snow	100%	25	59	597	1.39	295	0.69
LS	Fall/Winter	12/15/2016 14:45	12/16/2016 6:15	15:30	65,550	2.64	1,489	2.22	rain on snow	100%	21	86	944	3.86	193	0.79
LS	Fall/Winter	1/8/2017 10:15	1/9/2017 14:05	27:50	113,622	2.58	35	7.02	rain on snow	100%	26	187	461	3.27	198	1.40
LS	Fall/Winter	2/7/2017 0:10	2/9/2017 9:30	57:20	75,125	1.88	1,014	5.97	rain on snow	100%	28	130	569	2.67	179	0.84
LS	Spring	4/6/2017 14:35	4/8/2017 8:20	41:45	47,372	1.94	2,465	1.49	rain on snow	80%	13	39	346	1.02	117	0.35
LS	Spring	5/3/2017 13:30	5/6/2017 7:35	66:05	4,572	0.09	1,799	na	non-event snowmelt	100%	4	1	289	0.08	80	0.02

6.2.4 Speedboat

Figure 42 shows the average daily flow and cumulative precipitation for WY17 at the Speedboat catchment outfall.

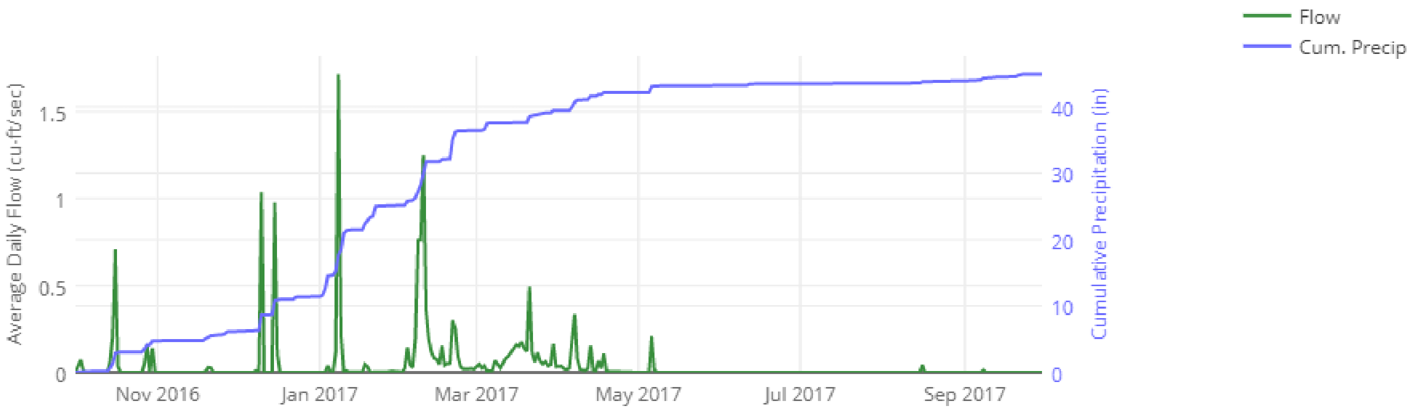

Figure 42 Average daily flow and cumulative precipitation at the Speedboat catchment outfall, WY17.

- 44.99 inches of total precipitation (36.47 in the fall/winter, 6.72 in the spring, 1.80 in the summer) recorded at the Nugget weather station.
- 51 precipitation events (25 fall/winter events, 13 spring events, 13 summer events).
- One very large storm, with close to 7 inches of precipitation, occurred between January 7th and 12th, 2017.
- A second very large storm, with close to 6 inches of precipitation occurred between February 5th and 10th, 2017.
- 65% of storms were less than half an inch.
- Highest average daily flows occurred in the fall/winter season (October – February).
- 86 days of intermittent snowmelt occurred in the spring (March – May).
- A couple thunderstorms occurred from mid-August through September and produced a small amount of flow.
- The highest instantaneous peak precipitation was 0.08 inches in 10 minutes during a frontal rain storm on May 6, 2017.
- The highest instantaneous peak flow was 5.88 cfs during a rain on snow event on January 8, 2017.

Daily flow and the FSP EMC summary at Speedboat are presented in Figure 43. Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

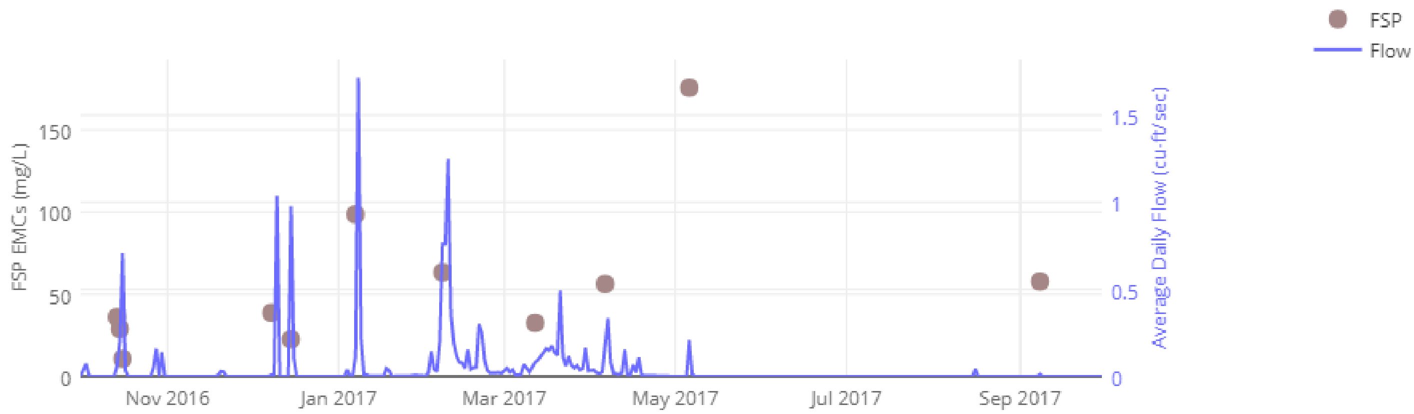

Figure 43 Daily flow and FSP EMC summary at the Speedboat catchment outfall, WY17.

- Eleven events sampled for FSP (seven in the fall/winter, three in the spring, and one in the summer).
- The highest FSP EMC occurred during the relatively small rain on snow event from May 6th to 7th, 2017.
- The highest FSP load occurred during the rain on snow event from January 7th to 9th, 2017 (refer to Table 10).
- Most of the FSP EMCs at this site fell within a similar range.
- The lowest FSP load occurred during the thunderstorm on September 8, 2017 (refer to Table 10).

Daily flow and the TN EMC summary are presented in Figure 44. Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

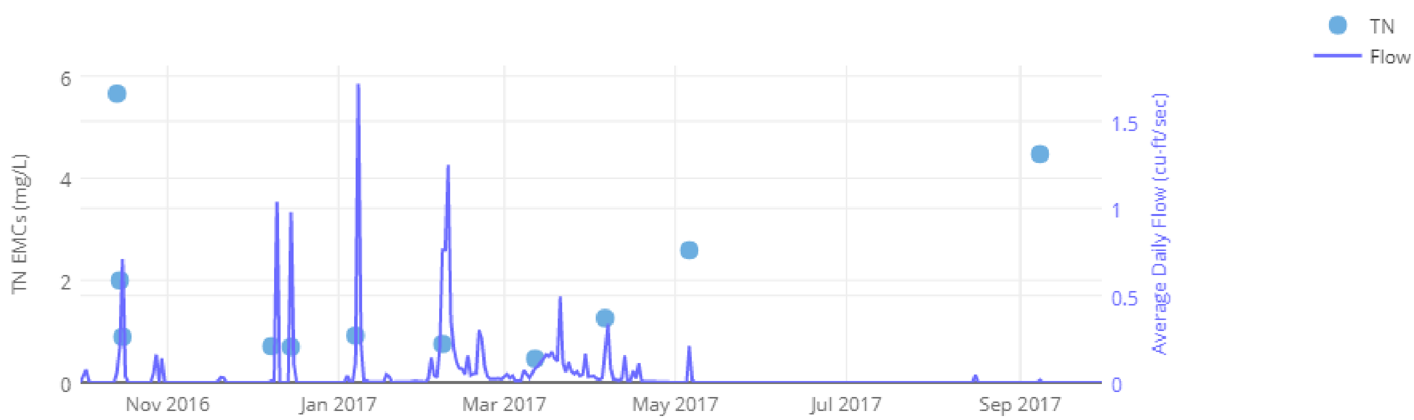

Figure 44 Daily flow and TN EMC summary at the Speedboat catchment outfall, WY17.

- Eleven events sampled for TN (seven in the fall/winter, three in the spring, and one in the summer).
- The highest TN EMCs occurred during the rain event on October 14, 2016 and a summer thunderstorm on September 8, 2017.
- The highest TN load occurred during the rain on snow event from January 7th to 9th, 2017 (refer to Table 10).
- Most of the TN EMCs at this site fell within a similar range.
- The lowest TN load occurred during the thunderstorm on September 8, 2017 (refer to Table 10).

Daily flow and the TP EMC summary are presented in Figure 45. Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

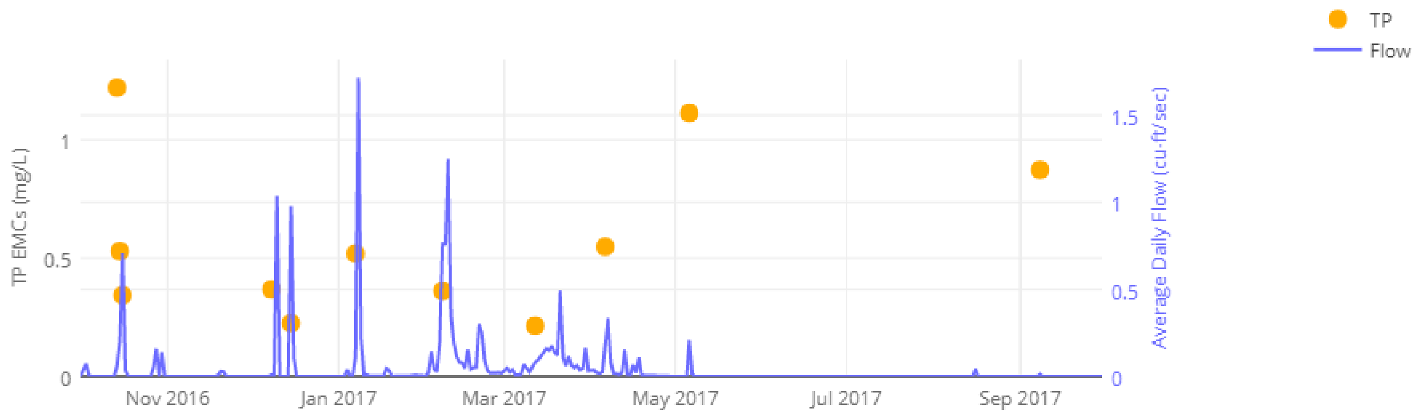

Figure 45	Daily flow and TP EMC summary at the Speedboat catchment outfall, WY17.

- Eleven events sampled for TP (seven in the fall/winter, three in the spring, and one in the summer).
- The highest TP EMCs occurred during the rain event on October 14, 2016 and the relatively small rain on snow event from May 6th to 7th, 2017.
- The highest TP load occurred during the rain on snow event from January 7th to 9th, 2017 (refer to Table 10).
- Most of the TP EMCs at this site fell within a similar range.
- The lowest TP load occurred during the thunderstorm on September 8, 2017 (refer to Table 10).

Seasonal load as a fraction of the water year load is presented in Figure 46. Event loads are presented in tabular form in Table 10.

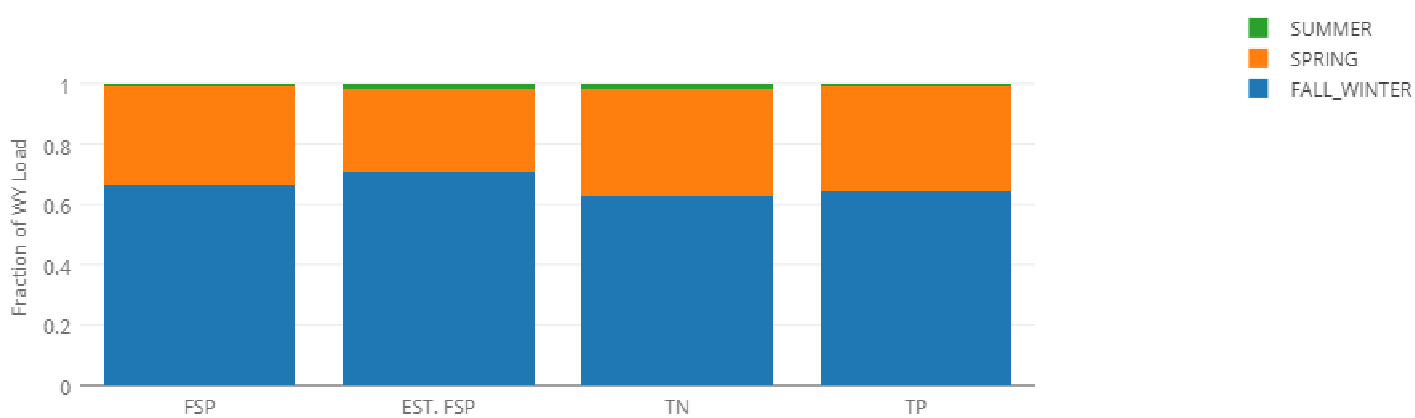

Figure 46	Seasonal load as a fraction of the water year load at the Speedboat catchment outfall, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads was generated fall/winter.
- The largest fraction of TN loads was generated in the fall/winter.
- The largest fraction of TP loads was generated in the fall/winter.
- Summer produced a very small fraction of the overall load for all three pollutants.

Eleven events were sampled at Speedboat in WY17. Event summary data is presented in Table 10.

Table 10 Event summary data at the Speedboat catchment outfall, WY17

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
SB	Fall/Winter	10/14/2016 15:50	10/14/2016 19:40	3:50	5,060	1.37	264	0.49	rain	90%	36	11	5,654	1.79	1,220	0.39
SB	Fall/Winter	10/15/2016 16:45	10/15/2016 22:45	6:00	17,710	2.18	540	0.69	rain	100%	29	32	1,998	2.21	529	0.58
SB	Fall/Winter	10/16/2016 1:20	10/17/2016 0:35	23:15	61,333	3.94	2,764	1.74	rain	100%	11	41	892	3.42	343	1.31
SB	Fall/Winter	12/8/2016 5:50	12/10/2016 20:45	62:55	90,541	4.01	905	2.54	rain on snow	100%	39	219	708	4.00	368	2.08
SB	Fall/Winter	12/15/2016 13:40	12/16/2016 4:50	15:10	93,604	4.62	309	2.29	rain	100%	23	132	694	4.06	225	1.31
SB	Fall/Winter	1/7/2017 10:05	1/9/2017 17:15	55:10	176,670	5.88	313	3.36	rain on snow	100%	99	1,087	917	10.1	519	5.72
SB	Fall/Winter	2/7/2017 0:05	2/9/2017 6:00	53:55	136,571	2.67	271	5.94	rain on snow	100%	63	540	753	6.42	361	3.08
SB	Spring	3/12/2017 9:00	3/15/2017 9:00	72:00	26,127	0.29	933	na	non-event snowmelt	100%	33	53	466	0.76	214	0.35
SB	Spring	4/6/2017 9:00	4/8/2017 3:20	42:20	42,319	1.84	2,397	1.54	rain	100%	56	149	1,258	3.32	548	1.45
SB	Spring	5/6/2017 12:35	5/7/2017 4:35	16:00	19,175	3.42	2,158	1.00	rain on snow	100%	176	210	2,588	3.10	1,113	1.33
SB	Summer	9/8/2017 16:00	9/8/2017 17:25	1:25	1,129	0.71	738	0.27	thunderstorm	100%	58	4	4,472	0.32	873	0.06

6.2.5 Tahoma

Figure 47 shows the average daily flow and cumulative precipitation for WY17 at the Tahoma catchment outfall.

