Annual Stormwater Monitoring Report

Water Year 2018

Developed by

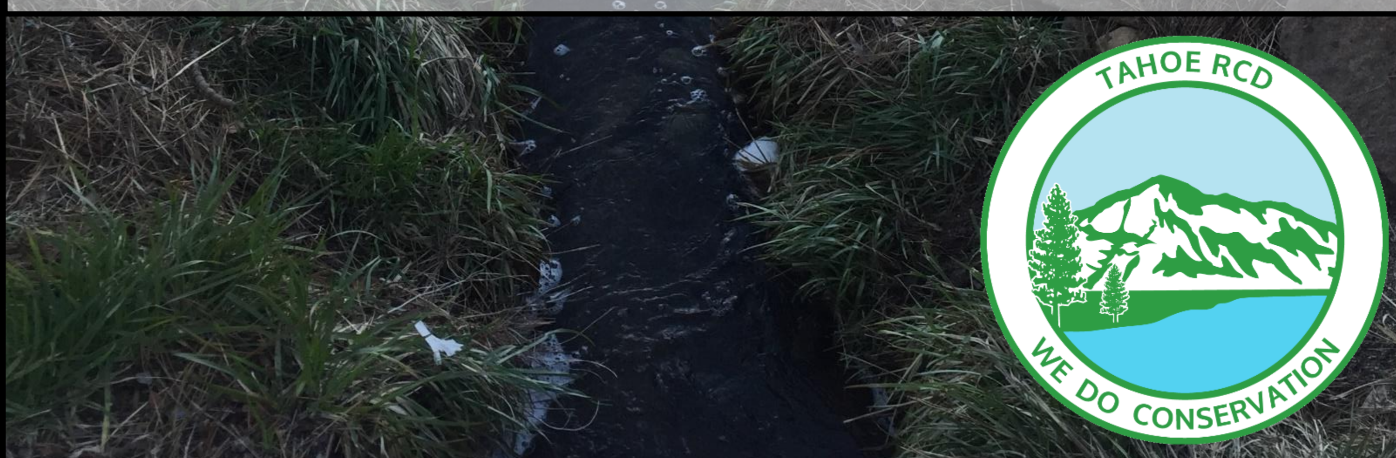
Tahoe Resource Conservation District

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

March 15, 2019

Annual Stormwater Monitoring Report

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

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Submitted by Tahoe Resource Conservation District in cooperation with:

California

El Dorado County

Placer County

City of South Lake Tahoe

Nevada

Douglas County

Washoe County

Nevada Department of Transportation

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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
EC	Elks Club
EDCY	El Dorado County Yard meteorological station
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 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 the second five-year term 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, and at this time RSWMP and IMP are the same.

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 in 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 for permit and agreement compliance initiate efforts to satisfy RSWMP's primary objective of establishing sites around the Lake Tahoe Basin for long-term stormwater monitoring and the secondary objective of refining CECs for the PLRM. Long-term data will be useful in identifying status and trends in the watershed and verifying PLRM estimates.

2. Study Design

During Water Year 2018 (WY18), eight catchments (monitoring sites) were monitored for continuous flow and sampled for water quality at eleven monitoring stations. The monitoring stations were the outfalls of seven of the eight selected catchments (seven stations) and the inflows to, and outflows from, two BMPs both located in the eighth catchment. One of the catchment outfalls is also monitored as a BMP. 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.

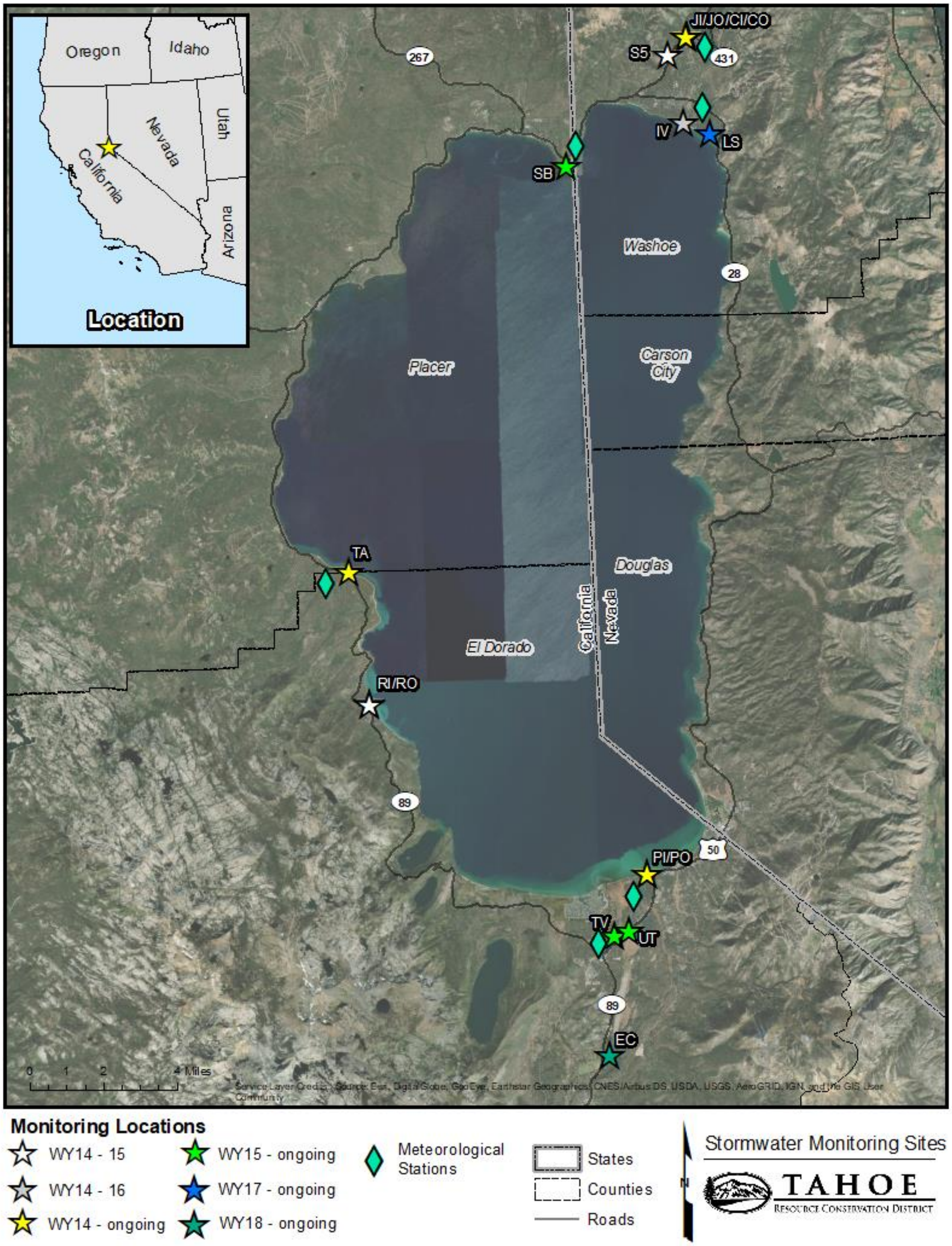

Figure 1 Past and current stormwater monitoring sites and ongoing meteorological stations. Jellyfish Inflow (JI), Jellyfish Outflow (JO), Contech MFS Inflow (CI), Contech MFS Outflow (CO), SR431 outfall (S5), Incline Village (IV), Lakeshore (LS), Speedboat (SB), Tahoma (TA), Rubicon Inflow (RI), Rubicon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

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 the 3rd 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	1.4	89%	0%	0%	0%	89%	0%	11%
Elks Club	√	√	1	El Dorado	14.4	29%	50%	0%	0%	9%	19%	22%
Lakeshore	√		1	Washoe	97.8	41%	2%	43%	31%	1%	10%	13%
Pasadena	√		1	CSLT	78.8	39%	52%	13%	5%	0%	16%	14%
Speedboat	√		1	Placer	29.0	30%	49%	3%	9%	4%	10%	25%
Tahoe Valley	√		1	CSLT, Caltrans	338.4	39%	19%	12%	20%	2%	13%	34%
Tahoma	√		1	Placer, El Dorado, Caltrans	49.5	30%	41%	4%	12%	3%	15%	25%
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 and ice may occasionally block stormwater infrastructure (like drop inlets) this catchment area may increase, 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.

Runoff enters a transverse drain across a parking pull-out directly adjacent to SR431. It then flows through a pipe to a splitter chamber that should theoretically route equal amounts of flow through two inflow pipes, one to the Contech MFS inflow flume and then to the Contech MFS vault, and one to the Jellyfish inflow flume and then to the Jellyfish vault. This splitter chamber gets filled with accumulated sediment very quickly and without proper, consistent maintenance the volume often does not get split evenly. After the runoff has been treated in each vault, the flow exits the vaults through respective pipes that lead either to the Contech MFS outflow flume or the Jellyfish outflow flume and then to Deer Creek.

2.2 Elks Club Catchment Description

The Elks Club monitoring site is located on the northwest corner of Elks Club Drive and Bel Aire Circle in El Dorado County. It is monitored as a catchment outfall and a BMP at one monitoring station (EC). At 14.4 acres it is a relatively small catchment comprised primarily of single family residential and secondary road land uses. Elks Club Drive is a relatively steep road that serves as the primary access road for this neighborhood. Runoff is channelized along the north side of the road and routed directly to the monitoring location adjacent to the roadside.

Prior to the summer of 2018, Elks Club Drive was in poor condition, covered in cracks and potholes. Visual observations and a pilot study on Pioneer Trail in El Dorado County from 2012-2014 suggested that the degraded road surface itself was contributing a substantial amount of fine sediment to stormwater runoff. The Elks Club monitoring site was established to determine if improving road condition would result in decreased FSP loads in stormwater runoff from this catchment. In the summer of 2018, El Dorado County completed an erosion control project in this catchment that included completely reconstructing Elks Club Drive and armoring the road shoulders with asphalt and rocks. A repaved road is more durable and less likely to deteriorate under the heavy equipment and plow blades used for snow removal operations. The smooth surface is easier to sweep and therefore more road abrasives can be recovered. New roads also look nicer and provide a better driving experience. The primary purpose of this monitoring site is to conduct pre and post project monitoring and perform source apportionment analyses on runoff samples to determine what portion of the fine sediment originates from native soil (road shoulder erosion), traction abrasives (road sand), and asphalt plus asphalt binder (the road itself).

The Pioneer Trail pilot study and preliminary pre-project data have shown that about 30% of the fine sediment in stormwater runoff is attributable to the road surface itself. If post project data collected at Elks Club indicates that repaving road contributes to improved water quality (less sediment), then improved pavement condition could be recognized as a water quality BMP, not only garnering credits for the Lake Tahoe TMDL Clarity Crediting Program but also potentially opening up water quality improvement funds for road maintenance and vice versa. New roads would be beneficial for public safety, vehicle maintenance costs, aesthetic appeal, driving pleasure, road maintenance and sweeping operations, long term durability, snow removal operations, stormwater quality, and lake clarity.

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. 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 Jellyfish cartridge filter similar to the one installed at State Route 431 (SR431) (see section 2.4) was also installed downstream of the new infiltration features and immediately upstream of the monitoring site. A flow split routes a small portion of the flow through the Jellyfish to be discharged to the lake through a 30 inch corrugated metal pipe (CMP) that passes through the old Incline Village monitoring site. The remaining flows are routed 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 Pasadena Catchment Description

The Pasadena monitoring site is located at the northernmost end of Pasadena Ave. in the City of South Lake Tahoe. It was monitored as a catchment outfall and BMP effectiveness site. Beginning water year 2018 it was monitored as a catchment outfall only as inflow monitoring was suspended. 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) was 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.

2.5 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.

2.6 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 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.

2.8 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 WY18 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 or weather station equipment sold by Campbell Scientific. The weather stations are installed at six locations in the vicinity of the eight monitored catchments and maintained following recommendations in the RSWMP FIG sections 10.2.3.1 and 10.2.3.2. All weather stations are maintained by Tahoe RCD. 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, June 2017, and May/June 2018. 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. Individual aliquots from 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 Suspended Solids	EPA 160.2 or SM 2540-D	Gravimetric	0.4 mg/L	1 mg/L
Turbidity	EPA 180.1 or SM 2130-B	Nephelometric	0.05 NTU	0.1 NTU
Total Kjeldahl Nitrogen	EPA 351.1; or EPA 351.2	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 Phosphorus as P	TERC Low Level Method	Colorimetric, Total Phosphorus, Persulfate digestion, low level	2 ug/L	10 ug/L
Particle Size Distribution	SM 2560 or RSWMP addendum SOP	Laser backscattering	0.5 mg/L	1 mg/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 individual aliquots from 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 any potential 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 or the ArcGIS Survey123 app and transcribed into Excel workbooks. Samples are transported to a processing lab immediately after collection. The DMS automatically calculates the recipe for compositing individual aliquots from single samples into an event composite for each monitoring station. All composite samples are measured for turbidity using a Hach 2100N benchtop turbidimeter 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 analytical laboratories within appropriate holding times for TSS, TN, TP, 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). Rainfall normalized seasonal and annual trends are calculated for catchments with at least five years of continuous data according to protocols outlined in the RSWMP FIG section 10.4.3.

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 1933-2018) from this station, WY18, at **32.02 total inches**, falls within the third quartile for this period of record and is therefore designated a wet year (Table 4, Figure 2), though it is fairly close to the average of 29.3 inches. WY18 was unusual in that nearly half of the total annual precipitation fell during the spring months. The months of December, January, and February were very dry and sufficient runoff for sampling only occurred in five of the eight catchments on one date in January. Similarly, the summer months only received about 4% of the total annual precipitation and there was insufficient runoff to sample in five of the eight catchments. Though the intention is to sample 10-12 events per year in each catchment, this was not possible during WY18. Between four and nine events were sampled in the eight catchments, the majority occurring between March and May.

Table 4 Annual precipitation statistics from the Tahoe City meteorological reference station, water years 1933-2018.

WY 1933-2018	Annual Precipitation (in)	Designation
1st quartile	8.8 - 21.9	very dry
2nd quartile	22.0 - 29.3	dry
3rd quartile	29.4 - 39.1	wet
4th quartile	39.2 - 69.8	very wet

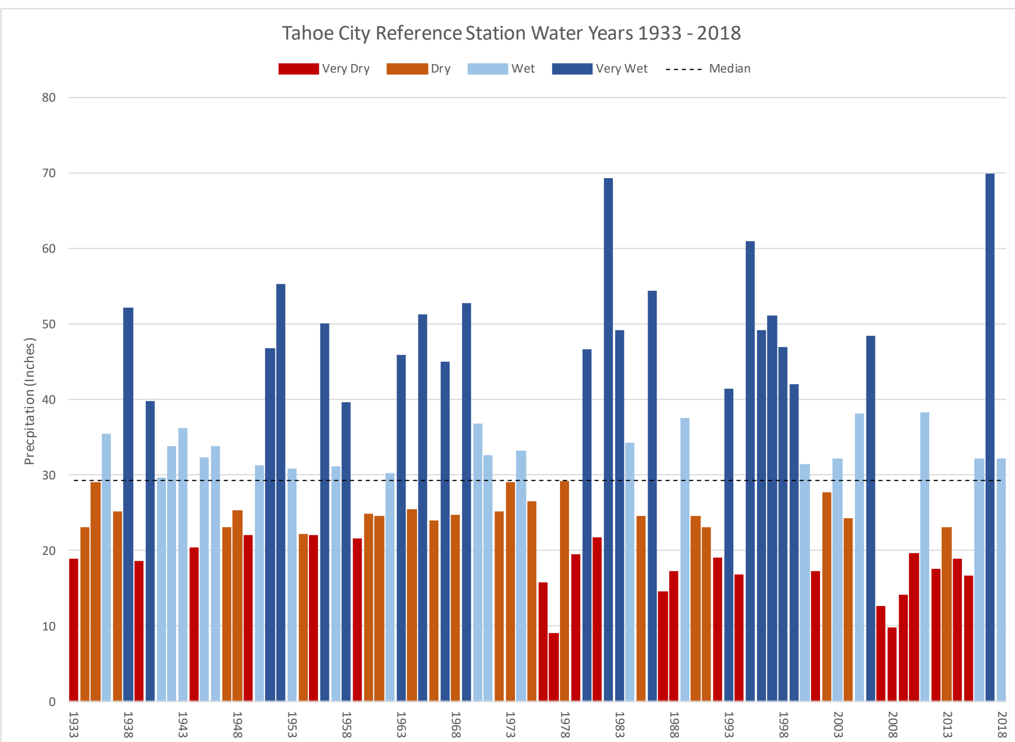

Figure 2 Long-term precipitation record at the Tahoe City meteorological station, water years 1933-2018.

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). These are the seasons used by RSWMP and 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), Elk's Club is EC, Lakeshore is LS, Pasadena is PO, Speedboat is SB, Tahoe Valley is TV, Tahoma is TA, and Upper Truckee is UT.

Table 5 Summary statistics for all catchments for WY18. Top table shows seasonal precipitation, seasonal volumes, and FSP data; bottom table shows seasonal volumes and nutrient data.

Water Year 2018 (October 1, 2017 - September 30, 2018)			Seasonal Precipitation (in)			Total Annual Precip (in)	Seasonal Runoff Volumes (cf)			Total Annual Runoff Volumes (cf)	Average Seasonal FSP Concentrations (mg/L)			Average Annual FSP Concen-trations (mg/L)	Seasonal FSP Loads (lbs)			Total Annual FSP Loads (lbs)	Seasonal Estimated 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	10.01	12.00	0.95	22.96	12,575	8,330	1,850	22,755	126	87	235	121	99	45	27	171	1.05E+16	4.11E+15	1.97E+15	1.66E+16
	Contech Out	CO	10.01	12.00	0.95	22.96	8,184	2,276	1,109	11,569	63	83	341	93	32	12	24	67	2.99E+15	1.09E+15	1.74E+15	5.82E+15
	Jellyfish In	JI	10.01	12.00	0.95	22.96	11,662	10,029	1,777	23,468	178	174	270	183	130	109	30	268	1.39E+16	1.06E+16	2.22E+15	2.68E+16
	Jellyfish Out	JO	10.01	12.00	0.95	22.96	11,063	9,275	1,673	22,010	84	17	169	62	58	10	18	85	5.67E+15	7.71E+14	1.23E+15	7.67E+15
Elk's Club	Elk's Club	EC	9.02	10.61	1.18	20.81	130,551	292,331	na	422,881	15	29	na	24	120	527	na	646	1.02E+16	4.59E+16	na	5.61E+16
Lakeshore	Lakeshore	LS	7.27	9.19	0.15	16.61	49,717	24,195	na	73,912	9	27	na	15	26	41	na	68	3.03E+16	4.20E+16	na	7.24E+16
Pasadena	Pasadena Out	PO	6.95	7.14	0.69	14.78	83,141	48,405	803	132,349	13	37	128	23	69	111	6	186	5.34E+15	9.14E+15	4.21E+14	1.49E+16
Speedboat	Speedboat	SB	7.27	9.19	0.15	16.61	196,588	210,886	95	407,569	27	88	na	59	332	1,160	na	1,492	1.21E+18	5.66E+17	1.01E+11	1.78E+18
Tahoe Valley	Tahoe Valley	TV	9.02	10.61	1.18	20.81	1,030,114	2,479,558	33,891	3,543,564	9	18	1	15	574	2,833	2	3,408	4.32E+16	2.30E+17	9.56E+13	2.73E+17
Tahoma	Tahoma	TA	14.22	15.67	1.22	31.11	305,027	254,497	7,160	566,684	16	30	421	28	307	483	188	978	3.12E+16	4.46E+16	1.51E+16	9.10E+16
Upper Truckee	Upper Truckee	UT	9.02	10.61	1.18	20.81	105,856	97,423	na	203,279	199	117	na	160	1,317	711	na	2,027	1.56E+17	6.64E+16	na	2.22E+17

Water Year 2018 (October 1, 2017 - September 30, 2018)			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	12,575	8,330	1,850	22,755	1,218	2,040	3,175	1,678	0.96	1.06	0.37	2.38	737	1,275	648	927	0.58	0.66	0.07	1.32
	Contech Out	CO	8,184	2,276	1,109	11,569	863	1,382	3,107	1,181	0.44	0.20	0.22	0.85	663	338	724	605	0.34	0.05	0.05	0.44
	Jellyfish In	JI	11,662	10,029	1,777	23,468	693	1,020	3,138	1,018	0.50	0.64	0.35	1.49	669	1,933	624	1,206	0.49	1.21	0.07	1.77
	Jellyfish Out	JO	11,063	9,275	1,673	22,010	935	1,516	2,739	1,317	0.65	0.88	0.29	1.81	601	517	700	573	0.42	0.30	0.07	0.79
Elk's Club	Elk's Club	EC	130,551	292,331	na	422,881	767	904	na	862	6.25	16.5	na	22.8	154	351	na	290	1.25	6.41	na	7.67
Lakeshore	Lakeshore	LS	49,717	24,195	na	73,912	753	779	na	761	2.34	1.18	na	3.51	167	299	na	210	0.52	0.45	na	0.97
Pasadena	Pasadena Out	PO	83,141	48,405	803	132,349	1,483	620	12,879	1,237	7.70	1.87	0.65	10.2	327	232	1,975	302	1.70	0.70	0.10	2.50
Speedboat	Speedboat	SB	196,588	210,886	95	407,569	1,863	1,020	na	1,427	22.9	13.4	na	36.3	389	727	na	564	4.77	9.58	na	14.3
Tahoe Valley	Tahoe Valley	TV	1,030,114	2,479,558	33,891	3,543,564	1,337	633	3,178	862	86.0	98.0	6.72	191	176	162	588	170	11.3	25.1	1.24	37.6
Tahoma	Tahoma	TA	305,027	254,497	7,160	566,684	746	2,001	na	1,300	14.2	31.8	na	46.0	130	1,298	na	653	2.47	20.6	na	23.1
Upper Truckee	Upper Truckee	UT	105,856	97,423	na	203,279	4,992	1,879	na	3,500	33.0	11.4	na	44.4	627	1,421	na	1,008	4.14	8.65	na	12.8

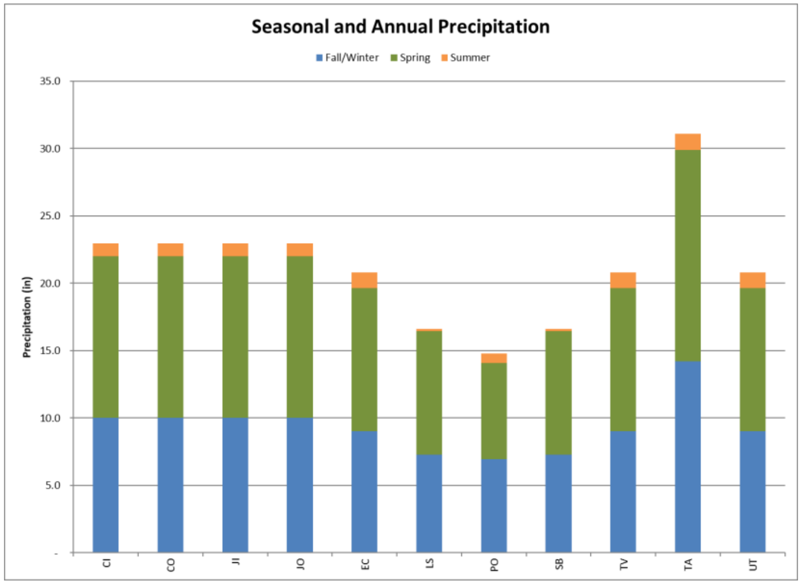

Figure 3 Precipitation totals at each monitoring station, WY18.

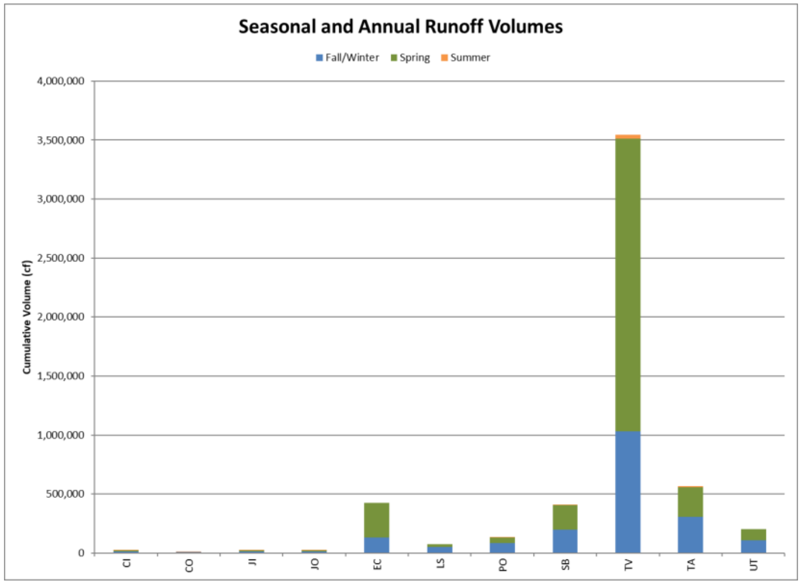

Figure 4 Runoff volumes at each monitoring station, WY18.

Precipitation

- The west shore of the lake received the most precipitation (TA), and the eastern side of south shore received the least (PO).
- The higher elevations on north shore received the second most precipitation (SR431: CI, CO, JI, JO), the western side of south shore received the third most (EC, TV, UT), and the lower elevations on north shore received the fourth most (LS, SB); there are no stations on the east shore.
- All regions of the lake received the greatest amount of precipitation during the spring 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 7.5 times the runoff volume. A large EIP project was completed in the Lakeshore catchment in 2016. One is planned in the Tahoma catchment in 2019.
- Impervious area influences runoff volumes. Pasadena and Upper Truckee have similar runoff volumes even though the Upper Truckee catchment area is about one eighth the size of Pasadena. Upper Truckee is 72% impervious and Pasadena is 39% impervious.
- Precipitation totals influence runoff volumes. All catchments had the most runoff in the fall/winter or spring and the least runoff in the summer.

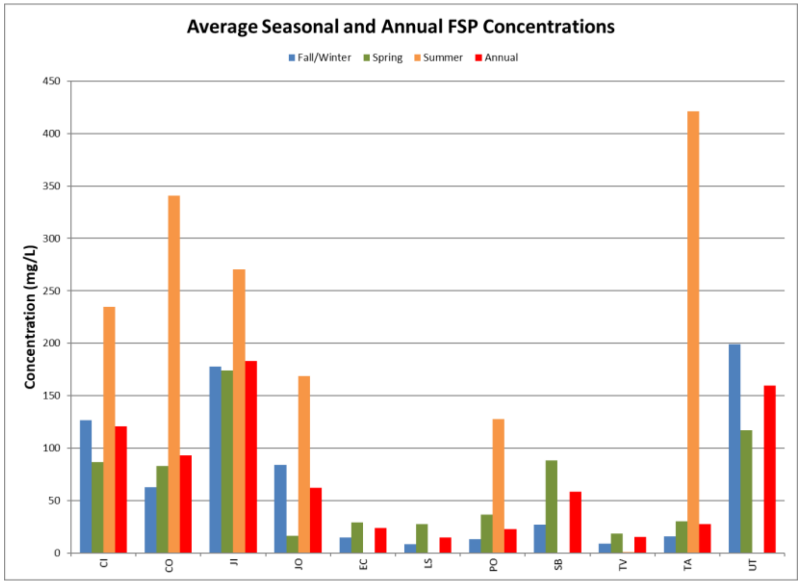

Figure 5 FSP concentrations at each monitoring station, WY18.

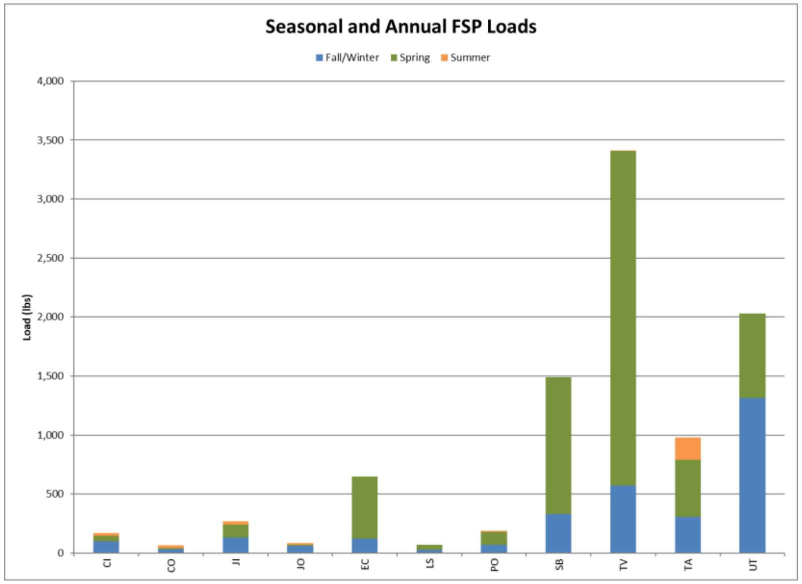

Figure 6 FSP loads at each monitoring station, WY18.

FSP Concentrations

- FSP concentrations were highest in the summer at all sites that received runoff in the summer. Of the sites that received no runoff in the summer, the highest FSP concentrations were in the fall/winter for the site most influenced by primary road (UT) and highest in the spring for the other sites (EC, LS, SB).
- Average annual FSP concentrations were highest at Upper Truckee, Jellyfish Inflow, and Contech MFS inflow - three sites highly influenced by primary road. JI and CI concentrations should be more similar. Average annual FSP concentrations and lowest at Elk's Club, Pasadena, Lakeshore, Tahoe Valley, and Tahoma.
- CO concentrations should be lower than CI concentrations, but in the summer season they were not.
- Overall, the highest average seasonal FSP concentration was observed during the summer season at Tahoma. Though no events were sampled at Tahoma in the summer, FSP was calculated using continuous turbidity measurements.

FSP Loads

- Runoff volume has the largest influence on loads. Tahoe Valley contributed 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.
- JI loads were higher than CI loads, they should be similar. This was due to higher concentrations measured at JI, though concentrations should be similar.

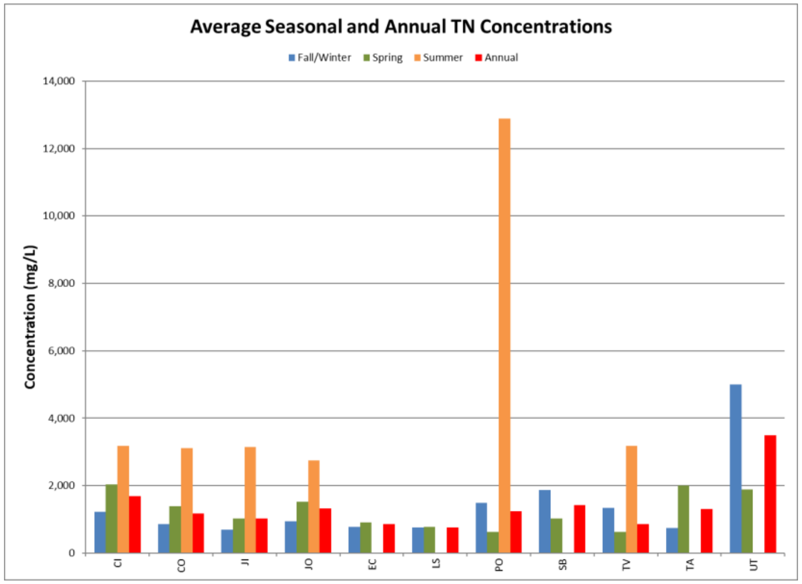

Figure 7 TN concentrations at each monitoring station, WY18.

