2018-2019

Country Club Heights ECP Monitoring Report

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Prepared by Tahoe RCD

Prepared for El Dorado County

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Funding for this project has been provided to the Tahoe Resource Conservation District through an agreement with El Dorado County.

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1. Monitoring Purpose

In 1968, the first year that UC Davis began taking routine measurements, lake clarity was 102 feet. Since then, clarity has decreased by more than 30 feet to its current level of about 70 feet. The Total Daily Maximum Load (TMDL) Program is the 65-year plan to restore lake clarity levels to what they were in the early 1970's, about 100 feet. Restoring clarity depends on reducing the amount of fine sediment particles (FSP) that enter the lake each year, primarily through stormwater runoff. These tiny particles stay suspended in the water column and make the pristine waters of Lake Tahoe appear cloudy. Jurisdictions around the lake are tasked with implementing the TMDL Program and are subject to regulations that require them to reduce FSP loads in stormwater runoff.

There are many sources of FSP, including several natural sources, but research has shown that about 72% of FSP originates in the urban environment. Controlling sources of FSP in the urban environment, especially from roads, is the primary way that jurisdictions are attempting to reduce FSP delivery to the lake. Historically, controlling sediment meant reducing erosion through soil stabilization and capturing and infiltrating stormwater in catch basins. More recently, in an attempt to control FSP specifically, jurisdictions have changed the type of sand they use during snowstorms to increase traction on slippery roads. The new aggregate is harder and less likely to pulverize when thousands of tires run over it repeatedly. They have also changed the way they apply the traction abrasives. Instead of one blanket application method, they now vary the amount of sand they put down; more abrasives are applied in steep, heavily trafficked areas, and less is applied in flat, low traffic areas. Lastly, they have increased the frequency of street sweeping, and even purchased better machines, in order to increase the recovery of the abrasives they apply.

Under the TMDL program, the jurisdictions must earn a certain number of "lake clarity credits" each year to track progress toward the 100-foot clarity goal. They earn credits for the pounds of sediment they prevent from entering the lake through the capital projects or improved management strategies described above. Each year it gets more and more difficult to identify new projects or management strategies to garner the requisite number of credits. However, the joint study between the Tahoe RCD and El Dorado County described in this report points to a new source of credits: controlling the FSP that comes from the road surface itself. El Dorado County staff noticed that the source of a large portion of sediment that accumulated on road shoulders appeared to be asphalt aggregate and binder. Roads in poor condition seemed to deteriorate more quickly and contribute more sediment to the total load than roads in good condition.

Elks Club Drive comprises a small portion of the total Country Club Heights Erosion Control Project (CCH) area. It was repaved in August 2018 as part of Phases 1 and 2 of the CCH project. Monitoring was conducted on Elks Club Drive as part of the larger CCH project. Stormwater samples were taken for a year prior to the repaving project, when the road was in very poor condition, and a year after the project, when the road was in excellent condition. Source apportionment analysis was conducted on the sediment in the stormwater runoff. Samples were also analyzed for sediment and nutrient concentrations. The objective of the study was to determine the total amount of sediment and nutrients delivered in stormwater runoff so the results could be used in Phase 3 of the CCH project. A secondary objective was to determine if the proportion of FSP derived from the road surface itself decreased after the road was repaved. In other words, will repaving a poor condition road result in water quality improvement? If so, could repaving roads be recognized as a water quality Best Management Practice (BMP) and earn credits under the TMDL Program?

Public roads are the arteries of a community; they are crucial to economic development and growth and provide fundamental social benefits. They are also vital to public safety, providing evacuation routes in the case of natural disasters like wildfire or flooding, and permitting emergency vehicles to easily reach locations where they are needed quickly. Investment in building and maintaining public roads is essential as road infrastructure is the public's most important asset. Lake Tahoe Is the public's most important natural asset, providing clean water, recreational opportunities and supporting the tourism-based economy. If repaving were recognized as a legitimate way to significantly reduce FSP to the lake and became an eligible expense in water quality grants, then more roads would be repaired, and it would be a win-win for the community and the lake.

2. Monitoring Design

During Water Years 2018 and 2019 the Elks Club catchment was monitored for continuous flow and turbidity and sampled for water quality at one monitoring station. All data has been collected in a manner consistent with Regional Stormwater Monitoring Program (RSWMP) monitoring protocols outlined in the RSWMP Framework and Implementation Guidance (FIG) document (Tahoe RCD et al 2017) designed to provide consistent data collection, management, analysis, and reporting approaches so that results can easily align with RSWMP objectives (see Appendix C). See Figure 1 for stormwater monitoring site and meteorological station locations.

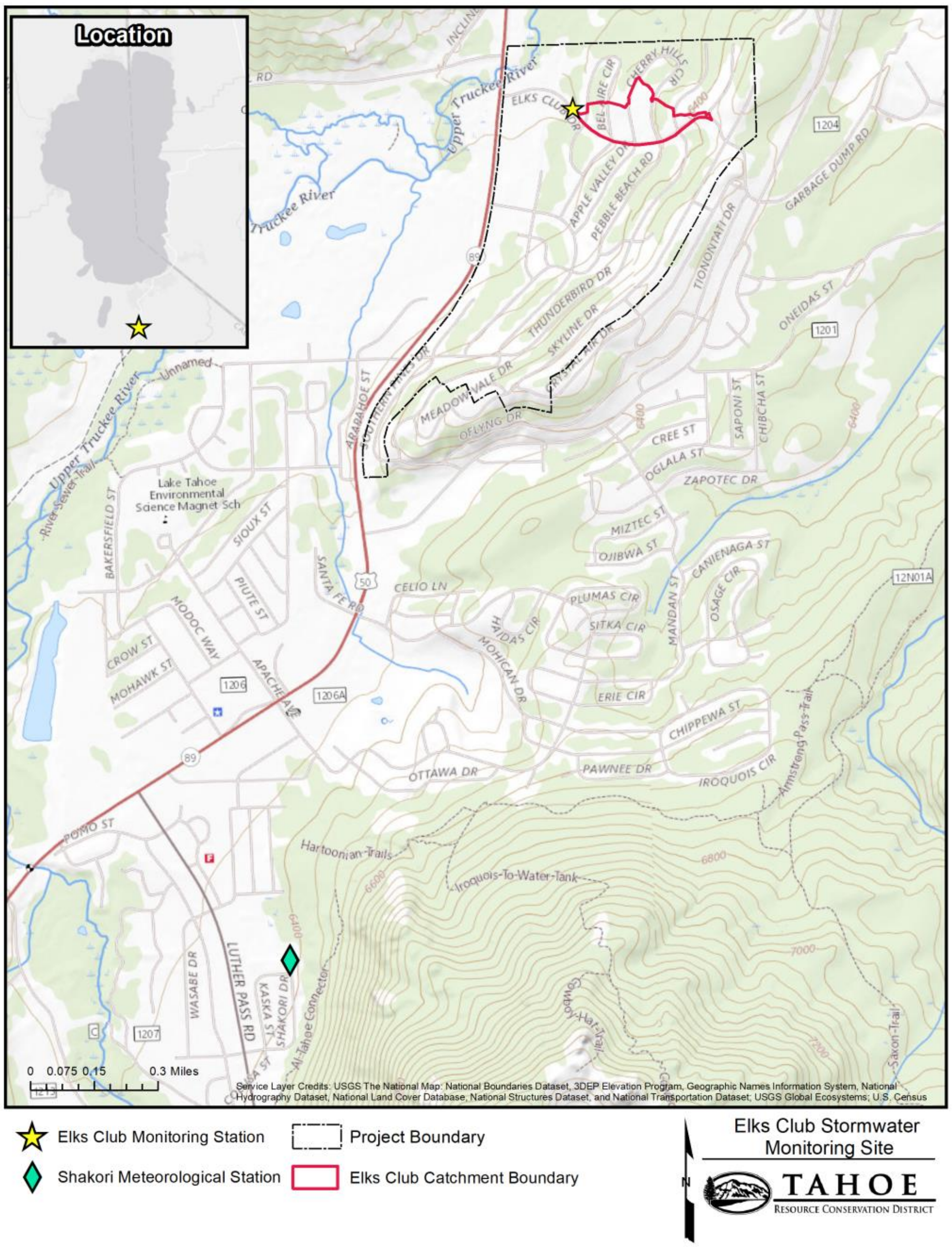

Figure 1 Elks Club monitoring station, Shakori meteorological station, CCH project boundary and EC catchment boundary.