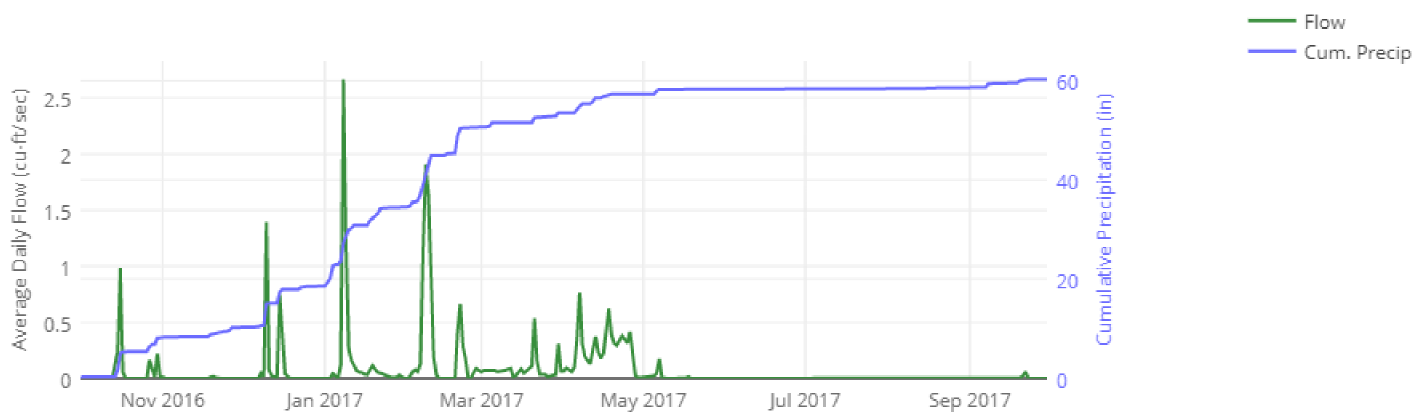

Figure 47 Average daily flow and cumulative precipitation at the Tahoma catchment outfall, WY17.

- 64.28 inches of total precipitation (51.54 in the fall/winter, 10.34 in the spring, and 2.40 in the summer) recorded at the EDCY weather station.
- 52 precipitation events (22 fall/winter events, 16 spring events, 14 summer events).
- One very large storm, with over 9 inches of precipitation, occurred between February 5th and 10th, 2017.
- A second very large storm, with close to 8 inches of precipitation occurred between January 7th and 12th, 2017.
- 57% of storms were less than half an inch.
- Highest average daily flows occurred in the fall/winter season (October – February).
- 73 days of continuous snowmelt occurred in the spring (March – May).
- Lake levels rose at the end of May and backwatered this site making flow measurement and sampling impossible.
- The highest instantaneous peak precipitation was 0.17 inches in 5 minutes during a summer thunderstorm on September 8, 2017 (not sampled).
- The highest instantaneous peak flow was 4.50 cfs during a rain on snow event on January 8, 2017.

Daily flow and the FSP EMC summary at Tahoma are presented in Figure 48. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

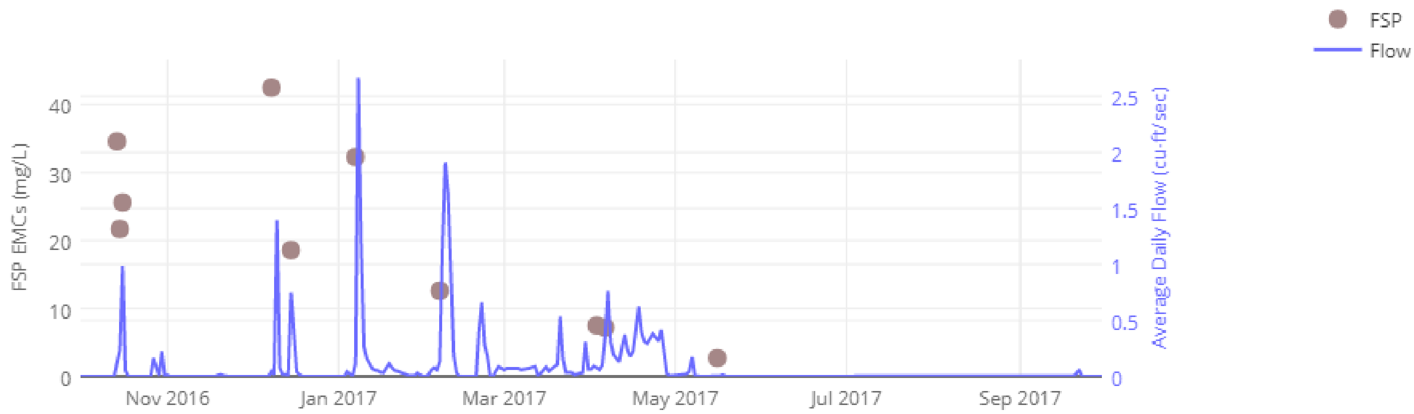

Figure 48 Daily flow and FSP EMC summary at the Tahoma catchment outfall, WY17.

- Ten events sampled for FSP (seven in the fall/winter, three in the spring, zero in the summer).
- The highest FSP EMCs fell within a similar range and occurred in the fall/winter.
- The highest FSP load occurred during the rain on snow event from January 7th to 10th, 2017 (refer to Table 11).
- The lowest FSP EMCs fell within a similar range and occurred in the spring.
- The lowest FSP load occurred during a rain on snow event May 16th to 17th, 2017 (refer to Table 11).

Daily flow and the TN EMC summary at Tahoma are presented in Figure 49. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

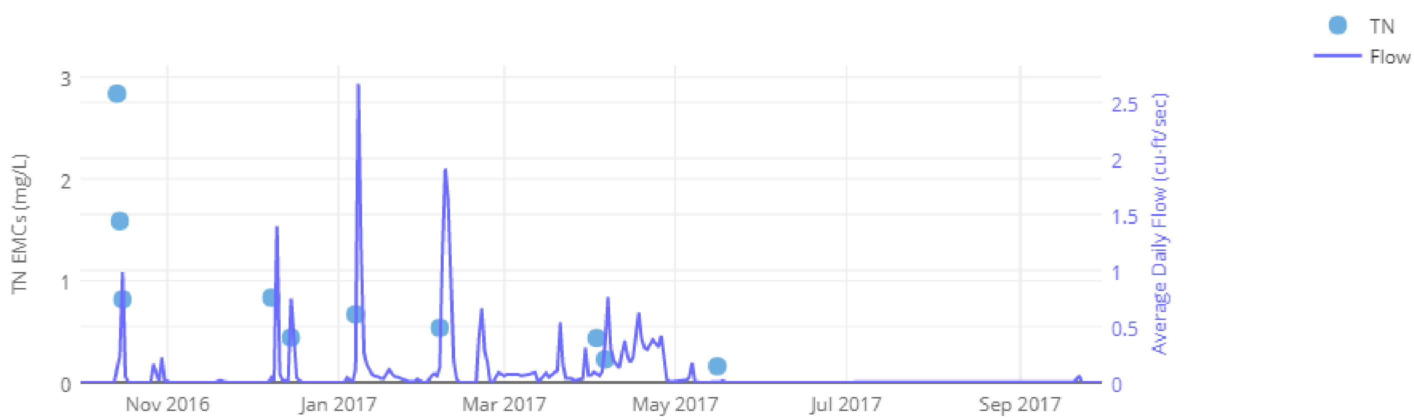

Figure 49 Daily flow and TN EMC summary at the Tahoma catchment outfall, WY17.

- Ten events sampled for TN (seven in the fall/winter, three in the spring, zero in the summer).
- The highest TN EMCs occurred during rain events in October 2016.
- The highest TN load occurred during the rain on snow event from January 7th to 10th, 2017 (refer to Table 11).
- Most of the TN EMCs at this site fell within a similar range but were generally lower in the spring than the fall/winter.
- The lowest TN load occurred during a rain on snow event May 16th to 17th, 2017 (refer to Table 11).

Daily flow and the TP EMC summary at Tahoma are presented in Figure 50. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

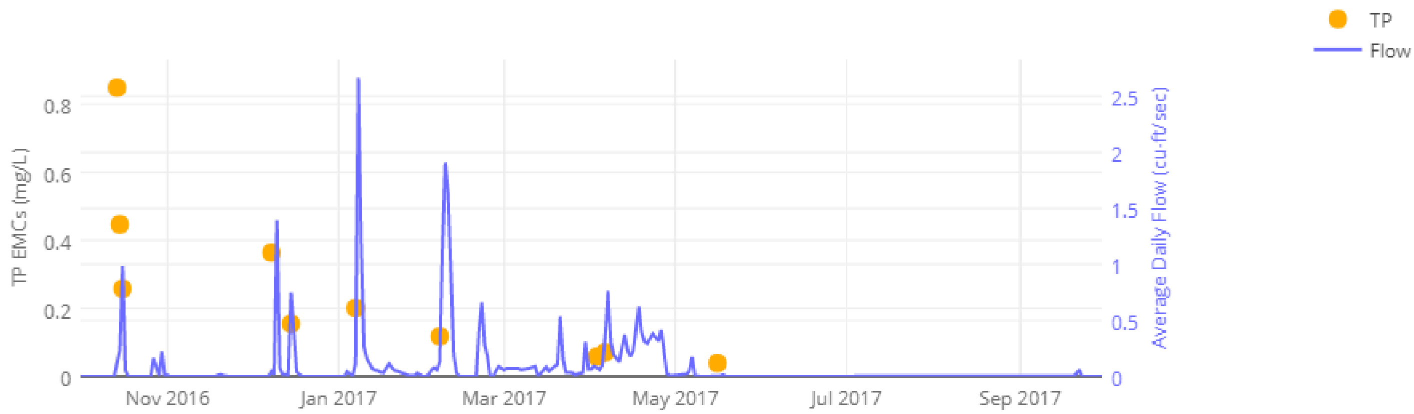

Figure 50 Daily flow and TP EMC summary at the Tahoma catchment outfall, WY17.

- Ten events sampled for TP (seven in the fall/winter, three in the spring, zero in the summer).
- The highest TP EMCs occurred during the rain events in October 2016.
- The highest TP load occurred during the rain on snow event from January 7th to 10th, 2017 (refer to Table 11).
- Most of the TP EMCs at this site fell within a similar range but were generally lower in the spring than the fall/winter.
- The lowest TP load occurred during a rain on snow event May 16th to 17th, 2017 (refer to Table 11).

Seasonal load as a fraction of the water year load at Tahoma is presented in Figure 51. Event loads are presented in tabular form in Table 11.

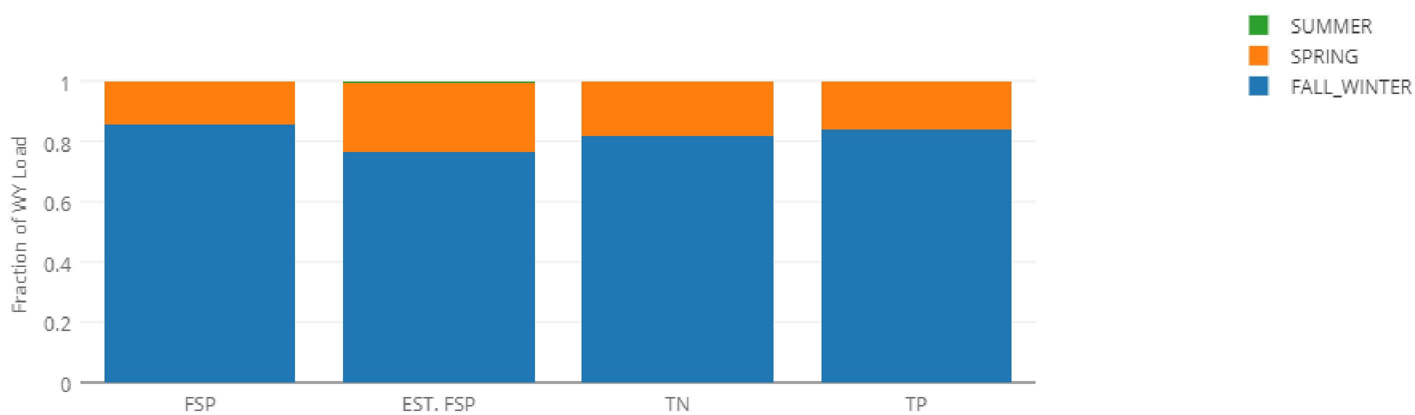

Figure 51 Seasonal load as a fraction of the water year load at the Tahoma catchment outfall, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads was generated fall/winter.
- The largest fraction of TN loads was generated in the fall/winter.
- The largest fraction of TP loads was generated in the fall/winter.

Ten events were sampled at Tahoma in WY17. Event summary data is presented in Table 11.

Table 11 Event summary data at the Tahoma catchment outfall, WY17

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
TA	Fall/Winter	10/14/2016 7:00	10/15/2016 11:05	28:05	10,410	1.25	1,585	0.01	rain	100%	35	22	2,836	1.84	849	0.55
TA	Fall/Winter	10/15/2016 14:30	10/16/2016 4:50	14:20	23,762	2.27	1,904	0.15	rain	100%	22	32	1,585	2.35	447	0.66
TA	Fall/Winter	10/16/2016 4:50	10/17/2016 7:00	26:10	86,380	3.20	264	4.86	rain	50%	26	138	815	4.39	258	1.39
TA	Fall/Winter	12/8/2016 2:15	12/11/2016 12:55	82:40	130,293	3.83	665	0.38	rain	100%	42	345	833	6.78	364	2.96
TA	Fall/Winter	12/15/2016 10:10	12/17/2016 10:15	48:05	98,831	2.32	219	2.77	rain on snow	90%	19	115	440	2.71	155	0.96
TA	Fall/Winter	1/7/2017 10:50	1/10/2017 17:10	78:20	362,051	4.46	1,225	7.94	rain on snow	100%	32	730	667	15.1	201	4.53
TA	Fall/Winter	2/6/2017 8:45	2/9/2017 9:10	72:25	287,488	4.50	246	9.36	rain on snow	100%	13	226	536	9.61	118	2.12
TA	Spring	4/3/2017 9:00	4/6/2017 9:00	72:00	113,529	0.21	21	na	non-event snowmelt	100%	8	53	435	3.08	58	0.41
TA	Spring	4/6/2017 6:05	4/8/2017 7:45	49:40	298,504	1.06	150	2.27	rain on snow	100%	7	135	226	4.21	71	1.32
TA	Spring	5/16/2017 16:10	5/17/2017 16:10	24:00	22,311	0.04	32	0.29	rain on snow	100%	3	4	159	0.22	39	0.05

6.2.6 Tahoe Valley

Figure 52 shows the average daily flow and cumulative precipitation for WY17 at the Tahoe Valley catchment outfall.

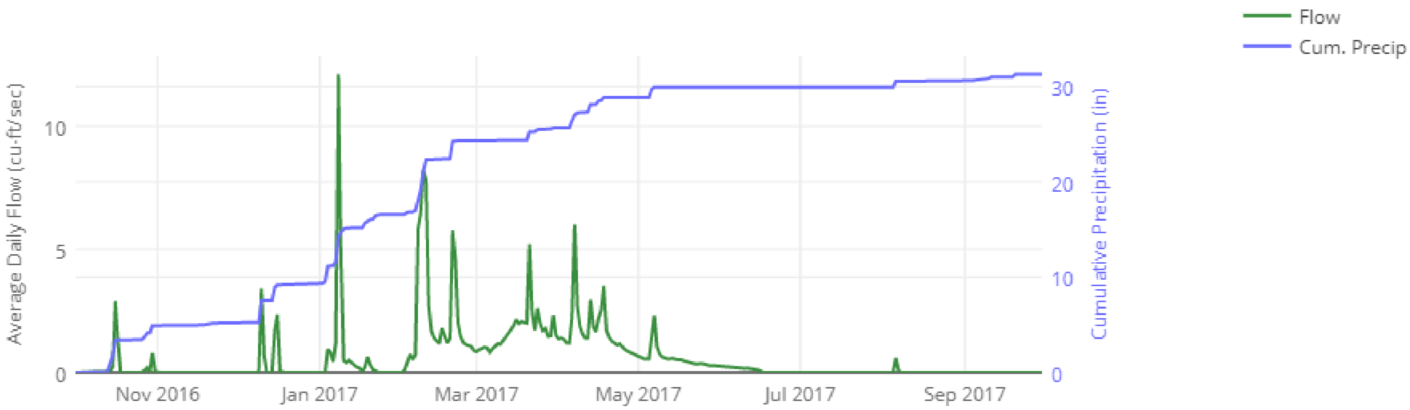

Figure 52 Average daily flow and cumulative precipitation at the Tahoe Valley catchment outfall, WY17.

- 37.46 inches of total precipitation (28.04 in the fall/winter, 7.66 in the spring, 1.76 in the summer) recorded at the Raph's Shop weather station.
- 46 precipitation events (22 fall/winter events, 12 spring events, 12 summer events).
- The largest storm, with over 6 inches of precipitation, occurred between February 5th and 10th, 2017.
- 65% of storms were less than half an inch.
- Highest average daily flows occurred in the fall/winter season (October – February).
- 104 days of continuous snowmelt runoff occurred in the spring and early summer.
- The highest instantaneous peak precipitation was 0.13 inches in 5 minutes during a summer thunderstorm on August 8, 2017.
- The highest instantaneous peak flow was 20.0 cfs during a rain on snow event on January 8, 2017.