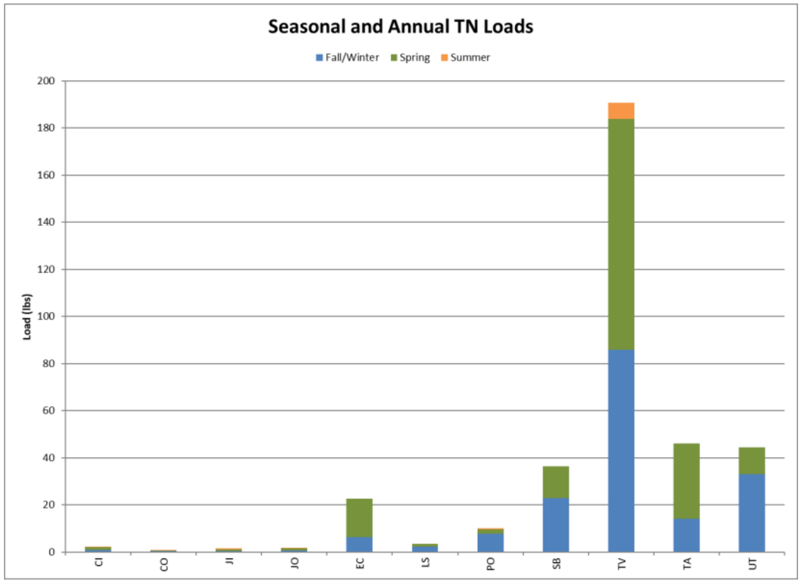

Figure 8 TN loads at each monitoring station, WY18.

TN Concentrations

- Average seasonal TN concentrations were substantially higher in the summer than any other season at all sites that were sampled during the summer. Average seasonal TN concentrations at Pasadena during the summer were significantly higher than at any other site.
- Average seasonal TN concentrations at Upper Truckee in the fall/winter were more than twice as high as any other site during that season. This resulted in the highest average annual TN concentration at Upper Truckee.
- CI concentrations were slightly higher than JI concentrations, they should be similar.
- 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 average seasonal TN concentrations similar to other sites 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 at SR431, Pasadena, and Tahoe Valley.

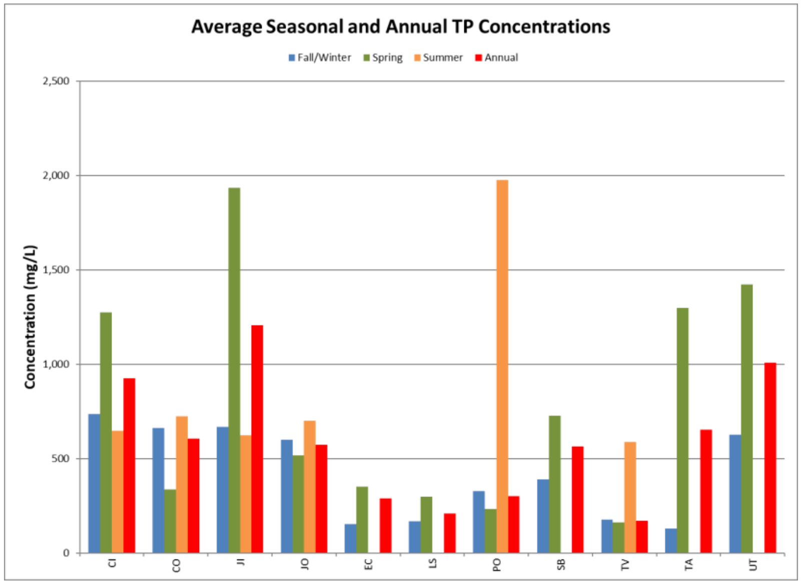

Figure 9 TP concentrations at each monitoring station, WY18.

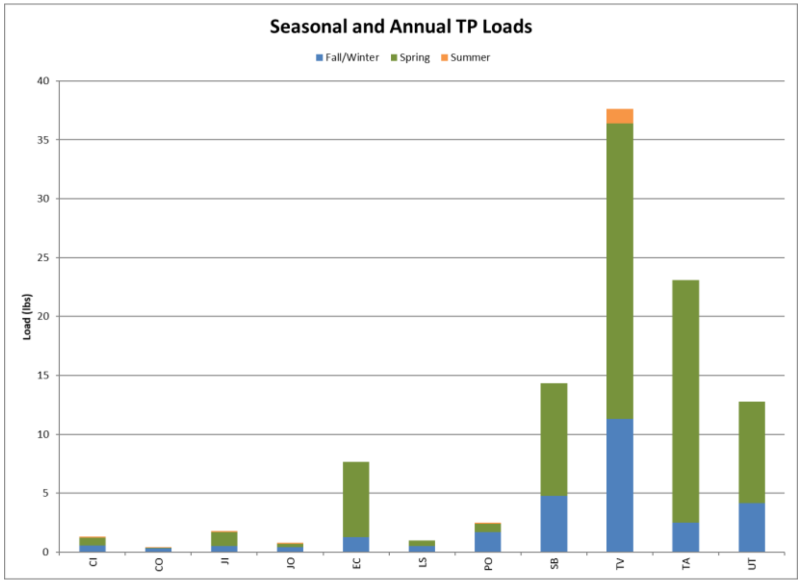

Figure 10 TP loads at each monitoring station, WY18.

TP Concentrations

- Average seasonal TP concentrations were higher in the spring than any other season at most sites, but summer concentrations were highest in at the remaining sites.
- Pasadena had the highest TP concentration of all sites during the summer season, followed closely by Jellyfish Inflow in the spring. JI and CI should be similar.

TP Loads

- Runoff volume has the largest influence on loads. Tahoe Valley contributed more TP to the lake than any other site, yet it had relatively low average seasonal TP concentrations in the fall/winter and spring.
- Concentrations influence loads. Though runoff volumes were universally low in the summer, high average seasonal TP concentrations resulted in proportionally higher summer TP loads at SR431, Pasadena, and Tahoe Valley.
- High runoff volumes coupled with high average seasonal TP concentrations resulted in high spring TP loads at all sites.

6.2 Summary Data for Individual Catchments

6.2.1 SR431

Figure 11 shows the average daily inflow and cumulative precipitation for WY18 at the SR431 treatment vaults. The treatment vaults are not designed to reduce flows so outflows are roughly equal to inflows for the Jellyfish. However, the Contech vault has a capacity of about 3,000 cf. This results in a significant amount of runoff evaporating from the vault instead of passing through the outflow and accounts for the large difference between inflow and outflow volumes in Table 5. This is especially true in a year like WY18 where there were many small storms that trickled in and didn't flow out.

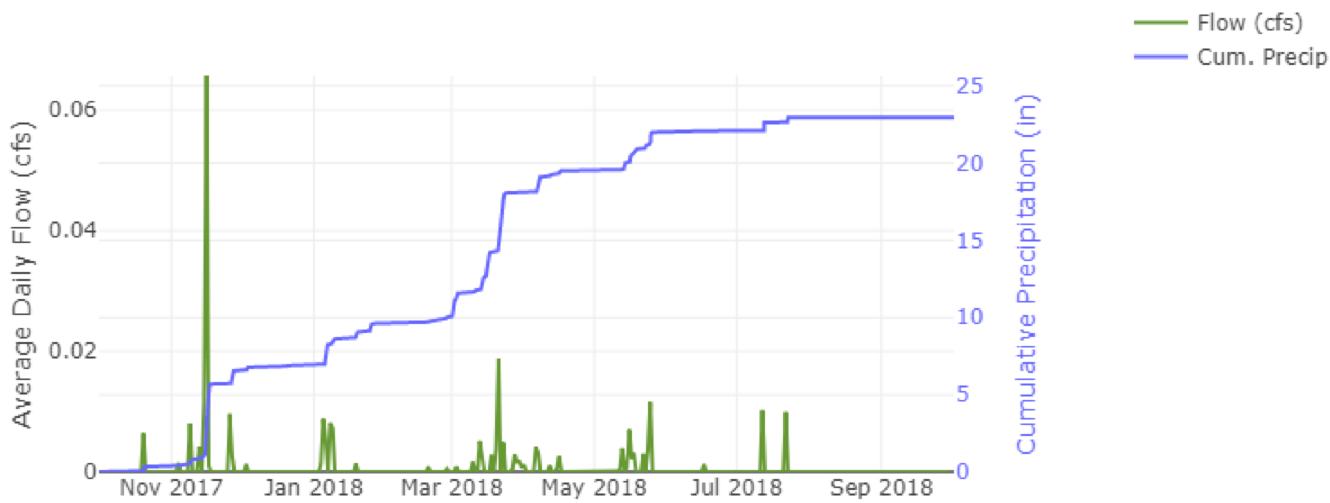

Figure 11 Average daily inflow and cumulative precipitation at the SR431 treatment vaults, WY18.

- Average daily flow in Figure 11 is from CI, but JI is similar so it is not shown.
- 22.96 inches of total precipitation (10.01 in the fall/winter, 12.00 in the spring, and 0.95 in the summer) were recorded at the NDOT weather station.
- 43 precipitation events occurred (21 fall/winter events, 17 spring events, 5 summer events).
- The largest storm event produced 4.67 inches of precipitation and occurred during an atmospheric river rain event from November 15-17, 2018.
- 74% of storms were less than half an inch.
- Highest average daily flows occurred in November of the fall/winter season.
- 19 days of snowmelt occurred in the fall/winter, spring and early summer seasons (October - June).
- The highest instantaneous peak precipitation was 0.11 inches in 5 minutes during the thunderstorm on July 12, 2018.
- The highest instantaneous peak flow was 0.6 cfs during the thunderstorm on July 12, 2018.
- The November 15-17, 2017 atmospheric river rain event produced the most runoff (5,671 cf).

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.

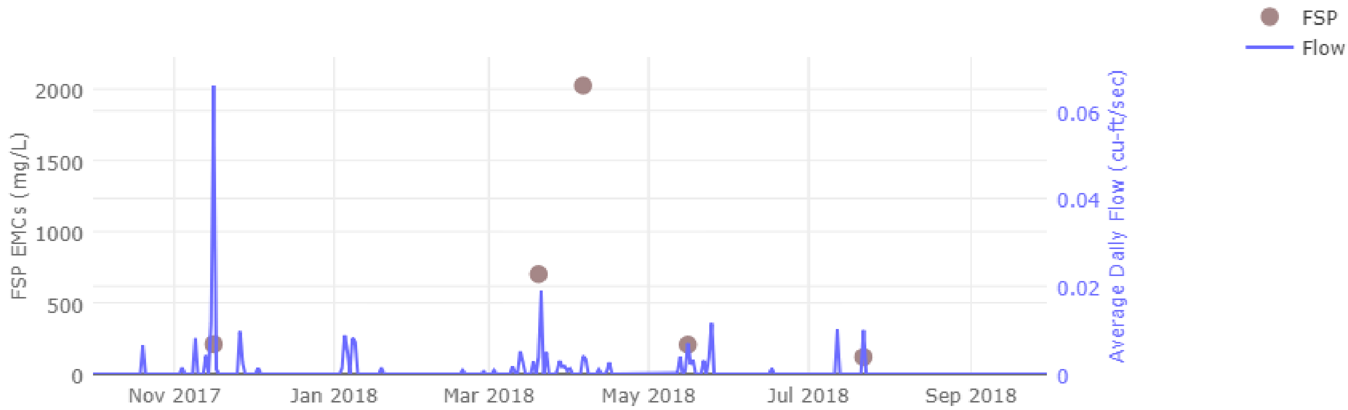

Figure 12 Daily inflow and FSP EMC summary at the Contech MFS, WY18.

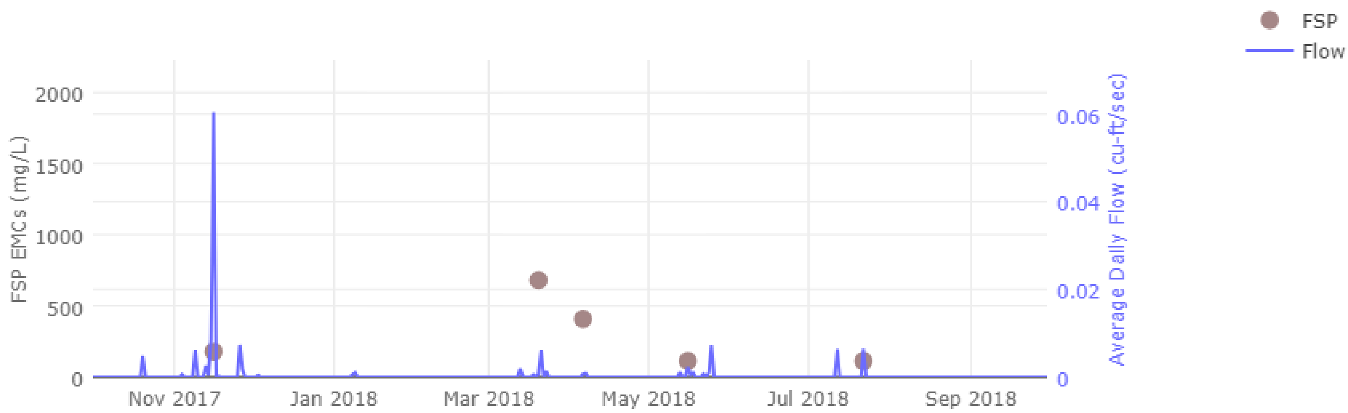

Figure 13 Daily outflow and FSP EMC summary at the Contech MFS, WY18.

- Five events were sampled for FSP (one in the fall/winter, three in the spring, one 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 EMC at the inflow occurred during the rain on snow event on April 6-7, 2018.
- The highest FSP EMC at the outflow occurred during the rain on snow event on March 20-21, 2018.
- The highest FSP load at the inflow occurred during the rain on snow event on March 20-21, 2018.
- The highest FSP load at the outflow occurred during the atmospheric river rain on snow event on November 16, 2017.
- The lowest FSP EMCs occurred during the thunderstorm on July 22, 2018.
- The lowest FSP loads occurred at the inflow during the thunderstorm event on July 22, 2018 and at the outflow during the rain event on May 16, 2018.

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.

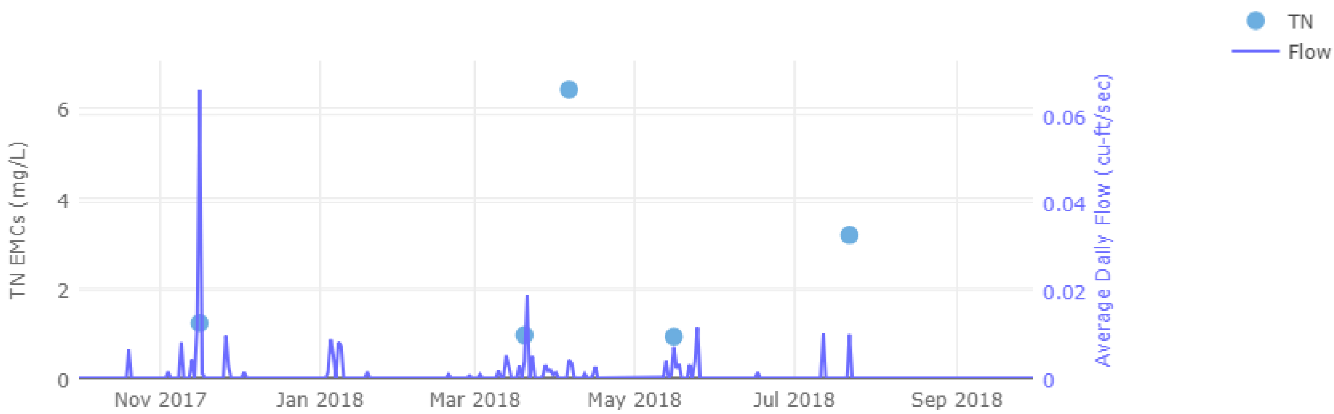

Figure 14 Daily inflow and TN EMC summary at the Contech MFS, WY18.

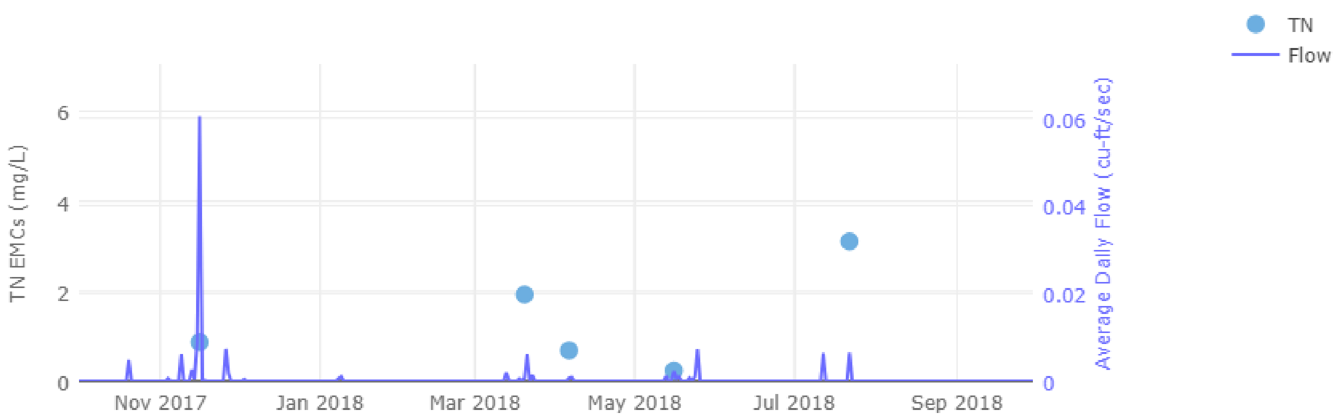

Figure 15 Daily outflow and TN EMC summary at the Contech MFS, WY18.

- Five events were sampled for TN (one in the fall/winter, three in the spring, one in the summer).
- 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 inflow occurred during the rain on snow event from April 6-7, 2018.
- The highest TN EMC at the outflow occurred during the thunderstorm on July 22, 2018.
- The highest TN load at the inflow and outflow occurred during the rain on snow event on November 16, 2017.
- The lowest TN EMCs and loads at the inflow and outflow occurred during the rain event on May 16, 2018.

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.

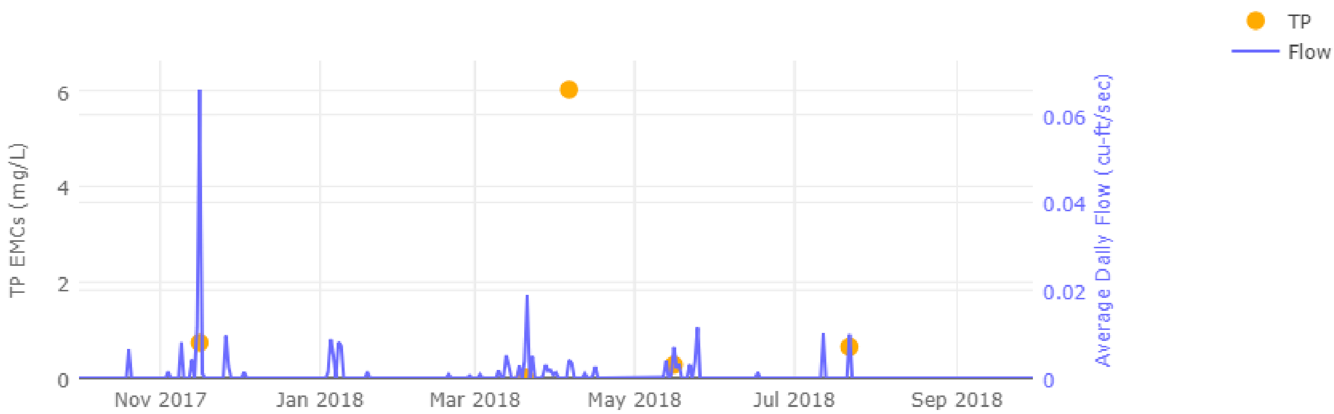

Figure 16 Daily inflow and TP EMC summary at the Contech MFS, WY18.

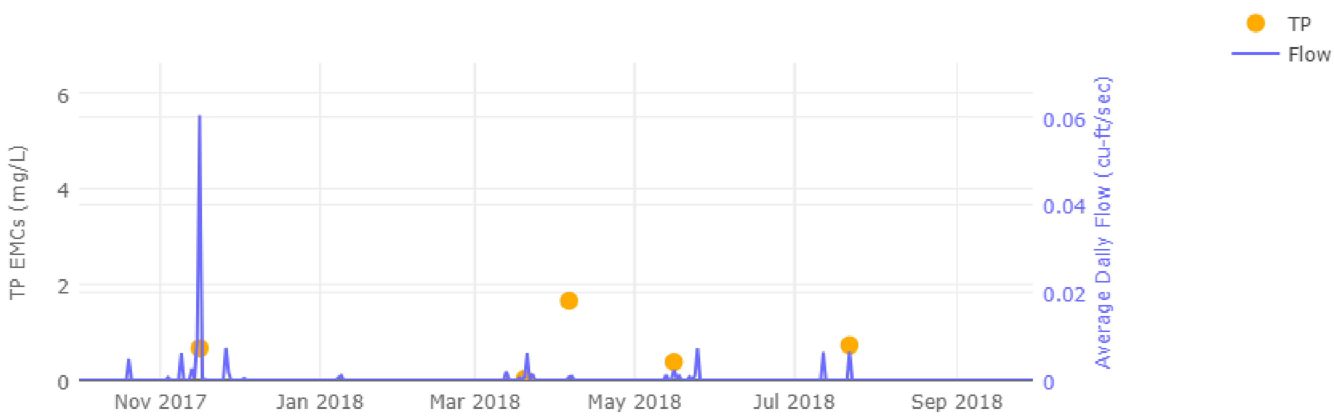

Figure 17 Daily outflow and TP EMC summary at the Contech MFS, WY18.

- Five events were sampled for TP (one in the fall/winter, three in the spring, one in the summer).
- In three out of the five events sampled, the TP EMCs were higher at the outflow than the inflow indicating TP release from the system.
- The highest TP EMCs at the inflow and outflow occurred during the rain on snow event from April 6-7, 2018.
- The highest TP loads at the inflow and outflow occurred during the rain on snow event on November 16, 2017.
- The lowest TP EMCs and loads at the inflow and outflow occurred during the rain on snow event from March 20-21, 2018.

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.

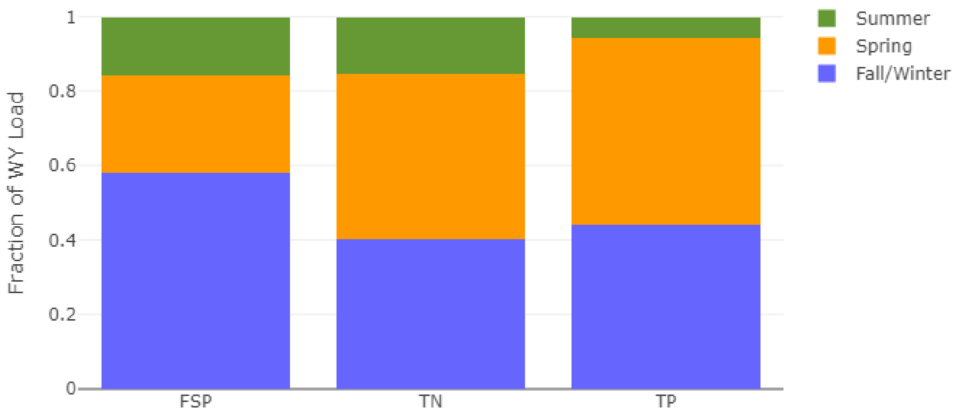

Figure 18 Seasonal load as a fraction of the water year load at the Contech MFS inflow, WY18.

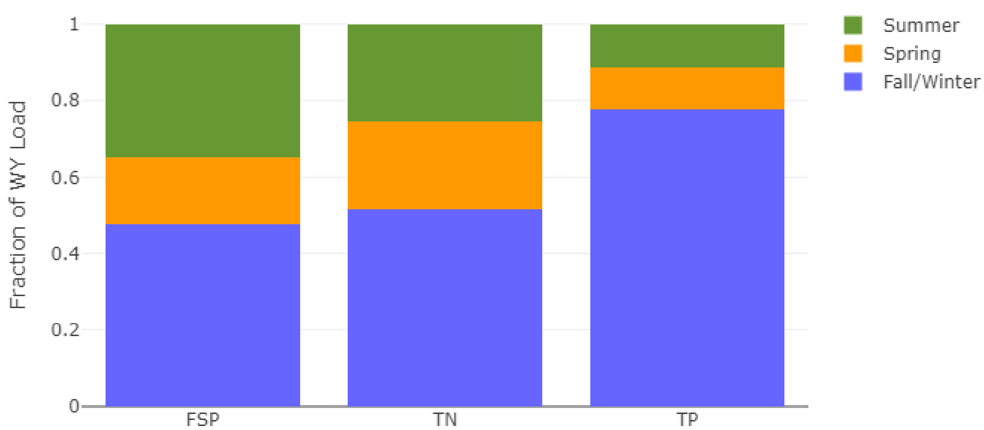

Figure 19 Seasonal load as a fraction of the water year load at the Contech MFS outflow, WY18.

- The largest fraction of FSP loads at the inflow was generated in the fall/winter.
- The largest fraction of FSP loads at the outflow was generated in the fall/winter.
- The largest fraction of TN loads at the inflow was split nearly evenly between the fall/winter and spring.
- The largest fraction of TN loads at the outflow was generated in the fall/winter.
- The largest fraction of TP loads at the inflow was split nearly evenly between the fall/winter and spring.
- The largest fraction of TP loads at the outflow was generated in fall/winter.

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.

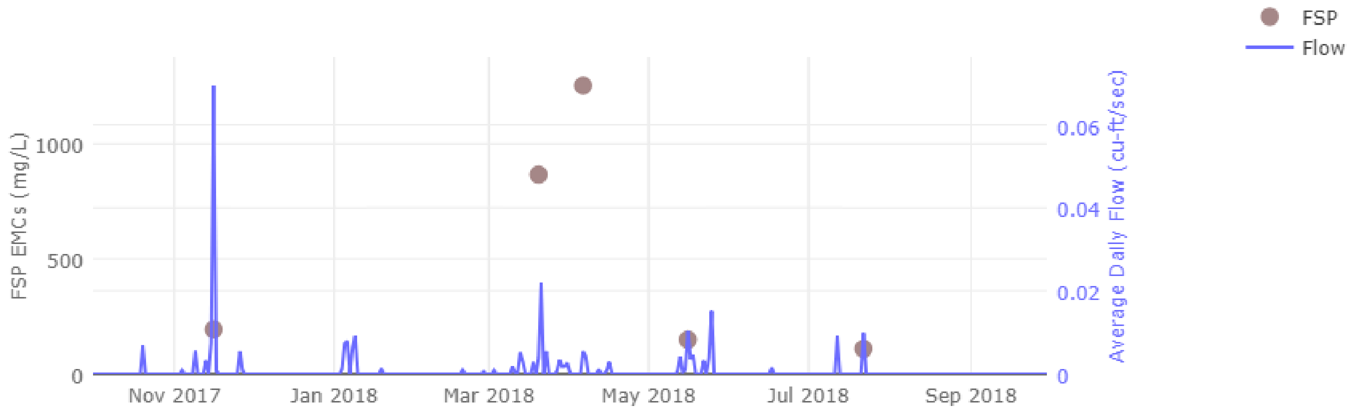

Figure 20 Daily inflow and FSP EMC summary at the Jellyfish, WY18.

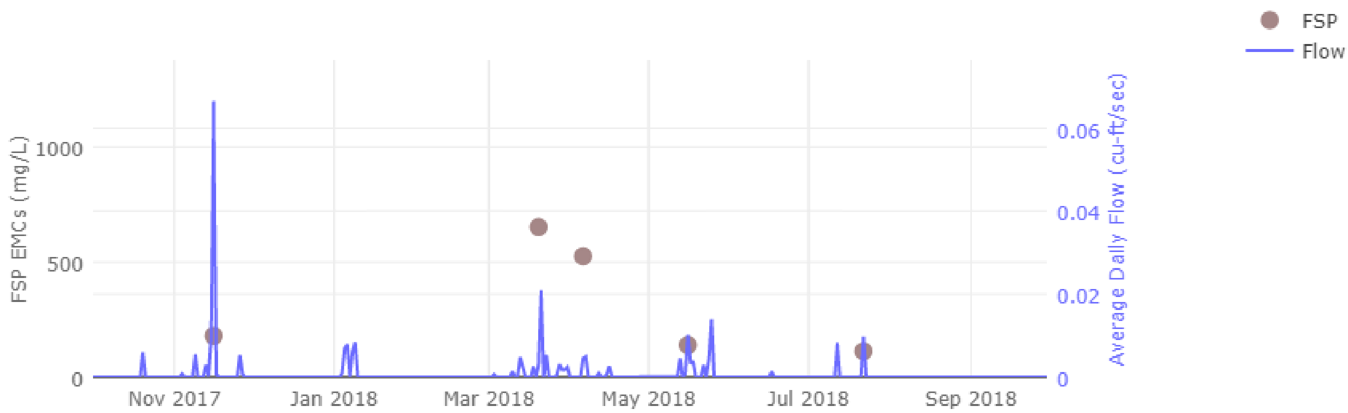

Figure 21 Daily outflow and FSP EMC summary at the Jellyfish, WY18.

- Five events were sampled for FSP (one in the fall/winter, three in the spring, one in the summer).
- In general, FSP EMCs were similar at the inflow and outflow indicating minimal treatment occurred in the Jellyfish vault. The July 22, 2018 thunderstorm saw a higher outflow FSP EMC than inflow FSP EMC indicating a need for maintenance.
- The highest FSP EMCs at the inflow and outflow occurred during two rain on snow events in the spring (March 20-21, 2018 and April 6-7, 2018).
- The highest FSP loads at the inflow and outflow occurred during the rain on snow event from March 20-21, 2018.
- The lowest FSP EMCs and loads at the inflow and outflow occurred during the thunderstorm on July 22, 2018.

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.