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, CA. 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 fairly 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 very 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 Phases 1 & 2 of the CCH erosion control project in this catchment that included completely reconstructing and repaving Elks Club Drive and armoring the road shoulders and roadside channels 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. A primary purpose of this monitoring site was 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 results will help inform the anticipated effectiveness of the improvements planned as part of the Phase 3 of the CCH project.

3. Monitoring Results

PCI is a numerical index between 0 and 100 used to indicate the general condition of pavement. It requires a manual survey and is widely used by transportation departments to evaluate road condition. PCI was developed by the United States Army Corps of Engineers and surveying and calculation methods were standardized by the American Society for Testing Materials (ASTM). The method is based on a visual survey of the number and types of distresses in the pavement including alligator cracking, block cracking, bumps and sags, corrugations, longitudinal and transverse cracking, patching and utility cut patching, potholes, swelling, weathering, raveling, etc. Assessing PCI on roads is the most widely used and accepted method for determining road surface condition so that condition can be tracked, and roads can be prioritized for funding for repaving or resurfacing.

Elks Club Drive was repaved in August 2018 as part of the CCH project, right before the start of WY19. Data collected at Elks Club in WY18 and WY19 represent pre and post project conditions respectively. Prior to repaving, Elks Club Drive was in poor condition, covered in cracks and potholes (Figure 2 - PCI: 29). In August 2018 it was repaved and is now in excellent condition (Figure 3 - PCI: 99).

Figure 2 Elks Club Drive prior to repaving. (R Wigart)

Figure 3 Elks Club Drive after repaving. (A Buxton)

Elks Club runoff samples were analyzed sediment and nutrient concentration (according to protocols outlined in the RSWMP FIG) as well as 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 to a specialized laboratory 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.

Table 1 shows results of the source apportionment analysis and the Total Suspended Sediment (TSS) and FSP concentration data and normalized load calculations. A t-test is a statistical test, resulting in a p-value, that is used to determine if there is a significant difference between the means of two sets of data. If the p-value is less than 0.001, then results are highly significant, meaning that there is only a 0.1% chance that the differences between the two sets of data were by chance. If the p-value is less than 0.05, results are significant, meaning that there is only a 5% chance the differences between the two sets of data were by chance.

Table 1 shows that there was a statistically significant decrease in the relative contribution of particles from road sources (asphalt aggregate plus binder and traction abrasives), and a significant increase in relative contribution of particles from non-road sources (roadside soil, vegetation debris, and atmospheric deposition) before and after pavement condition improvement. Figure 4 shows the percent composition of FSP in stormwater before and after paving. When relative contributions of asphalt aggregate plus binder and traction abrasives decrease, the relative contributions of naturally occurring roadside soil, vegetation debris, and atmospheric deposition increase as these contributions are not changed by improving pavement condition. Assuming traction abrasive application practices remain fairly consistent from year to year, the decrease in the relative contribution of traction abrasives with improved pavement condition can be reasonably attributed to more efficient sweeping. Street sweeping on a smooth road surface is more effective than on a road surface marred by cracks and potholes allowing more sediment to be recovered. Percent contribution to FSP from each source category in the pre and post pave condition describes only how the composition of FSP in stormwater changed, it does not indicate if total sediment loads decreased. However, Table 1 also shows statistically significant decreases in TSS concentration, FSP concentration, normalized TSS load, and normalized FSP load (pounds of sediment per acre per inch of rain).

Table 1 Results of Elks Club sediment analyses. P-values less than 0.001 indicate highly significant results (highlighted in green). P-values less than 0.05 indicate significant results (highlighted in yellow). FSP concentrations and loads are based on samples taken during precipitation events, not estimated from continuous turbidity.

Water Year	Statistic	Source Apportionment Analysis					Sediment Concentrations and Loads			
		Asphalt aggregate + binder (%)	Traction abrasives (%)	Road side soil (%)	Vegetation debris (%)	Atmos-pheric deposition (%)	TSS concen-tration (mg/L)	Normalized TSS load (lbs/acre/in)	FSP concen-tration (mg/L)	Normalized FSP load (lbs/acre/in)
Pre Paving 2018	Mean	45.00	16.60	34.00	3.00	2.70	83.90	6.30	32.50	1.50
	Standard Deviation	6.51	5.26	6.66	0.95	1.25	50.66	7.58	22.12	1.32
	Min	36.00	10.00	24.00	1.50	1.00	17.50	0.25	3.82	0.14
	Median	45.00	17.00	34.00	3.00	3.00	101.30	3.60	37.26	1.83
	Max	56.00	25.00	45.00	4.50	5.00	137.50	22.11	67.58	3.28
Post Paving 2019	Mean	24.90	8.20	42.20	16.50	5.00	22.70	0.60	6.90	0.10
	Standard Deviation	6.10	2.76	6.83	4.33	1.63	15.47	0.82	5.77	0.08
	Min	14.80	3.00	33.00	10.00	2.00	10.00	0.03	0.57	0.01
	Median	26.20	9.00	41.00	16.00	5.00	15.25	0.29	5.10	0.07
	Max	33.70	11.00	55.00	23.00	8.00	57.00	2.47	19.10	0.27
	T-test p-value	**0.000**	**0.004**	**0.023**	**0.000**	**0.003**	**0.018**	**0.050**	**0.013**	**0.026**