Daily flow and the FSP EMC summary at Tahoe Valley are presented in Figure 53. Table 11 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

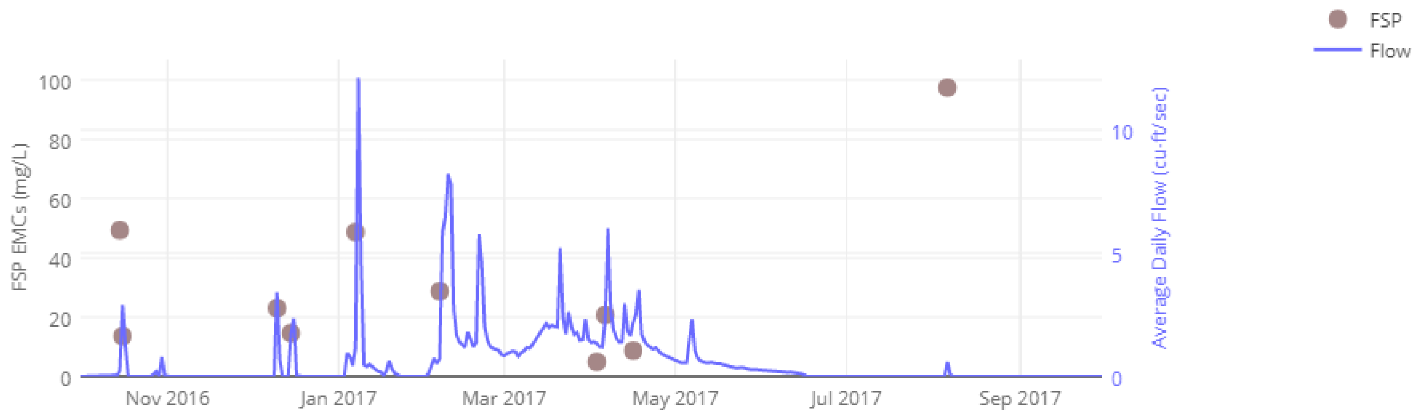

Figure 53 Daily flow and FSP EMC summary at the Tahoe Valley catchment outfall, WY17.

- Ten events sampled for FSP (six in the fall/winter, three in the spring, and one in the summer).
- The highest FSP EMC occurred during a summer thunderstorm on August 6, 2017.
- The highest FSP load occurred during the rain on snow event from January 7th to 10th, 2017 (refer to Table 12).
- The lowest FSP EMC occurred during a non-event snowmelt event in early April.
- The lowest TN load occurred on October 15, 2016 (refer to Table 12).

Daily flow and the TN EMC summary at Tahoe Valley are presented in Figure 54. Table 11 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

Figure 54 Daily flow and TN EMC summary at the Tahoe Valley catchment outfall, WY17.

- Ten events sampled for TN (six in the fall/winter, three in the spring, and one in the summer).
- The highest TN EMC occurred during a summer thunderstorm on August 6, 2017.
- The highest TN load occurred during the rain on snow event from January 7th to 10th, 2017 (refer to Table 12).
- The lowest TN EMC occurred during the rain on snow event from December 15th to 17th, 2016.
- The lowest TN load occurred on October 15th, 2016 (refer to Table 12).

Daily flow and the TP EMC summary at Tahoe Valley are presented in Figure 55. Table 11 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

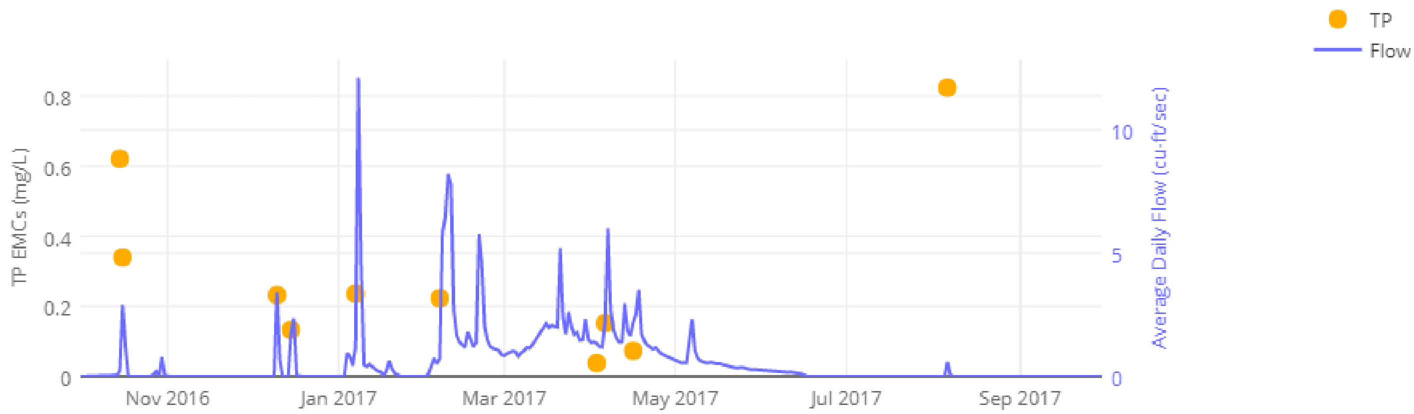

Figure 55 Daily flow and TP EMC summary at the Tahoe Valley catchment outfall, WY17.

- Ten events sampled for TP (six in the fall/winter, three in the spring, and one in the summer).
- The highest TP EMC occurred during a summer thunderstorm on August 6, 2017.
- The highest TP load occurred during the rain on snow event from February 6th to 9th, 2017 (refer to Table 12).
- The lowest TP EMC occurred during the non-event snowmelt from April 3rd to 6th, 2017.
- The lowest TP load occurred during the rain event on October 15th, 2016 (refer to Table 12).

Seasonal load as a fraction of the water year load at Tahoe Valley is presented in Figure 56. Event loads are presented in tabular form in Table 6.

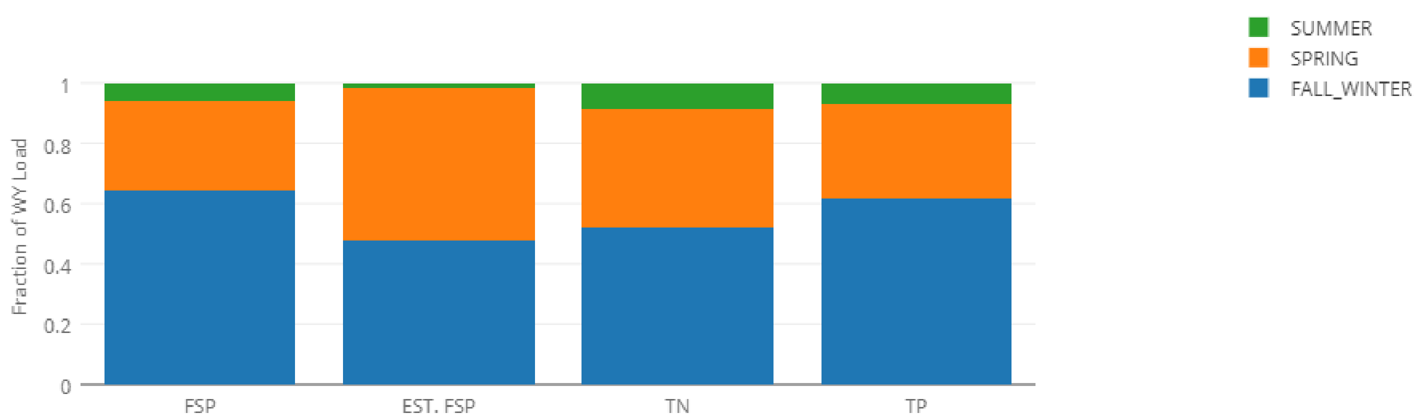

Figure 56 Seasonal load as a fraction of the water year load at the Tahoe Valley catchment outfall, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- For FSP calculated with the EMCs (Figure 56 – column 1), the largest fraction of FSP load was generated in the fall/winter. For the turbidity estimated FSP load (Figure 56 – column 2), the largest load was generated in the spring. The EMC FSP loads (Figure 56 – column 1) are calculated using EMCs from runoff events (not all events are sampled), and the turbidity estimated FSP load (Figure 56 – column 2) is based on continuous turbidity data collected throughout the water year, therefore differences are to be expected.
- The largest fraction of TN loads was generated in the fall/winter.

- The largest fraction of TP loads was generated in the fall/winter.
- Summer produces a very small fraction of the overall load for all three pollutants.

Ten events were sampled at Tahoe Valley in WY17. Event summary data is presented in Table 12.

Table 12 Event summary data at the Tahoe Valley catchment outfall, WY17

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
TV	Fall/Winter	10/15/2016 14:30	10/15/2016 20:40	6:10	10,798	2.19	172	0.89	rain	100%	49	33	1,148	0.77	621	0.42
TV	Fall/Winter	10/16/2016 9:20	10/17/2016 18:20	33:00	352,400	8.41	333	1.82	rain	100%	14	298	1,024	23	340	7.48
TV	Fall/Winter	12/10/2016 1:30	12/11/2016 16:20	38:50	354,666	6.84	563	2.29	event snowmelt	100%	23	509	550	12	232	5.14
TV	Fall/Winter	12/15/2016 14:00	12/17/2016 3:50	37:50	354,919	7.66	815	1.68	rain on snow	100%	15	324	465	10	133	2.95
TV	Fall/Winter	1/7/2017 0:00	1/10/2017 14:10	86:10	1,578,007	20.02	747	4.51	rain on snow	100%	49	4,795	1,206	119	236	23.2
TV	Fall/Winter	2/6/2017 8:00	2/9/2017 10:40	74:40	1,289,398	11.29	446	6.38	rain on snow	100%	29	2,313	726	58	223	18.0
TV	Spring	4/3/2017 8:00	4/6/2017 8:00	72:00	316,491	1.40	16	na	non-event snowmelt	100%	5	98	591	12	38	0.76
TV	Spring	4/6/2017 18:40	4/8/2017 8:20	37:40	714,864	10.22	199	2.10	rain on snow	100%	21	926	535	24	152	6.78
TV	Spring	4/16/2017 15:40	4/19/2017 6:30	62:50	673,237	6.26	71	1.10	rain on snow	100%	9	365	599	25	73	3.06
TV	Summer	8/6/2017 12:05	8/7/2017 5:00	16:55	54,664	3.48	715	0.61	thunderstorm	75%	97	332	4,538	15	824	2.81

6.2.7 Upper Truckee

Figure 57 shows the average daily flow and cumulative precipitation for WY17 at the Upper Truckee catchment outfall.

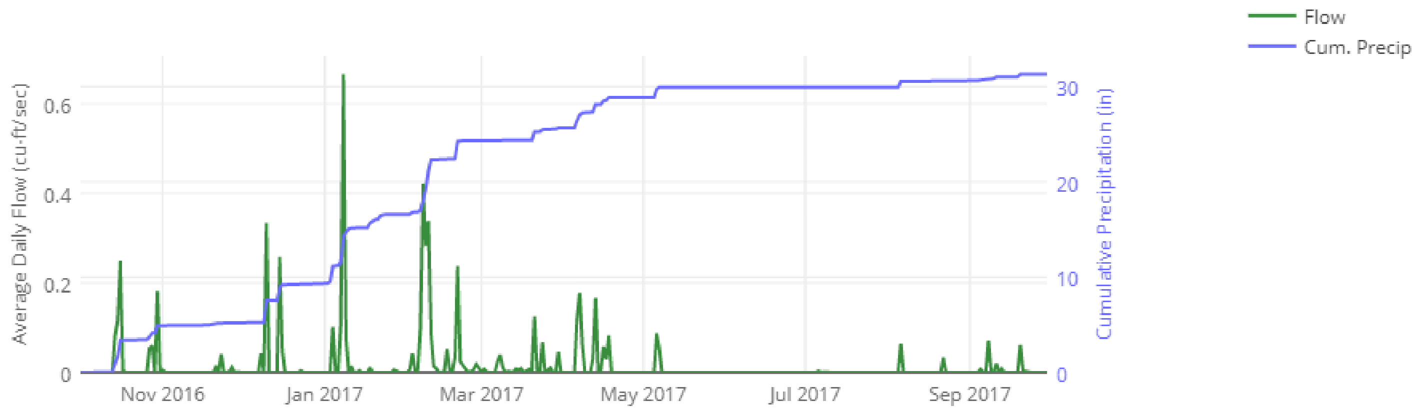

Figure 57 Average daily flow and cumulative precipitation at the Upper Truckee catchment outfall, WY17.

- 37.46 inches of total precipitation (28.04 in the fall/winter, 7.66 in the spring, 1.76 in the summer) recorded at the Raph's Shop weather station.
- 46 precipitation events (22 fall/winter events, 12 spring events, 12 summer events).
- The largest storm, with over 6 inches of precipitation, occurred between February 5th and 10th, 2017.
- 65% of storms were less than half an inch.
- Highest average daily flows occurred in the fall/winter season (October – February).
- 41 days of intermittent snowmelt runoff occurred in the spring.
- The highest instantaneous peak precipitation was 0.13 inches in 5 minutes during a summer thunderstorm on August 8, 2017.
- The highest instantaneous peak flow was 3.0 cfs during the thunderstorm on August 6, 2017.

Daily flow and the FSP EMC summary at Upper Truckee are presented in Figure 58. Table 11 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

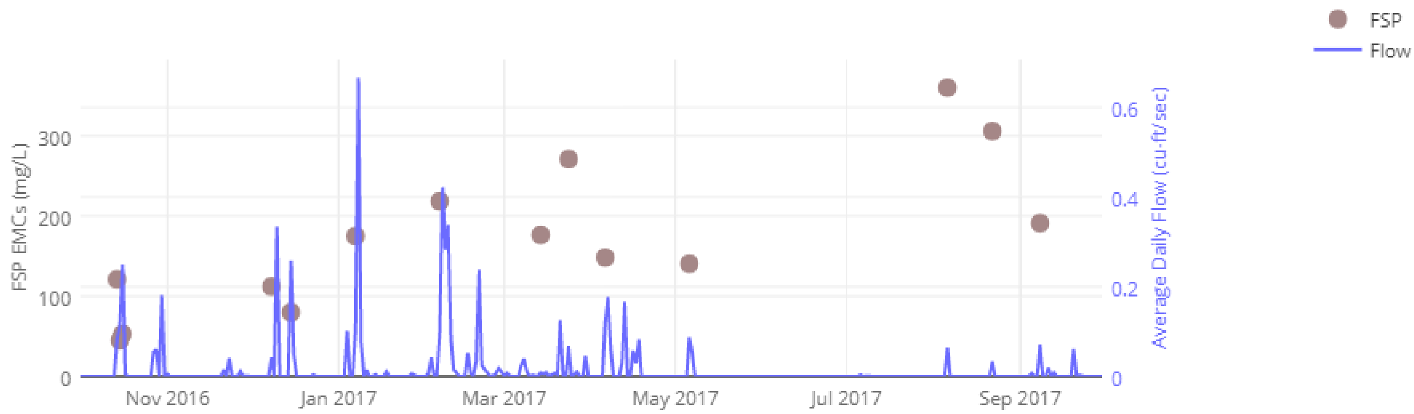

Figure 58 Daily flow and FSP EMC summary at the Upper Truckee catchment outfall, WY17.

- Fourteen events sampled for FSP (seven in the fall/winter, four in the spring, and three in the summer).
- The highest FSP EMC occurred during a summer thunderstorm on August 6, 2017.
- The highest FSP loads occurred during the rain on snow events from January 7th to 9th, 2017 and February 6th to 8th, 2017 (refer to Table 13).
- The lowest FSP EMCs occurred during the rain events from October 14th to 16th, 2016.
- The lowest FSP load occurred during the non-event snowmelt from March 14th to 16th, 2017 (refer to Table 13).

Daily flow and the TN EMC summary at Upper Truckee are presented in Figure 59. Table 11 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

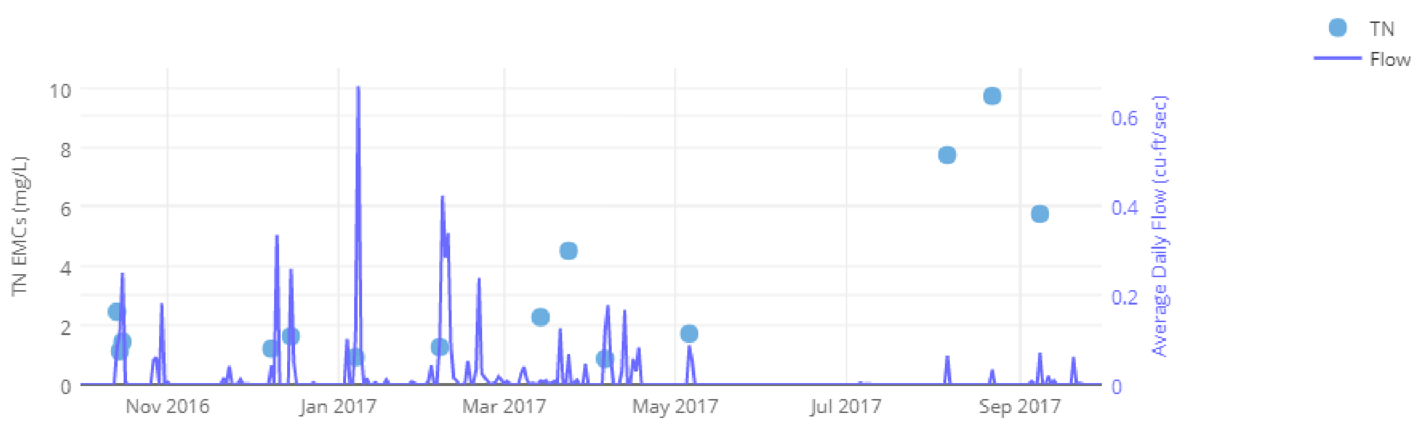

Figure 59 Daily flow and TN EMC summary at the Upper Truckee catchment outfall, WY17.