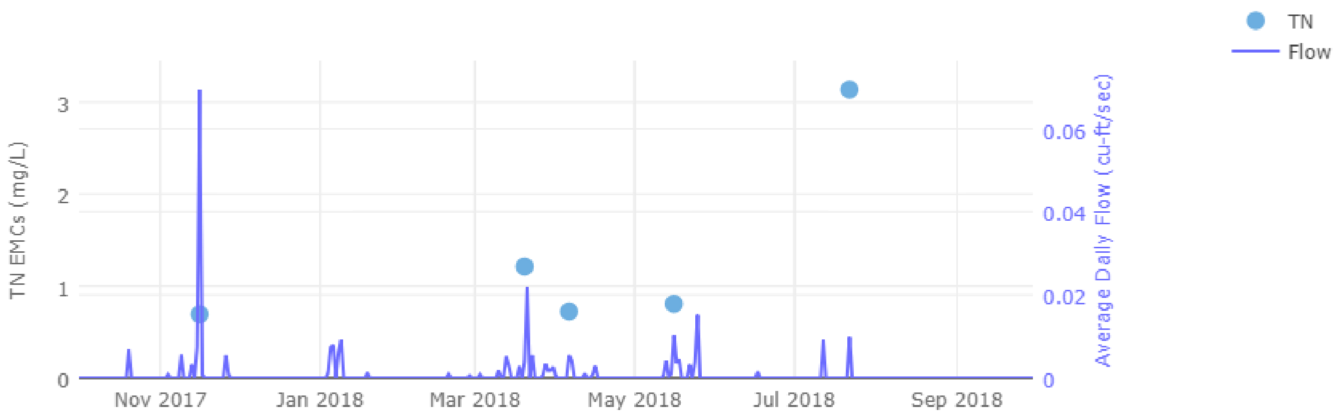

Figure 22 Daily inflow and TN EMC summary at the Jellyfish, WY18.

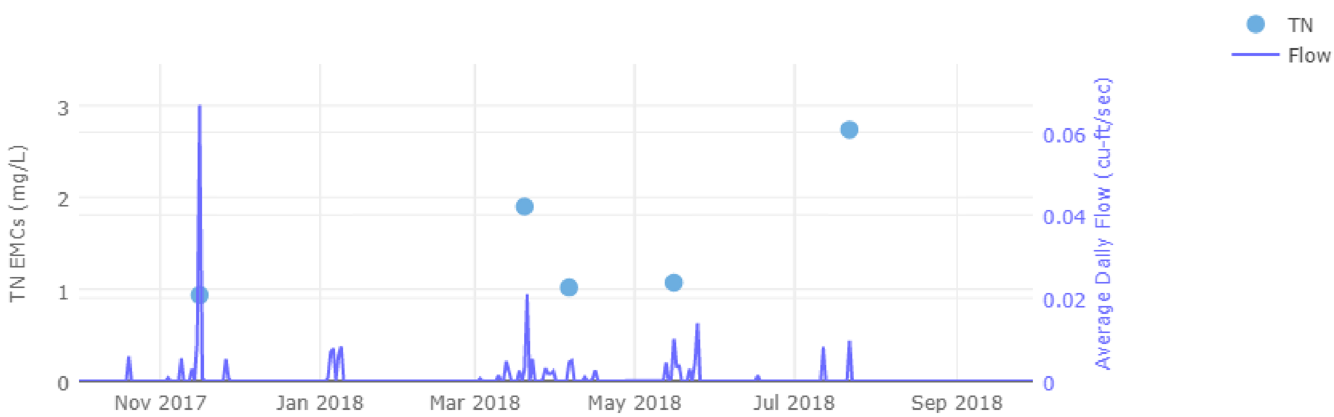

Figure 23 Daily outflow and TN EMC summary at the Jellyfish, WY18.

- Five events were sampled for TN (one in the fall/winter, three in the spring, one in the summer).
- In general, TN EMCs were higher at the outflow than the inflow, indicating a release of TN from the Jellyfish.
- The highest TN EMC at the inflow and outflow occurred during the thunderstorm on the July 22, 2018.
- The highest TN loads at the inflow and outflow occurred during the rain on snow event on November 16, 2017.
- The lowest TN EMCs at the inflow and outflow occurred during the rain on snow event on November 16, 2017.
- The lowest TN loads at the inflow and outflow occurred during a rain on snow event from April 6-7, 2018.

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.

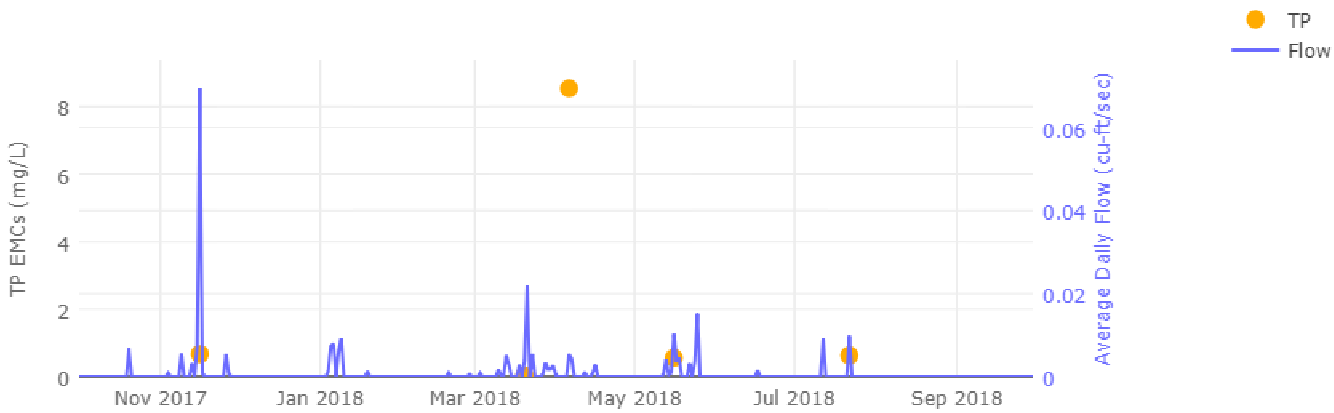

Figure 24 Daily inflow and TP EMC summary at the Jellyfish, WY18.

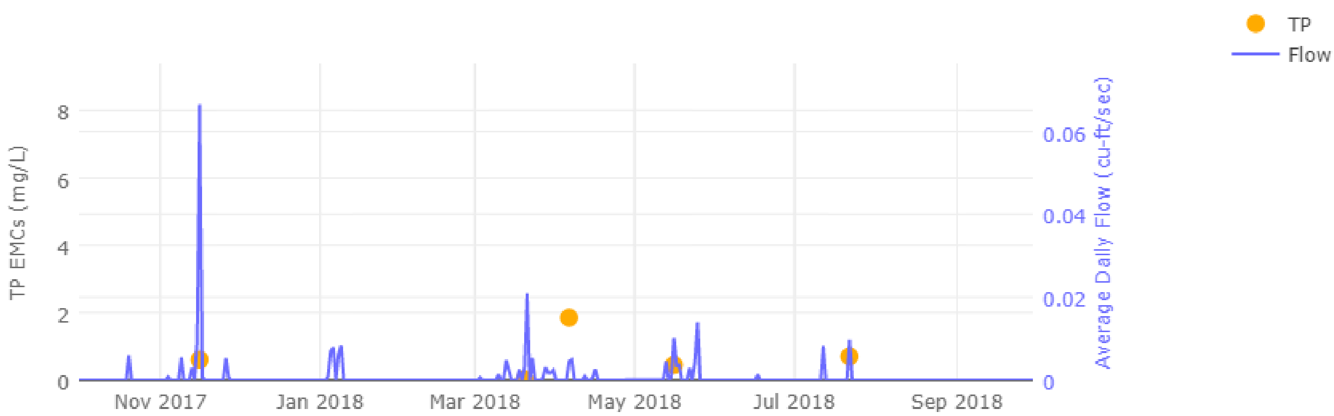

Figure 25 Daily outflow and TP EMC summary at the Jellyfish, WY18.

- Five events were sampled for TP (one in the fall/winter, three in the spring, one in the summer).
- In general, TP EMCs were similar at the inflow and outflow indicating minimal treatment occurred in the Jellyfish.
- The highest TP EMCs at the inflow and outflow occurred during the rain on snow event from April 6-7, 2018.
- The highest TP loads occurred at the inflow during a rain on snow event from April 6-7, 2018, and at the outflow during the rain on snow event on November 16, 2017.
- The lowest TP EMCs and loads at the inflow and outflow occurred during the rain on snow event from March 20-21, 2018.

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.

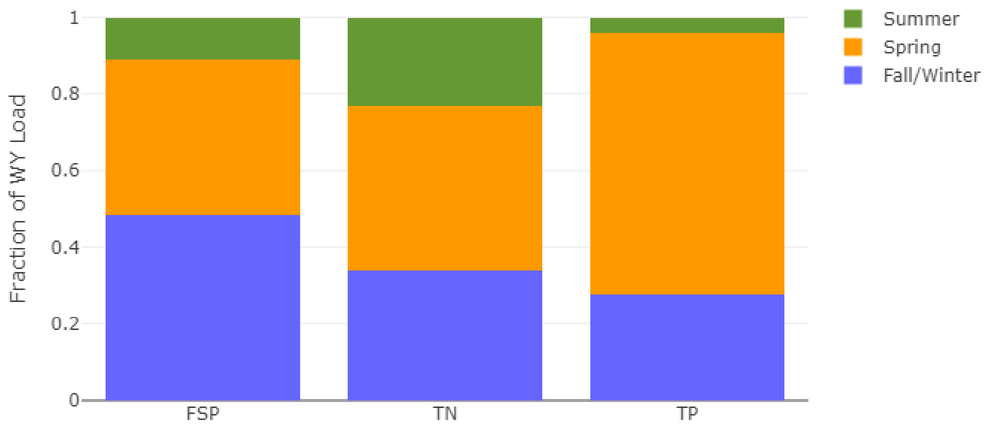

Figure 26	Seasonal load as a fraction of the water year load at the Jellyfish inflow, WY18.

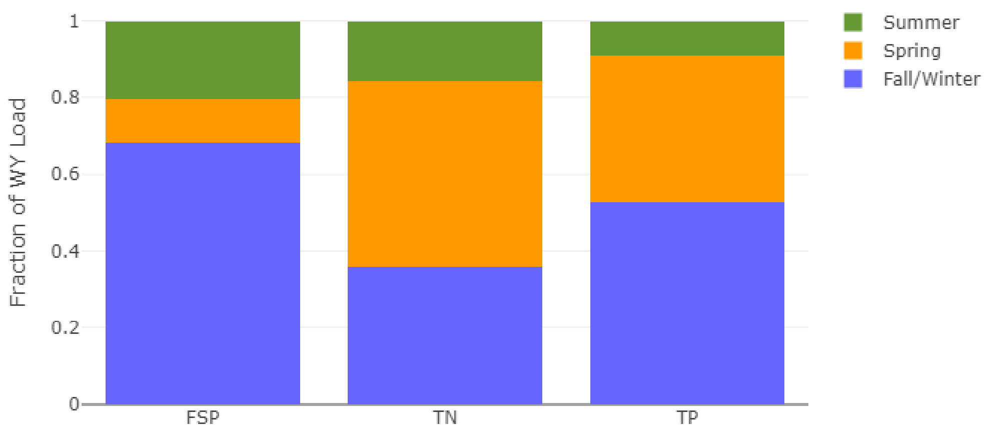

Figure 27	Seasonal load as a fraction of the water year load at the Jellyfish outflow, WY18.

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

Five events were sampled at SR431 in WY18. 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, WY18

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	11/16/2017 06:30	11/16/2017 20:25	13:55	5,671	0.44	2,341	4.67	Rain on snow	100%	209	74	1,218	0.43	737	0.26
CO	Fall/Winter	11/16/2017 07:15	11/16/2017 20:35	13:20	5,218	0.43	330	4.67	Rain on snow	100%	178	58	863	0.28	663	0.22
CI	Spring	3/20/2018 13:00	3/21/2018 22:50	33:50	1,968	0.15	486	3.87	Rain on snow	100%	700	86	948	0.12	19	0.002
CO	Spring	3/20/2018 23:30	3/21/2018 22:35	23:05	587	0.11	313	3.87	Rain on snow	100%	681	25	1,923	0.07	26	0.001
CI	Spring	4/6/2018 07:50	4/7/2018 06:56	23:06	648	0.09	105	0.99	Rain on snow	100%	2,025	82	6,408	0.26	6,022	0.24
CO	Spring	4/6/2018 09:07	4/7/2018 07:14	22:07	133	0.06	39	0.99	Rain on snow	100%	408	3.4	679	0.01	1,655	0.01
CI	Spring	5/16/2018 06:40	5/16/2018 14:30	7:50	608	0.13	97	0.54	Rain	100%	205	7.8	916	0.03	277	0.01
CO	Spring	5/16/2018 08:30	5/16/2018 14:30	6:00	195	0.05	59	0.54	Rain	100%	113	1.4	233	0.003	376	0.005
CI	Summer	7/22/2018 18:05	7/22/2018 20:00	1:55	865	0.53	807	0.32	Thunderstorm	100%	119	6.4	3,175	0.17	648	0.04
CO	Summer	7/22/2018 18:10	7/22/2018 19:50	1:40	572	0.43	925	0.32	Thunderstorm	100%	112	4.0	3,107	0.11	724	0.03

Table 7 Event summary data at the Jellyfish treatment vault, WY18

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	11/16/2017 06:30	11/16/2017 18:30	12:00	5,212	0.49	905	4.67	Rain on snow	100%	193	63	693	0.23	669	0.22
JO	Fall/Winter	11/16/2017 06:40	11/16/2017 19:30	12:50	5,200	0.45	576	4.67	Rain on snow	100%	179	58	935	0.30	601	0.20
JI	Spring	3/20/2018 13:00	3/21/2018 22:50	33:50	2,256	0.19	1,003	3.87	Rain on snow	100%	866	122	1,213	0.17	27	0.004
JO	Spring	3/20/2018 13:10	3/21/2018 22:55	33:45	2,070	0.16	30	3.87	Rain on snow	100%	652	84	1,900	0.25	26	0.003
JI	Spring	4/6/2018 08:10	4/7/2018 07:40	23:30	836	0.11	357	0.99	Rain on snow	100%	1,253	65	724	0.04	8,539	0.45
JO	Spring	4/6/2018 08:25	4/7/2018 12:35	28:10	810	0.09	6	0.99	Rain on snow	100%	525	27	1,019	0.05	1,853	0.09
JI	Spring	5/16/2018 06:30	5/16/2018 14:50	8:20	885	0.12	329	0.54	Rain	100%	149	8.2	806	0.04	554	0.03
JO	Spring	5/16/2018 06:45	5/16/2018 14:55	8:10	885	0.14	2	0.54	Rain	100%	139	7.7	1,071	0.06	445	0.02
JI	Summer	7/22/2018 18:05	7/22/2018 19:35	1:30	853	0.57	645	0.32	Thunderstorm	100%	109	5.8	3,138	0.17	624	0.03
JO	Summer	7/22/2018 18:10	7/22/2018 20:00	1:50	837	0.52	300	0.32	Thunderstorm	100%	112	5.8	2,739	0.14	700	0.04

6.2.2 Elks Club

Figure 28 shows the average daily flow and cumulative precipitation for WY18 at the Elks Club catchment outfall.

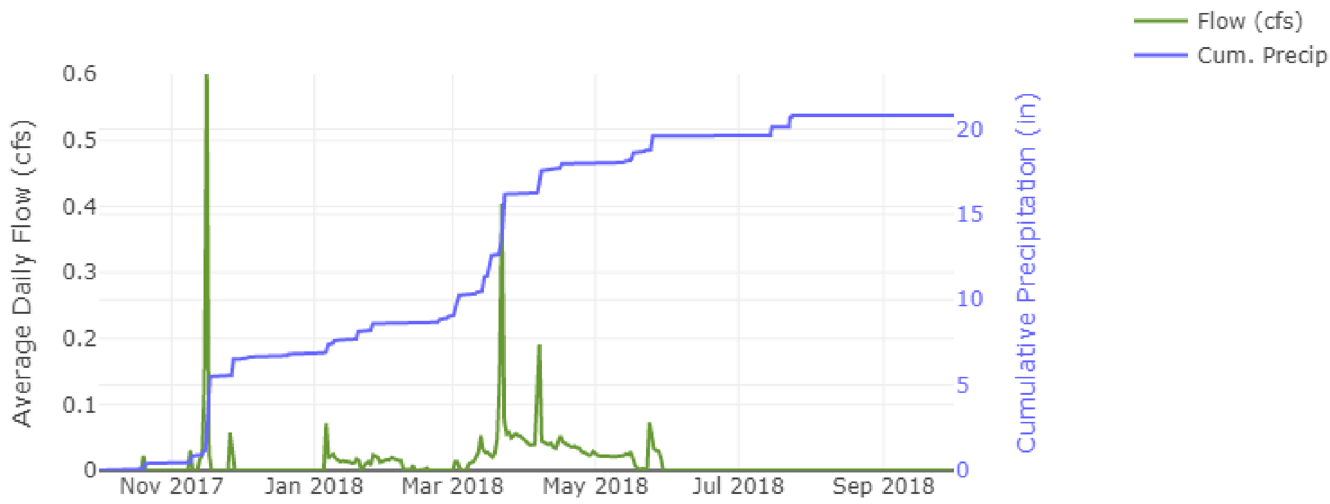

Figure 28 Average daily flow and cumulative precipitation at the Elks Club catchment outfall, WY18.

- 20.8 inches of total precipitation (9.02 in the fall/winter, 10.61 in the spring, 1.18 in the summer) were recorded at the Raph's Shop weather station.
- 37 precipitation events occurred (19 fall/winter events, 15 spring events, 3 summer events).
- The largest storm, with over 4 inches of precipitation, occurred during an atmospheric river rain event from November 15-17, 2017.
- 76% of storms were less than half an inch.
- Highest average daily flows occurred in November of the fall/winter season.
- 117 days of snowmelt runoff occurred in the fall/winter and spring.
- The highest instantaneous peak precipitation was 0.24 inches in 5 minutes during a summer thunderstorm on July 14, 2018.
- The highest instantaneous peak flow was 2.1 cfs during a rain event on May 24, 2018.
- The November 15-17, 2017atmospheric river rain event produced the most runoff (65,267 cf).

Daily flow and the FSP EMC summary at Elks Club are presented in Figure 29. Table 8 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

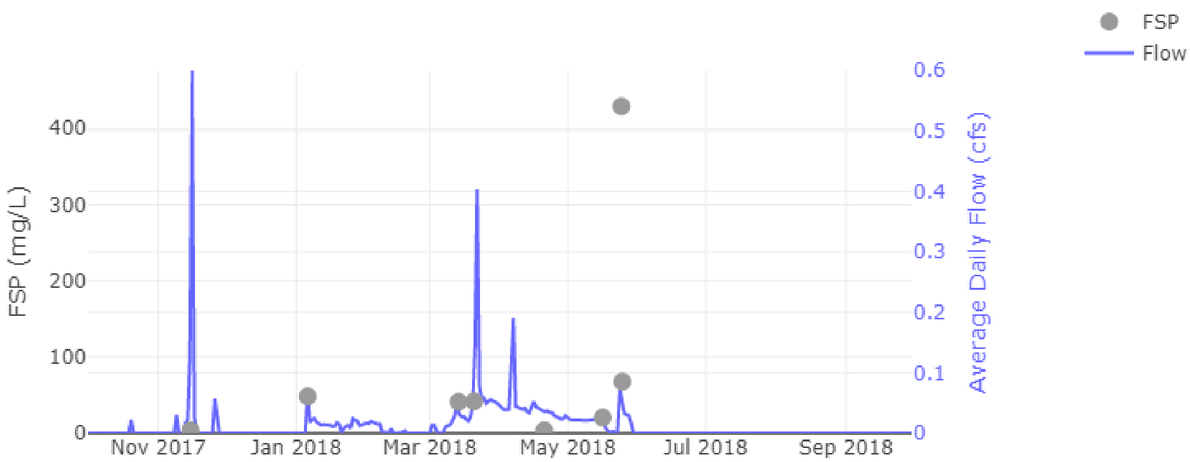

Figure 29	Daily flow and FSP EMC summary at the Elks Club catchment outfall, WY18.

- Eight events were sampled for FSP (two in the fall/winter, six in the spring, and zero in the summer).
- The highest FSP EMC occurred during the rain event on May 24, 2018.
- The highest FSP load occurred during the rain on snow event on March 20-23, 2018.
- The lowest FSP EMCs occurred during the rain event on November 15-17, 2017 and during a non-event snowmelt on April 20-23, 2018.
- The lowest FSP load occurred during the rain event on May 16, 2018.

Daily flow and the TN EMC summary at Elks Club are presented in Figure 30. Table 8 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

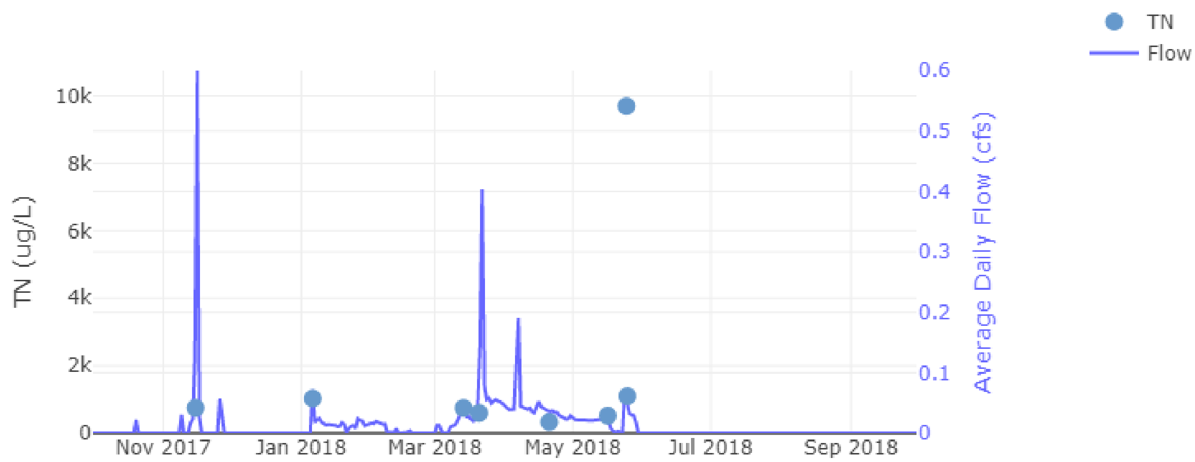

Figure 30 Daily flow and TN EMC summary at the Elks Club catchment outfall, WY18.

- Eight events were sampled for TN (two in the fall/winter, six in the spring, and zero in the summer).
- The highest TN EMC occurred during the rain event on May 24, 2018.
- The highest TN load occurred during the atmospheric river event from November 15-17, 2017.
- The lowest TN EMC occurred during the snowmelt event from April 20-23, 2018.
- The lowest TN load occurred during the rain event on May 16, 2018.

Daily flow and the TP EMC summary at Elks Club are presented in Figure 31. Table 8 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

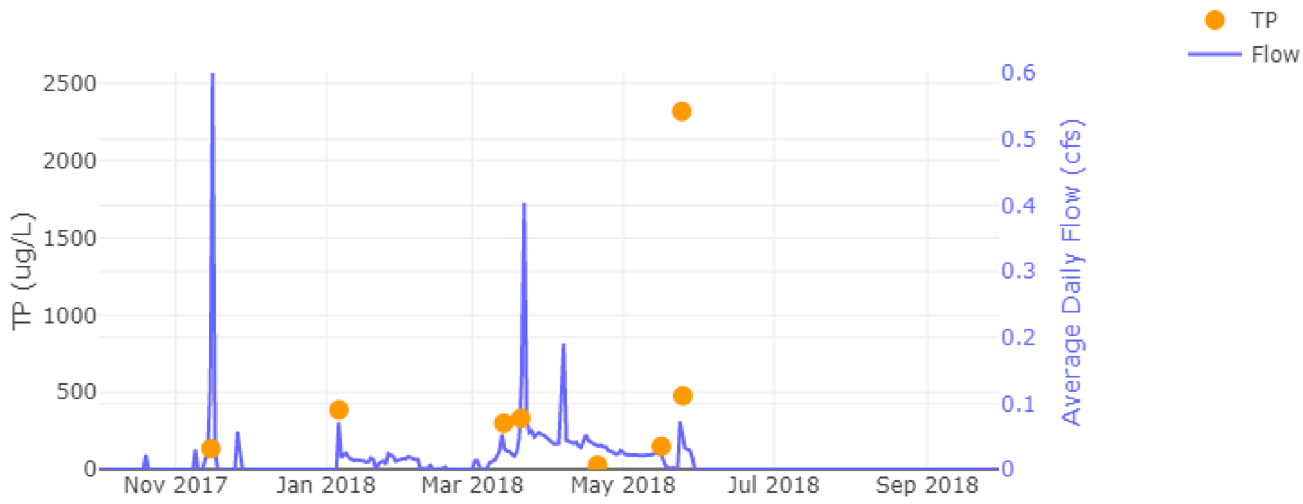

Figure 31 Daily flow and TP EMC summary at the Elks Club catchment outfall, WY18.

- Eight events were sampled for TN (two in the fall/winter, six in the spring, and zero in the summer).
- The highest TP EMC occurred during the rain event on May 24, 2018.
- The highest TP load occurred during the rain on snow event from March 20-23, 2018.
- The lowest TP EMC occurred during the non-event snowmelt from April 20-23, 2018.
- The lowest TP load occurred during the rain event on May 16, 2018 rain event.

Seasonal load as a fraction of the water year load at Elks Club is presented in Figure 32. Event loads are presented in tabular form in Table 8.

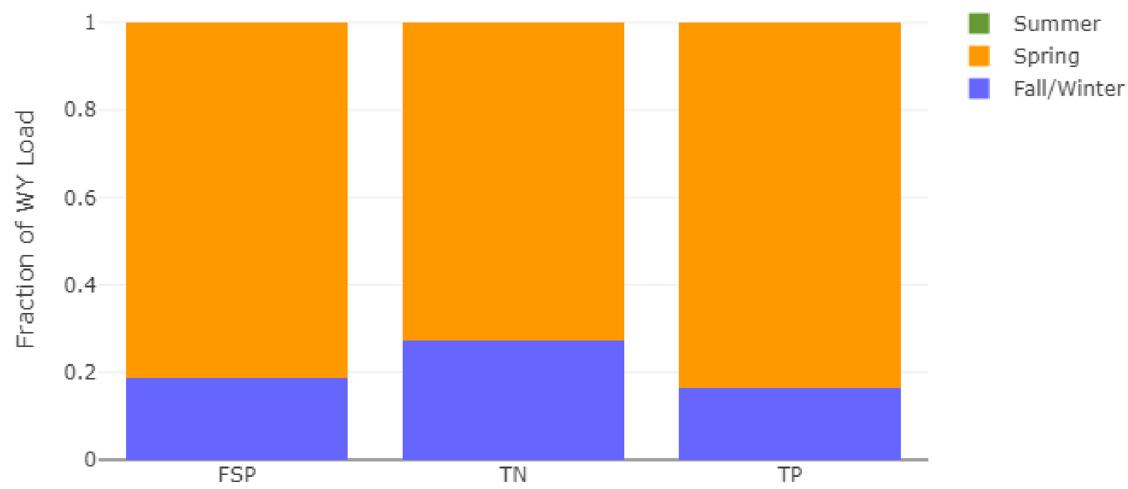

Figure 32 Seasonal load as a fraction of the water year load at the Elks Club catchment outfall, WY18.

- The largest fraction of FSP loads was generated spring.
- The largest fraction of TN loads was generated in the spring.
- The largest fraction of TP loads was generated in the spring.
- Summer produced no loads for FSP, TN, or TP because there was no runoff.

Eight events were sampled at Elks Club in WY18. Event summary data is presented in Table 8.

Table 8 Event summary data at the Elks Club catchment outfall, WY18

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)
EC	Fall/Winter	11/15/2017 07:00	11/17/2017 14:10	55:10	65,242	1.44	369	4.35	Rain	100%	3.9	16	746	3.04	135	0.55
EC	Fall/Winter	1/5/2018 23:50	1/6/2018 13:20	13:30	5,330	0.51	676	0.46	Rain on snow	100%	48	16	1,027	0.34	386	0.13
EC	Spring	3/13/2018 13:05	3/13/2018 20:35	7:30	2,911	0.38	1,225	2.15	Rain on snow	100%	41	7.5	745	0.14	300	0.05
EC	Spring	3/20/2018 12:45	3/23/2018 00:20	59:35	52,572	1.02	671	3.60	Rain on Snow	100%	42	137	597	1.96	331	1.09
EC	Spring	4/20/2018 11:25	4/23/2018 11:25	72:00	13,161	0.07	21	0.00	Non-event Snowmelt	100%	3.8	3.1	330	0.27	28	0.02
EC	Spring	5/16/2018 11:00	5/16/2018 14:09	3:09	751	0.18	103	0.47	Rain	100%	21	1.0	517	0.02	150	0.01
EC	Spring	5/24/2018 17:15	5/24/2018 18:50	1:35	2,740	2.33	567	0.54	Rain	100%	429	73	9,697	1.66	2,320	0.40
EC	Spring	5/25/2018 03:30	5/25/2018 06:00	2:30	1,879	0.64	148	0.30	Rain	100%	68	7.9	1,098	0.13	477	0.06

6.2.3 Lakeshore

Figure 33 shows the average daily flow and cumulative precipitation for WY18 at the Lakeshore catchment outfall.

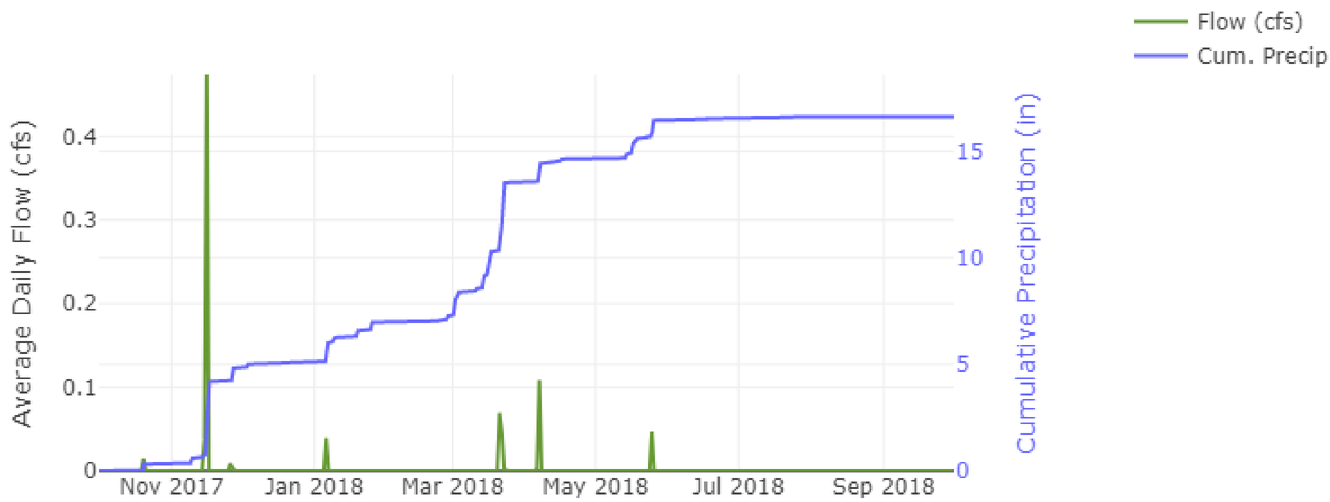

Figure 33 Average daily flow and cumulative precipitation at the Lakeshore catchment outfall, WY18.