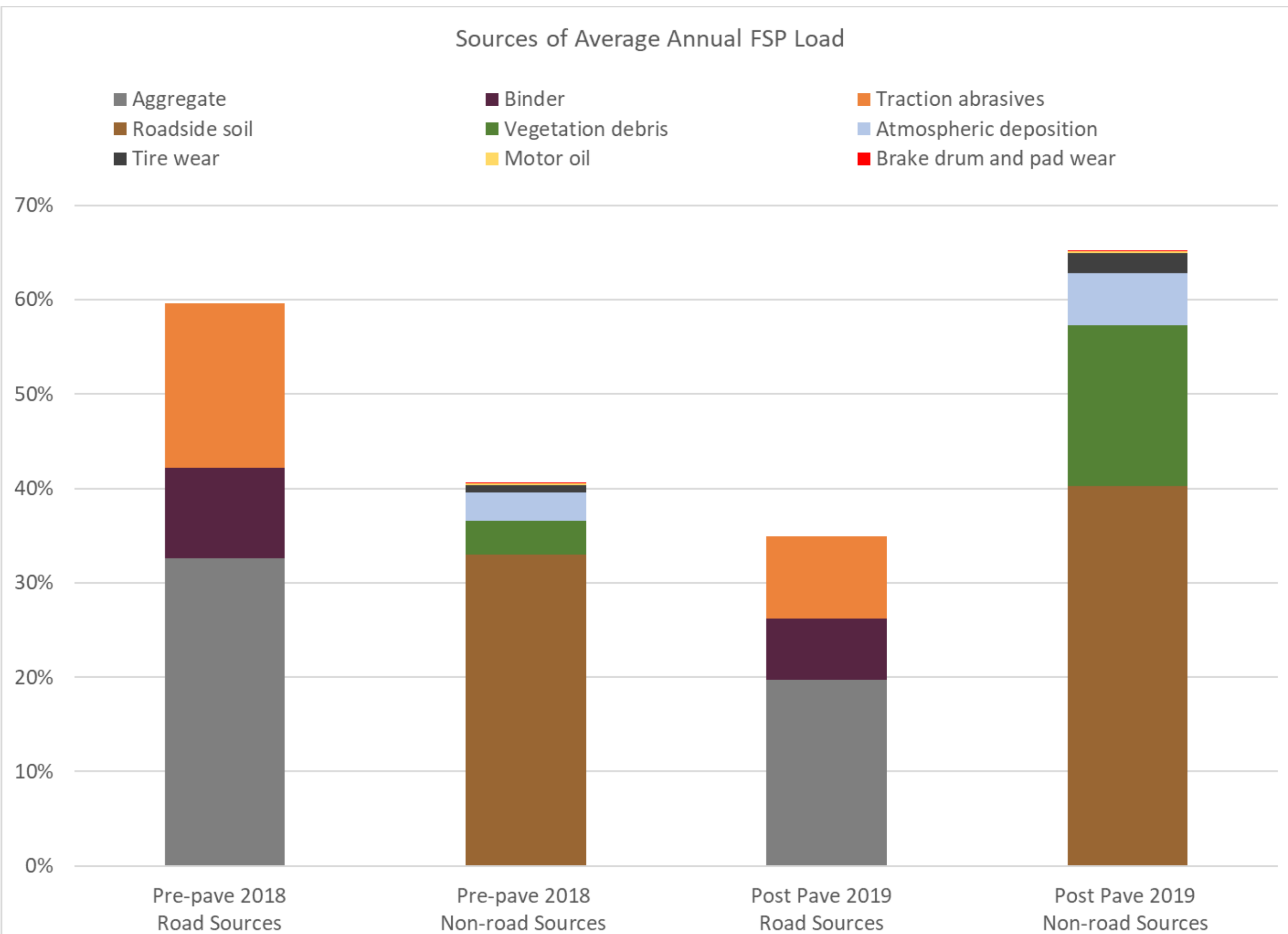

Figure 4 Average annual FSP load attributable to road and non-road sources at Elks Club, WY18 and WY19. 60% and 35% of the FSP in stormwater runoff from Elks Club Drive originated from road sources (asphalt aggregate, asphalt binder, and traction abrasives) in the pre- and post-pave conditions respectively.

Table 2 shows the substantial impact that improving pavement condition on Elks Club Drive had on water quality in terms of reduced sediment concentrations and loads. Mean annual TSS and FSP concentrations were reduced by 73% and 79% respectively, which resulted in mean annual normalized TSS and FSP load reductions of 90% and 93% respectively. (Normalized load values account for catchment size and remove year to year variability in precipitation frequency, size, intensity, and duration.) Since FSP load reduction is the primary objective of the Lake Tahoe TMDL, the remarkable results of this study indicate that repaving roads can be immensely beneficial to reaching the 65-year goal of increasing lake clarity to 100ft.

Table 2 Average annual sediment concentration and load reductions.

Water Year	TSS concen-tration (mg/L)	Normalized TSS load (lbs/acre/in)	FSP concen-tration (mg/L)	Normalized FSP load (lbs/acre/in)
Pre Paving 2018	83.90	6.30	32.50	1.50
Post Paving 2019	22.70	0.60	6.90	0.10
% Reduction	**73%**	**90%**	**79%**	**93%**

Table 3 shows that the average concentration and normalized load for Total Nitrogen (TN) and Total Phosphorus (TP) decreased substantially after repaving.

Table 3 Average annual nutrient concentration and load reductions.

Water Year	TN concen-tration (mg/L)	Normalized TN load (lbs/acre/in)	TP concen-tration (mg/L)	Normalized TP load (lbs/acre/in)
Pre Paving 2018	0.72	0.029	0.26	0.011
Post Paving 2019	0.42	0.010	0.09	0.002
% Reduction	**42%**	**65%**	**67%**	**77%**

See Appendix A for event summary data and Appendix B for raw analytical data.

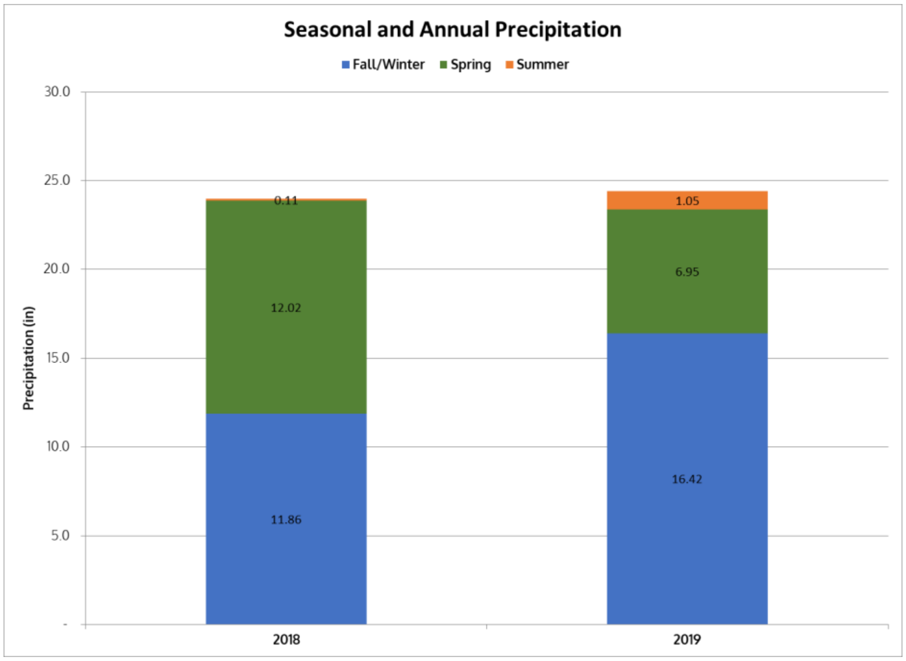

Figure 5 Precipitation totals at Shakori meteorological station near Elks Club Drive, WY18 and WY19.

Figure 5 shows that in WY18, 23.99 inches of precipitation were recorded at the Shakori meteorological station; 11.86 inches in the fall/winter, 12.02 inches in the spring, and 0.11 inches in the summer. In WY19, 24.42 inches of precipitation were recorded at the Shakori meteorological station; 16.42 inches in the fall/winter, 6.95 inches in the spring, and 1.05 inches in the summer. Table 4 shows this data in tabular format.