- Fourteen events sampled for TN (seven in the fall/winter, four in the spring, and three in the summer).
- The highest TN EMC occurred during a summer thunderstorm on August 22, 2017.
- The highest TN load occurred during the rain on snow event on March 24, 2017 (refer to Table 13).
- The lowest TN EMC and load occurred during the rain on snow event from April 6th to 7th, 2017 (refer to Table 13).

Daily flow and the TP EMC summary at Upper Truckee are presented in Figure 60. Table 11 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

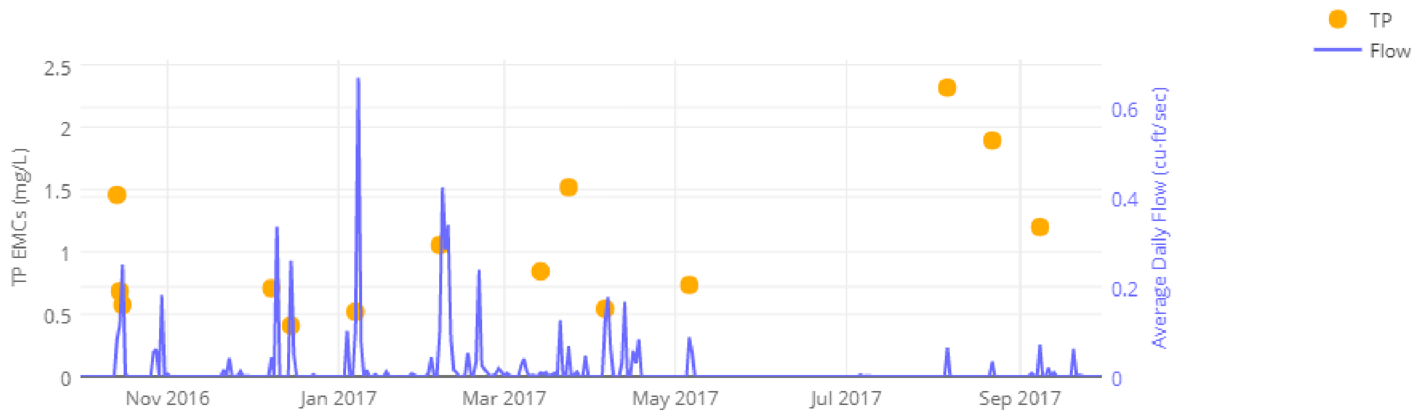

Figure 60 Daily flow and TP EMC summary at the Upper Truckee catchment outfall, WY17.

- Fourteen events sampled for TP (seven in the fall/winter, four in the spring, and three in the summer).
- The highest TP EMC occurred during a summer thunderstorm on August 6, 2017.
- The highest TP load occurred during the rain on snow event from February 6th to 8th, 2017 (refer to Table 13).
- The lowest TP EMC occurred during the rain on snow event from December 15th to 16th, 2016.
- The lowest TP load occurred during the non-event snowmelt from March 14th to 16th, 2017 (refer to Table 13).

Seasonal load as a fraction of the water year load at Upper Truckee is presented in Figure 61. Event loads are presented in tabular form in Table 6.

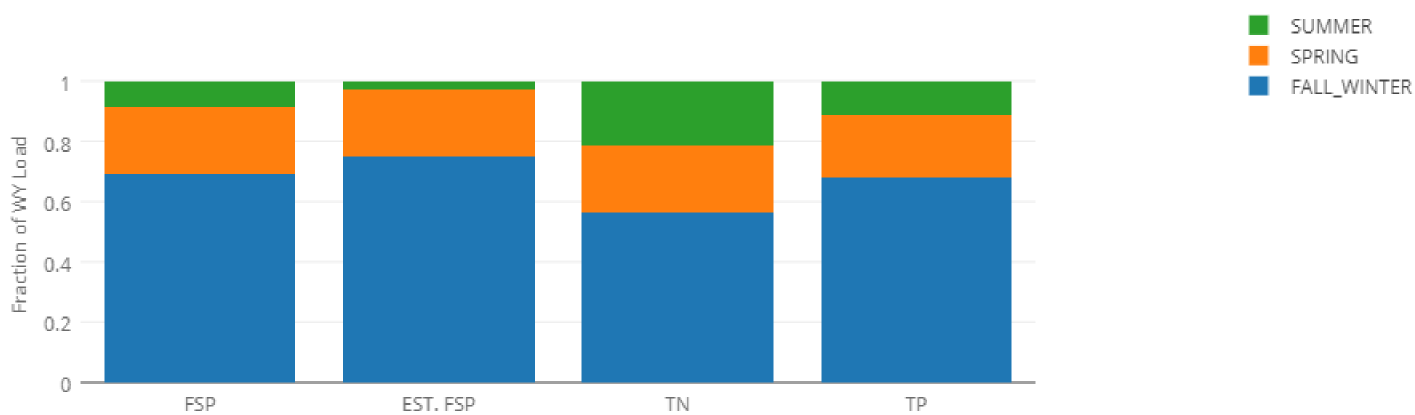

Figure 61 Seasonal load as a fraction of the water year load at the Upper Truckee catchment outfall, WY17. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads was generated fall/winter.
- The largest fraction of TN loads was generated in the fall/winter.
- The largest fraction of TP loads was generated in the fall/winter.
- Summer produced a very small fraction of the overall load for FSP and TP.
- Spring and summer generated similar fractions of TN

Fourteen events were sampled at Upper Truckee in WY17. Event summary data is presented in Table 13.

Table 13 Event summary data at the Upper Truckee catchment outfall, WY17

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
UT	Fall/Winter	10/14/2016 7:40	10/14/2016 19:30	11:50	7,061	0.47	869	0.91	rain	90%	121	53	2,453	1.08	1,457	0.64
UT	Fall/Winter	10/15/2016 14:30	10/15/2016 23:20	8:50	9,990	0.76	283	0.89	rain	75%	45	28	1,127	0.70	683	0.43
UT	Fall/Winter	10/16/2016 0:50	10/17/2016 1:40	24:50	22,000	0.96	502	1.82	rain	100%	53	73	1,442	1.98	574	0.79
UT	Fall/Winter	12/8/2016 1:10	12/10/2016 20:35	67:25	36,214	1.09	464	2.29	event snowmelt	100%	112	253	1,206	2.73	707	1.60
UT	Fall/Winter	12/15/2016 11:45	12/16/2016 3:25	15:40	26,435	0.75	538	1.68	rain on snow	100%	80	132	1,631	2.69	408	0.67
UT	Fall/Winter	1/7/2017 8:20	1/9/2017 4:35	44:15	72,834	1.54	1,581	4.51	rain on snow	100%	175	796	917	4.17	519	2.36
UT	Fall/Winter	2/6/2017 23:30	2/8/2017 19:55	44:25	60,990	0.87	930	6.38	rain on snow	100%	218	831	1,260	4.80	1,054	4.01
UT	Spring	3/14/2017 11:10	3/16/2017 19:45	56:35	1,924	0.06	2,372	na	non-event snowmelt	90%	176	21	2,270	0.27	843	0.10
UT	Spring	3/24/2017 8:15	3/24/2017 16:05	7:50	25,146	0.34	578	0.43	rain on snow	100%	271	425	4,516	7.09	1518	2.38
UT	Spring	4/6/2017 18:50	4/7/2017 17:25	22:35	5,809	1.14	428	2.10	rain on snow	100%	148	54	867	0.31	542	0.20
UT	Spring	5/6/2017 12:35	5/7/2017 10:15	21:40	11,956	0.84	321	1.14	rain on snow	100%	141	105	1,714	1.28	733	0.55
UT	Summer	8/6/2017 12:10	8/6/2017 14:45	2:35	5,521	2.47	444	0.61	thunderstorm	100%	360	124	7,753	2.67	2,317	0.80
UT	Summer	8/22/2017 14:10	8/22/2017 17:55	3:45	1,746	0.41	508	0.16	thunderstorm	90%	306	33	9,740	1.06	1,894	0.21
UT	Summer	9/8/2017 13:05	9/8/2017 16:25	3:20	6,179	1.64	949	0.16	thunderstorm	100%	191	74	5,758	2.22	1,199	0.46

7. BMP Effectiveness Monitoring

7.1 SR431

Data collected from matched inflow and outflow sampling at the Contech MFS stormwater cartridge filter vault and at the Jellyfish stormwater cartridge filter vault at SR431 during WY17 show variable removal efficiencies for sediment and nutrients. It should be noted that the Contech MFS and Jellyfish vaults were not necessarily maintained in the same condition, so comparing pollutant removal efficiencies for events should be cautioned (Tables 15 and 16). However, an overall comparison for the water year (annual load reductions) is valid if differences in the maintenance of the two vaults are acknowledged (Table 14). Below is a summary of the maintenance that occurred.

- Before the beginning of WY17, on August 3, 2016, the MFS filters were completely replaced.
- The splitter vault above the inflows filled with sediment on numerous occasions during the very wet 2017 water year, triggering the need for maintenance. As a result, five cleanouts occurred during WY17: October 20, 2016, April 20, 2017, June 28, 2017, August 15, 2017 and August 16, 2017.
- On October 20, 2016 the entire system was vactored: pipes between drop inlet and splitter vault, splitter vault itself, pipes between splitter vault and both inflows, pipes between both vaults and both outflows, and the Contech MFS and Jellyfish vaults. The Jellyfish tentacles were rinsed with high pressure water, but the Contech MFS filters were not replaced (only replacement can improve filter performance). The first sampled storm of water year 2017 occurred one week after the cleanout and saw the highest TN removal efficiency of all storms sampled.
- On April 20, 2017 the entire system was vactored (see October 20, 2016 description), except the Jellyfish vault was not vactored and the tentacles were not rinsed.
- On June 28, 2017 only the splitter vault above the inflows and the Jellyfish vault were vactored; the Contech MFS vault and the rest of the connection pipes were not.
- On August 15, 2017 the entire system was vactored (see October 20, 2016 description) and the Jellyfish tentacles were rinsed with high pressure water. A large thunderstorm occurred on the evening of August 15, 2017, flushing a large amount of sediment through the system necessitating vactoring of the system again on August 16, 2017. However, Jellyfish tentacles were not rinsed a second time. A thunderstorm was sampled 3 days later on August 19, 2017, and resulted in the highest FSP removal efficiency of all storms sampled in water year 2017.

Table 14 presents the seasonal and annual summary data on removal efficiency for each treatment vault at SR431 in WY17.

Table 14 Seasonal and annual efficiency data from the Contech MFS and Jellyfish vaults at SR431, WY17.

Water Year 2017 (October 1, 2016 - September 30, 2017)			Seasonal FSP Loads (lbs)			Total Annual FSP Loads (lbs)	Seasonal TN Loads (lbs)			Total Annual TN Loads (lbs)	Seasonal TP Loads (lbs)			Total Annual TP Loads (lbs)
Catchment Name	Station Name	Station Acronym	Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)	
SR431	Contech In	CI	254	303	22	578	4.7	3.7	0.08	8.5	1.7	4.2	0.06	5.9
	Contech Out	CO	147	250	14	411	1.7	3.0	0.07	4.8	1.1	3.0	0.03	4.1
		Load Reduction	107	53	8	168	3.1	0.7	0.01	3.7	0.6	1.2	0.03	1.8
		% Change	-42%	-17%	-35%	-29%	-65%	-18%	-16%	-44%	-36%	-28%	-54%	-31%
SR431	Jellyfish In	JI	267	190	16	474	2.5	3.9	0.10	6.6	1.7	4.3	0.05	6.1
	Jellyfish Out	JO	184	196	13	393	2.3	3.5	0.06	5.8	1.5	2.7	0.02	4.2
		Load Reduction	83	(6)	3	81	0.3	0.4	0.04	0.7	0.3	1.6	0.03	1.9
		% Change	-31%	3%	-20%	-17%	-11%	-10%	-44%	-11%	-16%	-37%	-59%	-31%

- The Contech MFS received about 16% more flow and was maintained less often than the Jellyfish, but had better FSP and TN removal efficiencies and similar TP removal efficiencies as the Jellyfish.
- The Contech MFS reduced annual FSP loads by 29%.
- The Jellyfish reduced annual FSP loads by 17%.
- The Contech MFS reduced FSP loads more effectively than the Jellyfish in all seasons.
- The Contech MFS reduced annual TN loads by 44%. The fall/winter reduction in TN was 65%.
- The Jellyfish reduced annual TN loads by 11%.
- The Contech MFS reduced TN more effectively than the Jellyfish in all seasons except summer.
- The Contech MFS and the Jellyfish both reduced annual TP loads by 31%.
- The Contech MFS and the Jellyfish reduced summer TP loads by more than one half (54% and 59% respectively).

Table 15 presents the efficiency of the Contech MFS at reducing concentrations and loads of all three pollutants for the individual events sampled in WY17.

Table 15 Event efficiency data from the Contech MFS vault at SR431, WY17.

Event Start Date	Event Volume as a % of Total Annual Volume (cf)	FSP Concentration (mg/L)			FSP Load (lbs)			TN Concentration (ug/L)			TN Load (lbs)			TP Concentration (ug/L)			TP Load (lbs)		
		in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change
10/27/2016	3%	35	29	-16%	6	4	-29%	6,608	1,140	-83%	1.14	0.17	-85%	271	197	-27%	0.05	0.03	-38%
12/8/2016	3%	399	260	-35%	82	47	-42%	1,465	1,086	-26%	0.30	0.20	-34%	1,277	738	-42%	0.26	0.13	-49%
1/7/2017	6%	289	245	-15%	99	85	-14%	830	686	-17%	0.28	0.24	-16%	916	663	-28%	0.31	0.23	-26%
4/6/2017	0.4%	902	321	-64%	21	6	-72%	2,367	1,928	-19%	0.06	0.04	-36%	4,263	2,717	-36%	0.10	0.05	-50%
4/16/2017	1%	664	402	-39%	34	20	-41%	2,142	1,599	-25%	0.11	0.08	-28%	3,749	2,160	-42%	0.19	0.11	-44%
5/6/2017	4%	372	274	-26%	94	68	-27%	1,374	1,270	-8%	0.35	0.32	-9%	1,714	1,486	-13%	0.43	0.37	-15%
5/19/2017	6%	10	9	-6%	3.8	3.7	-3%	397	295	-26%	0.16	0.12	-23%	65	43	-33%	0.03	0.02	-31%
8/19/2017	0.4%	181	161	-11%	4.2	3.7	-10%	na	na	na	na	na	na	na	na	na	na	na	na
9/21/2017	1%	197	91	-54%	7	2	-67%	855	1,118	31%	0.029	0.027	-5%	618	442	-28%	0.02	0.01	-48%

- The highest FSP concentration and load reductions occurred during the rain on snow event beginning April 6, 2017 when inflow concentrations were the greatest.
- The lowest FSP concentration and load reductions occurred during the rain on snow event beginning May 19, 2017 when inflow concentrations were the lowest.
- The highest TN concentration and load reductions occurred during the rain event on October 27th when inflow concentrations were the greatest. The filters were completed replaced prior to this water year (August 3, 2016), so this may be the reason the high TN removal was observed. However, the inflow TN concentration may have been due to contamination so the TN load reduction observed on this date may be false.
- The lowest TN load reduction occurred during the summer thunderstorm on September 21, 2017 when loads were the smallest. However, during this event the Contech MFS released TN as indicated by the increase in TN concentration at the outflow. However, volumes were small enough at the outflow that loads were still slightly smaller at the outflow.
- TP concentration and load reductions were not as variable as the other two pollutants, generally between 30-40%. The exception to this is the May 6, 2017 rain on snow event when the loads were very high and reduction efficiency was only 15%.

Contech MFS vault water level and bypass flow is presented in Figure 62. When bypass occurs untreated flow comingles with treated flow in the outflow to the vault.