- 16.61 inches of total precipitation (7.27 in the fall/winter, 9.19 in the spring, and 0.15 in the summer) were recorded at the TERC weather station.
- 33 precipitation events occurred (16 fall/winter events, 15 spring events, 2 summer events).
- The largest storm, with 3.5 inches of precipitation, was an atmospheric river rain event that occurred from November 15-17, 2017.
- 73% of storms were less than half an inch.
- Highest average daily flows occurred in November of the fall/winter season.
- 2 days of intermittent snowmelt occurred in during the fall/winter and spring seasons.
- No runoff occurred during the summer season.
- The highest instantaneous peak precipitation was 0.09 inches in 5 minutes during a rain event from May 24-25, 2018.
- The highest instantaneous peak flow was 1.22 cfs during the rain on snow event on April 7, 2018.
- The November 15-17, 2017 atmospheric river rain event produced the most runoff (44,133 cf).

Daily flow and the FSP EMC summary at Lakeshore are presented in Figure 34. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

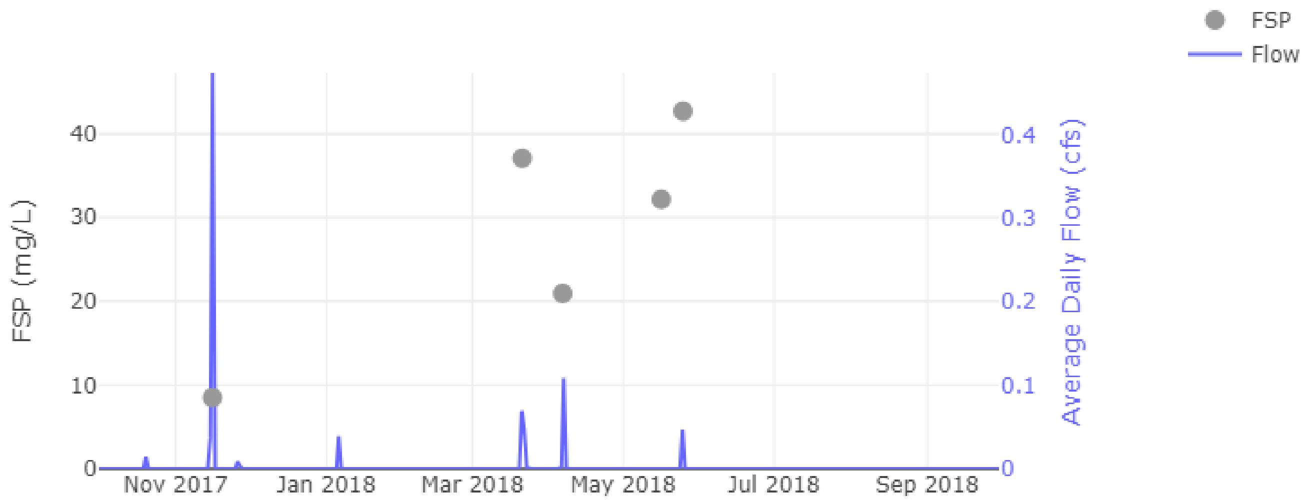

Figure 34 Daily flow and FSP EMC summary at the Lakeshore catchment outfall, WY18.

- Five events were sampled for FSP (one in the fall/winter, four in the spring, zero in the summer).
- The highest FSP EMC occurred during the rain event on May 25, 2018.
- The highest FSP loads occurred during the rain event on November 15-17, 2017 and the rain on snow event on March 21-22, 2018.
- The lowest FSP EMC occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest FSP load occurred during the rain event on May 16, 2018.

Daily flow and the TN EMC summary at Lakeshore are presented in Figure 35. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

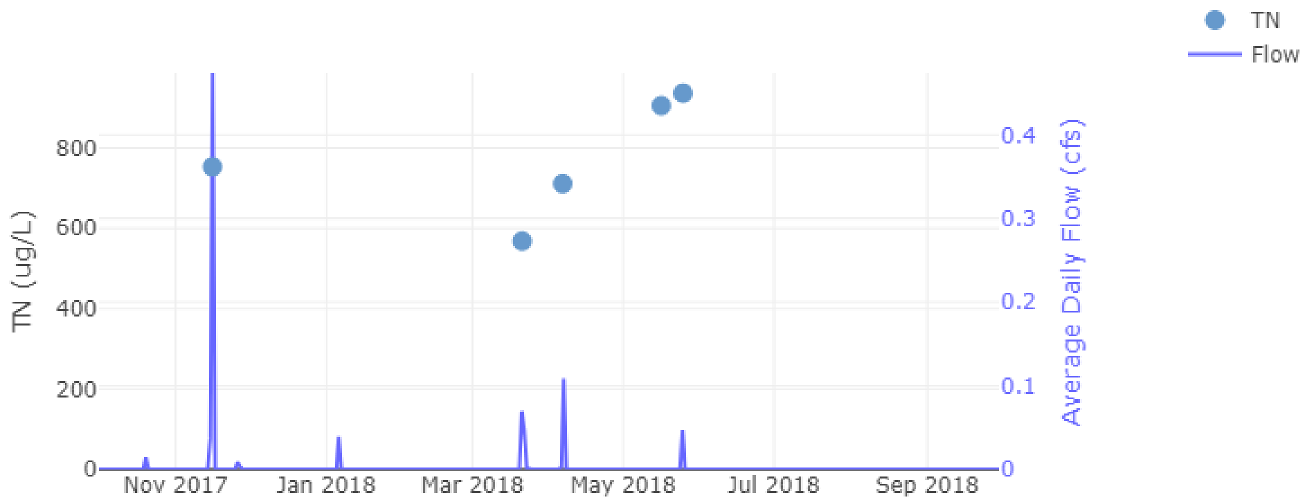

Figure 35 Daily flow and TN EMC summary at the Lakeshore catchment outfall, WY18.

- Five events were sampled for TN (one in the fall/winter, four in the spring, zero in the summer).
- The highest TN EMC occurred during the rain event on May 25, 2018.
- The highest TN load occurred during the atmospheric river rain event from November 15-16, 2017.
- The lowest TN EMC occurred during the rain on snow event from March 21-22, 2018.
- The lowest TN load occurred during the rain event on May 16, 2018.

Daily flow and the TP EMC summary at Lakeshore are presented in Figure 36. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

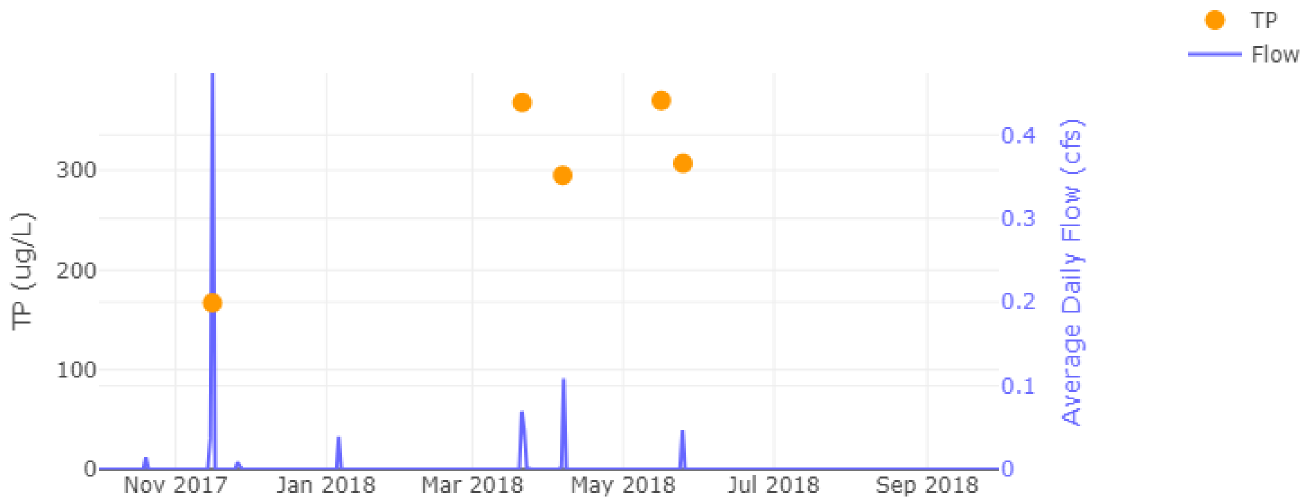

Figure 36 Daily flow and TP EMC summary at the Lakeshore catchment outfall, WY18.

- Five events were sampled for TP (one in the fall/winter, four in the spring, zero in the summer).
- The highest TP EMCs occurred during the rain on snow event from March 21-22, 2018 and the rain event on May 16, 2018.
- The highest TP load occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest TP EMC occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest TP load occurred during the rain event on May 16, 2018.

Seasonal load as a fraction of the water year load at Lakeshore is presented in Figure 37. Event loads are presented in tabular form in Table 9.

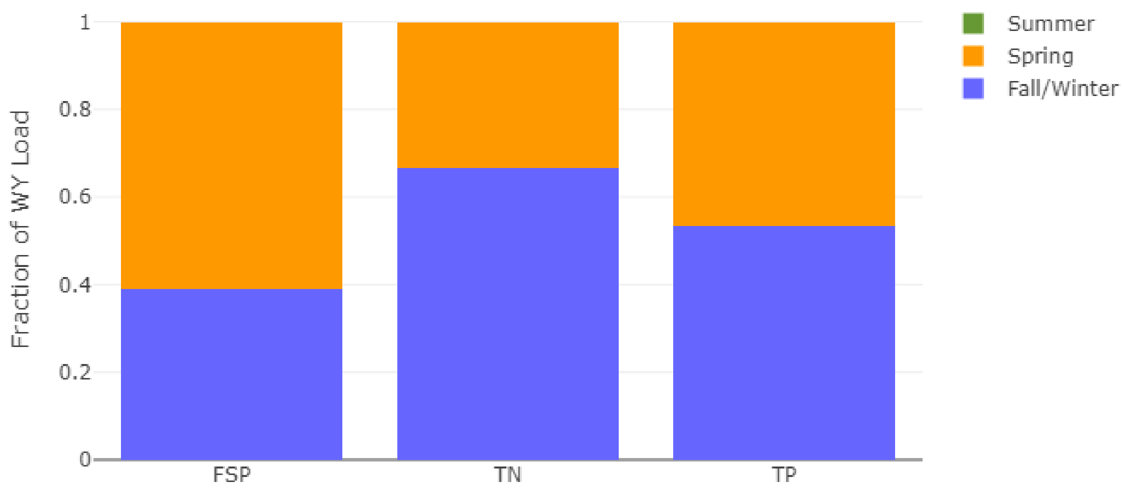

Figure 37 Seasonal load as a fraction of the water year load at the Lakeshore catchment outfall, WY18.

- The largest fraction of the FSP load was generated in the spring.
- The largest fraction of the TN load was generated in the fall/winter
- The TP load was split nearly evenly between the fall/winter and spring.
- Summer produced no loads for FSP, TN, or TP because there was no runoff.

Five events were sampled at Lakeshore in WY18. Event summary data is presented in Table 9.

Table 9 Event summary data at the Lakeshore catchment outfall, WY18

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	11/15/2017 21:10	11/16/2017 23:50	26:40	44,152	1.11	2,273	3.49	Rain	100%	8.5	23	753	2.08	167	0.46
LS	Spring	3/21/2018 00:35	3/22/2018 21:25	44:50	10,101	0.48	2,973	3.23	Rain on snow	100%	37	23	568	0.36	368	0.23
LS	Spring	4/6/2018 12:35	4/7/2018 12:30	23:55	9,616	1.22	2,020	0.89	Rain on Snow	100%	21	13	711	0.43	295	0.18
LS	Spring	5/16/2018 09:50	5/16/2018 15:10	5:20	82	0.03	16	0.53	Rain	100%	32	0.2	905	0.005	370	0.002
LS	Spring	5/25/2018 05:15	5/25/2018 08:10	2:55	4,070	0.99	1,903	0.77	Rain	100%	43	11	936	0.24	307	0.08

6.2.4 Pasadena

Figure 38 shows the average daily flow and cumulative precipitation for WY18 at the Pasadena outfall.

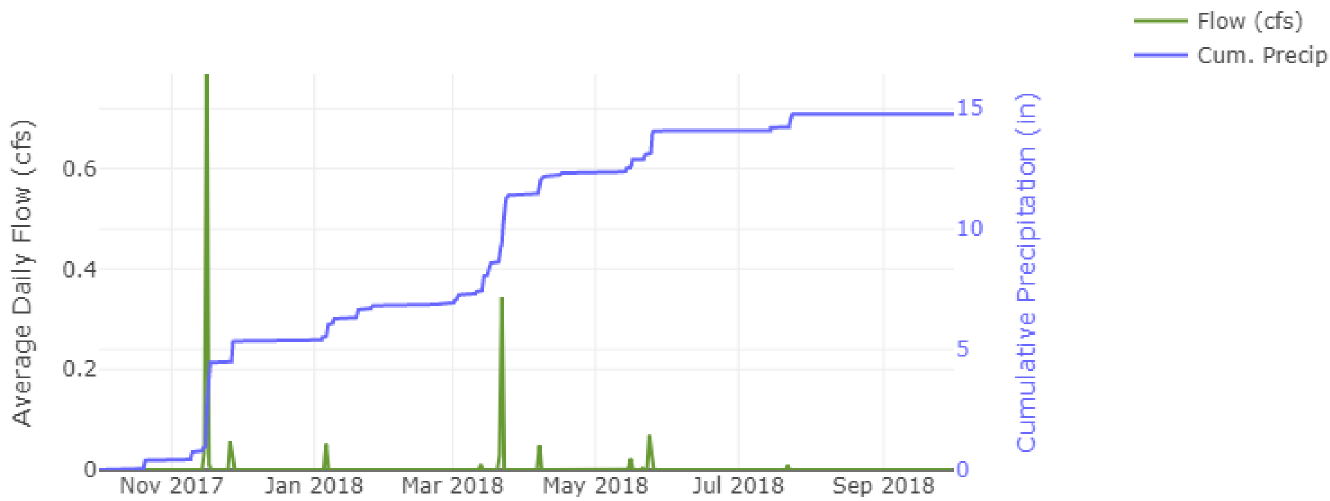

Figure 38 Average daily flow and cumulative precipitation at the Pasadena outfall, WY18.

- 14.78 inches of total precipitation (6.95 in the fall/winter, 7.14 in the spring, and 0.69 in the summer) were recorded at the Bellevue weather station.
- 36 precipitation events occurred (18 fall/winter events, 15 spring events, 3 summer events).
- The largest storm, with 3.5 inches of precipitation, was an atmospheric river rain event that occurred from November 15-17, 2017.
- 80% of storms were less than half an inch.
- Highest average daily flows occurred in November of the fall/winter season.
- There were zero days of snowmelt during the spring.
- The highest instantaneous peak precipitation was 0.19 inches in 5 minutes during the thunderstorm on July 22, 2018.
- The highest instantaneous peak flow was 2.19 cfs during the rain event on May 24, 2018.
- The November 15-17, 2017 atmospheric river rain event produced the most runoff (71,917 cf).

Daily flow and FSP EMC summaries at the Pasadena outfall are presented in Figure 39. Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

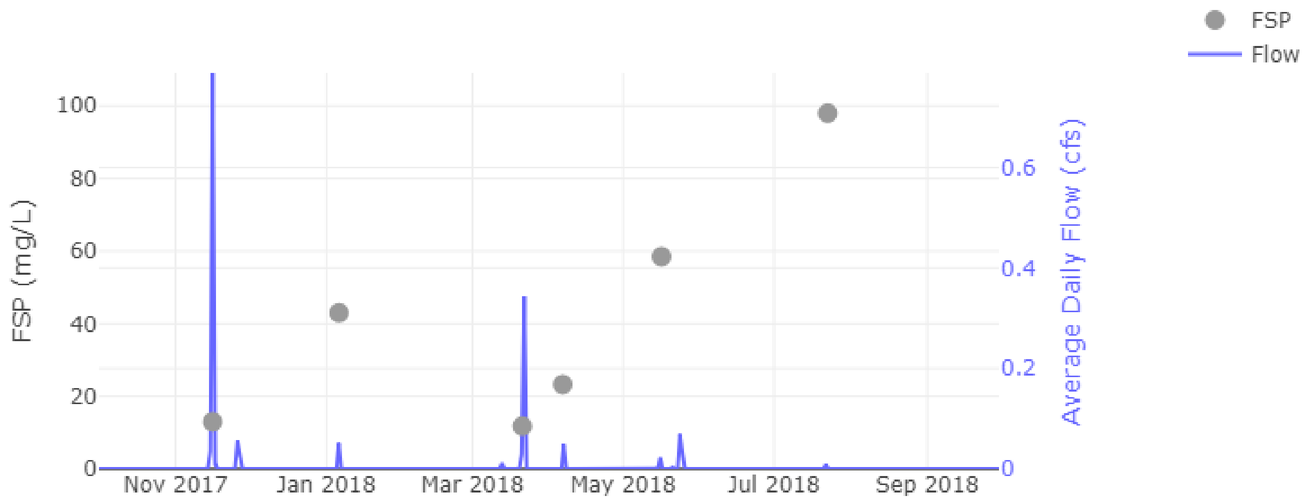

Figure 39 Daily outflow and FSP EMC summary at the Pasadena outfall, WY18.

- Six events were sampled for FSP (two in the fall/winter, three in the spring, one in the summer)
- The highest FSP EMC occurred during the thunderstorm on July 22, 2018.
- The highest FSP loads occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest FSP EMCs occurred during the atmospheric river rain event from November 15-17, 2017 and the rain on snow event from March 21-22, 2018.
- The lowest FSP load occurred during the thunderstorm on the July 22, 2018.

The daily flow and TN EMC summaries for the Pasadena outfall are presented in Figure 40. Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

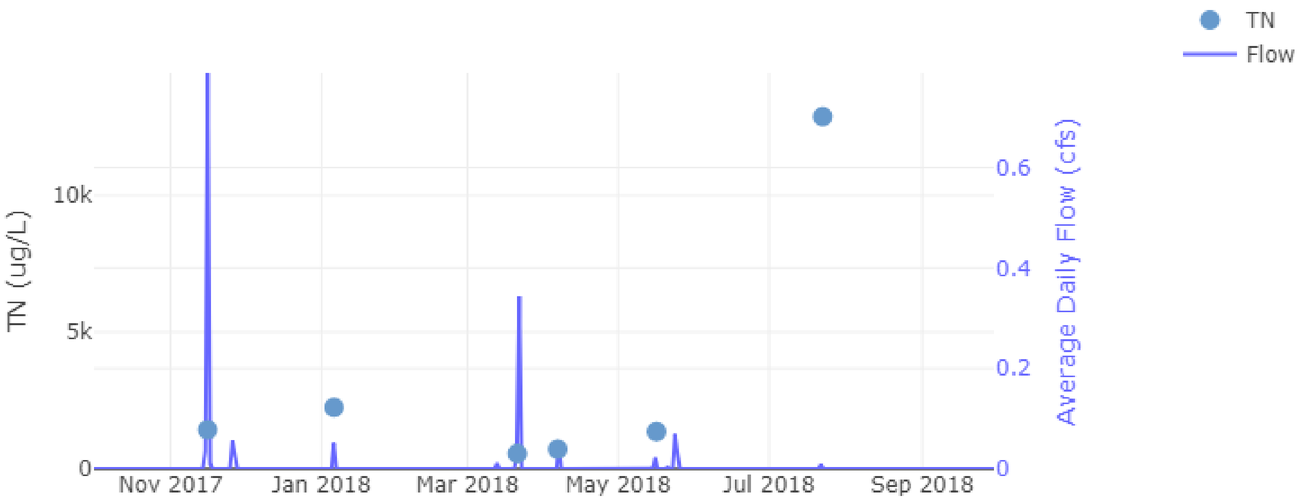

Figure 40 Daily outflow and TN EMC summary at the Pasadena outfall, WY18.

- Six events were sampled for TN (two in the fall/winter, three in the spring, one in the summer).
- The highest TN EMC occurred during the thunderstorm on July 22, 2018.
- The highest TN loads occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest TN EMC occurred during the rain on snow event from March 21-22, 2018.
- The lowest TN load occurred during the rain event on May 16, 2018.

The daily flow and TP EMC summary for the Pasadena outflow are presented Figure 41. Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

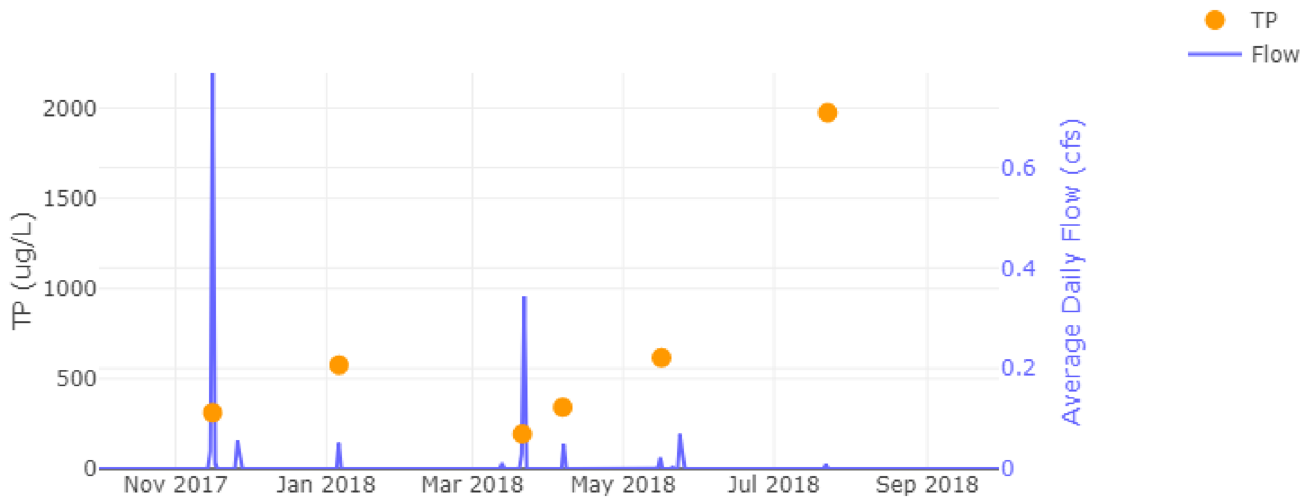

Figure 41 Daily outflow and TP EMC summary at the Pasadena outfall, WY18.

- Six events were sampled for TP (two in the fall/winter, three in the spring, one in the summer)
- The highest TP EMC occurred during the thunderstorm on July 22, 2018.
- The highest TP loads occurred during the atmospheric river rain event on November 15-17, 2017.
- The lowest TP EMC occurred during the rain on snow event from March 21-22, 2018.
- The lowest TP loads occurred during the rain event on May 16, 2018.

Seasonal load as a fraction of the water year load for the Pasadena outflow are presented in 0. Event loads are presented in tabular form in Table 10.

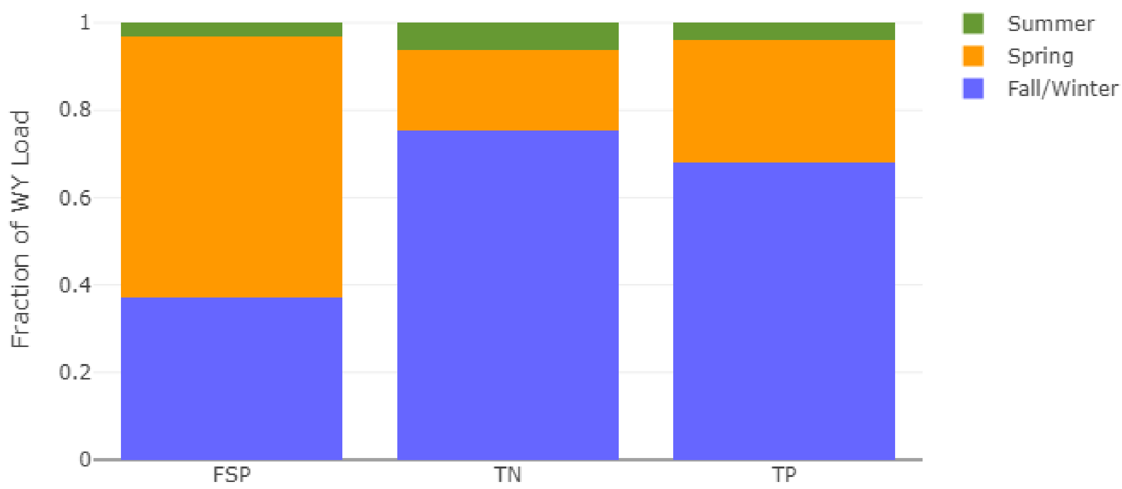

Figure 42 Seasonal load as a fraction of the water year load at the Pasadena outfall, WY18.

- The largest fraction of FSP load was generated in the spring.
- The largest fraction of TN was generated in the fall/winter.
- The largest fraction of TP was generated in the fall/winter.
- The smallest fractions of FSP, TN and TP loads were generated in the summer.

Six events were sampled at Pasadena in WY18. Event summary data for the Pasadena outfall is presented in Table 10.

Table 10 Event summary data at the Pasadena outfall, WY18

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)
PO	Fall/Winter	11/15/2017 22:50	11/17/2017 04:35	29:45	71,917	2.10	102	3.54	Rain	100%	13	58	1,436	6.45	312	1.40
PO	Fall/Winter	1/6/2018 01:55	1/6/2018 05:40	3:45	4,437	0.73	111	0.54	Rain on snow	100%	43	12	2,251	0.62	576	0.16
PO	Spring	3/21/2018 03:55	3/22/2018 19:15	63:20	32,344	1.16	380	2.83	Rain on Snow	100%	12	24	562	1.13	194	0.39
PO	Spring	4/6/2018 13:00	4/7/2018 08:50	19:50	4,266	0.70	853	0.78	Rain on Snow	100%	23	6.2	722	0.19	342	0.09
PO	Spring	5/16/2018 11:50	5/16/2018 14:00	2:10	1,951	0.70	390	0.36	Rain	100%	59	7.1	1,366	0.17	616	0.08
PO	Summer	7/22/2018 17:10	7/22/2018 19:05	1:55	803	0.64	1,929	0.36	Thunderstorm	100%	98	4.9	12,879	0.65	1,975	0.10

6.2.5 Speedboat

Figure 43 shows the average daily flow and cumulative precipitation for WY18 at the Speedboat catchment outfall.

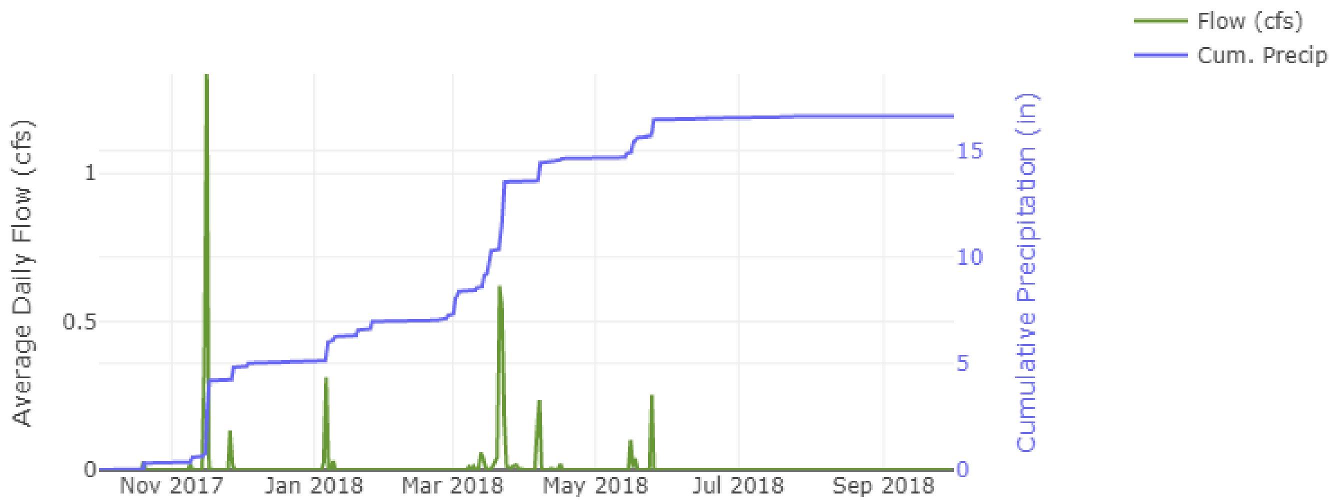

Figure 43 Average daily flow and cumulative precipitation at the Speedboat catchment outfall, WY18.

- 16.61 inches of total precipitation (7.27 in the fall/winter, 9.19 in the spring, and 0.15 in the summer) were recorded at the TERC weather station.
- 33 precipitation events (16 fall/winter events, 15 spring events, 2 summer events).
- The largest storm, with 3.5 inches of precipitation, was an atmospheric river rain event that occurred from November 15-17, 2017.
- 73% of storms were less than half an inch.
- Highest average daily flows occurred in November of the fall/winter season.
- 24 days of intermittent snowmelt occurred in the fall/winter and spring (October - May).
- Thunderstorms occurred during June and July and produced a small amount of flow.
- The highest instantaneous peak precipitation was 0.09 inches in 5 minutes during the rain event from May 24-25, 2018.
- The highest instantaneous peak flow was 8.33 cfs during the atmospheric river rain event from November 15-17, 2017.
- The November 15-17, 2017 atmospheric river rain event produced the most runoff (146,973 cf).

Daily flow and the FSP EMC summary at Speedboat are presented in Figure 44. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

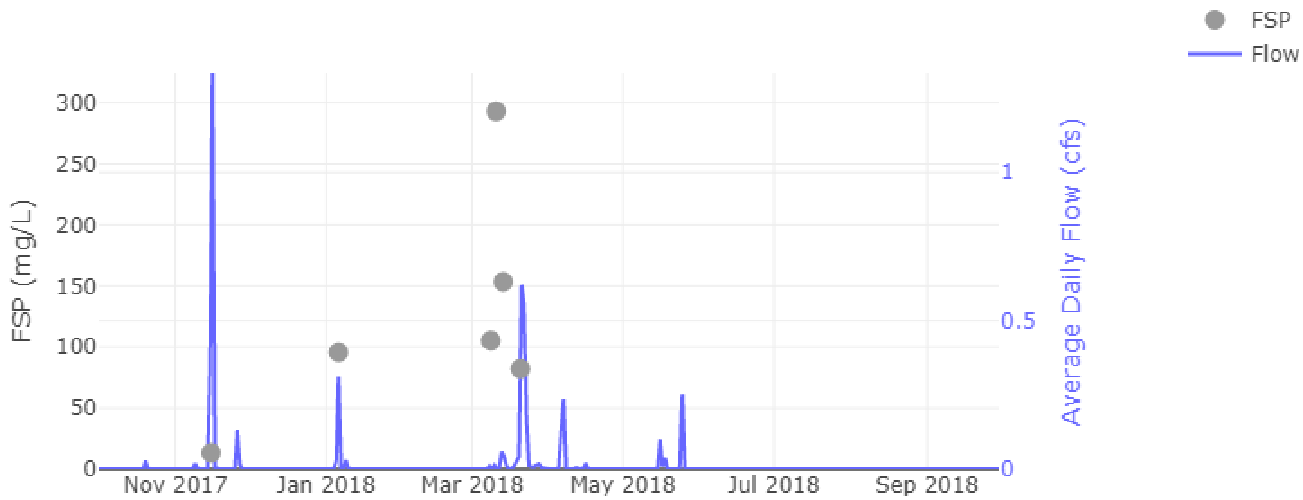

Figure 44 Daily flow and FSP EMC summary at the Speedboat catchment outfall, WY18.