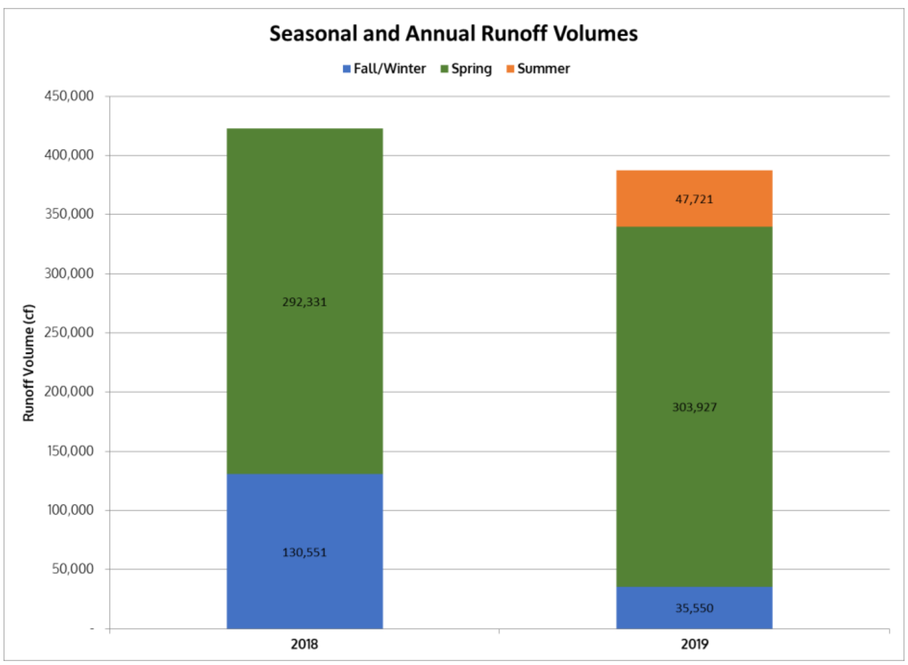

Figure 6 Runoff volumes at Elks Club monitoring station, WY18 and WY19. There was no summer runoff recorded in WY18.

Figure 6 shows that in WY18, 422,881 cubic feet (cf) of runoff were recorded at the Elks Club monitoring station; 130,551 cf in the fall/winter, 292,331 cf in the spring, and 0 cf in the summer. In WY19, 387,197 cf of runoff were recorded at the Elks Club monitoring station; 35,550 cf in the fall/winter, 303,927 cf in the spring, and 47,721 cf in the summer. Table 4 shows this data in tabular format.

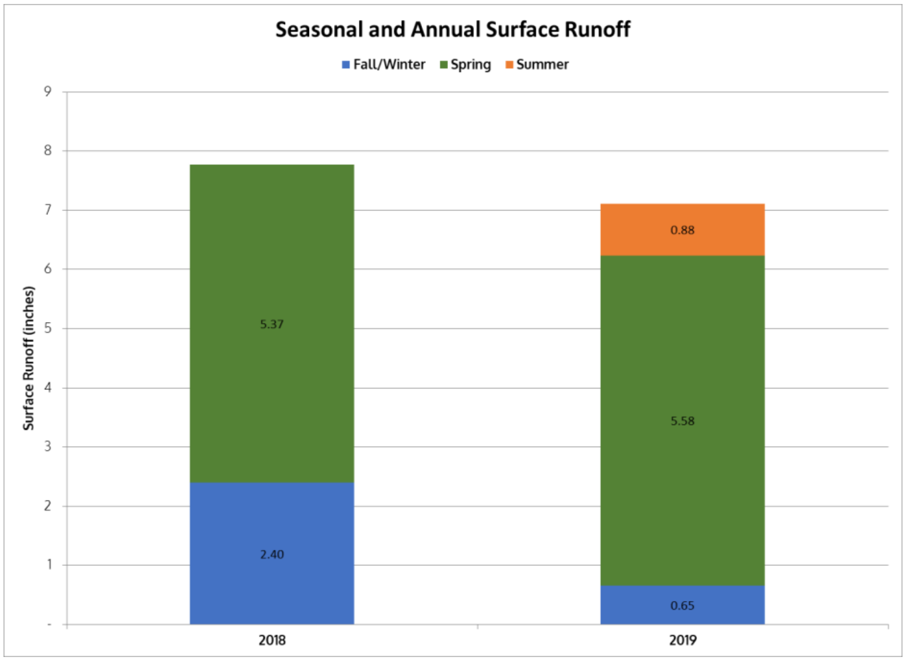

Figure 7 Surface runoff at Elks Club monitoring station, WY18 and WY19. There was no summer runoff recorded during WY18.

Figure 7 shows that in WY18 the surface runoff from Elks Club Drive was 8.09 inches; 2.50 inches in the fall/winter, 5.59 inches in the spring, and 0.00 inches in the summer. This corresponds to and annual runoff coefficient of 34%, and runoff coefficients for fall/winter, spring, and summer of 21%, 47%, and 0% respectively. In WY19, the surface runoff from Elks Club drive was 7.41 inches; 0.68 in the fall/winter, 5.81 in the spring, and 0.91 in the summer. This corresponds to and annual runoff coefficient of 30%, and runoff coefficients for fall/winter, spring, and summer of 4%, 84%, and 87% respectively. Table 4 shows this data in tabular format.

Table 4 Precipitation, runoff volumes, surface runoff, and runoff coefficients for Elks Club WY18 and WY19.

		Fall/Winter	Spring	Summer	Water Year
Precip (in)	WY18	11.86	12.02	0.11	23.99
	WY19	16.42	6.95	1.05	24.42
Runoff Volume (cf)	WY18	130,551	292,331	0	422,881
	WY19	35,550	303,927	47,721	387,197
Surface Runoff (in)	WY18	2.50	5.59	0.00	8.09
	WY19	0.68	5.81	0.91	7.41
Runoff Coefficient	WY18	21%	47%	0%	34%
	WY19	4%	84%	87%	30%

Figure 8 through Figure 11 show sediment and nutrient loads for Elks Club compared to total annual precipitation for WY18 and WY19. This illustrates how loading and precipitation have varied over the monitored period. Charts for FSP based on continuous turbidity are included for comparison.

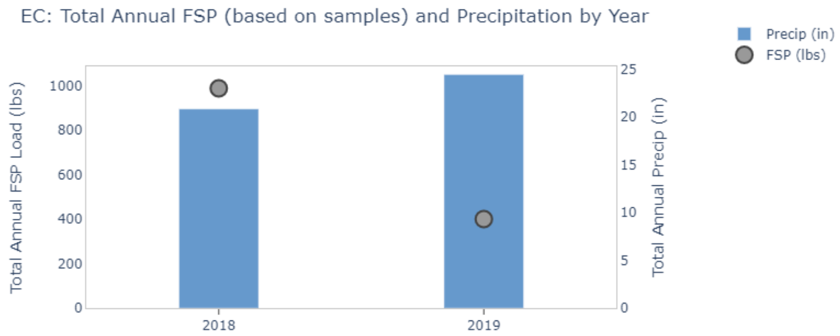

Figure 8 Total annual FSP load (based on samples) and precipitation by year for Elks Club WY18-WY19.

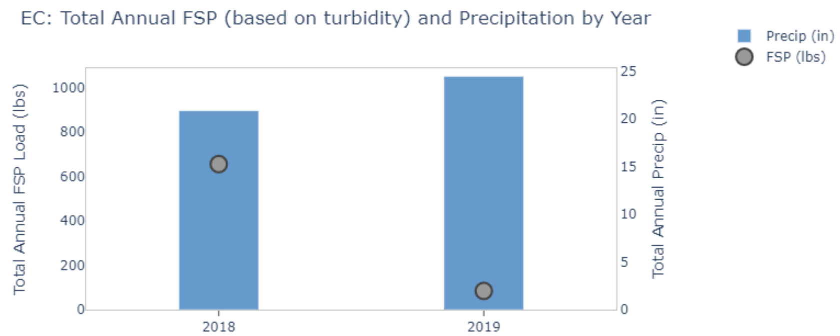

Figure 9 Total annual FSP load (based on continuous turbidity) and precipitation by year for Elks Club WY18-WY19.