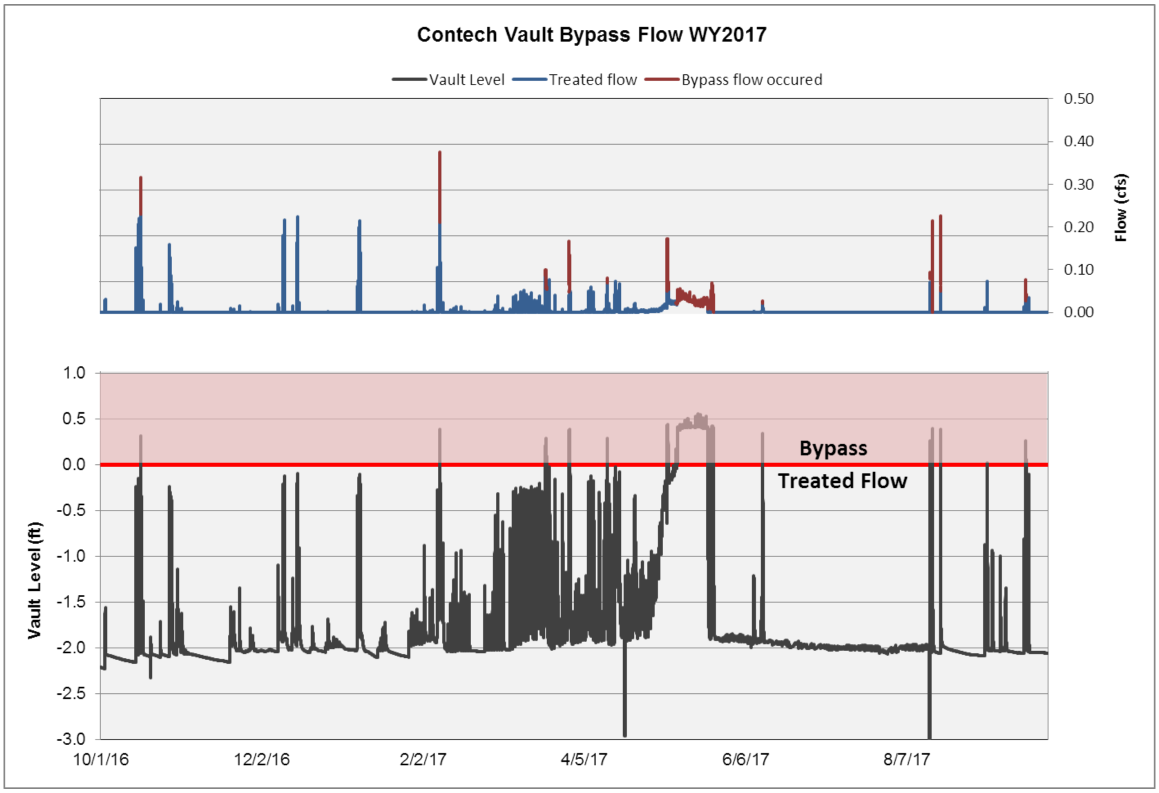

Figure 62 Contech MFS vault level at SR431, WY17 (bottom). Contech MFS outflow shown at top for reference. Vault level greater than 0 indicates bypass flow.

- During periods of flow, the Contech MFS filter was in bypass mode 24% of the time in water year 2017.
- The majority of bypass occurred during continuous snowmelt in the spring, when there was a constant water source to fill the vaults.
- Bypass occurred during 12 runoff events:
  - October 16, 2016 during a rain event that produced 3.6 inches of precipitation
  - February 8, 2017, March 21, 2017, March 30, 2017, April 13, 2017, and May 6-7, 2017, during rain on snow events
  - May 9-24, 2017 during weeks of continuous snowmelt
  - June 12, 2017 during an event snowmelt
  - August 15-16, 2017, August 19, 2017, and September 6, 2017, during high intensity thunderstorms
  - September 21, 2017 during a rain event
- The four sampled events that had bypass were the May 6, 2017 and May 19, 2017 rain on snow events, the August 19, 2017 thunderstorm event, and the September 21, 2017 rain event.

Table 16 presents the efficiency of the Jellyfish at reducing concentrations and loads of all three pollutants for the individual events sampled in WY17.

Table 16 Event efficiency data from the Jellyfish vault at SR431, WY17

Event Start Date	Event Volume as a % of Total Annual Volume (cf)	FSP Concentration (mg/L)			FSP Load (lbs)			TN Concentration (ug/L)			TN Load (lbs)			TP Concentration (ug/L)			TP Load (lbs)		
		in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change
10/27/2016	3%	35	27	-23%	6	5	-20%	2,077	1,155	-44%	0.36	0.21	-42%	326	178	-45%	0.06	0.03	-43%
12/8/2016	4%	374	360	-4%	83	84	2%	1,192	1,297	9%	0.26	0.30	15%	1,191	1,111	-7%	0.26	0.26	-1%
1/7/2017	7%	296	253	-14%	103	88	-15%	842	961	14%	0.29	0.33	14%	895	716	-20%	0.31	0.25	-20%
4/6/2017	1%	610	727	19%	47	58	23%	2,082	2,074	-0.4%	0.16	0.17	3%	3,175	3,198	1%	0.24	0.26	4%
4/16/2017	1%	572	405	-29%	28	20	-28%	1,706	1,431	-16%	0.08	0.07	-15%	2,831	2,160	-24%	0.14	0.11	-23%
5/6/2017	5%	344	324	-6%	84	76	-10%	1,671	1,469	-12%	0.41	0.34	-16%	1,809	1,638	-9%	0.44	0.38	-14%
5/19/2017	4%	16	12	-29%	3	2	-40%	492	354	-28%	0.11	0.06	-40%	83	56	-33%	0.02	0.01	-44%
8/19/2017	0.4%	191	112	-41%	4	3	-35%	na	na	na	na	na	na	na	na	na	na	na	na
9/21/2017	0.4%	138	237	72%	3	6	119%	1,263	854	-32%	0.03	0.02	-14%	681	325	-52%	0.01	0.01	-39%

- The highest FSP concentration reduction occurred during the summer thunderstorm on August 19, 2017. The filters had been fully cleaned out 3 days prior.
- The highest FSP load reduction occurred during the rain on snow event on May 19, 2017 when loads were very low.
- The lowest FSP concentration and load reduction occurred during the following thunderstorm on September 21, 2017 when the Jellyfish released FSP.
- The highest TN concentration and load reduction occurred during the rain event on October 27th when inflow concentrations and loads were the greatest.
- The Jellyfish released TN in December, January, and April. Bypass flow occurred during the January and April events. No events were sampled in February and March.
- The highest TP concentration reduction occurred during the summer thunderstorm on August 19, 2017.
- TP load reduction efficiencies reached 40% or greater during the events in October, late May, and September.
- The Jellyfish released TP during the rain on snow event beginning on April 6, 2017.

Jellyfish vault water level and bypass flow are presented in Figure 62. When bypass occurs untreated flow comingles with treated flow in the outflow to the vault.

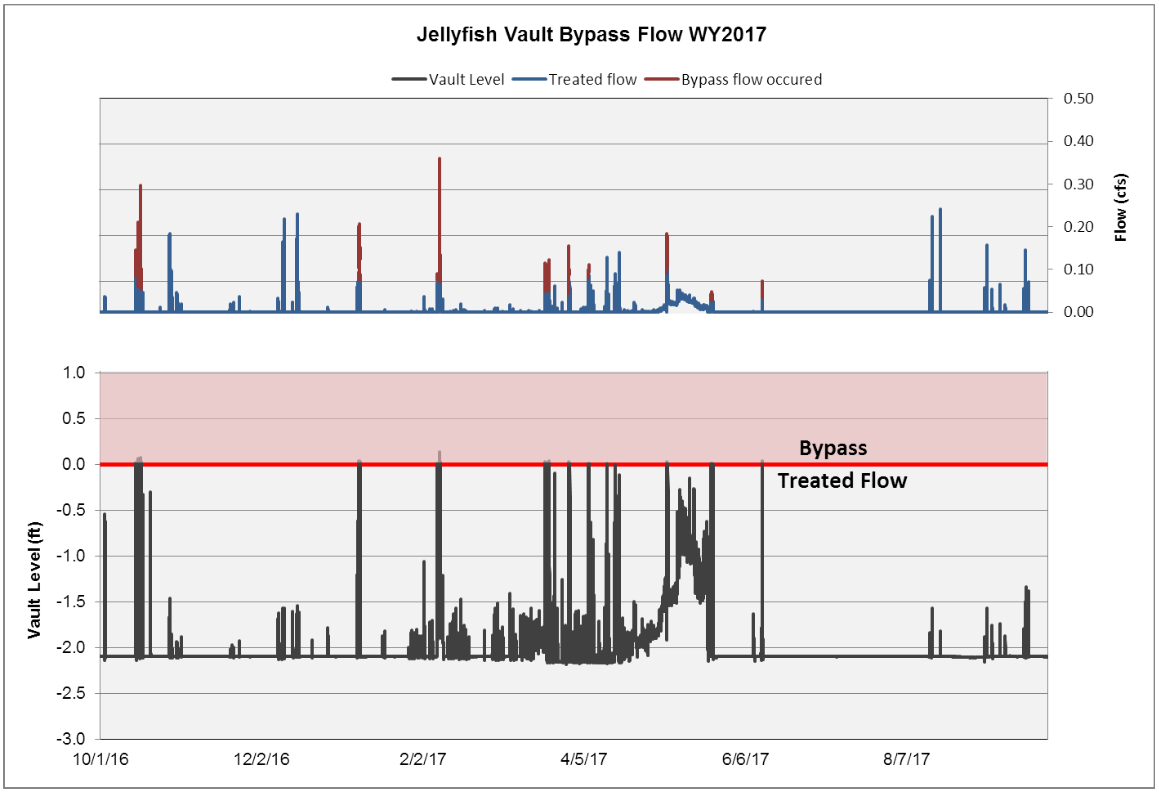

Figure 63 Jellyfish vault level at SR431, WY17 (bottom). Jellyfish outflow shown at the top for reference. Vault level greater than 0 indicates bypass flow.

- During periods of flow, the Jellyfish filter was in bypass mode 5% of the time in water year 2017 for a total of 1.8 days.
- Bypass occurred during 10 runoff events: on the October 14-16, 2016 rain event that produced 3.6 inches of precipitation; on Jan 8, 2017, February 7-8, 2017, March 21-22, 2017, March 30, 2017, April 6, 2017, April 13, 2017, and May 6-7, 2017 during rain on snow events; May 23-24, 2017 after weeks of continuous snowmelt; and on June 12, 2017 during an event snowmelt.
- The three sampled events that had bypass were the January 7-12, 2017, April 6, 2017, and the May 6, 2017 rain on snow events.

7.2 Pasadena

The cartridge filters installed in the Contech Stormfilter at Pasadena had treated no flow at the beginning of WY14 monitoring (see Section 2.2 for details), so the filters were functioning at optimal levels at the beginning of this study. To date, maintenance of the system includes only vactoring of the pre-treatment chambers in the spring and fall of WY14 and WY15. No maintenance occurred in WY16 or WY17.

Table 17 presents the summary data on removal efficiency for the treatment vault at Pasadena in WY17.

Table 17 Seasonal and annual efficiency data from the Pasadena vault, WY17.

Water Year 2017 (October 1, 2016 - September 30, 2017)			Seasonal FSP Loads (lbs)			Total Annual FSP Loads (lbs)	Seasonal TN Loads (lbs)			Total Annual TN Loads (lbs)	Seasonal TP Loads (lbs)			Total Annual TP Loads (lbs)
Catchment Name	Station Name	Station Acronym	Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)	
Pasadena	Pasadena In	PI	402	86	108	596	21.4	1.8	7.3	30.5	8.8	0.6	1.6	11.0
	Pasadena Out	PO	308	56	47	411	19.8	1.5	3.4	24.7	7.8	0.4	0.7	8.9
		Load Reduction	94	30	61	185	1.6	0.3	3.9	5.7	1.1	0.2	0.9	2.1
		% Change	-23%	-35%	-56%	-31%	-7%	-15%	-53%	-19%	-12%	-30%	-54%	-19%

- Overall, the filters provided net reduction in both seasonal and annual loads for all pollutants.
- The best load reduction (about half) occurred during the summer for all three pollutants when flow volumes were low.
- Annual FSP loads were reduced by 31%.
- Annual TN and TP loads were reduced by 19%.

Table 18 presents the efficiency of the Pasadena treatment vault at reducing concentrations and loads of all three pollutants for the individual events sampled in WY17.

Table 18 Event efficiency data from the Pasadena vault, WY17

Event Start Date	Event Volume as a % of Total Annual	FSP Concentration			FSP Load (lbs)			TN Concentration			TN Load (lbs)			TP Concentration			TP Load (lbs)		
		in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change
10/14/16	1%	84	94	12%	19	17	-12%	2,831	335	-88%	0.65	0.06	-91%	1,751	1,488	-15%	0.40	0.27	-34%
10/15/16	2%	40	29	-28%	21	13	-37%	2,586	1,922	-26%	1.33	0.86	-35%	821	1,002	22%	0.42	0.45	7%
10/16/16	8%	20	18	-6%	34	26	-21%	1,497	1,729	16%	2.57	2.48	-3%	602	739	23%	1.03	1.06	3%
12/10/16	11%	21	28	32%	51	50	-1%	689	743	8%	1.63	1.32	-19%	248	232	-6%	0.59	0.41	-30%
12/15/16	7%	85	22	-74%	128	26	-79%	917	1,175	28%	1.38	1.41	3%	519	269	-48%	0.78	0.32	-59%
2/7/17	11%	37	20	-46%	92	40	-57%	706	593	-16%	1.74	1.17	-33%	249	176	-29%	0.61	0.35	-43%
4/6/17	3%	50	69	38%	30.5	30.8	1%	1,494	1,778	19%	0.91	0.80	-13%	437	437	0%	0.27	0.20	-27%
4/18/17	1%	32	24	-25%	6	2	-59%	502	491	-2%	0.09	0.05	-47%	275	227	-17%	0.05	0.02	-55%
8/6/17	2%	159	130	-18%	71	36	-48%	11,584	8,779	-24%	5.16	2.46	-52%	2,335	1,888	-19%	1.04	0.53	-49%
9/8/17	1%	132	108	-18%	43	16	-62%	5,981	6,260	5%	1.94	0.95	-51%	1,594	1,331	-16%	0.52	0.20	-61%

- The highest FSP concentration and load reduction occurred during the rain on snow event beginning December 15, 2016 when inflow loads were the greatest.
- The lowest FSP concentration and load reduction occurred during a rain on snow event beginning April 6, 2017 when the Stormfilter discharged FSP.
- The highest TN concentration and load reduction occurred during the rain event on October 14, 2016.
- The lowest TN concentration and load reduction occurred during the rain on snow event on December 15, 2016, during which the Stormfilter discharged TN.
- The highest TP concentration reduction occurred during the rain on snow event beginning on December 15, 2017.
- The highest TP load reduction occurred during the September 8, 2017 thunderstorm.
- The lowest TP concentration and load reduction occurred during the October 15th to 16th, 2016 rain events during which the Stormfilter discharged TP.

8. PLRM Modeling Results

The Tahoe RCD compared average annual runoff volumes and pollutant loads predicted by PLRMv2.1 to annual volumes and pollutant loads measured in WY17 at all sites; results are presented in Table 19. The models used for this analysis were developed by Tahoe RCD and do not necessarily reflect the PLRM models that are used by the jurisdictions for registration. In reviewing model performance, **it is important to highlight that PLRM represents average annual conditions based on an 18-year meteorological average, and each water year is unique. Therefore, differences between PLRM estimates and measured values are expected.**

WY17 was the wettest year on record for the Tahoe basin, and as expected, all PLRM estimated volumes were lower than measured annual runoff. As expected, Contech MFS Outflow, Jellyfish Outflow, and Speedboat PLRM FSP load estimates were lower than measured FSP load. However, contrary to expectation, the remaining PLRM FSP load estimates were higher than measured. The majority of measured TN and TP loads were lower than PLRM estimates as would be expected, but Contech MFS Inflow, Jellyfish Inflow, Lakeshore, and Tahoma PLRM TN load estimates were higher than measured, and Lakeshore and Tahoma PLRM TP load estimates were higher than measured for TP. There are many reasons why the modeled estimates differ from measured values. As modeling parameters are refined to better represent actual conditions, the accuracy of modeled volume and pollutant loads should improve.

PLRM does a reasonable job estimating relative conditions. For example, Tahoe Valley has the greatest annual runoff volume of all sites, which was predicted by PLRM. It is also important to highlight that models calibrated using refined CEC values (Pasadena Outflow, Jellyfish Outflow, and Contech MFS Outflow) tended to perform better than uncalibrated models. The improved model performance when predicting FSP, TN, and TP load at the three cartridge filter vault ouflows emphasizes the utility of model calibration with empirical data (see section 9 for full discussion of refined CECs and model performance). Finally, PLRM is the standard basin-wide model for pollutant load reduction estimates for the Lake Tahoe TMDL. PLRM assumes that roads and commercial properties tend to be the highest polluting land uses, while multi-family residential and single family residential are less so, which conforms with our basic understanding of Tahoe stormwater pollutant sources. All seven jurisdictions across two states are using the same modeling tool and are thus speaking the same language with regards to pollutant load estimates, making it easier to compare pollutant load reductions across jurisdictions. It is unrealistic to expect the model to perform perfectly; however, comparing monitoring results to modeled estimates and continuing to improve modeling assumptions will help narrow the gap between modeled estimates and reality.