- Six events were sampled for FSP (two in the fall/winter, four in the spring, and zero in the summer).
- The highest FSP EMC occurred during the relatively small rain on snow event from March 10th, 2018.
- The highest FSP load occurred during the rain on snow event from March 20-23, 2018.
- The lowest FSP EMC occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest FSP load occurred during the post-event snowmelt event on March 8, 2018.

Daily flow and the TN EMC summary are presented in Figure 45. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

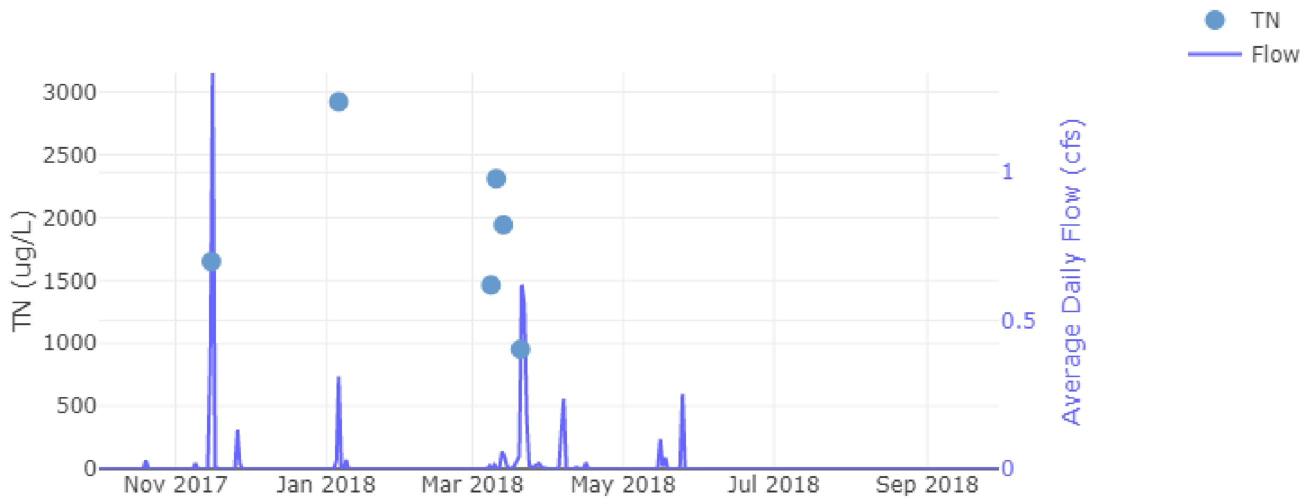

Figure 45 Daily flow and TN EMC summary at the Speedboat catchment outfall, WY18.

- Six events were sampled for TN (two in the fall/winter, four in the spring, and zero in the summer).
- The highest TN EMC occurred during the rain on snow event from January 5-6, 2018.
- The highest TN load occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest TN EMC occurred during the March 20-23, 2018 rain on snow event.
- The lowest TN load occurred during the post-event snowmelt event on March 8, 2018.

Daily flow and the TP EMC summary are presented in Figure 46. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

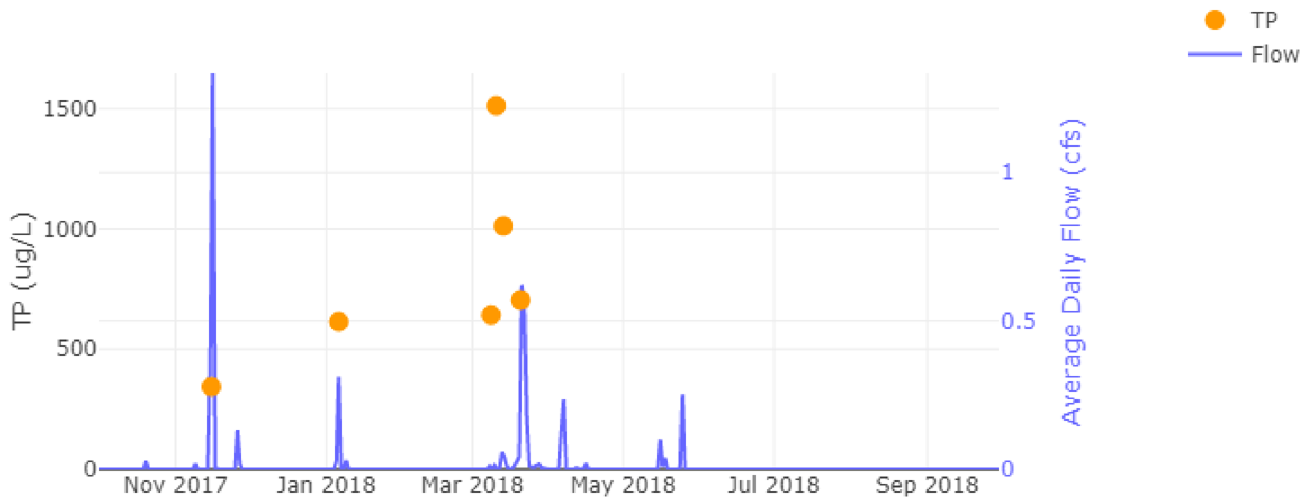

Figure 46 Daily flow and TP EMC summary at the Speedboat catchment outfall, WY18.

- Six events were sampled for TP (two in the fall/winter, four in the spring, and zero in the summer).
- The highest TP EMC occurred during the rain event on March 10th, 2018.
- The highest TP load occurred during the rain on snow event from March 20-23, 2018.
- The lowest TP EMC occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest TP load occurred during the post-event snowmelt event on March 8, 2018.

Seasonal load as a fraction of the water year load is presented in Figure 47. Event loads are presented in tabular form in Table 11.

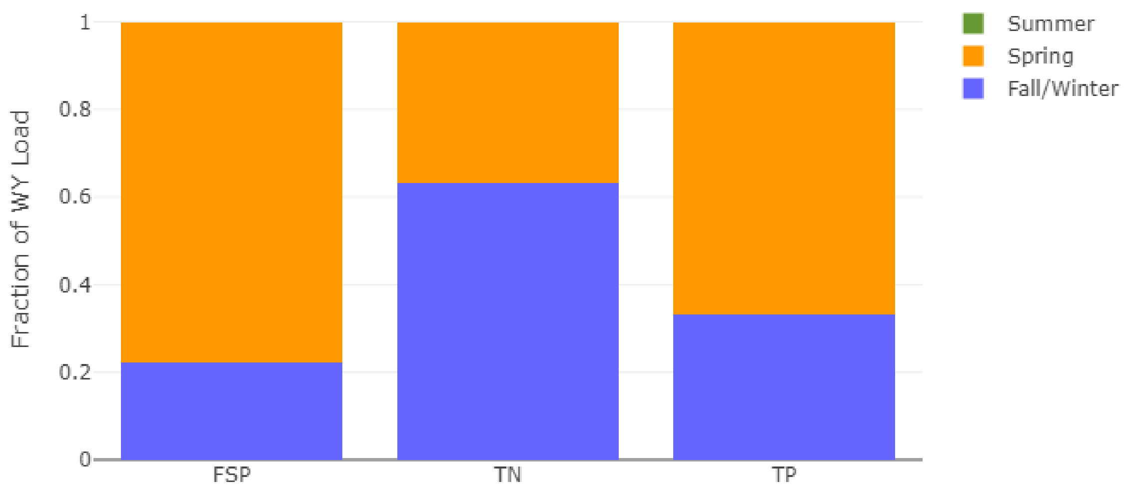

Figure 47 Seasonal load as a fraction of the water year load at the Speedboat catchment outfall, WY18.

- The largest fraction of FSP loads was generated in the spring.
- The largest fraction of TN loads was generated in the fall/winter.
- The largest fraction of TP loads was generated in the spring.
- Summer produced no loads for FSP, TN, or TP because there was insufficient runoff for sampling.

Six events were sampled at Speedboat in WY18. Event summary data is presented in Table 11.

Table 11 Event summary data at the Speedboat catchment outfall, WY18

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	11/15/2017 10:50	11/17/2017 05:40	42:50	147,207	8.35	2,727	3.49	Rain	100%	13	123	1,652	15.2	344	3.16
SB	Fall/Winter	1/5/2018 23:10	1/6/2018 06:25	7:15	29,323	4.28	2,644	0.88	Rain on snow	100%	96	175	2,923	5.35	614	1.12
SB	Spring	3/8/2018 11:40	3/8/2018 19:55	8:15	937	0.10	233	0.00	Post-event Snowmelt	100%	105	6.1	1,464	0.09	642	0.04
SB	Spring	3/10/2018 15:35	3/10/2018 22:00	6:25	1,145	0.15	479	0.17	Rain on snow	100%	293	21	2,311	0.17	1,512	0.11
SB	Spring	3/13/2018 13:10	3/14/2018 05:40	16:30	5,819	0.55	1,357	1.74	Rain on snow	100%	153	56	1,943	0.71	1,012	0.37
SB	Spring	3/20/2018 12:15	3/23/2018 05:30	65:15	106,275	2.06	1,880	3.23	Rain on snow	100%	82	545	952	6.32	704	4.67

6.2.6 Tahoe Valley

Figure 48 shows the average daily flow and cumulative precipitation for WY18 at the Tahoe Valley catchment outfall.

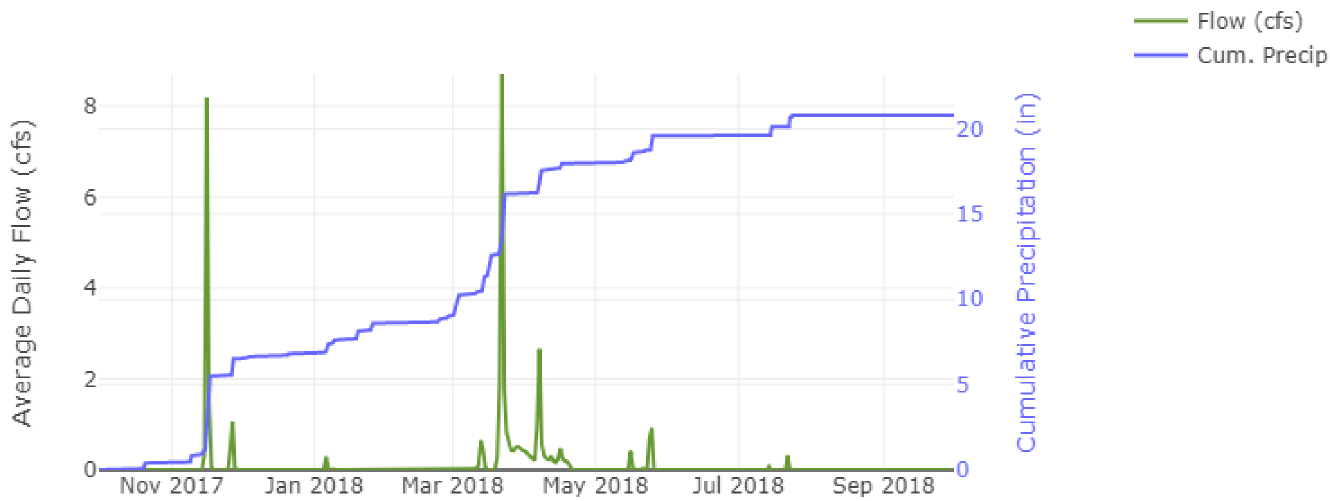

Figure 48 Average daily flow and cumulative precipitation at the Tahoe Valley catchment outfall, WY18.

- 20.8 inches of total precipitation (9.02 in the fall/winter, 10.61 in the spring, 1.18 in the summer) were recorded at the Raph's Shop weather station.
- 37 precipitation events occurred (19 fall/winter events, 15 spring events, 3 summer events).
- The largest storm, with over 4 inches of precipitation, occurred during an atmospheric river event from November 15-17, 2017.
- 76% of storms were less than half an inch.
- Highest average daily flows occurred in the spring season (March -May).
- 67 days of continuous snowmelt runoff occurred in the spring.
- The highest instantaneous peak precipitation was 0.24 inches in 5 minutes during a summer thunderstorm on July 14, 2018.
- The highest instantaneous peak flow was 13.8 cfs during a rain on snow event on March 22, 2018.
- The March 20-23, 2018 rain on snow event produced the most runoff (1,048,351 cf).

Daily flow and the FSP EMC summary at Tahoe Valley are presented in Figure 49. Table 12 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

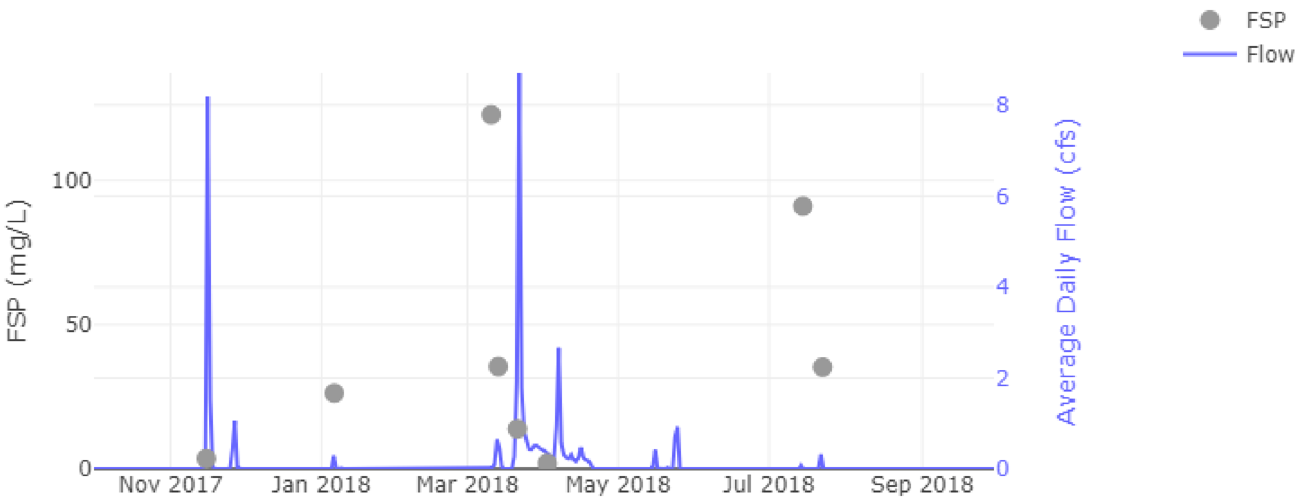

Figure 49 Daily flow and FSP EMC summary at the Tahoe Valley catchment outfall, WY18.

- Eight events were sampled for FSP (two in the fall/winter, four in the spring, and two in the summer).
- The highest FSP EMC occurred during the rain on snow event from March 10-11, 2018.
- The highest FSP load occurred during the rain on snow event from March 20-23, 2018.
- The lowest FSP EMC occurred during the spring snowmelt event from April 2-5, 2018.
- The lowest FSP load occurred during the rain on snow event from March 10-11, 2018.

Daily flow and the TN EMC summary at Tahoe Valley are presented in Figure 50. Table 12 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

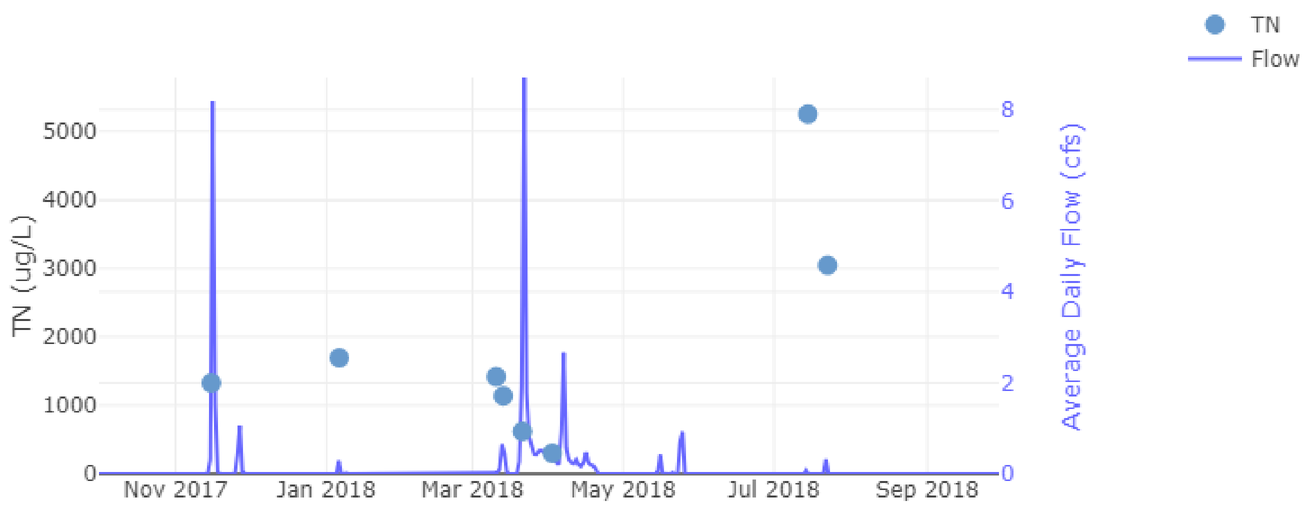

Figure 50 Daily flow and TN EMC summary at the Tahoe Valley catchment outfall, WY18.

- Eight events were sampled for TN (two in the fall/winter, four in the spring, and two in the summer).
- The highest TN EMC occurred during the summer thunderstorm on July 14, 2018.
- The highest TN load occurred during the atmospheric river rain event from November 15-18, 2017.
- The lowest TN EMC occurred during the spring snowmelt event from April 2-5, 2018.
- The lowest TN load occurred during the rain on snow event from March 10-11, 2018.

Daily flow and the TP EMC summary at Tahoe Valley are presented in Figure 51. Table 12 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

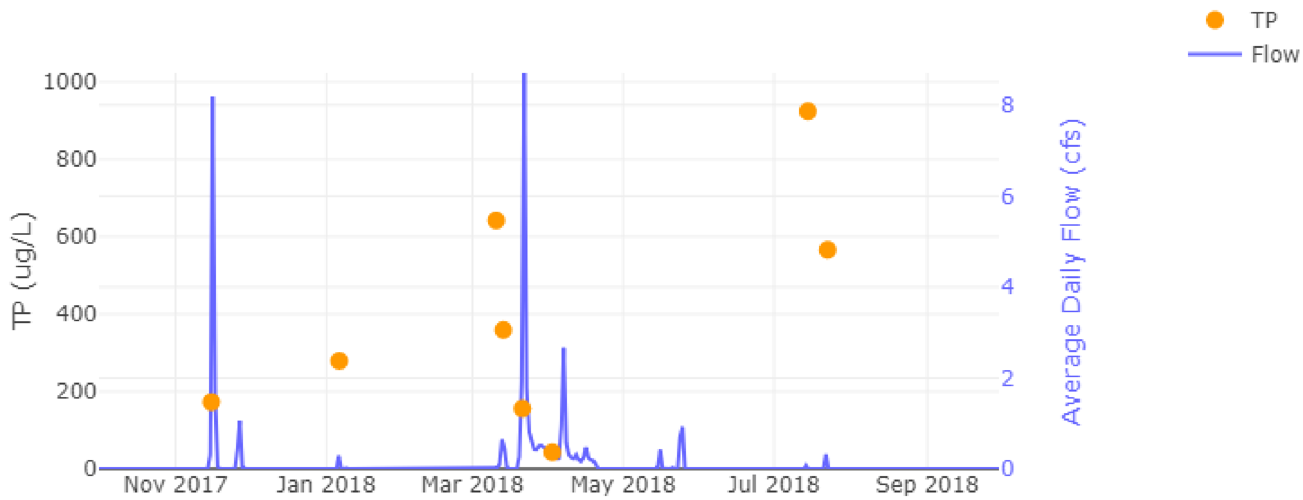

Figure 51 Daily flow and TP EMC summary at the Tahoe Valley catchment outfall, WY18.

- Eight events were sampled for TP (two in the fall/winter, four in the spring, and two in the summer).
- The highest TP EMC occurred during the summer thunderstorm on July 14, 2018.
- The highest TP load occurred during the rain on snow event from March 20-23, 2018.
- The lowest TP EMC occurred during the spring snowmelt from April 2-5, 2018.
- The lowest TP load occurred during the rain on snow event from March 10-11, 2018.

Seasonal load as a fraction of the water year load at Tahoe Valley is presented in Figure 52. Event loads are presented in tabular form in Table 12.

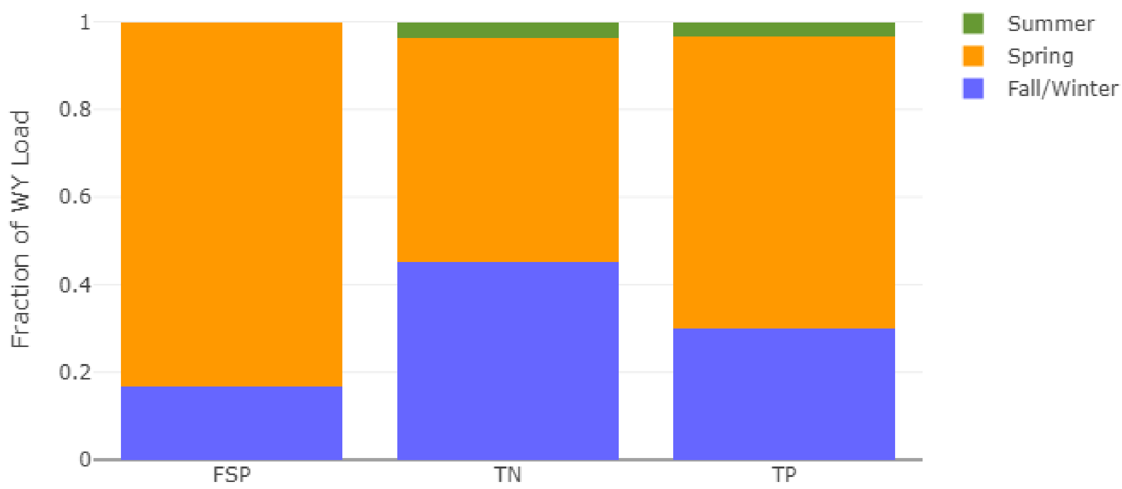

Figure 52 Seasonal load as a fraction of the water year load at the Tahoe Valley catchment outfall, WY18.

- The largest fraction of FSP loads was generated in the spring.
- The fraction of FSP generated in the summer was negligible and is not visible.
- The largest fraction of TN loads was generated in the fall/winter.
- The largest fraction of TP loads was generated in the spring.

Ten events were sampled at Tahoe Valley in WY18. Event summary data is presented in Table 12.

Table 12 Event summary data at the Tahoe Valley catchment outfall, WY18

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	11/15/2017 8:30	11/18/2017 8:00	71:30	860,431	11.94	297	4.35	Rain	100%	3.6	193	1,327	71.3	173	9.29
TV	Fall/Winter	1/6/2018 1:40	1/6/2018 15:55	14:15	24,097	1.42	263	0.46	Rain on snow	100%	26	40	1,693	2.55	279	0.42
TV	Spring	3/10/2018 13:25	3/11/2018 4:25	15:00	678	0.06	0.1	0.15	Rain on snow	100%	123	5.2	1,418	0.06	642	0.03
TV	Spring	3/13/2018 12:20	3/14/2018 9:45	21:25	67,815	3.41	597	2.15	Rain on snow	100%	36	150	1,138	4.82	359	1.52
TV	Spring	3/20/2018 16:05	3/23/2018 15:00	70:55	1,054,418	13.83	702	3.60	Rain on snow	100%	14	915	619	40.7	156	10.3
TV	Spring	4/2/2018 6:25	4/5/2018 10:15	75:50	61,248	0.40	146	0.00	Non-event Snowmelt	100%	2.0	7.6	302	1.15	43	0.16
TV	Summer	7/14/2018 17:30	7/14/2018 21:05	3:35	1,750	1.00	43	0.52	Thunderstorm	100%	91	10	5,249	0.57	924	0.10
TV	Summer	7/22/2018 16:45	7/22/2018 23:00	6:15	27,317	3.55	92	0.52	Thunderstorm	100%	35	60	3,045	5.19	566	0.97

6.2.7 Tahoma

Figure 53 shows the average daily flow and cumulative precipitation for WY18 at the Tahoma catchment outfall.

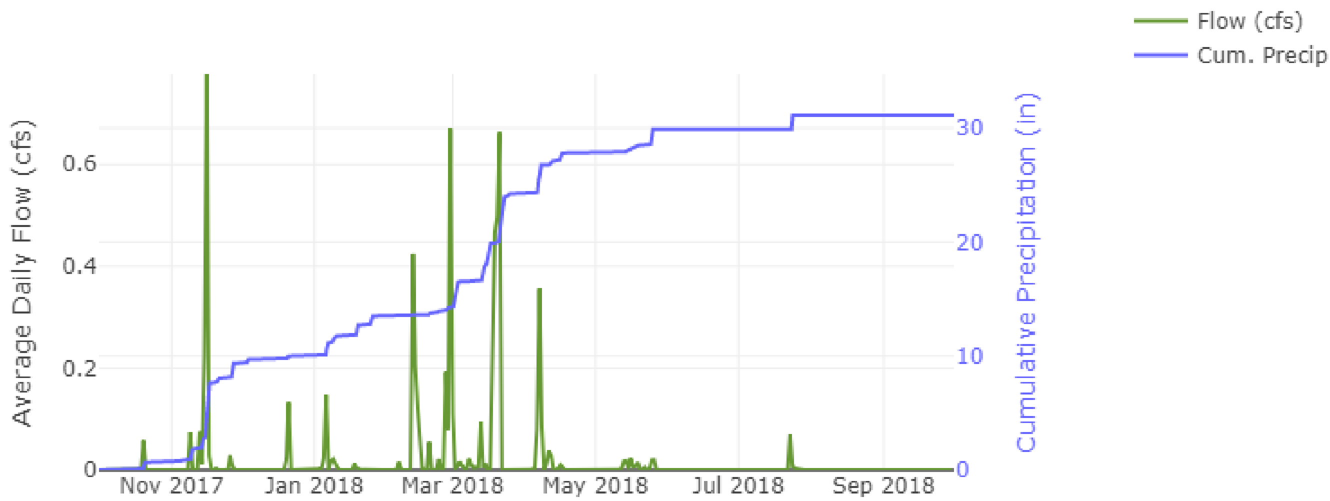

Figure 53 Average daily flow and cumulative precipitation at the Tahoma catchment outfall, WY18.

- 31.11 inches of total precipitation (14.22 in the fall/winter, 15.67 in the spring, 1.22 in the summer) were recorded at the El Dorado County Yard (EDCY) weather station.
- 39 precipitation events occurred (21 fall/winter events, 17 spring events, 1 summer event).
- The largest storm, with over almost 5 inches of precipitation, occurred during an atmospheric river event from November 15-17, 2017.
- 59% of storms were less than half an inch.
- Highest average daily flows occurred in November of the fall/winter season.
- 43 days of continuous snowmelt runoff occurred in the spring.
- The highest instantaneous peak precipitation was 0.29 inches in 5 minutes during a summer thunderstorm on July 23, 2018.
- The highest instantaneous peak flow was 5.10 cfs during the thunderstorm event on July 23, 2018.
- The November 15-17, 2017 atmospheric river rain event produced the most runoff (103,300 cf).

Tahoma was backwatered beginning in mid-March due to high lake levels and could not be sampled for the rest of the water year.

Daily flow and the FSP EMC summary at Tahoma are presented in Figure 54. Table 13 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

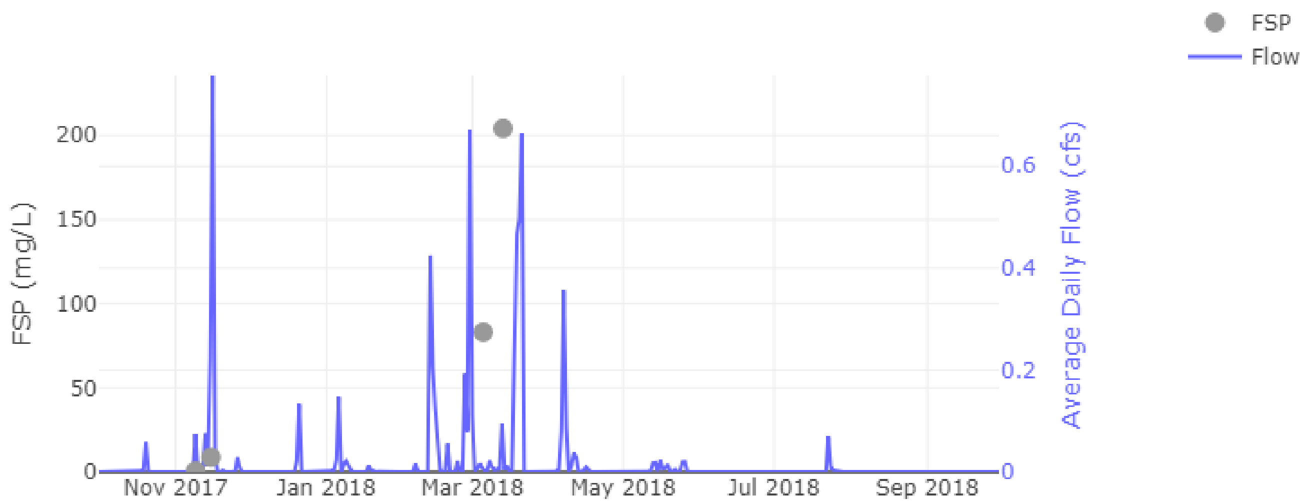

Figure 54 Daily flow and FSP EMC summary at the Tahoma catchment outfall, WY18.

- Four events were sampled for FSP (two in the fall/winter, two in the spring, and zero in the summer).
- The highest FSP EMC and load occurred during the rain on snow event on March 13, 2018.
- The lowest FSP EMC and load occurred during the rain event from November 9-10, 2017.