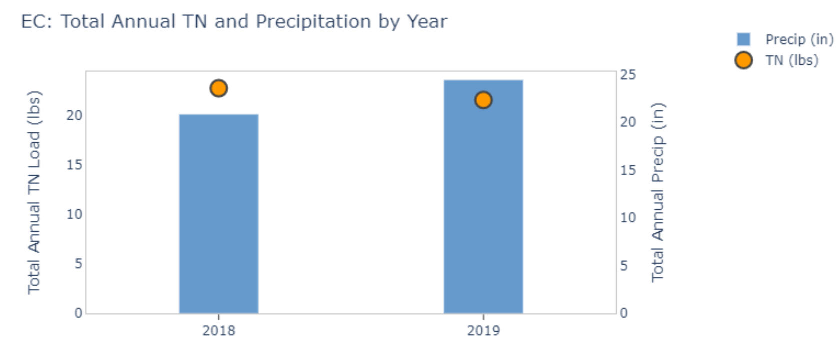

Figure 10 Total annual TN load and precipitation by year for Elks Club WY18-WY19.

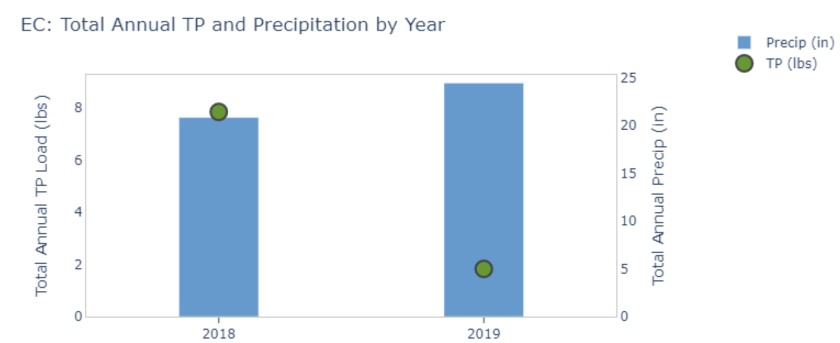

Figure 11 Total annual TP load and precipitation by year for Elks Club WY18-WY19.

4. Washoff Studies

The Elks Club washoff studies consisted of monitoring washoff from Elks Club Drive on two occasions; April 24, 2018 (WY18), before Elks Club Drive was repaved, and June 19, 2019 (WY19), after the road was repaved. Monitoring on both occasions followed the same protocols so that results could easily be compared. A water truck made four passes along the same stretch of the road, spilling approximately the same volume of water (about 5,000 total gallons), for approximately the same duration on each pass. Continuous flow and turbidity were measured at the catchment outfall monitoring site, and water quality samples were taken every minute for the duration of the flow. The study showed two very important results: a decrease in overall sediment loads and an indication that roads in good condition are not continually eroding. Table 5 and Table 6 show event summary statistics and source apportionment results for the washoff studies.

Table 5 Event summary statistics for the WY18 and WY19 washoff studies.

Water Year	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	FSP EMC (mg/L)	FSP event load (lbs)
2018	Spring	4/24/2018 11:29	4/24/2018 13:43	2:14	498	0.18	1,232	220	6.8
2019	Summer	6/19/2019 7:51	6/19/2019 9:12	1:21	241	0.22	509	12	0.2

Table 6 Source apportionment results (% contribution from each source and % change) for the WY18 and WY19 washoff studies.

Water Year	Asphalt aggregate	Asphalt binder	Traction abrasives	Road side soil	Vegetation debris	Atmos-pheric deposition	Tire wear	Motor oil	Brake drum and pad wear	Lead balance weight
2018	35	9	23	26	1.5	5.0	0.5	0.2	0.03	<0.0001
2019	18	5	18	48	3.0	3.0	5.0	0.2	0.10	<0.0001
% change	-49%	-44%	-22%	85%	100%	-40%	900%	0%	233%	na

Figure 12 and Figure 13 show the continuous flows and turbidities for the WY18 pre-project condition and the WY19 post project condition respectively. Pre-project condition shows a maximum turbidity of 1232 NTU and an average turbidity of 217 NTU, while the post project condition shows a maximum turbidity of 509 NTU and an average turbidity of 65 NTU, indicating a 50-60% decrease in overall sediment load. Peak flows were slightly higher in the post project condition. Figure 12 (pre-project condition) shows that turbidities were highest when the flows were highest, suggesting that there was a continuous source of sediment present. This indicates that the road surface was eroding in the pre paving condition. Figure 13 (post-project condition) shows that while turbidities did mirror flow intensity to a certain extent, at one point the turbidity leveled off and then rapidly dropped off even when flows were still high, suggesting that the source of sediment had been exhausted, and signaling a first flush condition.

Figure 14 and Figure 15 show the mass first flush ratios for the pre-project and post-project conditions respectively. A mass first flush ratio compares the cumulative sediment mass to the cumulative volume and gives an indication of whether most of the sediment is washed off in the beginning of a flow event or not. As alluded to above, if most of the sediment is washed off with the initial flush of water, then there is no indication of continual erosion of the road surface. The dotted line in Figure 14 and Figure 15 (plotted on the primary axis) show what the graph would look like if there was no first flush (mass to volume ratio equals 1.0). In other words, when 10% of the flow has passed, 10% of the sediment mass has also passed through the monitoring site, when 20% of the flow has passed, 20% of the mass has also passed, and when 50% of the flow has passed, 50% of the mass has also passed etc. The mass first flush ratio line (plotted on the secondary axis) in Figure 14 shows that sediment was delivered throughout the runoff period, most importantly, the ratio of mass to volume was less than 1.0 at about 20% of the flow indicating that there was no first flush. The mass first flush ratio line (plotted on the secondary axis) in Figure 15 shows that the majority of the sediment was delivered in the first 30% to 40% of the flow, in other words, the mass to volume ratio was far above 1.0 in the initial period of flow. This indicates that there was a first flush in the post project condition and suggests that the road surface was not eroding. These charts use only the continuous turbidity to estimate total sediment mass, but water quality sample analysis and source apportionment mass balance calculations confirm these results. Table 5 shows that average FSP concentration went from 220 mg/L to 12 mg/L after repaving, a 94% reduction. Table 5 also shows that FSP load went from 6.8 pounds to 0.2 pounds, a 97% reduction. Table 6 shows that the relative contribution from primary road based sources (aggregate, binder, and abrasives) all decreased after repaving while the relative contribution from primary non-road based sources (road side soil, vegetation debris) increased after repaving.

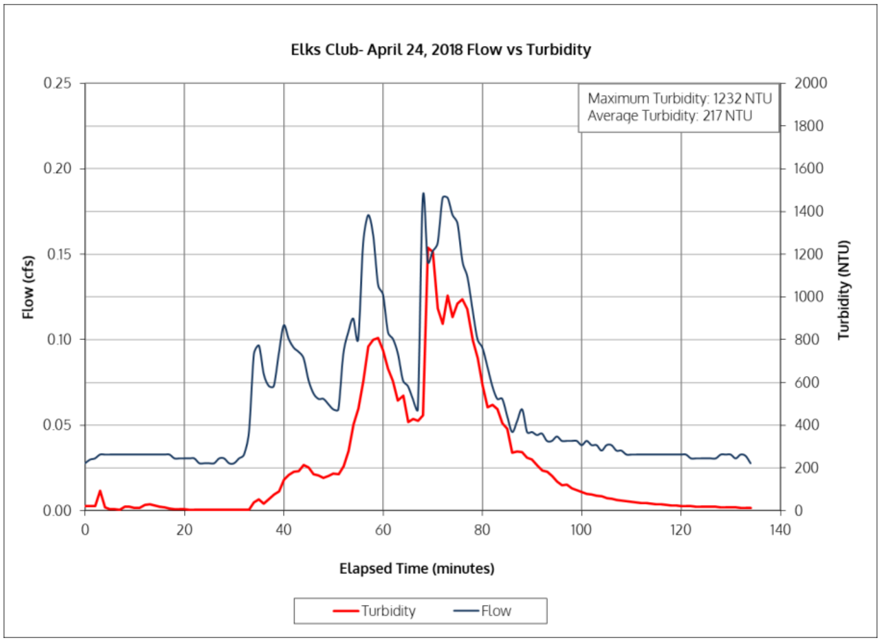

Figure 12 Continuous flow and turbidity for the pre-project condition, WY18.