Table 19 PLRM predicted and WY17 measured values for all monitored catchments.

Water Year 2017 Oct. 1, 2016 - Sept. 30, 2017		Annual Runoff Volumes (cf)		Annual FSP Loads (lbs)		Annual TN Loads (lbs)		Annual TP Loads (lbs)	
Catchment (Site) Name	**Station Name**	**PLRM**	**Measured**	**PLRM**	**Measured**	**PLRM**	**Measured**	**PLRM**	**Measured**
SR431	Contech Inflow	43,560	98,349	1,095	578	11.0	8.5	3.0	5.9
	Contech Outflow	43,560	95,767	391	411	4.0	4.8	2.0	4.1
	Jellyfish Inflow	43,560	83,718	1,095	474	11.0	6.6	3.0	6.1
	Jellyfish Outflow	43,560	82,391	355	393	4.0	5.8	2.0	4.2
Pasadena	Pasadena Inflow	143,748	359,579	1,184	596	20.0	30.5	5.0	11.0
	Pasadena Outflow	143,748	327,620	446	411	13.0	24.7	5.0	8.9
Lakeshore	Lakeshore	331,056	546,447	1,545	1,441	63.0	18.5	10.0	6.2
Speedboat	Speedboat	317,988	1,319,514	4,911	9,218	58.4	84.0	17.0	31.7
Tahoma	Tahoma	666,468	2,483,765	10,801	2,275	127.0	82.6	37.0	24.2
Tahoe Valley	Tahoe Valley	5,449,356	20,306,740	53,305	29,143	764.0	1050.4	196.0	225.3
Upper Truckee	Upper Truckee	213,444	496,690	4,658	3,902	47.0	60.4	14.0	20.9

9. Characteristic Effluent Concentrations

PLRMv2.1 uses a CEC to estimate pollutant loading from a particular BMP. Site specific FSP, TN, and TP CECs for the outflows from the SR431 Contech MFS, SR431 Jellyfish, and Pasadena treatment vaults were estimated as the average of the annual pollutant concentrations from WY14, WY15, WY16, and WY17 (see Table 5 of this report for average annual concentrations of each pollutant at each site for WY17, Table 5 of the Annual Stormwater Monitoring Report Water Years 2014-2016 for previous year average annual concentrations, and Table 20 for site specific CECs). The current default FSP, TN, and TP CEC values used in PLRMv2.1 for cartridge filters are 13 mg/L, 1500 µg/L, and 140 µg/L respectively. (NOTE: PLRM uses TN and TP concentrations in mg/L. However, this document reports all TN and TP concentrations in µg /L.) As the default FSP CEC of 13 mg/L is much lower than any of the estimated FSP CECs in Table 20 (49 to 140 mg/L) and the default TP CEC of 140 µg/L is lower than any of the estimated TP CECs in Table 20 (611 to 829 µg /L), using the default CECs when modeling these catchments results in an overestimation of vault pollutant removal efficiency based on the measured data to date. Accordingly, FSP and TP loads discharged from these catchments will be underestimated if the default CEC is used. The current default PLRM TN CEC value for cartridge filters of 1,500 µg/L is very similar to the estimated values in Table 20 (1,278 to 1,467 µg /L) so modeled pollutant loads from these three cartridge filter vaults should be similar to measured values if runoff volume is accurately predicted.

The PLRM was run on two catchments (Pasadena and SR431) using the refined site specific CECs for each BMP as shown in Table 20. PLRM estimated runoff volumes, FSP, TN, and TP loads (Table 20) were lower than measured in all model simulations, with the exception of FSP load at the Pasadena Outflow, which was within a similar range. **It is important to keep in mind that PLRM results represent average annual conditions based on an 18-year meteorological record, and WY17 was the wettest year on record.** Since loads are dependent on runoff volume, it is not surprising that PLRM loads tended to be lower than measured even when using the refined CECs. Overall PLRM provided very reasonable results for both runoff volumes and pollutant loads when the refined CECs were used.

Table 20 CECs for FSP, TN, and TP, PLRM estimated and measured (WY17) annual runoff volumes and pollutant loads for outflows at three monitored cartridge filter vaults. WY17 was the wettest year on record; therefore modeled results are expected to be lower than measured values. NOTE: PLRM uses TN and TP concentrations in mg/L, but this report reports all TN and TP concentrations in µg /L.

Water Year 2017 Oct. 1, 2016 - Sept. 30, 2017		Average CEC (WY14 - 17)			Annual Runoff Volumes (cf)		Annual FSP Loads (lbs)		Annual TN Loads (lbs)		Annual TP Loads (lbs)	
Station Name	Station Acronym	FSP (mg/L)	TN (ug/L)	TP (ug/L)	PLRM	Measured	PLRM	Measured	PLRM	Measured	PLRM	Measured
Pasadena Out	PO	49	1,467	611	143,748	327,620	446	411	13.0	24.7	5.0	8.9
Contech Out	CO	140	1,337	815	43,560	95,767	391	411	4.0	4.8	2.0	4.1
Jellyfish Out	JO	127	1,278	829	43,560	82,391	355	393	4.0	5.8	2.0	4.2

For the SR431 Contech MFS and Jellyfish cartridge filter vaults, the model results for percent FSP removed by the filters using the site specific CEC values from Table 20 is shown in Figure 64, depicted as a square and a triangle, respectively. Though obviously not as effective as the default CEC of 13mg/L (which provides a 97% FSP removal rate), the model with refined site-specific CEC values still shows very high FSP removal rates (64% for the Contech MFS and 68% for the Jellyfish). The PLRM models were also run with theoretical CECs for reference purposes (Figure 64). At this site, the relationship between FSP removed and FSP CEC is a negative linear relationship, and the filters continue to provide FSP removal up to a CEC of 393 mg/L. This means these filters should provide some FSP removal most of the time.

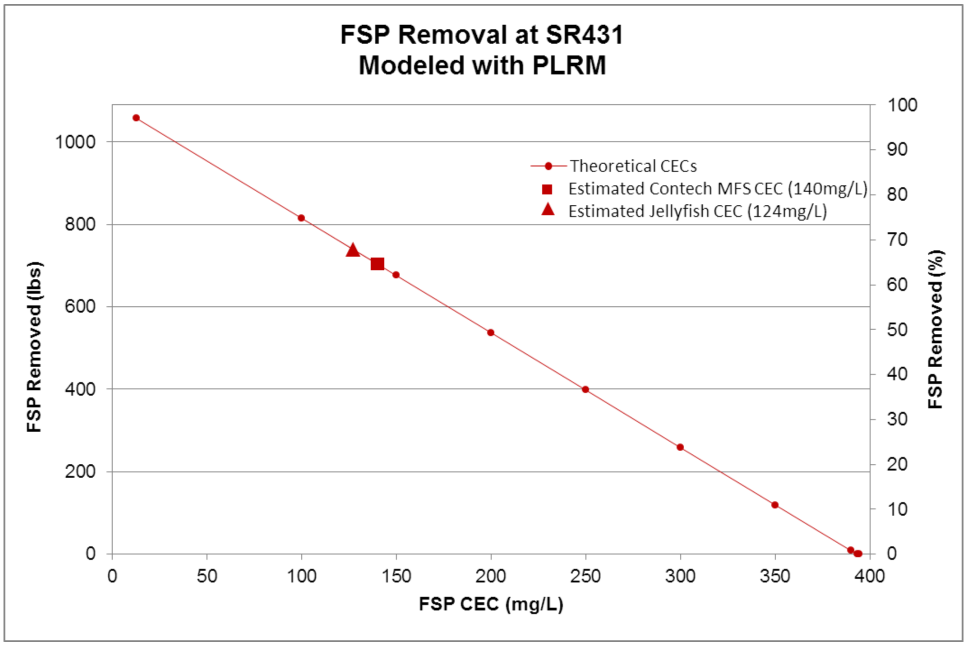

Figure 64 FSP removal at SR431 for the Contech MFS and Jellyfish cartridge filter vaults, as modeled by PLRM. Dots represent model runs with theoretical CECs, the square represents the model run with the refined CEC value for the Contech MFS filter (140 mg/L), and the triangle represents the model run with the refined CEC for the Jellyfish filter (127 mg/L).

For the Pasadena cartridge filter vaults, filter vault #1 is modeled to treat up to 0.6 cfs; flow greater than this are routed to filter vault #2, which treats up to 1.6 cfs, and any flow more than 1.6 cfs bypass the filter vaults and is routed directly to the outlet. PLRM was used to model the FSP removal using the refined site specific CEC as shown in Table 20 (Figure 65 and 66, represented as a diamond), as well as theoretical CECs for reference purposes. The refined site-specific CEC of 49 mg/L provides 62% FSP removal for this catchment as modeled by PLRM. For both filter vaults, the amount of FSP removed increases rapidly with decreasing CEC. With a CEC greater than 392 mg/L, filter vault #1 provides no water quality treatment, while filter vault #2 provides cartridge filter up to a CEC of 200 mg/L.

It is unlikely that typical cartridge filters in the Tahoe basin are treating runoff to a CEC of 13 mg/L for FSP, but a recent evaluation conducted by Northwest Hydraulic Consultants (NHC 2017) concluded that certain land uses, cleaner adjacent roads and better maintenance practices may allow for cartridge filters to perform at this level. However, the BMP effectiveness studies performed for this report provide data to better understand cartridge filter treatment efficiency and to refine CECs for the specific cartridge filters studied. Treatment efficiency of the filters depends on multiple factors, including catchment characteristics and storm event type that dictate the input pollutant concentration, and the maintenance extent (vactoring pre-treatment chamber versus cleaning and replacing filters) and timing which determines filter performance. Because of this, treatment efficiency varies widely between catchments and storms. If installation of filter devices in the Tahoe basin as a measure to reduced FSP continues, further monitoring of these and other filters in the Tahoe basin is suggested to better understand storm filter function/cost-effectiveness and to further refine static CECs to use in PLRM.

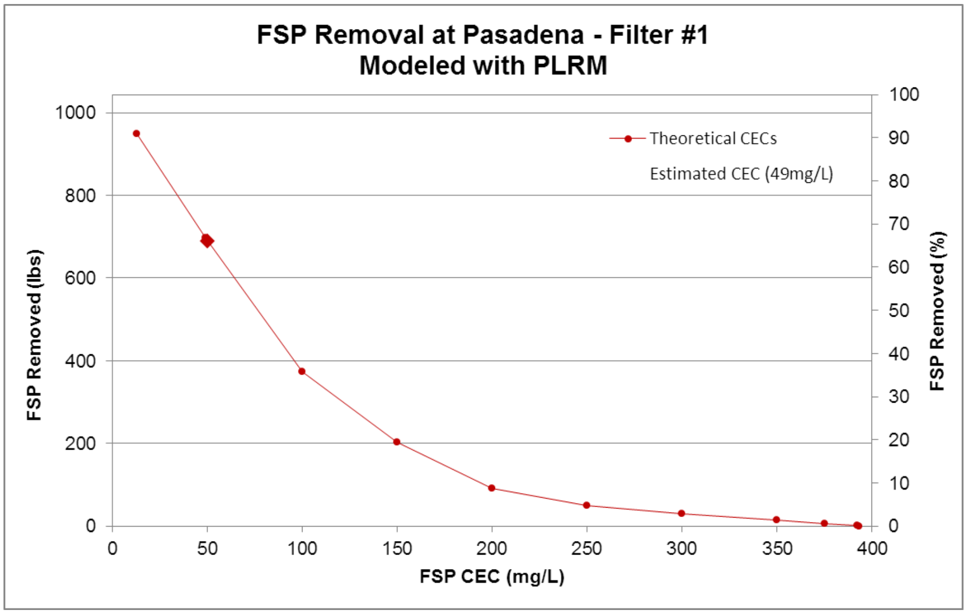

Figure 65 FSP removal at Pasadena filter vault #1, as modeled by PLRM. Dots represent model runs with theoretical CECs and the diamond represents the model run with the estimated CEC (49 mg/L).

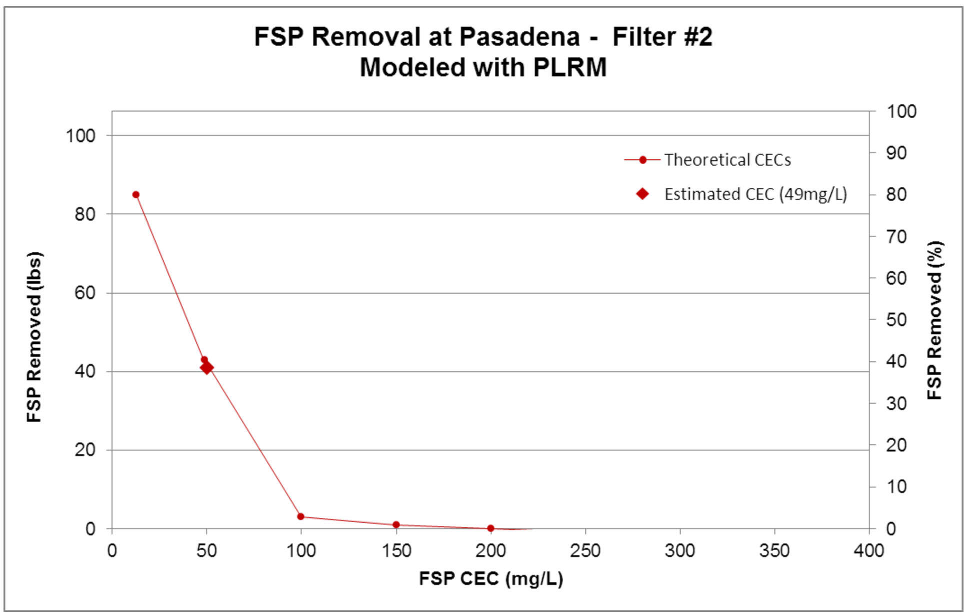

Figure 66 FSP removal at Pasadena filter vault #2, as modeled by PLRM. Dots represent model runs with theoretical CECs and the diamond represents the model run with the estimated CEC (49 mg/L).

10. Lessons Learned

Monitoring stations should be checked regularly, especially during runoff events, to identify any potential equipment malfunctions that may result in data gaps. There are a multitude of technical difficulties that can be encountered with stormwater monitoring, including equipment failure, freezing conditions, power failure, vandalism, and obstruction by sediment, snow, trash or other debris. Identifying and correcting these problems early results in a more accurate data set with fewer and shorter data gaps.

Water year 2017 was the first year in which all monitoring and weather stations were remotely accessible. This enabled access to the stations and their status during all weather conditions and any time of day or night and allowed for problems to be detected and remedied earlier than was previously possible when site visits were required to know station status. Additionally, alarms can be set to send email or text alerts when certain parameters reach a pre-determined threshold.

The biggest cause of data gaps in the past was power failure. Although all stations are equipped with solar panels to recharge batteries, some stations do not have enough sun exposure to keep batteries continuously charged (especially during winter), and during periods of extended cloud cover and subsequent decrease in solar recharge, all stations are subject to power failure. Checking battery voltage remotely on a regular basis and having alerts sent when charge drops below a voltage threshold have virtually eliminated this problem.

In a year like WY17, where snow accumulation was frequent and often excessive, it was very important to stay on top of site maintenance (Figure 67). Keeping the sites dug out and unfrozen was a large task, but necessary to maintain data integrity. The remote access system was very beneficial in identifying when the sites were frozen and in need of maintenance.

Field verifying data as a QAQC procedure is essential to ensure an accurate and reliable dataset. Tahoe RCD staff members regularly check stage and make note of precipitation type and totals during storms to ensure equipment is functioning properly. The greater the level of QAQC during precipitation events, the higher the level of certainty the dataset is representative. The importance of detailed field notes and photographs cannot be understated. With passing time, the human memory lapses, while field notes and photographs can be referred to years and even decades after a monitoring event to explain what happened throughout the monitoring period.

Short duration, high intensity thunderstorms can be particularly difficult to sample, as the sometimes unpredictably large flow volumes can quickly fill all 24 sample bottles in the autosampler if the flow pacing is set too low. The result is that a portion of the end of the runoff hydrograph is not sampled. Due to the short nature of these events, it is incredibly difficult for staff to reach sites before runoff has ended to replace the full bottles with empty ones. Summer thunderstorms also tend to be very episodic in nature, and not all sites receive runoff over the summer period. As a result, several of the requisite summer events were missed or did not produce enough runoff to sample. In the future, it may be advisable to amend permit and agreement language to relax the summer thunderstorm sampling requirement.

Storm events not captured in a particular season due to insufficient runoff can be substituted by a different storm in the next season to meet permit and agreement requirements of one storm event per season as approved by the Lahontan Regional Water Quality Control Board (Lahontan). However, all efforts should be made to successfully sample an event within each season so that average seasonal pollutant concentrations and loads can be calculated. Fortunately, FSP concentrations and loads can be calculated from the continuous turbidity data, so these values should never be missing from any season.