Daily flow and the TN EMC summary at Tahoma are presented in Figure 55. Table 13 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

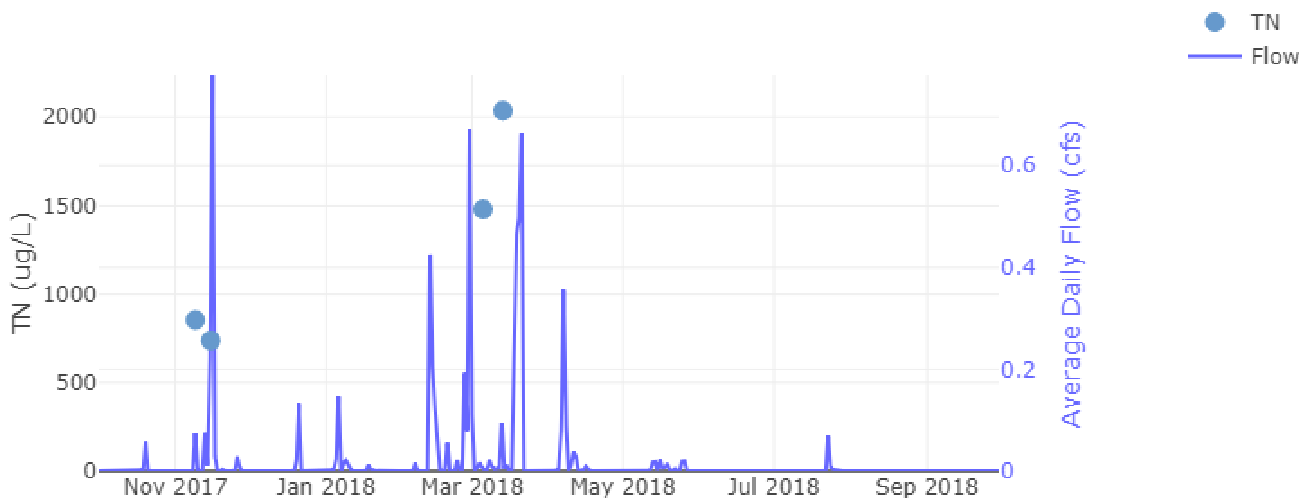

Figure 55 Daily flow and TN EMC summary at the Tahoma catchment outfall, WY18.

- Four events were sampled for TN (two in the fall/winter, two in the spring, and zero in the summer).
- The highest TN EMC occurred during the rain on snow event on March 13, 2018.
- The highest TN load occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest TN EMC occurred during the rain event from November 15-17, 2017.
- The lowest TN load occurred during the post event snowmelt from March 5-6, 2018.

Daily flow and the TP EMC summary at Tahoma are presented in Figure 56. Table 13 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

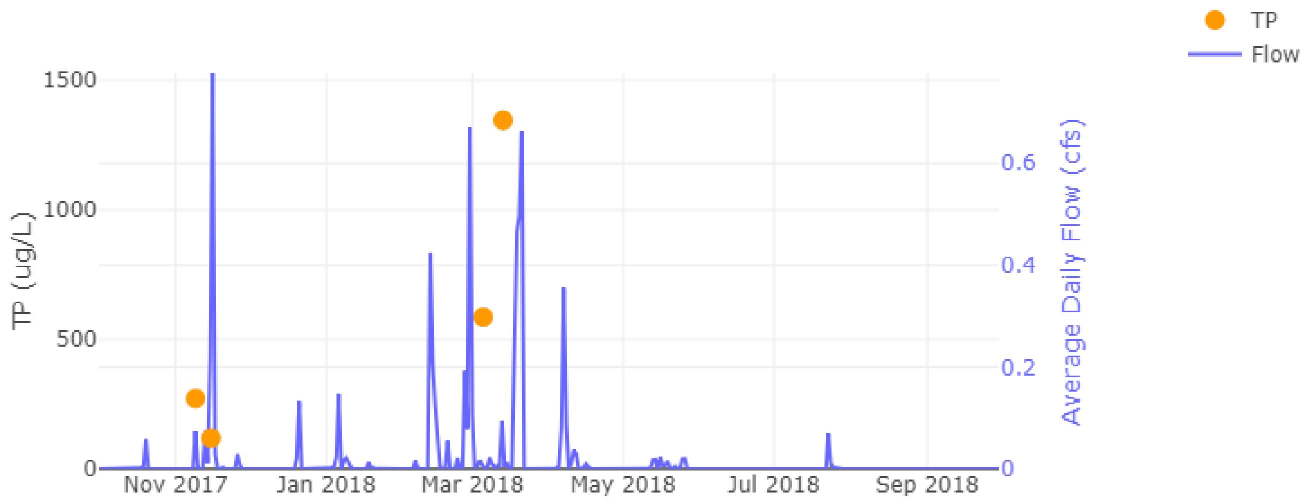

Figure 56 Daily flow and TP EMC summary at the Tahoma catchment outfall, WY18.

- Four events were sampled for TP (two in the fall/winter, two in the spring, and zero in the summer).
- The highest TP EMC occurred during the rain on snow event on March 13, 2018.
- The highest TP load occurred during the rain event from November 15-17, 2017.
- The lowest TP EMC occurred during the rain event from November 15-17, 2017.
- The lowest TP load occurred during the post event snowmelt from March 5-6, 2018.

Seasonal load as a fraction of the water year load at Tahoma is presented in Figure 57. Event loads are presented in tabular form in Table 13.

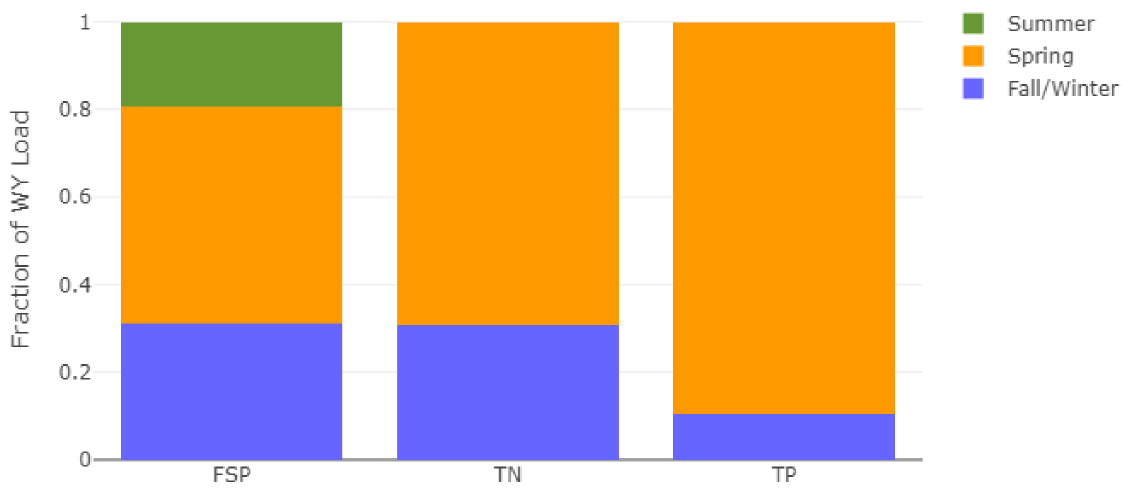

Figure 57 Seasonal load as a fraction of the water year load at the Tahoma catchment outfall, WY18.

- The largest fraction of FSP loads was generated in the spring.
- The fraction of FSP generated in the summer was estimated from continuous turbidity.
- The largest fraction of TN loads was generated in the spring.
- The largest fraction of TP loads was generated in the spring.

Four events were sampled at Tahoma in WY18. Event summary data is presented in Table 13.

Table 13 Event summary data at the Tahoma catchment outfall, WY18

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	11/9/2017 00:55	11/10/2017 01:55	25:00	7,966	0.52	1,641	0.64	Rain	100%	0.5	0.2	854	0.42	272	0.14
TA	Fall/Winter	11/15/2017 07:30	11/17/2017 09:30	50:00	103,300	2.14	856	4.93	Rain	100%	8.7	56	738	4.76	119	0.77
TA	Spring	3/5/2018 09:00	3/6/2018 18:00	33:00	525	0.03	1,259	0.00	Post-event Snowmelt	100%	83	2.7	1,479	0.05	586	0.02
TA	Spring	3/13/2018 08:15	3/13/2018 19:02	10:47	7,859	0.56	777	3.30	Rain on snow	100%	204	100	2,036	1.00	1,346	0.66

6.2.8 Upper Truckee

Figure 58 shows the average daily flow and cumulative precipitation for WY18 at the Upper Truckee catchment outfall.

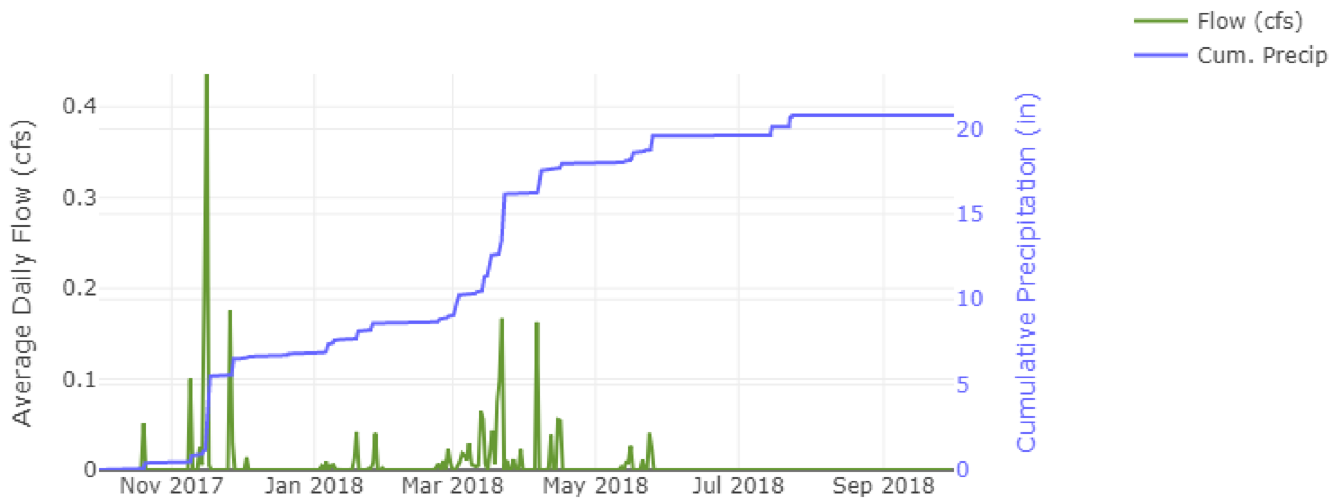

Figure 58 Average daily flow and cumulative precipitation at the Upper Truckee catchment outfall, WY18.

- 20.8 inches of total precipitation (9.02 in the fall/winter, 10.61 in the spring, 1.18 in the summer) were recorded at the Raph's Shop weather station.
- 37 precipitation events occurred (19 fall/winter events, 15 spring events, 3 summer events).
- The largest storm, with over 4 inches of precipitation, occurred during an atmospheric river event from November 15-17, 2017.
- 76% of storms were less than half an inch.
- Highest average daily flows occurred in November of the fall/winter season.
- 29 days of intermittent snowmelt runoff occurred in the fall/winter and spring.
- The highest instantaneous peak precipitation was 0.24 inches in 5 minutes during the summer thunderstorm on July 14, 2018.
- The highest instantaneous peak flow was 1.84 cfs during the rain event on May 24, 2018.
- The November 15-17, 2017 atmospheric river rain event produced the most runoff (55,287 cf).

Daily flow and the FSP EMC summary at Upper Truckee are presented in Figure 59. Table 14 presents this data in tabular form. Table 14 also presents the load data referenced in some bullet points below.

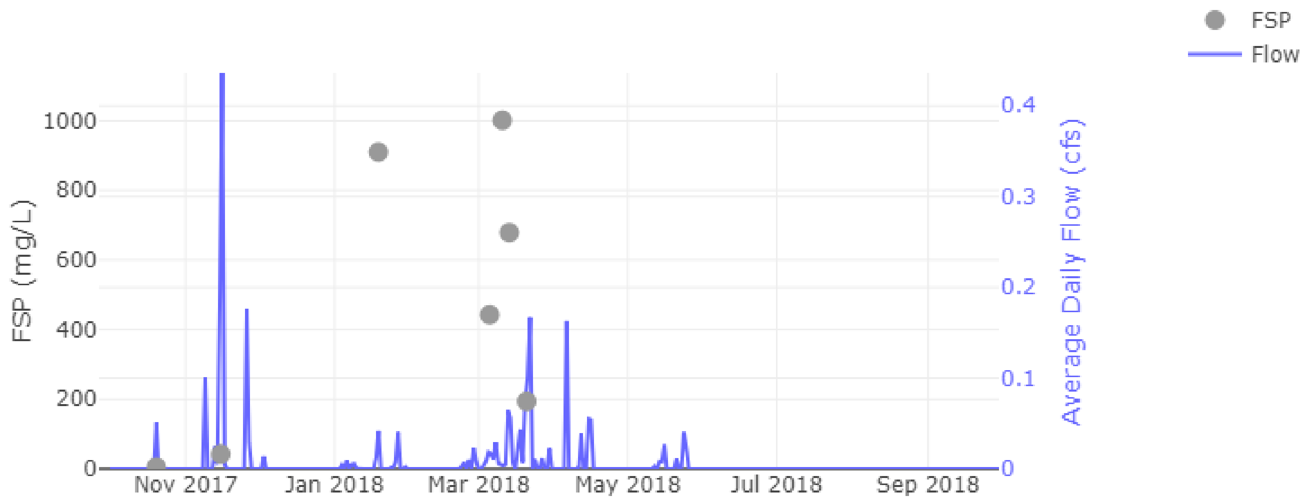

Figure 59 Daily flow and FSP EMC summary at the Upper Truckee catchment outfall, WY18.

- Seven events were sampled for FSP (three in the fall/winter, four in the spring, and zero in the summer).
- The highest FSP EMC occurred during the rain on snow event on March 10, 2018.
- The highest FSP loads occurred during the rain on snow event from March 20-22, 2018.
- The lowest FSP EMC and load occurred during the rain event on October 20, 2017.

Daily flow and the TN EMC summary at Upper Truckee are presented in Figure 60. Table 14 presents this data in tabular form. Table 14 also presents the load data referenced in some bullet points below.

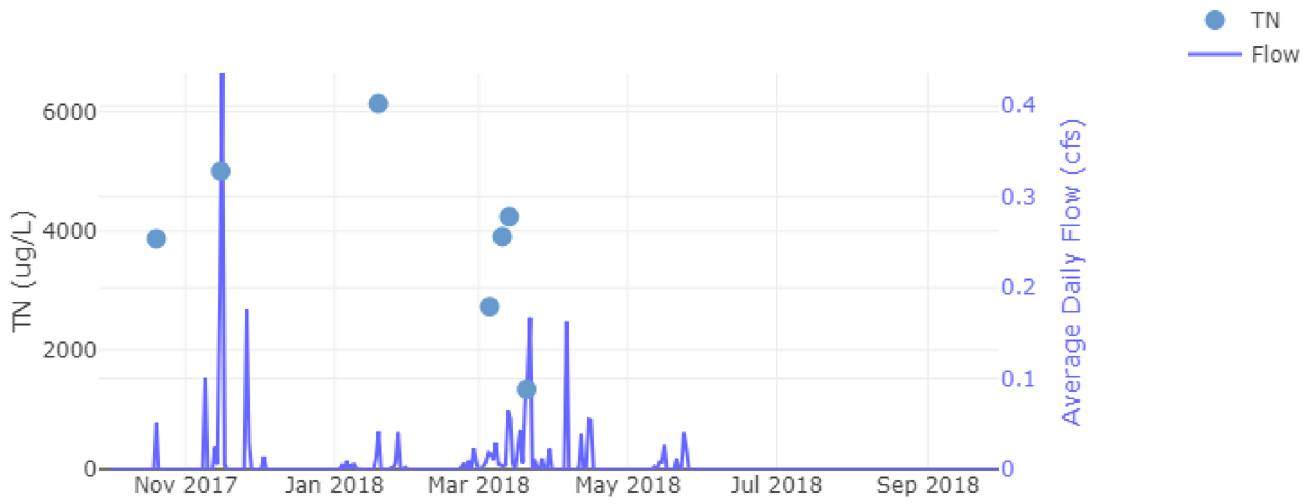

Figure 60 Daily flow and TN EMC summary at the Upper Truckee catchment outfall, WY18.

- Seven events were sampled for TN (three in the fall/winter, four in the spring, and zero in the summer).
- The highest TN EMC occurred during a rain on snow event on January 18-19, 2018.
- The highest TN load occurred during the atmospheric river rain event on November 15-17, 2017.
- The lowest TN EMC occurred during the rain on snow event from March 20-22, 2018.
- The lowest TN load occurred during the post-event snowmelt on March 5, 2018.

Daily flow and the TN EMC summary at Upper Truckee are presented in Figure 61. Table 14 presents this data in tabular form. Table 14 also presents the load data referenced in some bullet points below.

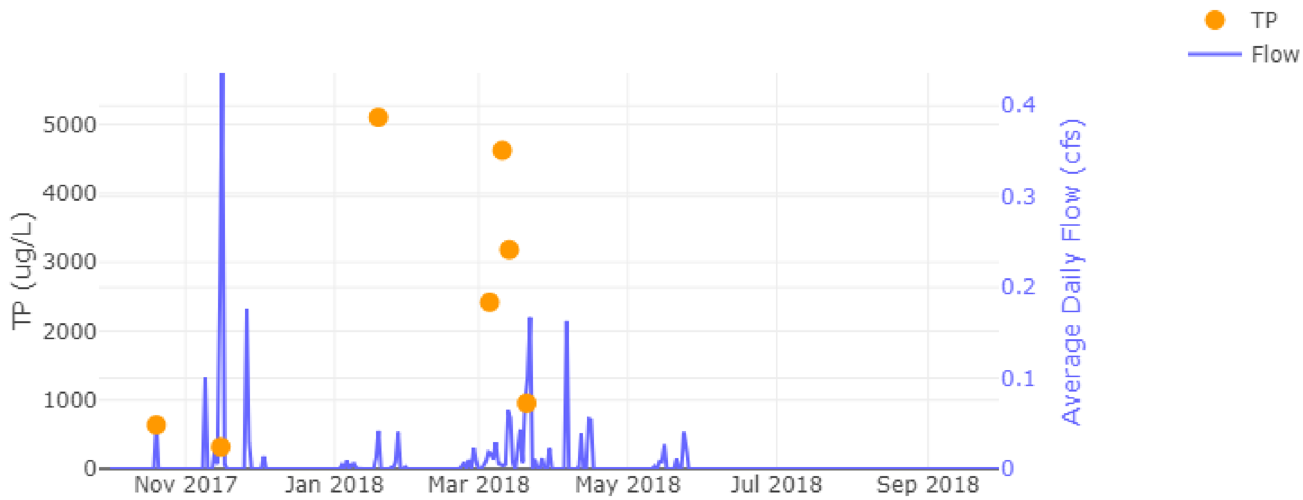

Figure 61 Daily flow and TP EMC summary at the Upper Truckee catchment outfall, WY18.

- Seven events were sampled for TP (three in the fall/winter, four in the spring, and zero in the summer).
- The highest TP EMC occurred during the rain on snow event from January 18-19, 2018.
- The highest TP load occurred during the rain on snow event from March 20-22, 2018.
- The lowest TP EMC occurred during the atmospheric river rain event from November 15-17, 2017.
- The lowest TP load occurred during the post-event snowmelt on March 5, 2018.

Seasonal load as a fraction of the water year load at Upper Truckee is presented in Figure 62. Event loads are presented in tabular form in Table 14.

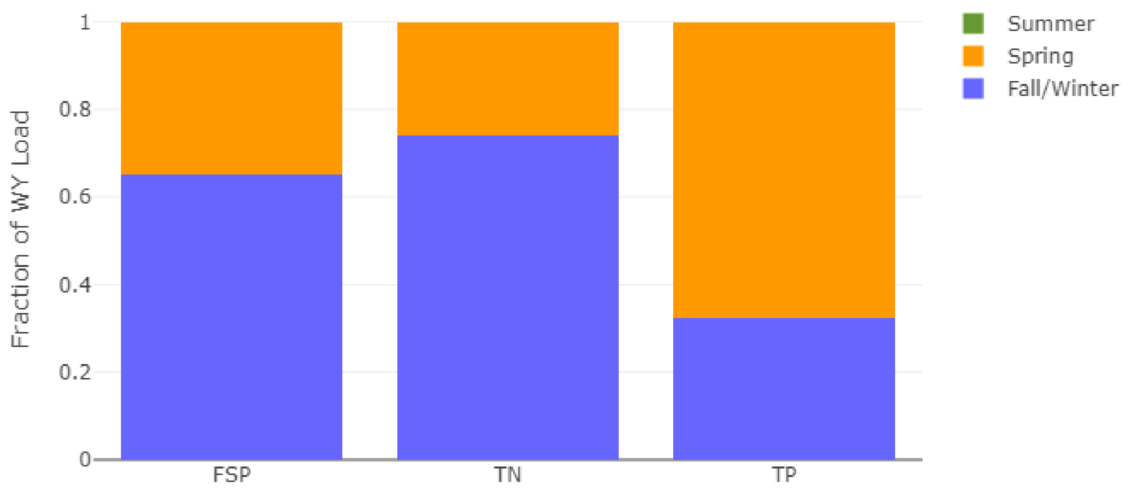

Figure 62 Seasonal load as a fraction of the water year load at the Upper Truckee catchment outfall, WY18.

- 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 spring.
- Summer produced no loads for FSP, TN, or TP because there was no runoff.

Seven events were sampled at Upper Truckee in WY18. Event summary data is presented in Table 14.

Table 14 Event summary data at the Upper Truckee catchment outfall, WY18

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	10/20/2017 00:40	10/20/2017 04:30	3:50	4,399	0.51	28	0.40	Rain	100%	5.2	1.4	3,871	1.06	638	0.18
UT	Fall/Winter	11/15/2017 07:40	11/17/2017 01:40	42:00	54,087	1.25	2,368	4.35	Rain	100%	43	144	5,005	16.9	319	1.08
UT	Fall/Winter	1/18/2018 21:15	1/19/2018 16:30	19:15	3,709	0.33	2,983	0.49	Rain on snow	100%	910	211	6,137	1.42	5,103	1.18
UT	Spring	3/5/2018 11:25	3/5/2018 16:15	4:50	685	0.24	784	0.00	Post-event Snowmelt	100%	443	19	2,731	0.12	2,419	0.10
UT	Spring	3/10/2018 12:50	3/10/2018 21:45	8:55	1,026	0.11	0.1	0.15	Rain on snow	100%	1,001	64	3,905	0.25	4,624	0.30
UT	Spring	3/13/2018 12:35	3/13/2018 19:00	6:25	5,595	0.78	357	2.15	Rain on snow	100%	678	237	4,240	1.48	3,181	1.11
UT	Spring	3/20/2018 14:20	3/22/2018 23:35	57:15	29,613	0.71	1,366	3.60	Rain on Snow	100%	194	359	1,343	2.48	955	1.77

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 WY18 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 (Table 16 and Table 17). 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 15). Below is a summary of the maintenance that occurred.

- On August 15-16, 2017, a month and a half prior to the beginning of WY18, the entire system was vactored (splitter chamber, inflow pipes, Contech MFS vault, and Jellyfish vault) and the Jellyfish tentacles were rinsed with high pressure water. The Contech MFS cartridges were not replaced.
- On February 5, 2018 the splitter chamber, Contech MFS vault, and Jellyfish vault were vactored and the MFS cartridges were sprayed down but not replaced. Spraying the MFS cartridges only removes accumulated sediment on the surface of the cartridge and does not constitute a full restoration of performance.
- On May 30, 2018 the splitter chamber and slotted drain above splitter chamber were vactored.
- On July 11, 2018 the splitter chamber, flume inlet chambers, Contech MFS vault, Jellyfish vault, and flume outlet chambers were pressure washed and vactored. The Jellyfish tentacles were power washed. During cleaning one of the tentacle filters broke and was not replaced, so the Jellyfish may not have performed at optimally since that time, though the difference is likely insignificant.

Table 15 presents the seasonal and annual summary data on removal efficiency for each treatment vault at SR431 in WY18.

Table 15 Seasonal and annual efficiency data from the Contech MFS and Jellyfish vaults at SR431, WY18.

Water Year 2018 (October 1, 2017 - September 30, 2018)			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	99	45	27	171	0.96	1.06	0.37	2.38	0.58	0.66	0.07	1.32
	Contech Out	CO	32	12	24	67	0.44	0.20	0.22	0.85	0.34	0.05	0.05	0.44
		Load Reduction	67.2	33.2	3.50	104.0	0.5	0.9	0.15	1.5	0.2	0.6	0.02	0.9
		% Change	-68%	-74%	-13%	-61%	-54%	-81%	-41%	-64%	-42%	-93%	-33%	-67%
SR431	Jellyfish In	JI	130	109	30	268	0.50	0.64	0.35	1.49	0.49	1.21	0.07	1.77
	Jellyfish Out	JO	58	10	18	85	0.65	0.88	0.29	1.81	0.42	0.30	0.07	0.79
		Load Reduction	71.4	99.2	12.40	183.0	(0.1)	(0.2)	0.06	(0.3)	0.1	0.9	(0.00)	1.0
		% Change	-55%	-91%	-41%	-68%	28%	37%	-18%	21%	-15%	-75%	5%	-55%

- Annual removal efficiencies for FSP, TN, and TP at the Contech MFS and for FSP and TP at the Jellyfish all fell between 55% and 68%. However, TN was released from the Jellyfish and increased the TN load by 21%.
- There were very high removal efficiencies (74%-93%) in the spring in both vaults for all three pollutants (with the exception of TN in the Jellyfish).
- The Contech MFS reduced annual FSP loads by 61%.
- The Jellyfish reduced annual FSP loads by 68%.
- Both the Contech MFS and the Jellyfish were least efficient at reducing FSP in the summer and most effective in the spring.
- The Contech MFS reduced annual TN loads by 64%. The greatest TN reduction efficiency occurred in the spring at 81%.
- The Jellyfish increased annual TN loads by 21%.
- The Contech MFS reduced TN and TP more effectively than the Jellyfish in all seasons.
- The Contech MFS reduced annual TP loads by 67%. The greatest TP reduction efficiency occurred in the spring at 93%.
- The Jellyfish reduced annual TP loads by 55%. The greatest TP reduction efficiency occurred in the spring at 75%.

Table 16 presents the efficiency of the Contech MFS at reducing concentrations and loads of all three pollutants for the individual events sampled in WY18.

Table 16 Event efficiency data from the Contech MFS vault at SR431, WY18.

Event Start Date	Event Volume as a % of Total Annual Volume (cf)	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
11/16/2017	25%	209	178	-15%	74	58	-21%	1,218	863	-29%	0.43	0.28	-35%	737	663	-10%	0.26	0.22	-17%
3/20/2018	9%	700	681	-3%	86	25	-71%	948	1,923	103%	0.12	0.07	-39%	19	26	33%	0.002	0.001	-60%
4/6/2018	3%	2,025	408	-80%	82	3.4	-96%	6,408	679	-89%	0.26	0.01	-98%	6,022	1,655	-73%	0.24	0.01	-94%
5/16/2018	3%	205	113	-45%	7.8	1.4	-82%	916	233	-75%	0.03	0.003	-92%	277	376	36%	0.01	0.005	-57%
7/22/2018	4%	119	112	-6%	6.4	4.0	-38%	3,175	3,107	-2%	0.17	0.11	-35%	648	724	12%	0.04	0.03	-26%

- The highest FSP concentration and load reductions occurred during the rain on snow event beginning April 6, 2018 when inflow concentrations were the greatest.
- The lowest FSP concentration reductions occurred during the rain on snow event beginning March 20, 2018.
- The lowest FSP load reductions occurred during the rain event beginning November 16, 2017 when runoff volumes were greatest.
- The highest TN concentration and load reductions occurred during the rain on snow event beginning April 6, 2018 when inflow concentrations were the greatest.
- The lowest TN concentration reduction occurred during the rain on snow event beginning March 20, 2018 when the Contech MFS released higher concentrations of TN at the outflow than came in. However, this did not result in an increase in TN load at the outflow because the vault retained enough runoff volume to result in an overall TN load reduction of 39%
- The lowest TN load reduction occurred during the events beginning November 16, 2017 and July 22, 2018.
- The highest TP concentration and load reductions occurred during the rain on snow event beginning April 6, 2018 when inflow concentrations were the greatest.
- TP concentrations were higher at the outflow than at the inflow for events beginning March 20, 2018, May 16, 2018, and July 22, 2018, however, enough runoff volume was retained in the vault to result in an overall TP load reduction for all three of these events.
- The lowest TP load reduction occurred during the rain event beginning November 16, 2017 when runoff volumes were greatest.

Contech MFS vault water level and bypass flow are presented in Figure 63. When bypass occurs, untreated flow comingles with treated flow in the outflow from the Contech MFS vault.

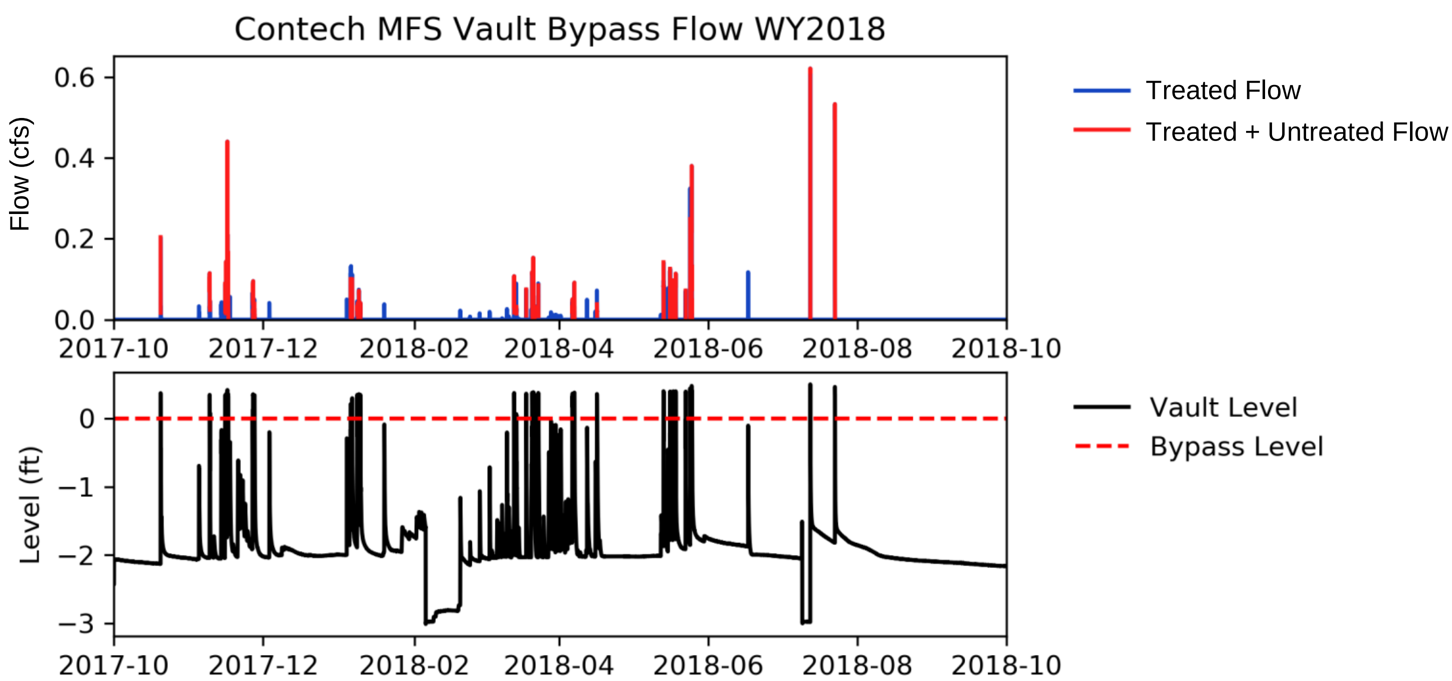

Figure 63 Contech MFS vault level at SR431, WY18 (bottom). Contech MFS outflow shown at top for reference. Vault level greater than 0 indicates bypass flow.