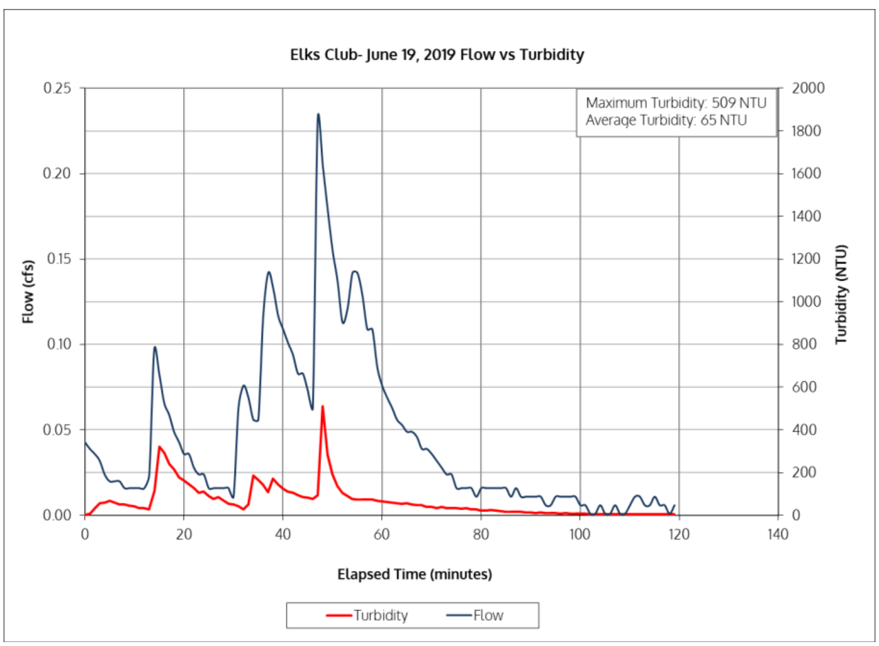

Figure 13 Continuous flow and turbidity for the post-project condition.

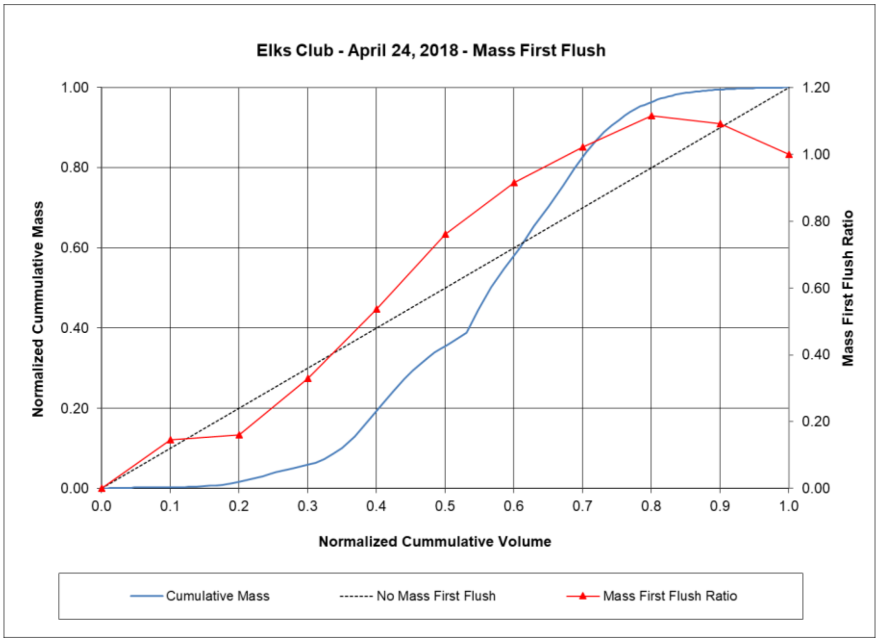

Figure 14 Mass first flush ratio for the pre-project condition.

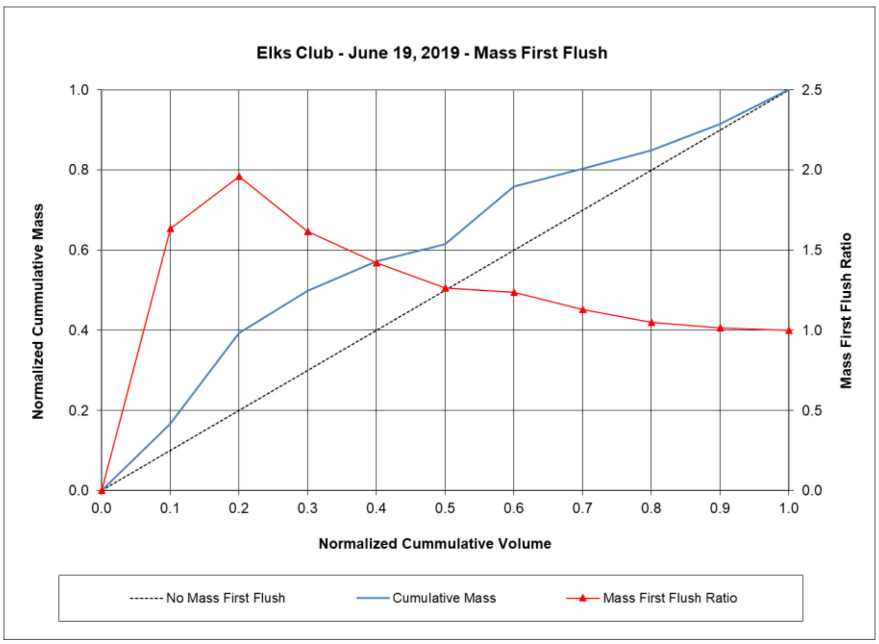

Figure 15 Mass first flush ratio for the post-project condition.

Washoff Study Photos

WY2018: April 24, 2018	WY2019: June 19, 2019
  	  

5. PLRM Modeling Results

Tahoe RCD compared average annual normalized runoff volumes (cubic feet per acre per inch) and pollutant loads (pounds per acre per inch) predicted by PLRMv2.1 to average annual normalized volumes and pollutant loads measured in WY18 and WY19 at all Elks Club; results are presented in Table 7. Measured and modeled runoff volumes and pollutant loads are normalized by precipitation and catchment area in order to compare between water years and to compare to PLRM modeled results (PLRM modeled results represent average annual conditions based on an 18-year meteorological average). To model the anticipated sediment load reductions attributable to paving the road, the Road RAM value for Elks Club drive was changed. The median of measured RAM values was used for the WY18 and WY19 model runs; 2.7 and 3.1 respectively. No other model parameters were modified between the WY18 and WY19 model runs.

Between WY18 and WY19, PLRM predicted a reduction in normalized pollutant loads for all pollutants, however the measured reduction was much greater than the modeled reduction. Normalized modeled runoff volumes are lower than normalized measured runoff volumes. The modeled runoff volumes predicted zero difference between WY18 and WY19, and a 45% increase was observed in normalized measured runoff volumes. This difference might be explained by differences in snowmelt runoff year to year, changes in surface runoff routing caused by repaving Elks Club Drive, or the lack of cracks in the pavement effectively making the road surface more permeable. In WY18, the modeled normalized TSS and FSP are higher than measured but are similar in magnitude. In WY19 the normalized modeled TSS and FSP are much higher than measured, meaning the model underpredicted the improvement to water quality from paving the road. For TSS, PLRM predicted a 7% reduction, while a 90% reduction was observed, and for FSP PLRM predicted a 7% reduction, while a 93% reduction was observed. Both PLRM modeled normalized TN and modeled normalized TP performed very well for WY18 and WY19, with very similar ranges of normalized pollutant loads between modeled and measured results. For TN, the model predicted a 3% reduction in normalized pollutant loads, while a 66% reduction was observed. For TP, the model predicted a 10% reduction in normalized pollutant loads, while an 82% reduction was observed.