Figure 67 Staff worked hard to keep sites clear of snow during the very wet 2017 winter. Tahoma outfall pictured.

11. Changes: Accepted and Proposed

Changes Accepted

New Nevada ILAs were executed in 2016 and require participation in the Implementers' Monitoring Program (as a component of RSWMP). A new NPDES permit was issued for California jurisdictions in 2017. The new permit aligned all monitoring activities with the Regional Stormwater Monitoring Program (RSWMP) Framework and Implementation Guidance Document (Tahoe RCD et al 2015), most notably that six (rather than four) catchment outfalls and two (rather than three) BMPs must be monitored. Additionally, the first flush sampling requirement was dropped as sample analysis costs are high and continuous turbidimeter readings can replace this information.

In the spring of WY16 the Tahoe RCD proposed a new location for the Incline Village monitoring site. The new location was approved by IMP, Lahontan, NDEP and monitoring equipment was installed at a nearby site called Lakeshore as described in section 2.3. Monitoring at Lakeshore began in WY17.

Changes Proposed

In the summer of WY17 the Tahoe RCD and implementing jurisdictions proposed moving the equipment located at the inflow to the Pasadena Stormfilter to a new site on Elk's Club Drive. The purpose of monitoring runoff from Elk's Club Drive is to assess concentrations of FSP and the sources of that FSP before and after a pavement resurfacing project slated for summer 2018. This move was approved by Lahontan and NDEP. Elks Club Drive will be considered a BMP site as resurfacing the road with a polymer enhanced asphalt mixture should be considered a best management practice for reducing FSP in stormwater runoff since it will be easier to sweep and less prone to degradation from chains, heavy equipment, plow blades, and the freeze/thaw cycle.

Because summer thunderstorms tend to be very episodic in nature and not all sites receive runoff over the summer period, several of the requisite summer events were missed or did not produce enough runoff to sample. In the future, it may be advisable to amend permit and agreement language to relax the summer thunderstorm sampling requirement.

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Appendix A: Raw Analytical Data

Table A.1-Table A.8 present all available raw analytical data for autosampler composite (AC) samples. Other than QAQC samples, only AC samples were analyzed in WY17.

Table A.1 Raw analytical data for samples taken at the inflow and outflow of the SR431 Contech MFS in WY17.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
CI-AC	10/27/2016 9:54	65	42	35	6,608	271	0.33	3.38	9.22	18.0	32.3	54.1	61.9	84.0	92.1	98.3	100	100	100
CO-AC	10/27/2016 10:01	36	30	29	1,140	197	0.56	5.73	15.9	31.4	53.7	80.8	89.0	100	100	100	100	100	100
CI-AC	12/8/2016 9:07	838	1,500	808	3,161	3,499	1.33	11.0	29.4	54.2	79.2	96.4	100	100	100	100	100	100	100
CO-AC	12/8/2016 9:07	611	603	595	2,735	1,055	0.87	9.71	29.6	55.0	80.9	97.4	100	100	100	100	100	100	100
CI-AC	12/10/2016 1:28	420	399	318	1,311	887	0.59	5.12	14.8	28.9	51.4	75.7	83.3	100	100	100	100	100	100
CO-AC	12/10/2016 1:56	262	329	209	917	633	0.48	5.33	16.4	33.1	56.4	79.6	85.4	95.8	99.1	100	100	100	100
CI-AC	12/10/2016 15:21	566	578	410	1,307	1,283	0.48	5.17	15.0	28.6	49.1	72.4	79.0	94.6	98.6	100	100	100	100
CO-AC	12/10/2016 15:34	313	450	266	1,024	807	0.60	6.55	19.4	37.1	61.1	85.1	91.2	99.2	100	100	100	100	100
CI-AC	1/7/2017 15:59	473	455	289	830	916	0.43	4.56	13.0	24.5	40.5	61.1	68.0	90.1	97.0	100	100	100	100
CO-AC	1/7/2017 16:06	307	393	245	686	663	0.62	6.67	19.5	36.0	57.2	79.7	86.6	100	100	100	100	100	100
CI-AC	4/6/2017 21:02	1,367	1,026	902	2,367	4263	0.46	4.91	14.2	26.8	45.4	66.0	72.0	90.5	95.9	98.9	100	100	100
CO-AC	4/6/2017 17:43	649	729	321	1,928	2717	0.36	3.95	12.1	23.0	37.2	49.5	52.5	57.8	61.0	68.9	88.0	100	100
CI-AC	4/16/2017 16:14	1,021	643	664	2,142	3,749	0.39	4.22	12.2	23.9	42.9	65.0	71.7	92.9	98.7	100	100	100	100
CO-AC	4/16/2017 16:31	513	364	402	1,599	2,160	0.48	5.23	15.5	30.8	54.2	78.4	84.6	97.4	100	100	100	100	100
CI-AC	5/6/2017 12:24	474	280	372	1,374	1,714	0.46	5.01	14.8	29.1	51.7	78.4	85.5	100	100	100	100	100	100
CO-AC	5/6/2017 12:33	359	253	274	1,270	1,486	0.47	5.03	14.8	29.3	51.9	76.1	82.4	95.2	98.6	100	100	100	100
CI-AC	5/19/2017 7:39	41	8	12	453	72	0.18	1.64	4.33	8.27	16.2	29.2	35.0	66.4	83.1	91.1	97.7	100	100
CO-AC	5/19/2017 7:03	28	8	15	286	59	0.08	1.13	4.64	10.9	25.2	53.4	65.9	100	100	100	100	100	100
CI-AC	5/20/2017 6:24	28	7	8	452	61	0.15	1.38	3.61	6.74	14.3	29.0	35.9	75.2	90.0	96.2	98.1	100	100
CO-AC	5/20/2017 6:24	22	6	7	293	39	0.14	1.29	3.33	6.58	15.1	30.8	37.4	71.1	84.6	92.9	98.0	100	100
CI-AC	5/21/2017 8:17	33	10	10	302	64	0.12	1.29	3.61	6.90	14.2	29.6	36.8	74.5	88.3	95.2	99.0	100	100
CO-AC	5/21/2017 8:06	20	4	7	304	35	0.12	1.30	3.91	7.43	16.3	33.2	40.0	75.0	89.0	97.4	100	100	100
CI-AC	8/19/2017 15:22	356	156	181	na	na	0.27	2.84	7.90	15.5	29.4	51.0	58.6	86.8	94.5	100	100	100	100
CO-AC	8/19/2017 16:02	254	140	161	na	na	0.33	3.44	9.58	18.9	36.5	63.3	71.8	93.5	98.7	100	100	100	100
CI-AC	9/21/2017 10:21	294	194	197	855	618	0.45	4.81	14.2	27.1	45.2	66.8	73.1	90.7	97.0	100	100	100	100
CO-AC	9/21/2017 12:49	118	86	91	1,118	442	0.55	5.86	17.0	32.2	53.0	76.5	83.0	96.3	99.2	100	100	100	100

Table A.2 Raw analytical data for samples taken at the inflow and outflow of the SR431 Jellyfish in WY17.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
JI-AC	10/27/2016 9:54	81	47	35	2,077	326	0.26	2.64	7.17	13.8	25.1	43.7	50.6	71.6	79.2	85.9	95.2	100	100
JO-AC	10/27/2016 10:32	32	27	27	1,155	178	0.53	5.60	16.3	32.1	55.2	84.8	91.9	100	100	100	100	100	100
JI-AC	12/8/2016 9:07	837	1,516	764	2,636	144	0.73	8.18	25.3	47.6	72.3	91.3	95.7	99.4	100	100	100	100	100
JO-AC	12/8/2016 9:07	529	1,108	500	2,427	978	0.80	8.87	27.0	50.5	76.4	94.5	98.4	100	100	100	100	100	100
JI-AC	12/10/2016 1:25	477	462	290	946	1,064	0.35	3.86	11.8	23.5	40.7	60.8	66.8	85.0	92.8	98.3	100	100	100
JO-AC	12/10/2016 1:27	431	445	289	1,213	903	0.39	4.25	12.9	25.7	44.9	67.0	73.3	91.0	97.2	100	100	100	100
JI-AC	12/10/2016 15:21	492	562	357	1,074	1,532	0.48	5.22	15.4	29.5	49.6	72.5	78.8	92.8	97.7	100	100	100	100
JO-AC	12/10/2016 15:22	532	603	387	1,086	1,330	0.47	5.02	14.7	28.2	48.4	72.8	79.8	94.7	98.6	100	100	100	100
JI-AC	1/7/2017 15:59	482	454	296	842	895	0.44	4.69	13.3	24.6	41.1	61.3	67.7	90.1	97.6	100	100	100	100
JO-AC	1/7/2017 16:00	364	411	253	961	716	0.54	5.72	16.1	29.6	47.7	69.5	76.3	94.7	99.0	100	100	100	100
JI-AC	4/6/2017 15:41	840	680	610	2,082	3,175	0.48	5.27	15.7	30.6	52.0	72.6	77.7	92.2	97.0	100	100	100	100
JO-AC	4/6/2017 15:44	839	1,067	727	2,074	3198	0.59	6.43	19.3	37.8	64.3	86.6	91.9	100	100	100	100	100	100
JI-AC	4/16/2017 16:15	765	442	572	1,706	2,831	0.44	4.83	14.4	28.2	49.2	74.8	82.2	100	100	100	100	100	100
JO-AC	4/16/2017 16:19	540	344	405	1,431	2,160	0.45	4.93	14.7	29.2	51.4	75.0	81.5	95.9	99.0	100	100	100	100
JI-AC	5/6/2017 12:36	505	290	344	1,671	1,809	0.43	4.55	13.1	25.5	45.3	68.0	74.4	92.1	97.7	100	100	100	100
JO-AC	5/6/2017 12:42	387	269	324	1,469	1,638	0.52	5.61	16.4	32.2	57.3	83.7	91.6	100	100	100	100	100	100
JI-AC	5/19/2017 10:13	48	13	16	460	95	0.14	1.45	4.01	7.97	16.1	33.2	40.6	77.7	92.5	98.3	99.4	100	100
JO-AC	5/19/2017 10:15	36	13	18	414	73	0.13	1.58	5.30	11.9	25.4	50.8	60.5	99.4	100	100	100	100	100
JI-AC	5/20/2017 6:24	37	12	16	541	81	0.12	1.38	4.31	9.15	19.9	43.7	53.6	98.2	100	100	100	100	100
JO-AC	5/20/2017 6:24	28	7	9	351	50	0.13	1.37	3.91	7.72	16.3	32.4	39.6	76.9	89.6	95.8	98.6	100	100
JI-AC	5/21/2017 7:47	39	11	17	473	75	0.15	1.62	4.80	9.83	20.2	42.7	52.6	96.1	100	100	100	100	100
JO-AC	5/21/2017 7:47	25	6	8	299	46	0.12	1.35	4.02	7.84	16.6	32.3	39.0	74.9	90.4	97.3	100	100	100
JI-AC	8/19/2017 15:22	382	162	191	na	na	0.26	2.74	7.69	15.2	28.8	50.1	57.6	85.2	93.1	97.8	100	100	100
JO-AC	8/19/2017 15:25	196	115	112	na	na	0.30	3.09	8.43	16.5	32.0	57.2	66.0	91.9	97.5	100	100	100	100
JI-AC	9/21/2017 10:22	210	205	138	1,263	681	0.44	4.73	13.7	26.0	43.7	65.7	72.4	90.5	96.9	100	100	100	100
JO-AC	9/21/2017 10:24	327	105	237	854	325	0.53	5.49	15.3	28.6	48.0	72.5	79.7	94.0	98.3	100	100	100	100

Table A.3 Raw analytical data for samples taken at the inflow and outflow of the Pasadena treatment vault in WY17.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
PI-AC	10/14/2016 16:52	226	216	84	2,831	1,751	0.14	1.41	4.45	11.5	23.5	37.0	41.9	64.5	78.1	84.9	90.2	99.2	100
PO-AC	10/14/2016 16:51	188	177	94	335	1,488	0.19	2.00	6.38	15.7	31.3	50.0	56.5	81.9	94.9	99.1	100	100	100
PI-AC	10/15/2016 16:51	63	61	40	2,586	821	0.32	2.71	7.54	20.2	42.1	64.3	72.1	93.2	100	100	100	100	100
PO-AC	10/15/2016 17:11	54	77	29	1,922	1,002	0.17	1.81	6.21	16.7	33.9	53.8	60.1	82.1	95.4	99.1	100	100	100
PI-AC	10/16/2016 10:09	37	36	20	1,497	602	0.19	1.98	6.44	16.4	32.5	52.5	59.3	80.4	93.7	98.5	100	100	100
PO-AC	10/16/2016 11:04	48	33	18	1,729	739	0.14	1.42	4.62	11.7	23.6	38.7	43.8	63.2	77.0	86.9	95.3	100	100
PI-AC	12/10/2016 3:33	48	52	21	689	248	0.23	2.40	7.15	15.2	28.1	44.7	50.1	69.6	80.1	89.4	95.8	100	100
PO-AC	12/10/2016 2:48	51	58	28	743	232	0.28	2.95	8.62	18.3	33.5	55.3	63.3	86.2	96.1	100	100	100	100
PI-AC	12/15/2016 14:36	170	52	85	917	519	0.24	2.54	7.58	16.1	29.9	50.0	56.1	80.1	90.6	96.8	100	100	100
PO-AC	12/15/2016 15:14	37	46	22	1,175	269	0.30	3.21	9.60	20.2	36.9	59.9	66.1	88.6	97.4	100	100	100	100
PI-AC	2/7/2017 2:26	79	82	43	799	283	0.31	3.19	9.00	17.9	33.3	55.3	62.5	83.6	91.2	96.8	98.6	100	100
PO-AC	2/7/2017 1:58	49	57	32	769	226	0.40	4.18	11.8	23.2	40.9	64.4	71.9	90.0	95.2	98.6	100	100	100
PI-AC	2/8/2017 7:55	50	53	29	575	200	0.33	3.39	9.65	19.5	35.6	57.7	65.2	86.9	94.3	98.8	100	100	100
PO-AC	2/8/2017 4:30	26	33	14	488	147	0.33	3.37	9.11	17.2	31.4	53.1	59.6	83.8	94.1	99.1	100	100	100
PI-AC	4/6/2017 18:48	97	31	50	1,494	437	0.27	2.82	7.98	16.3	31.0	51.6	58.6	86.7	95.3	100	100	100	100
PO-AC	4/6/2017 19:28	105	77	69	1,778	437	0.32	3.40	9.91	20.7	39.9	65.9	74.2	100	100	100	100	100	100
PI-AC	4/18/2017 2:00	52	45	32	502	275	0.32	3.37	9.87	20.6	38.1	61.0	68.3	90.7	97.0	100	100	100	100
PO-AC	4/18/2017 2:35	40	37	24	491	227	0.35	3.63	10.3	20.7	37.1	59.2	66.6	88.3	96.3	100	100	100	100
PI-AC	8/6/2017 13:08	673	342	159	11,584	2,335	0.11	1.10	3.00	6.22	12.6	23.6	28.2	55.3	73.3	84.5	91.5	99.3	100
PO-AC	8/6/2017 13:25	395	210	130	8,779	1,888	0.14	1.44	4.10	8.97	18.1	33.0	38.6	67.4	86.6	95.9	98.4	100	100
PI-AC	9/8/2017 12:51	377	206	132	5,981	1,594	0.15	1.56	4.31	9.37	19.3	35.1	41.6	78.1	91.6	99.3	100	100	100
PO-AC	9/8/2017 13:36	285	171	108	6,260	1,331	0.17	1.75	4.73	10.0	20.8	38.1	45.2	83.2	95.2	100	100	100	100

Table A.4 Raw analytical data for samples taken at Lakeshore, WY17.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
LS-AC	10/15/2016 17:41	34	16	22	809	264	0.37	3.49	9.60	21.7	41.6	64.9	76.8	94.4	97.7	100	100	100	100
LS-AC	12/10/2016 3:36	32	28	25	597	295	0.47	5.17	15.1	28.6	50.0	78.5	88.4	100	100	100	100	100	100
LS-AC	12/15/2016 14:51	36	38	21	944	193	0.40	4.16	11.7	22.1	38.1	58.3	67.6	87.0	96.2	100	100	100	100
LS-AC	1/8/2017 10:25	42	46	26	461	198	0.34	3.60	10.5	21.8	39.7	63.6	71.3	92.3	99.0	100	100	100	100
LS-AC	2/7/2017 0:55	49	48	34	373	207	0.39	4.07	11.8	23.7	43.2	70.0	78.5	95.8	100	100	100	100	100
LS-AC	2/8/2017 4:48	39	36	26	622	172	0.39	4.05	11.6	23.4	42.1	67.3	75.1	93.1	96.7	99.0	100	100	100
LS-AC	4/6/2017 18:55	21	42	13	346	117	0.34	3.57	10.4	21.2	39.0	62.8	69.6	88.5	93.6	97.7	100	100	100
LS-AC	5/3/2017 14:16	8	7	2	306	83	0.12	1.29	3.61	6.90	14.2	29.6	36.8	74.5	88.3	95.2	99.0	100	100
LS-AC	5/4/2017 13:48	8	7	5	293	81	0.81	7.30	17.6	28.2	45.5	60.5	66.9	87.4	94.6	100	100	100	100
LS-AC	5/5/2017 15:23	6	5	6	255	71	0.00	0.00	78.1	100	100	100	100	100	100	100	100	100	100