- During periods of flow, the Contech MFS filter was in bypass mode 35% of the time in WY18 which represents up to 68% of the flow volume (15,424 cf). During bypass mode treated flow is co-mingled with untreated (bypass) flow, so the exact amount of untreated flow is difficult to determine.
- Bypass occurred during 16 runoff events:
  - October 20, 2017 during a snow event that produced less than half an inch of water equivalent.
  - November 9, 2017 during a rain event that produced less than half an inch.
  - November 15-16, 2017 during an atmospheric river rain then snow event that produced over 4 inches of rain.
  - November 26-27, 2018 during a rain event that produced 0.84 inches.
  - January 5-6, 2018 during a 1.27 inch rain on snow event.
  - January 8-9, 2018 during a rain event that produced less than half an inch.
  - March 13-14, 2018 during a large rain on snow event.
  - March 18, 2018 during a snowmelt event.
  - March 20-21, 2018 and March 23, 2018 during a large rain on snow event.
  - April 6-7, 2018 during a rain on snow event.
  - May 13, 2018 during a rain event.
  - May 16, 2018 during a rain event.
  - May 18, 2018 during a rain event.
  - May 24-25, 2018 during a rain event.
  - July 12, 2018 during a thunderstorm event.
  - July 22, 2018 during a thunderstorm event.
- All five sampled events had untreated (bypass) flow.

Table 17 presents the efficiency of the Jellyfish at reducing concentrations and loads of all three pollutants for the individual events sampled in WY18.

Table 17 Event efficiency data from the Jellyfish vault at SR431, WY18.

Event Start Date	Event Volume as a % of Total Annual Volume (cf)	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
11/16/2017	22%	193	179	-7%	63	58	-8%	693	935	35%	0.23	0.30	35%	669	601	-10%	0.22	0.20	-10%
3/20/2018	10%	866	652	-25%	122	84	-31%	1,213	1,900	57%	0.17	0.25	44%	27	26	-4%	0.004	0.003	-11%
4/6/2018	4%	1,253	525	-58%	65	27	-59%	724	1,019	41%	0.04	0.05	36%	8,539	1,853	-78%	0.45	0.09	-79%
5/16/2018	4%	149	139	-7%	8.2	7.7	-7%	806	1,071	33%	0.04	0.06	33%	554	445	-20%	0.03	0.02	-20%
7/22/2018	4%	109	112	3%	5.80	5.84	1%	3,138	2,739	-13%	0.17	0.14	-14%	624	700	12%	0.03	0.04	10%

- The highest FSP concentration and load reductions occurred during the rain on snow event beginning April 6, 2018 when inflow concentrations were the greatest.
- The lowest FSP concentration and load reductions occurred during the summer thunderstorm on July 22, 2018 when the Jellyfish released FSP. Due to a missing tentacle, the Jellyfish may have been performing sub-optimally at the time.
- The highest TN concentration and load reductions occurred during the summer thunderstorm on July 22, 2018 when inflow concentrations were the greatest. This was the only event that reduced TN for the whole year, however the reduction was small. The system had been maintained 11 days earlier.
- The Jellyfish released TN in November, March, April and May. No events were sampled in the interim months of December, January, or February.
- The highest TP concentration and load reductions occurred during the rain on snow event beginning April 6, 2018 when inflow concentrations were the greatest.
- The Jellyfish released TP during the summer thunderstorm on July 22, 2018. Due to a missing tentacle, the Jellyfish may have been performing sub-optimally at the time.

Jellyfish vault water level and bypass flow are presented in Figure 64. When bypass occurs, untreated flow comingles with treated flow in the outflow from the Jellyfish vault.

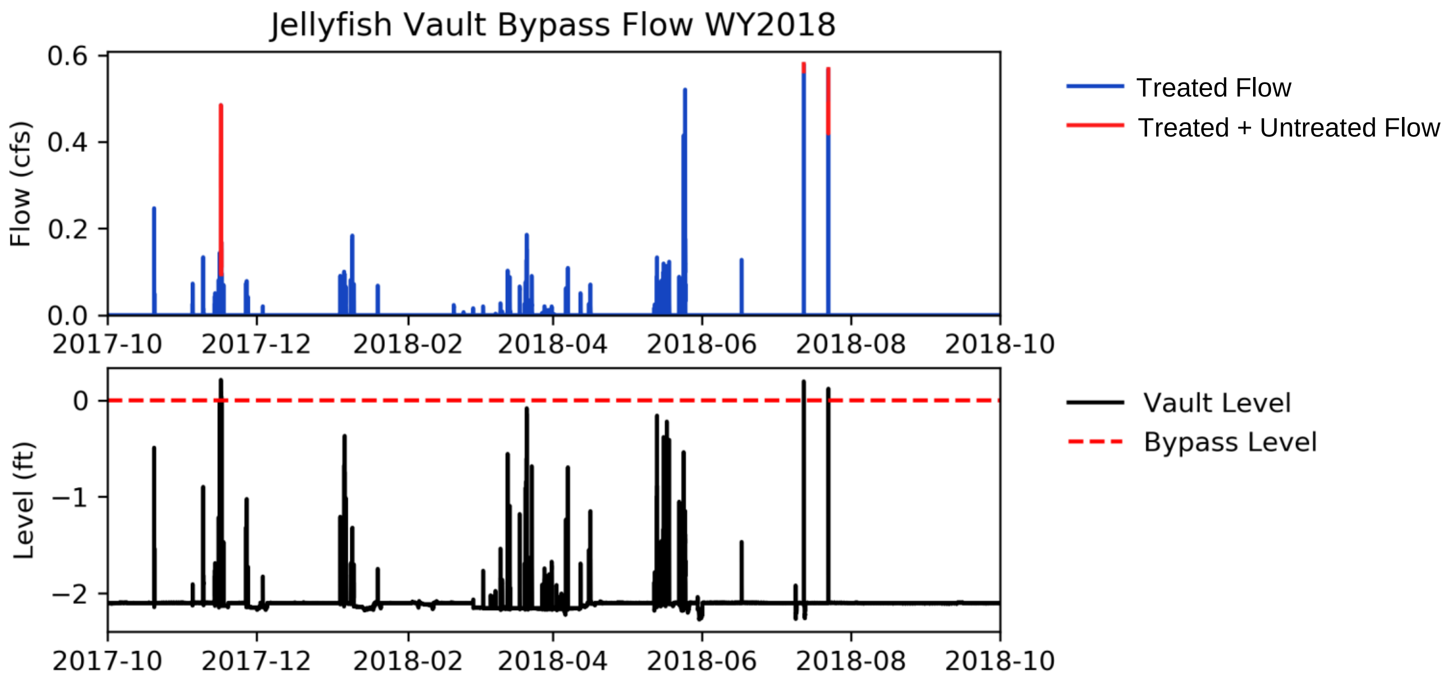

Figure 64 Jellyfish vault level at SR431, WY18 (bottom). Jellyfish outflow shown at the top for reference. Vault level greater than 0 indicates bypass flow.

- During periods of flow, the Jellyfish filter was in bypass mode 3% of the time in WY18 which represents up to 25% of the flow volume (5,878 cf). During bypass mode treated flow is co-mingled with untreated (bypass) flow, so the exact amount of untreated flow is difficult to determine.
- Bypass occurred during 3 runoff events:
  - November 16, 2017 during at atmospheric river rain event that produced more than 4 inches of precipitation.
  - July 12, 2018 during a thunderstorm event.
  - July 22, 2018 during a thunderstorm event.
- The two sampled events that had untreated (bypass) flow were the November 16, 2017 atmospheric river rain event and the July 22, 2018 thunderstorm event.

7.2 Elks Club

Data collected at Elks Club in WY18 represents pre-project conditions. Therefore, no conclusions can be drawn in this annual report regarding the efficacy of repaving a road to reduce FSP loads in stormwater runoff. Data collected in post project conditions will be presented and compared to WY18 data in the WY19 annual report.

In addition to analyzing samples for sediment and nutrient content, Elks Club runoff samples also underwent a source apportionment analysis. Samples of asphalt aggregate, asphalt binder, roadside soil (i.e. soil that erodes off the adjacent road shoulder of adjoining land), traction abrasives (i.e. road sand), and vegetation debris were collected near the monitoring site were submitted at the beginning of the project and molecular markers were identified for each of these sediment types. Subsequent runoff samples were then analyzed using the molecular markers and a chemical mass balance model to determine what portion of the sediment in each sample originated from each source.

Figure 65 shows the distribution of the average annual FSP load attributable to the different sediment sources. The sum of asphalt aggregate and asphalt binder represents the amount of FSP attributable to the degradation of the road surface. WY18 data indicate that 43% of the FSP in stormwater runoff from Elks Club Drive comes from the road itself. This is greater than the contribution from roadside soil, and nearly equivalent to the sum of roadside soil and traction abrasives combined (50%).

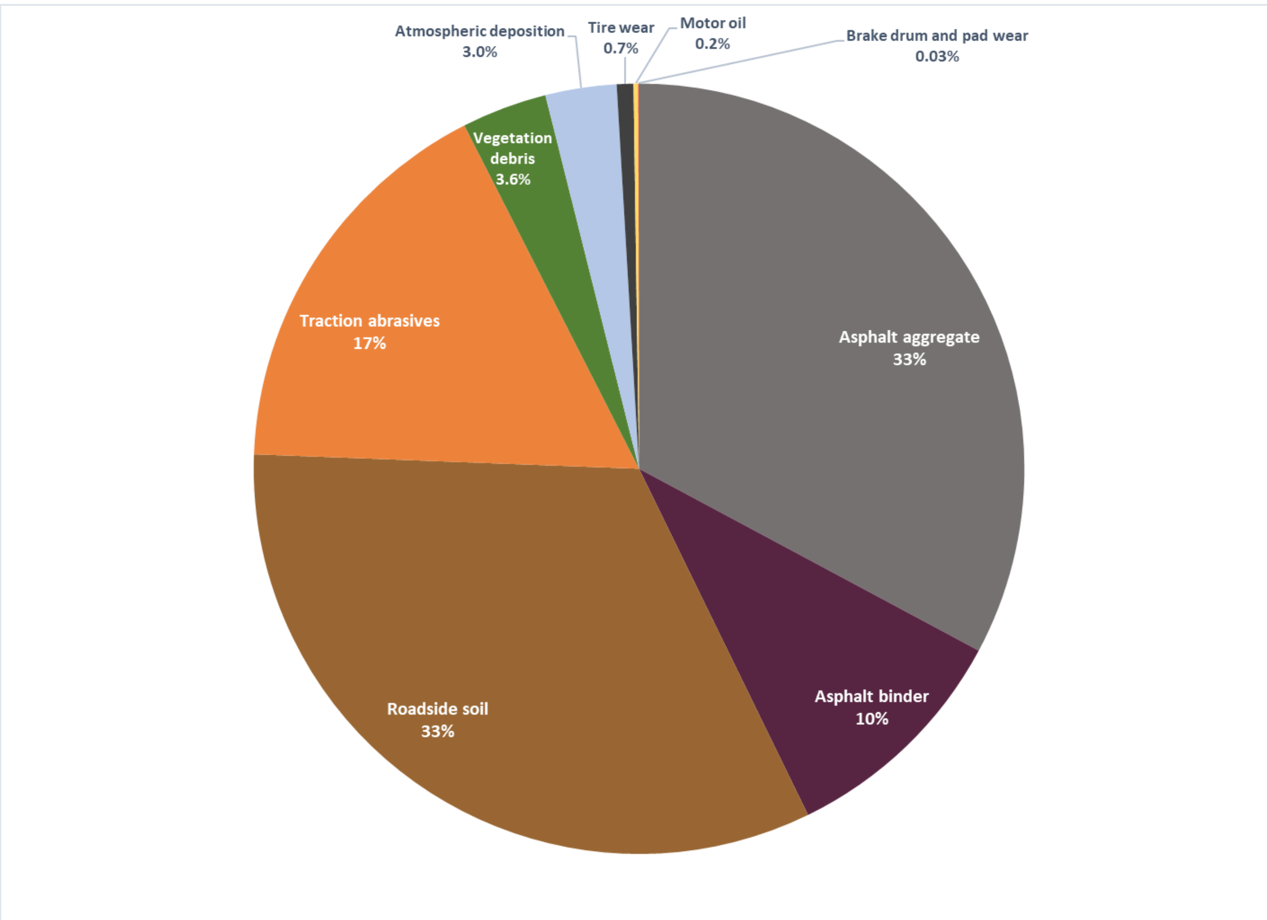

Figure 65 Average annual FSP load attributable to different source categories at Elks Club, WY18. 43% of the FSP in stormwater runoff from Elks Club Dr. originated from degradation of the road surface (asphalt aggregate plus asphalt binder).

Table 18 shows the percentage of FSP that originated from each source for each event sampled and the average percentage for each source for WY18. Averages are depicted in Figure 65.

Table 18 Percentage of FSP originating from each source for each event sampled and average percentage for each source in WY18

Sample Date/Time	Event Type	Asphalt aggregate	Asphalt binder	Roadside soil	Traction abrasives	Vegetation debris	Atmospheric deposition	Tire wear	Motor oil	Brake drum and pad wear	Lead balance weight
11/15/17 7:10	Rain	35	10	36	12	3.0	3.0	0.7	0.2	0.02	<0.0001
1/6/18 1:11	Rain on snow	36	10	38	10	3.0	2.0	0.8	0.2	0.02	<0.0001
3/13/18 17:00	Rain on snow	40	16	24	13	3.0	3.0	1.0	0.2	0.09	<0.0001
3/20/18 14:25	Rain on snow	35	10	31	20	1.5	2.0	0.4	0.2	0.03	<0.0001
4/6/18 0:00	Rain on snow	32	10	34	17	3.0	3.0	0.6	0.2	0.03	<0.0001
4/24/18 0:00	Washoff study	35	9	26	23	1.5	5.0	0.5	0.2	0.03	<0.0001
5/24/18 17:23	Rain	29	7	30	19	9.0	5.0	0.9	0.2	0.02	<0.0002
5/25/18 3:43	Rain	19	5	45	25	4.5	1.0	0.7	0.2	0.03	<0.0003
	Average	**33%**	**10%**	**33%**	**17%**	**3.6%**	**3.0%**	**0.7%**	**0.2%**	**0.03%**	**<0.0001%**

8. Trends Analysis

In accordance with the RSWMP FIG section 2.1, monitoring for trends at urban catchment outfalls is important because it provides information needed for evaluating progress toward TMDL and other regulatory goals. Trend analyses are only performed on monitoring sites with at least five years of continuous data. The objective of the trend monitoring is to detect and report the cumulative load reduction benefits of all actions implemented within the catchment over long time frames and ultimately demonstrate a local and regional improvement in pollutant loading to the lake.

Water year 2018 marked the fifth year of monitoring at SR431, Pasadena outflow, and Tahoma. Trend analyses will only be reported for the inflow locations at SR431 (CI and JI) as these results will indicate trends in pollutant loading from the catchment. Trend analyses on the outflow locations (CO and JO) are an indication of how well the vaults are maintained over the years and will be included in the seasonal progress reports submitted to NDOT and available on Tahoe RCD's website.

Average annual loads for FSP, TN, and TP are normalized by catchment size (acres) and by inches of precipitation. Normalizing by catchment size allows for comparison between sites, but this analysis is not highlighted here as the objective of trends analysis is to detect load reductions resulting from improved management activities within each catchment, not between catchments. Normalizing by precipitation allows for comparison between water years in a particular catchment, which addresses the objective. Percent runoff is a function of catchment size, the amount of rainfall received, and the volume measured at the catchment outfall. It represents the fraction of runoff that was measured at the outfall compared to what would theoretically be expected if all the rainfall that fell in the catchment were measured at the outfall.

Rainfall normalized average annual load charts for each site (Figure 66 - Figure 69) show whether there is an upward, downward, or neutral trend in average annual loading of FSP, TN, and TP at each site. Also presented for each site is a table (Table 19 - Table 22) that shows rainfall normalized seasonal and average annual loads and trend statistics. The trend statistics indicate if there has been an upward, downward, or neutral trend in pollutant loading over the last five years in the selected catchments. Tau is a non-parametric measure of the relationship between data when data does not have a normal distribution, similar to the r^2 value in a regression on normalized data. Tau is a correlation coefficient that returns a value of 0 to 1 where 0 is no relationship and 1 is a perfect relationship. Because of the way it is calculated, Tau can be negative. The p-value indicates the confidence level in Tau; a p-value less than 0.05 ($p<0.05$) denotes a significant relationship. The Theil slope is similar to the slope for a regression on normalized data, but used for data that is not normally distributed.

8.1 Contech MFS Inflow

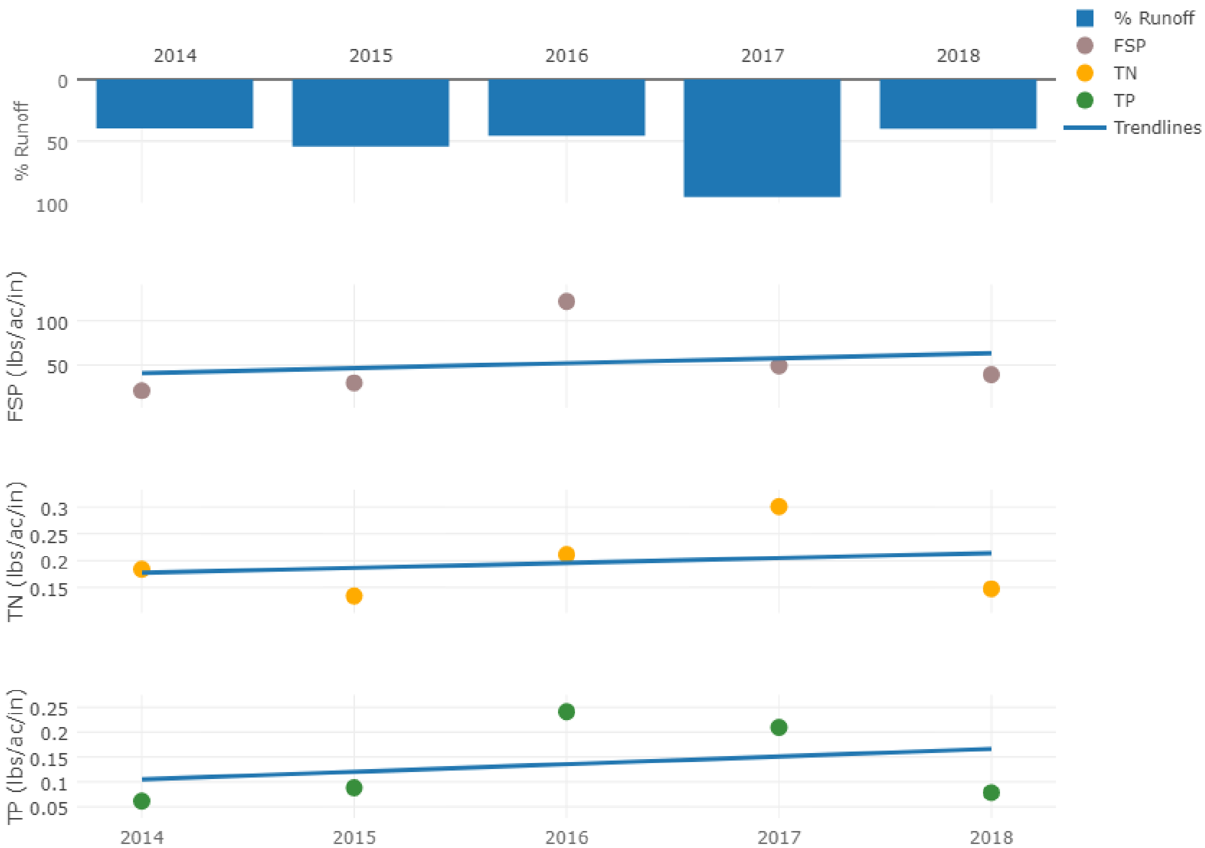

Figure 66 5-year rainfall normalized trends in FSP, TN, and TP loads at the Contech MFS Inflow, WY14-18.

- Percent runoff varied between 34.7% in WY15 to 95.7% in WY17. Differences in % runoff between CI and JI are attributed to sediment accumulation in the splitter chamber that caused an unequal division of runoff to each vault.
- Average annual FSP loads appear to be increasing, but a low Tau value and p-value greater than 0.05 indicate no significant trend.
- Average annual TN loads appear to be increasing, but a low Tau value and p-value greater than 0.05 indicate no significant trend.
- Average annual TP loads appear to be increasing, but a low Tau value and p-value greater than 0.05 indicate no significant trend.

Table 19 5-year seasonal and annual rainfall normalized pollutant loads at the Contech MFS Inflow, WY14-18.

Year	% Runoff	FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
		Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2014	39.7%	8.604	44.745	23.773	21.219	0.067	0.237	0.398	0.184	0.021	0.125	0.082	0.061
2015	34.7%	30.754	42.680	7.739	29.979	0.131	0.169	0.089	0.134	0.100	0.113	0.015	0.088
2016	46.0%	87.307	188.963	0.000	121.628	0.184	0.268	0.000	0.211	0.153	0.410	0.000	0.241
2017	95.7%	23.035	176.286	26.179	49.268	0.213	0.770	0.065	0.301	0.077	0.866	0.045	0.210
2018	40.2%	24.079	53.407	21.420	39.296	0.141	0.120	0.570	0.147	0.085	0.070	0.116	0.078
Tau	na	0.200	0.200	0.000	0.400	0.600	0.000	0.000	0.200	0.200	0.000	0.333	0.200
P-Value	na	0.624	0.624	1.000	0.327	0.142	1.000	1.000	0.624	0.624	1.000	0.497	0.624
Theil Slope (per year)	na	2.456	2.870	0.107	6.640	0.035	0.000	0.016	0.009	0.012	0.065	0.012	0.015

8.2 Jellyfish Inflow

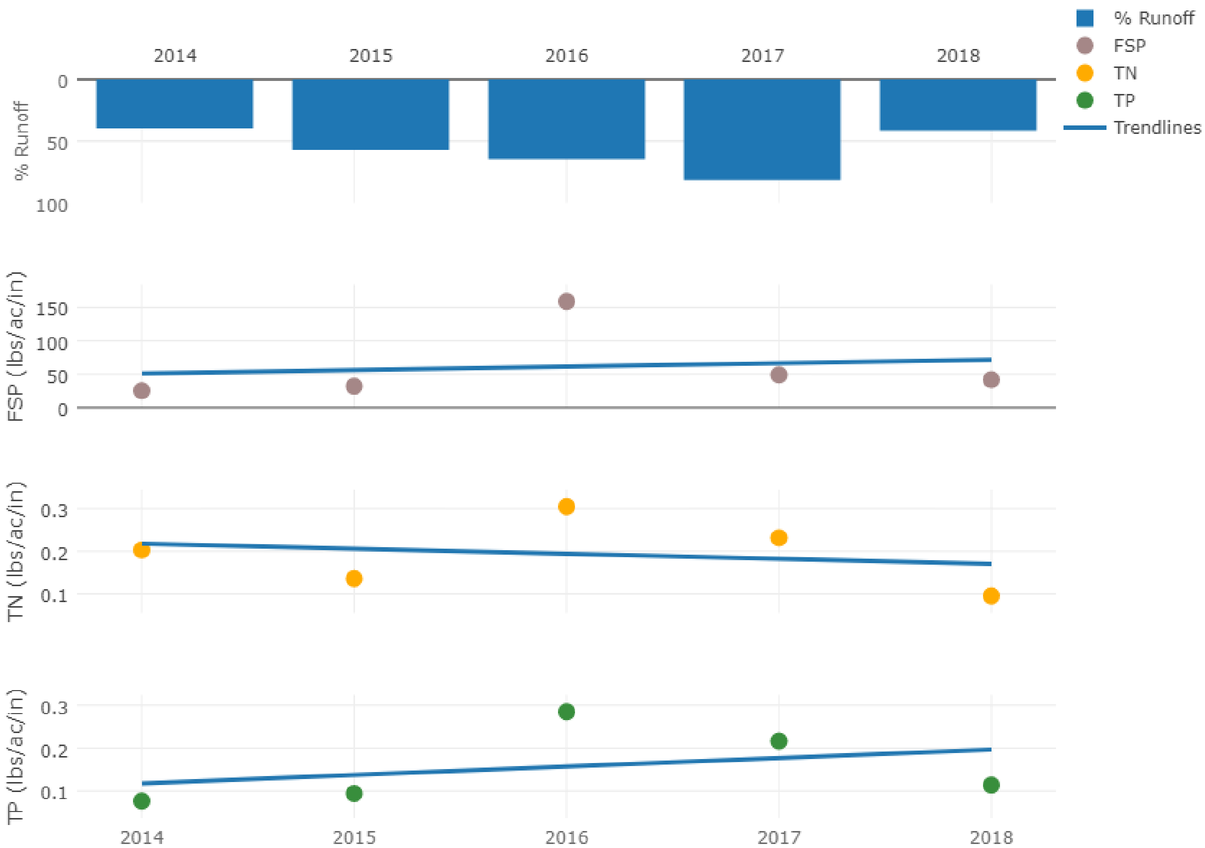

Figure 67 5-year rainfall normalized trends in FSP, TN, and TP loads at the Jellyfish Inflow, WY14-18.

- Percent runoff varied between 39.7% in WY14 to 81.5% in WY17. Differences in % runoff between CI and JI are attributed to sediment accumulation in the splitter chamber that caused an unequal division of runoff to each vault.
- Average annual FSP loads appear to be increasing slightly, but a low Tau value and p-value greater than 0.05 indicate no significant trend.
- Average annual TN loads appear to be decreasing slightly, but a low Tau value and p-value greater than 0.05 indicate no significant trend.
- Average annual TP loads appear to be increasing, but a low Tau value and p-value greater than 0.05 indicate no significant trend.

Table 20 5-year seasonal and annual rainfall normalized pollutant loads at the Jellyfish Inflow, WY14-18.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2014	39.7%	7.069	26.540	9.774	12.640	0.031	0.161	0.198	0.101	0.017	0.082	0.039	0.038
2015	57.2%	15.667	23.993	4.151	15.975	0.060	0.090	0.056	0.068	0.049	0.068	0.009	0.047
2016	64.8%	60.367	117.456	0.000	79.490	0.110	0.235	0.000	0.152	0.115	0.198	0.000	0.142
2017	81.5%	11.864	86.677	9.997	24.519	0.057	0.405	0.040	0.116	0.039	0.450	0.021	0.108
2018	41.4%	10.329	30.602	9.400	20.885	0.037	0.039	0.271	0.048	0.036	0.075	0.054	0.057
Tau	na	0.000	0.200	0.000	0.400	0.000	0.000	0.000	-0.200	0.000	0.200	0.333	0.400
P-Value	na	1.000	0.624	1.000	0.327	1.000	1.000	1.000	0.624	1.000	0.624	0.497	0.327
Theil Slope (per year)	na	-0.360	1.609	-0.010	2.698	0.000	0.010	0.005	-0.010	0.001	0.030	0.005	0.007

8.3 Pasadena

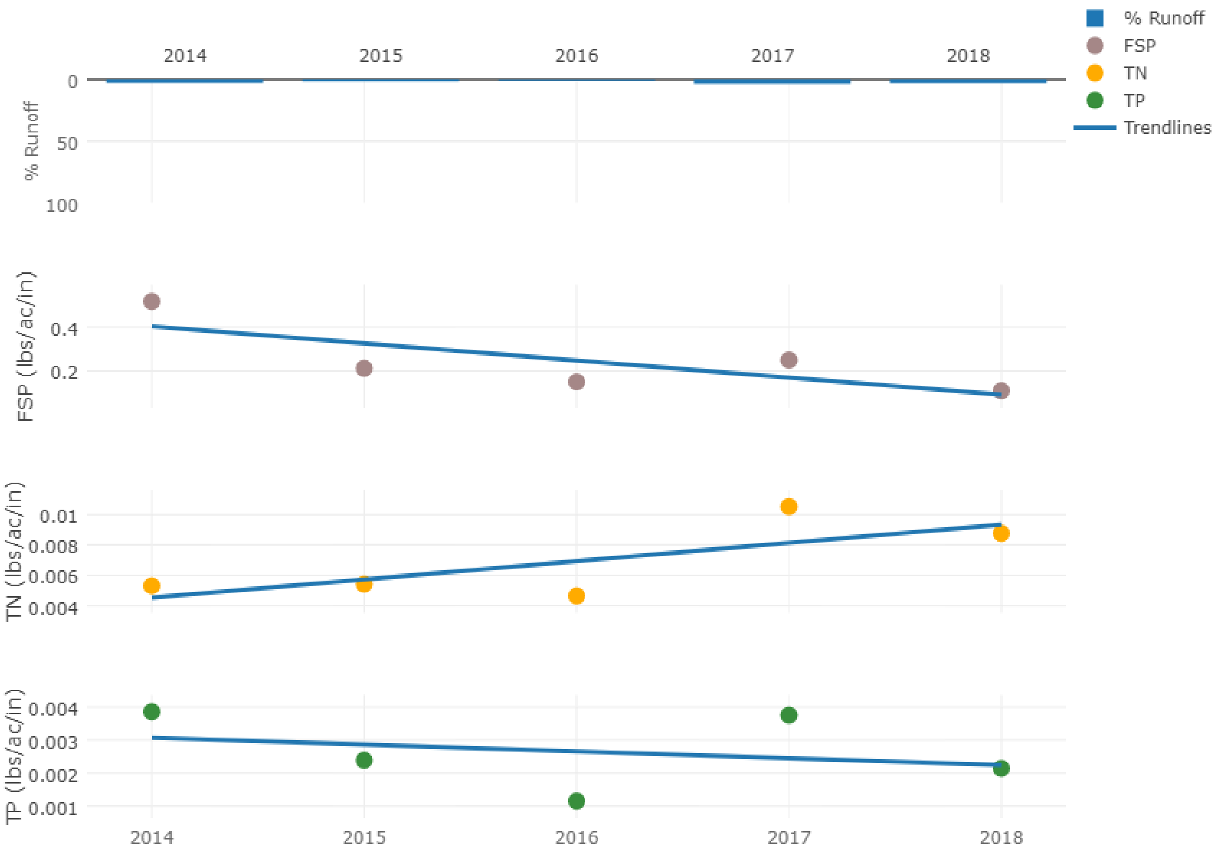

Figure 68 5-year rainfall normalized trends in FSP, TN, and TP loads at the Pasadena Outflow, WY14-18.

- Percent runoff was less than 4% in all five water years but varied between 0.8% in WY16 to 3.9% in WY17.
- Average annual FSP loads appear to be decreasing, but a low Tau value and p-value greater than 0.05 indicate no significant trend.
- Average annual TN loads appear to be increasing, but a low Tau value and p-value greater than 0.05 indicate no significant trend.
- Average annual TP loads appear to be decreasing slightly, but a low Tau value and p-value greater than 0.05 indicate no significant trend.