Table 7 PLRM predicted and measured values (normalized by rainfall and catchment area) for WY18 and WY19 for Elks Club.

Normalized Annual Runoff Volumes and Loads		WY18	WY19	% Reduction
Runoff Volumes (cf/acre/inch)	PLRM	355	355	0%
	Measured	761	1,101	-45%
TSS Load (lbs/acre/inch)	PLRM	8.42	7.87	7%
	Measured	6.30	0.60	90%
FSP Load (lbs/acre/inch)	PLRM	5.02	4.68	7%
	Measured	1.50	0.10	93%
TN Load (lbs/acre/inch)	PLRM	0.068	0.066	3%
	Measured	0.029	0.010	66%
TP Load (lbs/acre/inch)	PLRM	0.019	0.017	10%
	Measured	0.011	0.002	82%

6. Road RAM

Though PCI is the standardized measure for assessing pavement condition, it does not take into account day to day or season to season variability in the amount of sediment that accumulates on the roadway from pavement deterioration, hillside erosion, traction abrasive application, atmospheric deposition and the like. For this reason, the Lake Tahoe TMDL program uses Road RAM (Road Rapid Assessment Methodology) to evaluate road condition (not pavement condition). Road RAM is a proxy measurement that estimates the amount of FSP on the roadway; thus, better Road RAM scores correlate with lower FSP loads. Road RAM scores are used to verify that roads are being kept at or above an expected condition established by each jurisdiction for a particular road segment in a catchment registered under the Lake Clarity Crediting Program.

Preliminary calculations show that though there is no discernible direct correlation between PCI and Road RAM score, there is a highly significant improvement in overall Road RAM scores after PCI increases. At Elks Club, a t-test was run to compare the Road RAM scores before repaving (PCI = 29) to Road RAM scores after repaving (PCI = 99). The p-value was equal to 0.00001, indicating a highly significant difference between the two datasets. Figure 16 shows box and whisker plots of Road RAM scores before and after repaving. Table 8 shows summary statistics for the Road RAM measurements used to create Figure 16.

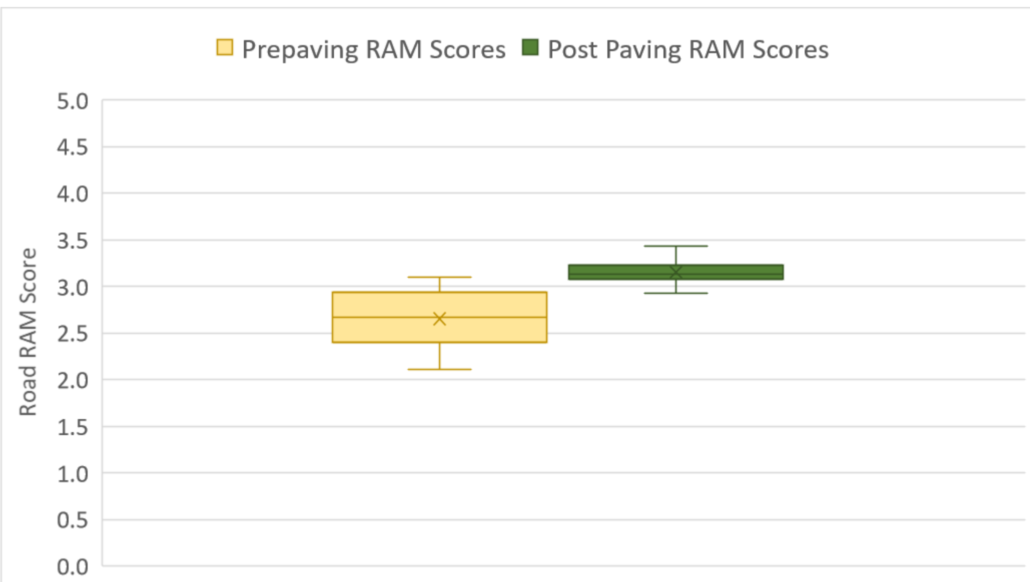

Figure 16 Box plots indicating overall improvement in Road RAM scores following repaving. Mean Road RAM score before paving was 2.7 (n=16) and after paving was 3.2 (n=11).

Table 8 Road RAM measurements in WY18 and WY19.

2018	Season	RAM Score	2019	Season	RAM Score
10/2/2017	fall/winter	2.4	10/12/2018	winter	3.3
10/25/2017	fall/winter	2.7	11/20/2018	winter	3.2
10/31/2017	fall/winter	2.9	3/19/2019	spring	3.4
11/13/2017	fall/winter	2.9	4/1/2019	spring	3.1
12/15/2017	fall/winter	3.0	4/24/2019	spring	3.0
12/29/2017	fall/winter	3.0	4/25/2019	spring	2.9
1/14/2018	fall/winter	3.1	5/13/2019	spring	3.2
1/14/2018	fall/winter	2.5	6/11/2019	summer	3.1
3/30/2018	spring	2.3	6/18/2019	summer	3.2
4/20/2018	spring	2.4	7/22/2019	summer	3.1
4/23/2018	spring	2.2	8/21/2019	summer	3.1
5/29/2018	spring	2.5			
6/22/2018	summer	2.9			
7/20/2018	summer	2.7			
8/20/2018	summer	2.7			
12/31/2019	fall/winter	2.1			
Mean		2.7	Mean		3.2
Standard Deviation		0.3	Standard Deviation		0.1
Min		2.1	Min		2.9
1st quartile		2.4	1st quartile		3.1
Median		2.7	Median		3.1
3rd quartile		2.9	3rd quartile		3.2
Max		3.1	Max		3.4

References

Desert Research Institute Division of Hydrologic Sciences and University of California, Davis, Tahoe Environmental Research Center. 2011a. Tahoe Regional Storm Water Monitoring Program Quality Assurance Project Plan, (RSWMP QAPP). May 10, 2011.

Desert Research Institute Division of Hydrologic Sciences and University of California, Davis, Tahoe Environmental Research Center. 2011b. Tahoe Regional Storm Water Monitoring Program Sampling and Analysis Plan, (RSWMP SAP). May 10, 2011.

Northwest Hydraulic Consultants, Inc. 2017. PLRM Stormwater Treatment BMP Data Evaluation Project. Prepared for the Nevada Division of Environmental Protection. September 2017.

Tahoe Resource Conservation District (Tahoe RCD). 2013. Implementers' Monitoring Plan, Implementers' Monitoring Program (IMP), Component of the Regional Storm Water Monitoring Program (RSWMP), Tahoe Resource Conservation District, Submitted to the Lahontan Regional Water Quality Control Board and the Nevada Division of Environmental Protection, April 30, 2013.

Tahoe Resource Conservation District (Tahoe RCD). 2018. Annual Stormwater Monitoring Report. Submitted to the Lahontan Regional Water Quality Control Board and the Nevada Division of Environmental Protection, March 15, 2018.

Tahoe Resource Conservation District (Tahoe RCD). 2019. Annual Stormwater Monitoring Report. Submitted to the Lahontan Regional Water Quality Control Board and the Nevada Division of Environmental Protection, March 15, 2019.