Table A.5 Raw analytical data for samples taken at Speedboat, WY17.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
SB-AC	10/14/2016 16:01	94	98	36	5,654	1,220	0.25	2.52	6.64	13.3	24.3	38.4	43.4	66.6	81.5	90.3	95.4	100	100
SB-AC	10/15/2016 16:53	79	36	29	1,998	529	0.18	1.62	4.39	9.84	20.0	36.9	44.3	74.9	88.3	95.9	99.2	100	100
SB-AC	10/16/2016 1:25	45	23	11	892	343	0.37	1.98	4.05	8.54	17.1	24.0	35.8	54.1	68.0	77.3	88.5	100	100
SB-AC	12/8/2016 6:35	58	70	55	1,165	375	0.97	9.93	26.9	47.4	70.0	95.3	98.6	100	100	100	100	100	100
SB-AC	12/10/2016 2:16	91	61	39	703	368	0.25	2.64	7.41	14.4	25.4	42.6	50.3	75.9	87.2	96.7	100	100	100
SB-AC	12/15/2016 13:48	57	34	23	694	225	0.22	2.48	7.20	13.0	23.5	39.6	47.4	71.8	83.4	95.0	100	100	100
SB-AC	1/7/2017 11:43	170	108	99	917	519	0.35	3.64	10.1	19.5	34.4	58.0	67.0	92.8	98.4	100	100	100	100
SB-AC	2/7/2017 1:55	133	95	74	885	419	0.31	3.19	8.88	17.4	32.6	55.7	63.5	88.3	94.7	97.8	98.9	100	100
SB-AC	2/8/2017 0:36	91	74	53	631	308	0.34	3.47	9.61	18.9	35.2	59.0	66.9	91.3	97.5	100	100	100	100
SB-AC	3/12/2017 11:31	45	47	34	506	224	0.54	5.64	15.8	31.0	53.5	77.5	82.5	95.7	97.8	99.1	100	100	100
SB-AC	3/13/2017 9:18	43	57	37	488	221	0.66	6.68	18.0	34.5	58.5	85.1	91.7	99.2	100	100	100	100	100
SB-AC	3/14/2017 9:00	36	42	28	421	202	0.55	5.56	15.3	30.2	52.7	78.0	83.7	94.4	96.8	100	100	100	100
SB-AC	4/6/2017 11:38	145	124	56	1,258	548	0.31	3.17	8.73	16.0	26.4	38.8	42.5	54.2	59.8	66.7	80.8	98.9	100
SB-AC	5/6/2017 13:15	359	147	176	2,588	1113	0.27	2.77	7.50	14.4	27.1	48.9	57.5	94.3	100	100	100	100	100
SB-AC	9/8/2017 16:06	174	97	58	4,472	873	0.20	2.01	5.33	9.91	18.3	33.3	39.7	77.6	91.0	96.3	96.8	100	100

Table A.6 Raw analytical data for samples taken at Tahoma, WY17.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
TA-AC	10/14/2016 8:08	99	69	35	2,836	849	0.16	1.66	4.97	11.2	20.9	35.1	41.0	70.1	83.1	92.7	97.7	100	100
TA-AC	10/15/2016 16:40	83	39	22	1,585	447	0.15	1.25	3.17	7.02	14.2	26.1	32.3	59.6	74.8	87.4	96.4	100	100
TA-AC	10/16/2016 11:51	73	25	26	815	258	0.27	2.11	5.07	11.0	21.5	34.9	47.7	73.7	82.0	91.7	100	100	100
TA-AC	12/8/2016 8:05	181	336	152	2,206	1,029	0.84	8.75	23.9	41.6	62.6	84.0	89.3	96.6	98.8	100	100	100	100
TA-AC	12/10/2016 0:10	95	64	38	777	337	0.25	2.60	7.35	14.0	24.0	40.2	47.0	70.8	83.1	92.1	100	100	100
TA-AC	12/15/2016 10:35	42	27	19	440	155	0.21	2.57	8.42	15.5	27.2	44.8	54.1	75.3	85.1	94.0	100	100	100
TA-AC	1/7/2017 11:58	98	92	65	764	349	0.45	4.80	13.9	26.4	44.4	66.8	72.7	90.8	96.6	100	100	100	100
TA-AC	1/8/2017 18:41	13	6	7	591	84	0.17	1.94	6.34	13.7	28.8	50.0	56.5	88.3	98.0	99.3	100	100	100
TA-AC	2/6/2017 8:51	35	35	27	344	169	0.60	6.36	18.1	34.2	55.5	77.9	82.7	94.6	96.3	97.1	100	100	100
TA-AC	2/7/2017 2:58	33	17	16	424	137	0.30	3.09	8.55	16.4	30.0	50.6	57.8	82.4	89.5	94.6	100	100	100
TA-AC	2/8/2017 2:28	22	12	11	588	109	0.24	2.61	7.65	15.3	28.4	47.9	54.8	81.7	90.7	96.2	100	100	100
TA-AC	4/3/2017 10:56	32	15	18	722	101	0.28	3.00	8.82	17.4	32.2	54.5	60.9	83.2	89.9	95.5	98.9	100	100
TA-AC	4/4/2017 11:10	5	3	2	275	33	0.44	3.20	7.15	11.9	21.2	32.5	37.1	60.4	67.2	87.3	100	100	100
TA-AC	4/5/2017 11:23	8	8	4	329	44	0.35	3.67	11.1	20.3	35.4	52.9	59.3	82.3	89.5	97.9	100	100	100
TA-AC	4/6/2017 11:38	14	12	7	226	71	0.28	3.10	9.33	18.1	33.2	53.1	59.4	81.8	91.3	98.4	100	100	100
TA-AC	5/16/2017 16:13	7	5	3	159	39	0.39	3.45	9.47	17.1	28.2	39.8	44.6	67.3	79.6	94.7	100	100	100

Table A.7 Raw analytical data for samples taken at Tahoe Valley, WY17.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
TV-AC	10/15/2016 14:38	100	69	49	1,148	621	0.24	2.43	7.16	15.8	30.5	49.3	55.6	80.2	90.5	96.7	99.3	100	100
TV-AC	10/16/2016 11:34	20	21	14	1,024	340	0.44	4.45	12.4	25.4	44.4	66.5	72.3	90.8	94.1	99.1	100	100	100
TV-AC	12/10/2016 1:21	38	43	23	550	232	0.46	4.69	12.9	24.3	40.6	61.3	70.0	88.5	94.2	100	100	100	100
TV-AC	12/15/2016 14:06	21	25	15	465	133	0.64	6.57	18.0	32.3	51.4	71.3	78.1	89.1	97.2	100	100	100	100
TV-AC	1/7/2017 8:33	57	64	49	1,206	236	0.58	6.18	18.5	37.5	61.9	85.4	90.6	99.2	100	100	100	100	100
TV-AC	2/6/2017 11:59	73	147	59	755	343	1.08	10.5	25.4	41.1	61.9	81.9	86.3	94.0	96.4	100	100	100	100
TV-AC	2/7/2017 3:21	55	71	31	665	232	0.39	3.94	10.4	20.0	36.0	56.6	62.9	83.0	92.1	98.4	100	100	100
TV-AC	2/8/2017 4:37	38	44	24	775	207	0.42	4.30	11.7	22.9	41.3	65.2	72.1	90.4	95.7	99.4	100	100	100
TV-AC	4/3/2017 9:02	6	3	6	635	35	0.00	0.00	0.66	18.0	46.1	94.1	100	100	100	100	100	100	100
TV-AC	4/4/2017 9:02	6	5	6	657	40	0.00	0.57	7.32	22.1	46.5	95.4	100	100	100	100	100	100	100
TV-AC	4/5/2017 8:59	7	6	3	481	40	0.19	1.78	5.27	10.4	24.6	45.2	49.1	75.0	82.6	94.7	100	100	100
TV-AC	4/6/2017 18:48	34	100	21	535	152	0.34	3.46	9.51	19.1	35.9	60.3	68.3	88.6	94.9	99.4	100	100	100
TV-AC	4/16/2017 16:02	18	15	14	820	92	0.41	4.39	13.0	26.4	49.3	79.2	86.5	100	100	100	100	100	100
TV-AC	4/17/2017 8:26	10	12	6	508	65	0.46	4.63	12.4	22.4	40.7	63.9	71.6	86.2	92.9	100	100	100	100
TV-AC	8/6/2017 13:55	164	186	97	4,538	824	0.37	3.83	10.6	20.6	36.4	59.4	66.9	86.0	94.7	100	100	100	100

Table A.8 Raw analytical data for samples taken at Upper Truckee, WY17.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
UT-AC	10/14/2016 8:16	244	241	121	2,453	1,457	0.28	2.96	8.68	18.2	32.6	49.6	55.2	74.3	85.1	93.2	97.8	100	100
UT-AC	10/15/2016 14:34	155	92	45	1,127	683	0.14	1.45	4.17	9.00	17.3	29.1	33.2	51.2	61.3	72.8	83.5	98.6	100
UT-AC	10/16/2016 2:28	106	86	53	1,442	574	0.27	2.83	8.07	16.4	30.3	50.1	56.8	78.1	87.0	93.5	98.1	100	100
UT-AC	12/8/2016 1:05	233	513	208	3,343	1,308	1.03	10.7	29.8	51.0	71.7	89.5	93.8	98.9	100	100	100	100	100
UT-AC	12/10/2016 8:09	198	168	101	964	639	0.31	3.24	9.37	18.5	32.6	51.2	57.2	77.4	87.7	95.4	99.3	100	100
UT-AC	12/15/2016 13:26	128	143	80	1,631	408	0.42	4.41	13.0	25.6	42.4	62.4	69.4	83.8	90.1	98.0	100	100	100
UT-AC	1/7/2017 10:56	357	227	175	917	519	0.36	3.64	9.88	18.3	30.9	49.1	56.1	82.9	94.3	100	100	100	100
UT-AC	2/7/2017 2:28	455	457	247	1,210	1,193	0.35	3.71	10.4	19.6	34.7	54.3	61.1	87.3	94.9	99.0	100	100	100
UT-AC	2/8/2017 2:06	306	318	175	1,335	844	0.38	4.00	11.2	21.2	36.4	57.2	64.2	87.7	94.6	98.6	100	100	100
UT-AC	3/14/2017 14:06	243	337	215	2,932	988	0.62	6.71	19.9	39.1	64.0	88.8	95.0	100	100	100	100	100	100
UT-AC	3/15/2017 12:35	153	240	140	1,872	696	0.58	6.35	19.3	39.2	65.3	91.9	97.4	100	100	100	100	100	100
UT-AC	3/16/2017 11:58	185	257	165	1,936	810	0.66	7.19	21.6	41.4	66.3	89.4	95.2	100	100	100	100	100	100
UT-AC	3/24/2017 8:21	401	310	271	4,516	1518	0.47	5.01	14.6	28.1	47.3	67.6	73.4	89.1	95.2	100	100	100	100
UT-AC	4/6/2017 19:00	193	134	148	867	542	0.49	5.22	15.0	29.3	50.7	76.7	84.2	100	100	100	100	100	100
UT-AC	5/6/2017 13:15	221	144	141	1,714	733	0.43	4.57	13.1	25.2	42.7	63.5	69.6	86.6	93.7	98.9	100	100	100
UT-AC	8/6/2017 12:28	829	316	360	7,753	2,317	0.23	2.42	6.79	13.5	25.4	43.4	50.1	80.5	94.0	100	100	100	100
UT-AC	8/22/2017 14:25	404	418	306	9,740	1,894	0.61	6.58	19.1	35.4	55.9	75.7	81.0	91.4	96.3	100	100	100	100
UT-AC	9/8/2017 13:16	497	227	191	5,758	1,199	0.19	1.92	5.25	10.6	20.9	38.4	45.7	83.2	93.0	100	100	100	100

Appendix B: Quality Assurance/Quality Control Summary

Field duplicates are samples collected at the same time and treated identically and are used to assess the reproducibility of collected data. This provides a measure of analytical precision and can be used for detecting problems in sample collection, handling, transport processing, and analysis. The actual procedures for collecting field duplicate samples depend on the sampling methods and protocols used. When automated sampling equipment is used, duplicates need to be collected manually either by: (a) triggering the sampler manually twice in quick succession (two MS samples) or (b) manually triggering a sample and then collecting a grab sample at the same time (one MS sample and one GS sample), (RSWMP SAP, 2011). Field blanks (FB) are collected to identify sample contamination occurring during field collection, handling, transport, storage, and during laboratory handling and analysis. Field blanks are collected throughout the sampling season by pouring reagent-grade "blank" water into the autosampler bottles in the field and then exposing them to conditions equivalent to the standard sample bottles.

Table B.1 MS and GS sample data from all sites in WY17. Pink cells indicate paired samples that have a difference between them of greater than 20%.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
TA-MS	12/9/2016 14:13	70	101	57	838	403.00	0.82	8.38	22.4	38.6	58.7	81.5	89.3	100	100	100	100	100	100
TA-GS	12/9/2016 14:14	71	105	55	848	403.00	0.77	7.92	21.4	37.3	56.6	78.3	84.8	95.1	98.4	100	100	100	100
PI-MS	12/10/2016 8:18	30	35	18	640	219.82	0.33	3.46	10.1	21.4	38.1	59.7	67.4	88.8	97.0	99.4	100	100	100
PI-GS	12/10/2016 8:19	36	30	11	485	133.41	0.18	1.86	5.58	11.7	20.4	31.0	35.0	47.3	56.3	67.3	78.7	100	100
PO-MS	12/10/2016 8:24	24	31	17	522	226.14	0.43	4.50	13.5	28.3	48.8	70.8	76.4	93.1	98.2	100	100	100	100
PO-GS	12/10/2016 8:25	23	31	16	603	230.57	0.39	4.19	12.7	27.1	47.7	70.2	75.4	93.2	98.8	100	100	100	100
TV-MS	12/11/2016 9:53	10	12	6	764	138.00	1.43	11.5	22.2	34.0	52.2	63.9	78.6	100	100	100	100	100	100
TV-GS	12/11/2016 9:54	10	14	9	799	149.00	0.47	20.7	59.5	78.6	88.4	94.8	99.3	100	100	100	100	100	100
TA-MS	1/8/2017 10:40	50	28	26	476	162.00	0.31	3.22	9.25	18.3	32.6	52.2	58.4	81.8	90.0	94.8	98.2	100	100
TA-GS	1/8/2017 10:41	45	27	25	430	155.00	0.31	3.27	9.43	18.7	33.8	55.4	62.4	87.2	94.6	99.5	100	100	100
TV-MS	1/8/2017 14:42	92	96	58	2064	293.00	0.35	3.65	10.5	21.3	38.8	63.1	71.0	89.8	95.2	99.1	100	100	100
TV-GS	1/8/2017 14:43	90	91	56	2037	302.00	0.34	3.56	10.0	20.1	37.7	62.0	69.5	89.9	96.1	99.5	100	100	100
UT-MS	1/8/2017 17:10	151	114	76	999	412.00	0.34	3.48	9.68	18.3	31.5	50.2	56.8	81.8	91.1	96.9	99.2	100	100
UT-MS	1/8/2017 17:11	155	117	79	1029	425.00	0.33	3.48	9.69	18.3	31.7	50.7	57.3	83.4	92.2	97.3	99.0	100	100

Table B.2 Field blank sample data from all sites in WY17. No values were greater than the method detection limit indicating no contamination. All samples were too clear for PSD analysis.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
UT-FB	12/8/2016 9:00	<0.3	0.36	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
PI-FB	12/10/2016 9:30	<0.3	0.27	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
PO-FB	12/10/2016 9:35	<0.3	0.28	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
TV-FB	12/11/2016 10:00	<0.3	0.06	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
TA-FB	12/16/2016 9:30	<0.3	0.48	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
TA-FB	1/9/2017 11:11	<0.3	0.19	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
TV-FB	2/7/2017 13:01	<0.3	0.30	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
PI-FB	2/7/2017 13:30	<0.3	0.36	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
PO-FB	2/7/2017 13:35	<0.3	0.43	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
TV-FB	4/7/2017 6:00	<0.3	0.12	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
UT-FB	4/7/2017 6:30	<0.3	0.24	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na
SB-FB	4/7/2017 12:00	<0.3	0.10	<0.3	<35	<10	na	na	na	na	na	na	na	na	na	na	na	na	na