Table 21 5-year seasonal and annual rainfall normalized pollutant loads at the Pasadena Outflow, WY14-18.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2014	2.8%	0.453	0.000	1.042	0.517	0.006	0.000	0.009	0.005	0.004	0.000	0.007	0.004
2015	1.4%	0.166	0.038	0.495	0.212	0.004	0.001	0.013	0.005	0.002	0.000	0.006	0.002
2016	0.8%	0.129	0.178	0.000	0.150	0.006	0.002	0.000	0.005	0.001	0.001	0.000	0.001
2017	3.9%	0.245	0.206	0.397	0.249	0.010	0.005	0.026	0.011	0.004	0.001	0.005	0.004
2018	3.1%	0.140	0.082	0.090	0.110	0.014	0.003	0.012	0.009	0.003	0.001	0.002	0.002
Tau	na	-0.400	0.333	-1.000	-0.600	0.800	0.667	0.333	0.400	-0.200	0.667	-1.000	-0.400
P-Value	na	0.327	0.497	0.042	0.142	0.050	0.174	0.497	0.327	0.624	0.174	0.042	0.327
Theil Slope (per year)	na	-0.053	0.022	-0.227	-0.075	0.003	0.001	0.003	0.001	0.000	0.000	-0.001	0.000

8.4 Tahoma

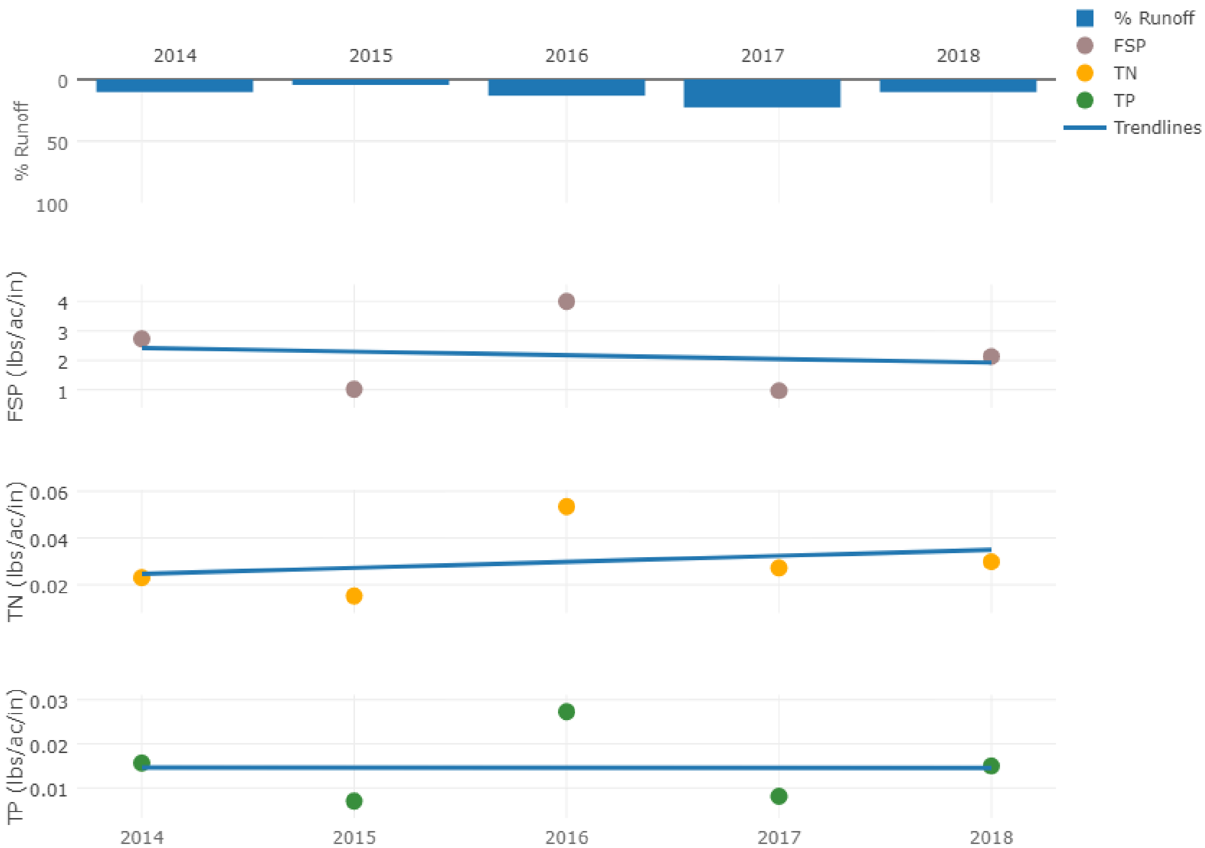

Figure 69 5-year rainfall normalized trends in FSP, TN, and TP loads at Tahoma, WY14-18.

- Percent runoff varied between 4.8% in WY15 to 22.9% in WY17.
- Average annual FSP loads appear to be decreasing slightly, but a low Tau value and p-value greater than 0.05 indicate no significant trend.
- Average annual TN loads appear to be increasing slightly, but a low Tau value and p-value greater than 0.05 indicate no significant trend.
- Average annual TP loads appear to be static, and a low Tau value and p-value greater than 0.05 confirm no significant trend.

Table 22 5-year seasonal and annual rainfall normalized pollutant loads at Tahoma, WY14-18.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2014	10.2%	1.482	7.679	4.643	2.733	0.011	0.061	0.044	0.023	0.007	0.044	0.031	0.016
2015	4.8%	0.971	0.567	1.858	1.020	0.006	0.009	0.067	0.015	0.006	0.003	0.015	0.007
2016	13.1%	4.410	2.797	9.639	4.002	0.036	0.016	0.634	0.053	0.028	0.010	0.181	0.027
2017	22.9%	0.987	1.105	0.000	0.969	0.026	0.040	0.000	0.027	0.008	0.010	0.000	0.008
2018	10.1%	0.220	4.032	0.000	2.132	0.020	0.041	0.000	0.030	0.004	0.027	0.000	0.015
Tau	na	-0.400	0.000	0.333	-0.200	0.200	0.200	1.000	0.400	-0.200	0.200	0.333	0.000
P-Value	na	0.327	1.000	0.602	0.624	0.624	0.624	0.117	0.327	0.624	0.624	0.602	1.000
Theil Slope (per year)	na	-0.283	-0.321	2.498	-0.088	0.003	0.004	0.295	0.002	-0.001	0.002	0.075	0.000

9. PLRM Modeling Results

Tahoe RCD compared average annual runoff volumes and pollutant loads predicted by PLRMv2.1 to annual volumes and pollutant loads measured in WY18 at all sites; results are presented in Table 23. 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.**

WY18 was an average to wet precipitation year for the Tahoe basin therefore modeled results are expected to be lower than measured values. The PLRM estimated runoff volumes were all within a similar range as the measured runoff volumes. However, all of the PLRM modeled FSP, TN, and TP loads were higher than the measured loads.

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. 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 to our basic understanding of Tahoe stormwater pollutant sources. All seven jurisdictions in two states are using the same modeling tool for estimating pollutant loads, allowing for comparisons of pollutant load reductions to be made 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 real conditions.

Table 23 PLRM predicted and WY18 measured values for all monitored catchments.

Water Year 2018 Oct. 1, 2017 - Sept. 30, 2018		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	22,755	810	171	10.0	2.4	3.0	1.3
	Contech Outflow	43,560	11,569	365	67	4.0	0.9	2.0	0.4
	Jellyfish Inflow	43,560	23,468	810	268	10.0	1.5	3.0	1.8
	Jellyfish Outflow	43,560	22,010	318	85	4.0	1.8	2.0	0.8
Elk's Club	Elk's Club	304,920	422,881	4,431	646	62.0	22.8	16.0	7.7
Lakeshore	Lakeshore	357,192	73,912	2,885	68	56.0	3.5	14.0	1.0
Pasadena	Pasadena Outflow	143,748	132,349	446	186	13.0	10.2	5.0	2.5
Speedboat	Speedboat	317,988	407,569	4,911	1,492	58.4	36.3	17.0	14.3
Tahoe Valley	Tahoe Valley	5,449,356	3,543,564	53,305	3,408	764.0	190.7	196.0	37.6
Tahoma	Tahoma	666,468	566,684	10,801	978	127.0	46.0	37.0	23.1
Upper Truckee	Upper Truckee	352,836	203,279	5,039	2,027	67.0	44.4	18.0	12.8

10. 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 and SR431 Jellyfish cartridge filters over the last five years were estimated as the average of the annual pollutant concentrations from WY14, WY15, WY16, WY17, and WY18 (see Table 5 of this report for average annual concentrations of each pollutant at each site for WY18, Table 5 of the both the Annual Stormwater Monitoring Report Water Years 2014-2016 and the Annual Stormwater Monitoring Report Water Year 2017 for previous year average annual concentrations, and Table 24 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 24 (114 to 131 mg/L) and the default TP CEC of 140 µg/L is lower than any of the estimated TP CECs in Table 24 (773 to 778 µg /L), using the default CECs when modeling these catchments would result in an overestimation of vault pollutant removal efficiency when compared to the measured data to date. Accordingly, FSP and TP loads discharged from these catchments will be underestimated if the default CEC is used. If vaults were to be maintained to pristine condition after every event, loads could theoretically approach what would be predicted using the default CEC. The current default PLRM TN CEC value for cartridge filters of 1,500 µg/L is very similar to the estimated values in Table 24 (1,286 to 1,306 µg /L) so modeled pollutant loads from these two cartridge filter vaults should be similar to measured values if runoff volume is accurately predicted.

Table 24 CECs for FSP, TN, and TP, PLRM estimated and measured (WY18) annual runoff volumes and pollutant loads for outflows at two monitored cartridge filter vaults.

Water Year 2018 Oct. 1, 2017 - Sept. 30, 2018		Average CEC (WY14 - WY18)			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
Contech Out	CO	131	1,306	773	43,560	11,569	365	67	4.0	0.9	2.0	0.4
Jellyfish Out	JO	114	1,286	778	43,560	22,010	318	85	4.0	1.8	2.0	0.8

PLRM was run on the SR431 catchment using the refined site-specific average CECs from Table 24 for each BMP. The modeled results for percent FSP removed by the Contech MFS and Jellyfish are shown in Figure 70, depicted as a square and a triangle, respectively. Though not as effective as the default CEC of 13mg/L (which provides a 95% FSP removal rate), using refined site-specific CEC values in the model still results in high FSP removal rates (55% for the Contech MFS and 61% for the Jellyfish). The PLRM models were also run with theoretical (default) CECs for reference purposes (Figure 70). 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 ~300 mg/L. This means these filters should theoretically provide some FSP removal most of the time.

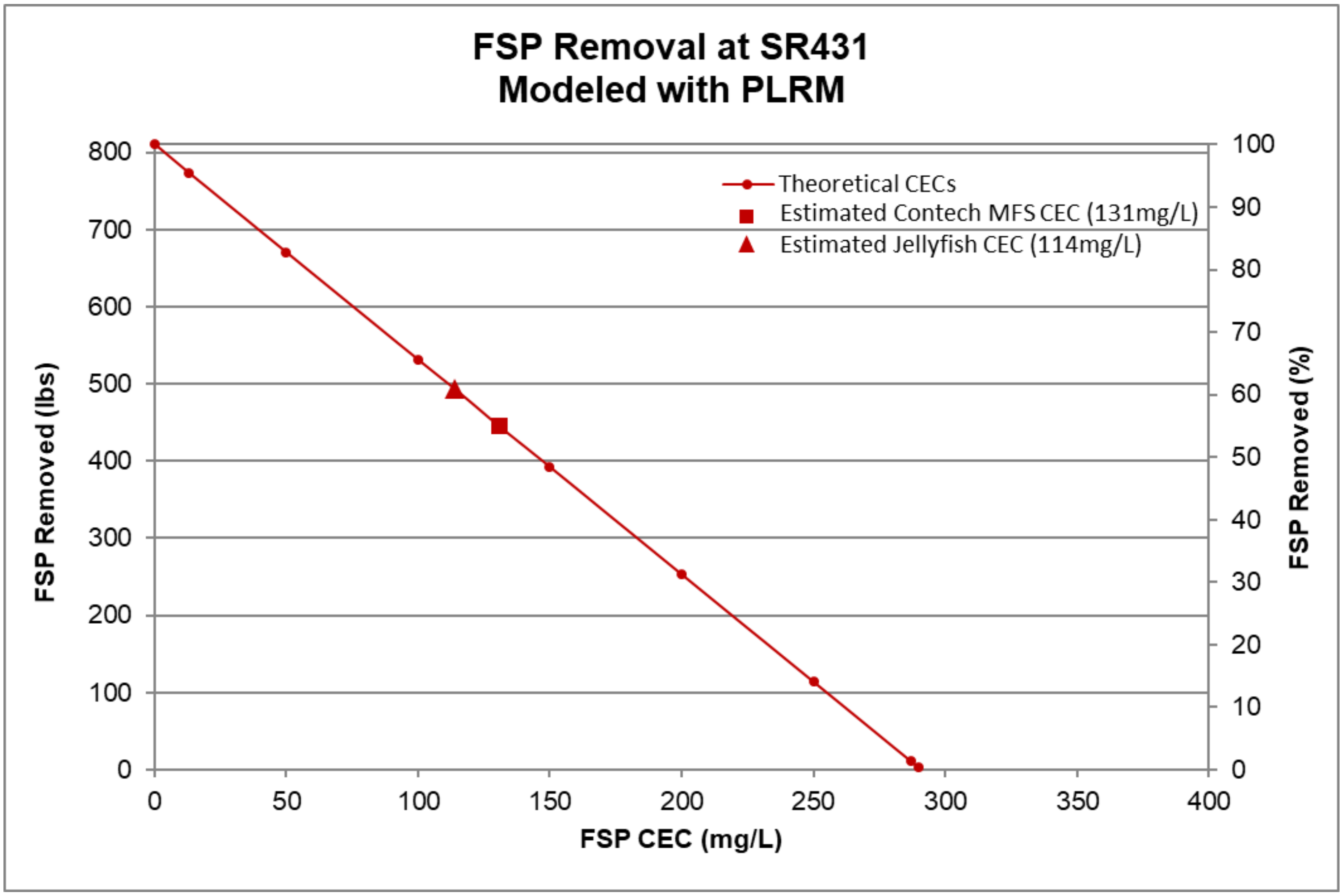

Figure 70 FSP removal at SR431 for the Contech MFS and Jellyfish cartridge filter vaults, as modeled by PLRM. Dots represent model runs with theoretical CECs, the square represents the model run with the refined CEC value for the Contech MFS filter (131 mg/L), and the triangle represents the model run with the refined CEC for the Jellyfish filter (114 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 maintenance intervals and extent (vactoring pre-treatment chamber versus cleaning and replacing filters). 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 and cost-effectiveness and to further refine static CECs to use in PLRM.

11. 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. Beginning WY17 all monitoring and weather stations are remotely accessible. This enables access to the stations and their status during all weather conditions and any time of day or night and allows for problems to be detected and remedied earlier than was previously possible when site visits were required to know station status. Additionally, alarms are set to send email or text alerts when certain parameters reach a pre-determined threshold.

The biggest cause of data gaps is 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 or snow blockage 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 has alleviated this problem but batteries must be continuously checked and changed.

When snow accumulation is frequent and excessive, it is very important to stay on top of site maintenance. Keeping the sites dug out and unfrozen is a continuous task, but necessary to maintain data integrity. The remote access system is very beneficial in identifying when the sites are frozen and in need of maintenance.

High lake levels following WY17 caused backwatered conditions at Tahoma beginning in late March 2018. No further sampling could be conducted at Tahoma for the rest of the water year (Figure 71).

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 requisite summer events can easily be missed or do not produce enough runoff to sample.

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). **All efforts are made to successfully sample several events during each season so that average seasonal pollutant concentrations and loads can be calculated. However, annual precipitation patterns are highly variable, and in some years there is insufficient runoff for sampling in any given season. Approval of the annual permit/ILA monitoring requirement should not be withheld for this reason.** Fortunately, FSP concentrations and loads can be calculated from the continuous turbidity data, so these values should never be missing from any season unless there is no runoff at all.

Figure 71	Backwatered conditions at the Tahoma catchment outfall due to high lake levels, March 23, 2018. The pipe is under the snow and the lake water extends into the flume.

12. Changes: Accepted and Proposed

Changes Accepted

A new NPDES permit was issued 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 WY17 Tahoe RCD proposed a new BMP monitoring site. The new location was approved by IMP, Lahontan, NDEP and monitoring equipment was removed from the Pasadena Inflow and installed at a Elks Club Drive as described in section 2.2. Monitoring at Elks Club began in WY18. 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.

Changes Proposed

Because annual precipitation during all seasons is highly variable, and summer thunderstorms in particular tend to be very episodic in nature, not all sites receive sufficient runoff to sample the requisite number of events in every season, especially in the summer. **It may be advisable to amend permit and agreement language to acknowledge that all efforts are made to successfully sample several events during each season so that average seasonal pollutant concentrations and loads can be calculated. However, this is not always possible, and approval of the annual permit/ILA monitoring requirement should not be withheld for this reason.**

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Appendix A: Raw Analytical Data

Table A.1-Table A.9 present all available raw analytical data for autosampler composite (AC) samples. Other than QAQC samples, only AC samples were analyzed in WY18.

Table A.1 Raw analytical data for samples taken at the inflow and outflow of the SR431 Contech MFS in WY18.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
CI-AC	11/16/2017 7:16	371	169	209	1,218	737	0.30	3.13	8.55	16.5	31.9	56.3	64.7	92.7	97.6	100	100	100	100
CO-AC	11/16/2017 7:32	285	127	178	863	663	0.32	3.40	9.60	19.0	36.8	62.6	70.8	93.7	98.6	100	100	100	100
CI-AC	3/20/2018 13:18	1,024	888	700	948	19	0.45	4.79	13.9	26.8	46.3	68.4	74.9	94.5	99.3	100	100	100	100
CO-AC	3/20/2018 23:44	936	930	680	1,923	26	0.49	5.19	15.0	28.7	49.2	72.7	79.3	96.3	99.6	100	100	100	100
CI-AC	4/6/2018 9:33	3,013	2,600	2,025	6,408	6,022	0.37	3.91	11.2	22.8	43.3	67.2	74.9	97.5	99.0	100.0	100.0	100	100
CO-AC	4/7/2018 5:15	608	468	408	679	1,655	0.35	3.68	10.7	22.1	42.2	67.0	74.6	96.3	99.1	100	100	100	100
CI-AC	5/16/2018 6:49	274	169	205	916	277	0.43	4.67	13.8	26.9	47.7	75.1	83.0	100	100	100	100	100	100
CO-AC	5/16/2018 8:56	157	132	113	233	376	0.51	5.35	15.4	29.5	49.3	72.0	78.0	87.1	91.1	95.3	98.0	100	100
CI-AC	7/22/2018 18:15	273	113	119	3,175	648	0.23	2.33	6.34	12.2	23.3	43.7	51.8	84.3	93.3	99.0	99.6	100	100
CO-AC	7/22/2018 18:21	253	111	112	3,107	724	0.22	2.29	6.22	12.1	23.6	44.2	52.4	85.4	94.4	99.7	100	100	100

Table A.2 Raw analytical data for samples taken at the inflow and outflow of the SR431 Jellyfish in WY18.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
JI-AC	11/16/2017 7:18	342	141	193	693	669	0.30	3.13	8.67	16.8	32.4	56.5	64.7	91.8	97.8	100	100	100	100
JI-AC	3/20/2018 13:16	1,143	1,336	866	1,213	27	0.51	5.44	15.7	30.4	52.8	75.8	82.2	98.0	99.9	100	100	100	100
JI-AC	4/6/2018 8:52	1,908	2,047	1,253	724	8,539	0.34	3.58	10.4	21.4	41.2	65.7	72.8	93.0	98.5	100	100	100	100
JI-AC	5/16/2018 6:49	235	132	149	806	554	0.41	4.34	12.5	24.1	41.2	63.5	70.4	87.6	94.2	98.5	99.3	100	100
JI-AC	7/22/2018 18:15	254	114	109	3,138	624	0.23	2.33	6.35	12.2	23.1	42.9	51.0	86.5	94.9	99.8	100	100	100
JO-AC	11/16/2017 7:18	296	164	179	935	601	0.32	3.30	9.19	18.0	34.8	60.5	69.1	94.7	99.1	100	100	100	100
JO-AC	3/20/2018 23:37	848	924	652	1,900	26	0.51	5.47	16.0	31.0	52.8	76.9	83.5	98.4	100	100	100	100	100
JO-AC	4/6/2018 9:35	728	1,039	525	1,019	1,853	0.38	4.06	12.1	25.1	46.9	72.2	79.4	98.2	99.9	100	100	100	100
JO-AC	5/16/2018 6:52	183	148	139	1,071	445	0.50	5.32	15.4	29.9	51.0	75.6	81.9	93.3	96.6	99.1	100	100	100
JO-AC	7/22/2018 18:16	249	118	112	2,739	700	0.23	2.38	6.44	12.5	24.0	44.9	53.3	86.3	95.6	99.9	100	100	100

Table A.3 Raw analytical data for samples taken at Elks Club in WY18.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
EC-AC	11/15/2017 7:10	42	27	4	746	135	0.08	0.64	1.47	2.72	5.16	9.25	11.1	18.9	23.9	30.5	42.1	55.7	100
EC-AC	1/6/2018 1:11	121	85	48	1,027	386	0.23	2.21	5.71	11.1	21.8	39.9	47.1	83.6	94.7	99.7	100	100	100
EC-AC	3/13/2018 17:00	101	117	41	745	300	0.21	2.10	5.68	11.2	21.8	40.7	48.5	87.6	96.5	99.9	100	100	100
EC-AC	3/20/2018 14:25	138	117	42	597	331	0.17	1.72	4.61	8.94	17.3	30.4	35.4	60.8	70.8	80.3	89.1	98.4	100
EC-AC	4/20/2018 15:01	18	2	4	330	28	0.05	0.58	2.48	5.62	11.1	21.8	27.2	60.2	79.3	90.3	94.8	100	100
EC-AC	5/16/2018 11:21	36	29	20	517	150	0.38	3.87	10.5	20.4	36.2	57.7	64.5	84.7	93.2	98.9	99.9	100	100
EC-AC	5/24/2018 17:23	1,005	400	429	9,697	2,320	0.24	2.47	6.56	12.5	24.1	42.7	49.9	83.0	93.1	100	100	100	100
EC-AC	5/25/2018 3:43	133	94	68	1,098	477	0.30	3.11	8.55	16.6	30.6	51.0	57.9	83.9	93.9	98.8	99.9	100	100

Table A.4 Raw analytical data for samples taken at Lakeshore in WY18

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
LS-AC	11/15/2017 21:21	34	24	8	753	167	0.09	0.91	2.49	5.17	11.2	24.9	31.5	69.4	84.1	91.5	95.6	100	100
LS-AC	3/21/2018 3:46	81	80	37	568	368	0.23	2.32	6.42	13.0	25.3	45.8	53.7	89.7	97.2	100	100	100	100
LS-AC	4/6/2018 13:10	88	82	21	711	295	0.10	1.05	2.93	6.12	12.4	23.7	28.6	63.7	81.6	90.8	91.1	95.3	100
LS-AC	5/16/2018 10:01	50	51	32	905	370	0.52	5.15	13.4	24.6	42.0	64.9	72.5	89.6	94.7	98.1	99.3	100	100
LS-AC	5/25/2018 5:23	64	59	43	936	307	0.38	3.96	11.2	22.5	41.8	67.1	74.4	90.8	96.7	99.8	100	100	100

Table A.5 Raw analytical data for samples taken at Pasadena in WY18.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
PO-AC	11/15/2017 22:53	43	30	13	1,436	312	0.15	1.50	4.12	8.37	16.2	30.7	37.1	73.9	91.3	99.9	100	100	100
PO-AC	1/6/2018 2:03	109	88	43	2,251	576	0.21	2.02	5.43	11.2	22.2	39.6	46.5	81.4	93.1	96.3	96.8	100	100
PO-AC	3/21/2018 4:50	38	33	12	562	194	0.16	1.62	4.63	9.57	18.2	31.4	36.1	52.7	59.3	66.3	83.7	99.9	100
PO-AC	4/6/2018 13:20	69	65	23	722	342	0.18	1.81	4.94	9.79	19.0	34.0	40.0	77.0	93.7	100	100	100	100
PO-AC	5/16/2018 11:56	125	78	59	1,366	616	0.23	2.30	6.34	13.1	26.2	47.0	54.8	88.3	97.0	100	100	100	100
PO-AC	7/22/2018 17:18	270	189	98	12,879	1,975	0.22	2.21	6.01	11.9	22.1	36.3	41.2	68.0	96.4	98.2	98.9	100	100

Table A.6 Raw analytical data for samples taken at Speedboat, WY18.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
SB-AC	11/15/2017 10:58	79	46	13	1,652	344	0.10	0.97	2.56	4.84	9.14	17.0	20.1	34.5	40.0	47.7	64.8	91.0	100
SB-AC	1/5/2018 23:18	198	95	96	2,923	614	0.26	2.70	7.44	14.5	27.2	48.3	56.1	87.5	96.0	100	100	100	100
SB-AC	3/8/2018 13:30	144	126	105	1,464	642	0.71	7.42	20.6	36.5	54.9	73.0	78.1	90.0	95.4	99.7	100	100	100
SB-AC	3/10/2018 16:26	312	363	293	2,311	1,512	1.01	10.8	31.0	54.6	77.5	93.9	97.2	99.9	100	100	100	100	100
SB-AC	3/13/2018 13:25	287	249	153	1,943	1,012	0.28	2.93	8.38	16.8	31.1	53.4	61.4	90.8	97.2	100	100	100	100
SB-AC	3/20/2018 12:51	206	140	82	952	704	0.23	2.43	6.75	13.0	23.7	39.9	45.6	66.5	72.3	79.0	90.0	100	100

Table A.7 Raw analytical data for samples taken at Tahoe Valley, WY18.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
TV-AC	11/15/2017 10:33	30	23	4	1,327	173	0.07	0.70	1.81	3.35	6.20	12.1	14.9	34.0	45.1	53.8	68.8	90.7	100
TV-AC	1/6/2018 4:38	52	57	26	1,693	279	0.33	3.33	8.98	17.0	30.2	50.5	58.1	87.5	93.8	97.1	98.1	100	100
TV-AC	3/10/2018 15:38	129	173	123	1,418	642	1.07	11.2	31.3	55.6	79.1	95.0	96.6	98.3	98.8	100	100	100	100
TV-AC	3/13/2018 13:06	126	128	36	1,138	359	0.14	1.45	3.88	7.67	15.1	28.2	33.5	61.1	69.2	75.6	86.6	96.9	100
TV-AC	3/21/2018 5:41	38	34	14	619	156	0.20	1.99	5.45	10.9	20.5	37.0	44.1	74.9	84.6	89.6	96.8	100	100
TV-AC	4/2/2018 8:20	20	4	2	302	43	0.04	0.36	0.88	1.72	4.13	10.5	14.1	39.6	59.9	78.7	86.1	98.2	100
TV-AC	7/14/2018 17:36	202	96	91	5,249	924	0.34	3.40	9.08	16.8	28.9	45.1	50.5	72.7	87.3	94.3	97.6	100	100
TV-AC	7/22/2018 16:55	123	72	35	3,045	566	0.16	1.62	4.47	9.18	17.5	28.6	32.0	43.8	50.3	57.7	82.5	99.4	100

Table A.8 Raw analytical data for samples taken at Tahoma, WY18.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
TA-AC	11/9/2017 1:38	34	24	0.5	854	272	0.005	0.06	0.24	0.42	0.77	1.48	1.87	4.78	7.17	12.7	26.6	53.3	100
TA-AC	11/15/2017 7:36	29	16	9	738	119	0.16	1.51	4.05	8.06	15.5	30.5	37.9	75.7	91.0	99.7	100	100	100
TA-AC	3/5/2018 9:51	113	162	83	1,479	586	0.62	6.54	18.6	33.8	52.6	73.7	80.7	97.2	99.6	100	100	100	100
TA-AC	3/13/2018 10:43	367	374	204	2,036	1,346	0.32	3.39	9.60	18.9	34.3	55.7	62.9	90.3	97.4	100	100	100	100

Table A.9 Raw analytical data for samples taken at Upper Truckee, WY18.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
UT-AC	10/20/2017 0:50	73	42	5	3,871	638	0.02	0.23	0.77	2.02	4.18	7.17	8.33	14.5	17.4	25.1	61.1	98.3	100
UT-AC	11/15/2017 9:35	146	97	42	5,005	319	0.13	1.30	3.73	7.84	15.6	29.1	34.5	65.2	79.7	91.4	94.9	99.4	100
UT-AC	1/18/2018 21:41	1,199	2,983	910	6,137	5,103	0.56	6.01	17.6	33.7	56.2	75.9	81.8	97.4	99.4	100	100	100	100
UT-AC	3/5/2018 11:35	551	714	443	2,731	2,419	0.60	6.52	19.3	36.7	59.7	80.3	86.1	97.6	99.5	100	100	100	100
UT-AC	3/10/2018 16:03	1,125	2,355	1,001	3,905	4,624	0.83	9.04	26.9	49.2	72.5	89.0	92.8	97.9	99.2	100	100	100	100
UT-AC	3/13/2018 12:36	1,315	1,482	678	4,240	3,181	0.29	2.97	8.31	16.7	31.6	51.6	58.9	88.8	95.7	99.8	100	100	100
UT-AC	3/20/2018 15:20	413	318	194	1,343	955	0.26	2.68	7.29	14.4	27.7	47.1	54.3	85.5	94.8	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 WY18. Pink cells indicate paired samples that have a difference between them of greater than 20%. The MS sample from Tahoma picked up more fine sediment than the GS sample taken at the same time as indicated by greater fractions in the smaller particle size bins. This can occur because the autosampler has an easier time drawing up smaller particles.

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-GS	11/16/2017 11:56	49	37	10	865	205	0.08	0.80	2.13	4.39	9.68	21.3	26.7	60.0	71.0	78.7	87.4	99.7	100
LS-MS	11/16/2017 11:55	57	42	11	880	211	0.07	0.71	1.91	3.95	8.68	19.0	23.8	57.1	71.0	80.8	89.2	98.6	100
TA-GS	11/9/2017 18:06	42	44	2	866	329	0.03	0.32	0.82	1.45	2.55	5.17	6.63	18.5	27.1	36.9	58.1	86.2	100
TA-MS	11/9/2017 18:05	42	45	5	873	332	0.06	0.66	1.79	3.37	6.09	12.3	15.6	42.2	57.7	63.0	75.3	99.6	100
TV-MS	3/14/2018 10:31	39	40	na	691	115	na	na	na	na	na	na	na	na	na	na	na	na	na
TV-MS	3/14/2018 10:32	38	38	na	665	115	na	na	na	na	na	na	na	na	na	na	na	na	na

Table B.2 Field blank sample data from all sites in WY18. 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
EC-FB	11/16/2017 17:00	<0.3	0.09	na	<35	<1	na	na	na	na	na	na	na	na	na	na	na	na	na
LS-FB	11/16/2017 11:57	<0.3	0.10	na	<35	<1	na	na	na	na	na	na	na	na	na	na	na	na	na
PO-FB	7/22/2018 17:30	<0.3	0.12	na	<35	<1	na	na	na	na	na	na	na	na	na	na	na	na	na
TV-FB	11/16/2017 14:00	<0.3	0.30	na	<35	<1	na	na	na	na	na	na	na	na	na	na	na	na	na