Tahoe RCD, 2NDNATURE, Desert Research Institute, Northwest Hydraulic Consultants. 2017. RSWMP Framework and Implementation Guidance Document 2017 Update. Submitted the California State Water Board. October 31, 2017.

Appendix A: Event Summary Data

Eight and thirteen events were sampled at Elks Club in WY18 and WY19 respectively. Event summary data is presented in Table 9 through Table 12. Not all events were analyzed for both sediments/nutrients and source apportionment.

Table 9 Sediment and nutrient data at the Elks Club catchment outfall, WY18.

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)
Fall/Winter	11/15/2017 7:00	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
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
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
Spring	3/20/2018 12:45	3/23/2018 0:20	59:35	52,572	1.02	671	3.60	Rain on Snow	100%	42	137	597	1.96	331	1.09
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
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
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
Spring	5/25/2018 3:30	5/25/2018 6:00	2:30	1,879	0.64	148	0.30	Rain	100%	68	7.9	1,098	0.13	477	0.06

Table 10 Source apportionment data at the Elks Club catchment outfall, WY18.

Runoff Start	Event Type	Asphalt aggregate	Asphalt binder	Asphalt Aggregate + Binder	Traction abrasives	Road side soil	Vegetation debris	Atmos-pheric deposition	Tire wear	Motor oil	Brake drum and pad wear	Lead balance weight
11/15/2017 7:00	Rain	35	10	45	12	36	3	3	0.7	0.2	0.02	<0.0001
1/5/2018 23:50	Rain on snow	36	10	46	10	38	3	2	0.8	0.2	0.02	<0.0001
3/13/2018 13:05	Rain on snow	40	16	56	13	24	3	3	1.0	0.2	0.09	<0.0001
3/20/2018 12:45	Rain on snow	35	10	45	20	31	2	2	0.4	0.2	0.03	<0.0001
4/5/2018 21:55	Rain on snow	32	10	42	17	34	3	3	0.6	0.2	0.03	<0.0001
5/24/2018 17:15	Rain	29	7	36	19	30	9	5	0.9	0.2	0.02	<0.0002
5/25/2018 3:30	Rain	19	5	24	25	45	5	1	0.7	0.2	0.03	<0.0003

Table 11 Sediment and nutrient data at the Elks Club catchment outfall, WY19.

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)
Fall/Winter	10/3/2018 11:05	10/3/2018 16:30	5:25	623	0.16	319	0.76	Thunderstorm	100%	98	4	4,680	0.18	1,032	0.04
Fall/Winter	11/23/2018 13:35	11/24/2018 2:10	12:35	540	0.02	29	1.22	Rain	100%	5	0	510	0.02	106	0.004
Fall/Winter	11/27/2018 16:50	11/29/2018 5:30	36:40	1,354	0.23	56	0.40	Rain on snow	100%	4	0.4	730	0.06	128	0.01
Fall/Winter	1/16/2019 18:30	1/17/2019 18:30	24:00	3,895	0.24	40	1.43	Rain on snow	100%	1	0.1	310	0.08	117	0.03
Fall/Winter	2/2/2019 1:25	2/2/2019 13:40	12:15	1,565	0.10	44	0.75	Rain on snow	100%	9	1	1,030	0.10	125	0.01
Spring	3/5/2019 9:40	3/6/2019 9:10	23:30	2,879	0.09	32	0.38	Rain on snow	100%	8	1	270	0.05	73	0.01
Spring	3/27/2019 2:50	3/27/2019 12:55	10:05	3,632	0.20	72	0.37	Rain on snow	100%	19	4.3	400	0.09	132	0.03
Spring	3/29/2019 6:00	4/1/2019 6:00	72:00	13,471	0.10	9	0.00	Non-event Snowmelt	100%	2	2	210	0.18	34	0.03
Spring	4/1/2019 16:15	4/3/2019 0:15	32:00	14,240	0.39	49	0.99	Rain on snow	100%	18	15.7	320	0.28	88	0.08
Spring	5/16/2019 17:15	5/17/2019 6:25	13:10	1,926	0.06	11	0.55	Event Snowmelt	100%	2	0.3	190	0.02	18	0.002
Spring	5/26/2019 1:10	5/26/2019 12:50	11:40	2,603	0.24	15	0.48	Rain	100%	3	1	200	0.03	29	0.005
Summer	9/16/2019 12:00	9/16/2019 14:20	2:20	212	0.08	120	0.41	Rain	100%	63	1	4,870	0.06	59	0.001

Table 12 Source apportionment data at the Elks Club catchment outfall, WY19.

Runoff Start	Event Type	Asphalt aggregate	Asphalt binder	Asphalt Aggregate + Binder	Traction abrasives	Road side soil	Vegetation debris	Atmos-pheric deposition	Tire wear	Motor oil	Brake drum and pad wear	Lead balance weight
10/3/2018 11:05	Rain	17	3	20	3	50	19	8	0.2	0.2	0.07	<0.0001
11/23/2018 13:35	Rain, snow	19	5	24	9	36	22	6	2.0	0.2	0.07	<0.0001
11/27/2018 16:50	Rain on snow	19	7	26	7	38	23	4	1.3	0.2	0.06	<0.0001
1/16/2019 18:30	Rain, snow	21	10	31	9	35	16	7	2.0	0.2	0.05	<0.0001
1/19/2019 12:20	Rain on snow	19	3	22	11	44	17	4	1.5	0.2	0.05	<0.0001
2/2/2019 1:25	Rain, snow	20	6	26	11	41	14	6	2.0	0.2	0.04	<0.0001
2/13/2019 5:20	Rain, snow	22	8	30	11	42	10	5	2.1	0.2	0.05	<0.0001
3/5/2019 9:40	Rain, snow	21	10	31	11	33	15	6	4.0	0.2	0.05	<0.0001
3/27/2019 2:50	Rain/snow	22	8	30	9	37	17	5	1.7	0.2	0.04	<0.0001
4/1/2019 16:15	Rain/snow	12	3	15	8	47	23	5	2.1	0.2	0.05	<0.0001
4/8/2019 17:00	Rain/snow	25	9	34	7	39	12	4	4.5	0.2	0.09	<0.0001
5/16/2019 17:15	Event snowmelt	17	3	20	7	51	11	2	9.0	0.2	0.50	<0.0001
5/26/2019 1:10	Rain on snow	14	2	16	3	55	15	3	8.0	0.2	0.50	<0.0001

Appendix B: Raw Analytical Data

Table 13 and Table 14 present all available raw analytical data for autosampler composite (AC) samples. Other than QAQC samples, only AC samples were analyzed.

Table 13 Raw analytical data for samples taken at Elks Club in WY18. Turbidity, TSS, FSP, TN, and TP concentrations, and particle size distribution.

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 14 Raw analytical data for samples taken at Elks Club in WY19. Turbidity, TSS, FSP, TN, and TP concentrations, and particle size distribution.

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	10/3/2018 11:16	140	138	98	4,680	1,032	0.50	5.21	14.6	28.3	48.0	69.8	76.0	93.3	97.6	99.8	100	100	100
EC-AC	11/23/2018 14:06	18	14	5	510	106	0.16	1.55	3.74	6.80	13.9	29.9	36.8	74.2	89.1	97.2	99.1	100	100
EC-AC	11/27/2018 16:55	32	32	4	730	128	0.07	0.73	1.91	3.68	7.03	13.4	16.2	31.8	38.7	47.7	75.4	98.3	100
EC-AC	1/16/2019 18:36	13	17	1	310	117	0.09	0.73	1.49	2.42	3.62	4.54	4.77	4.81	5.95	14.0	45.8	88.6	100
EC-AC	2/2/2019 2:41	35	38	9	1,030	125	0.14	1.38	3.70	6.95	12.9	26.5	33.6	79.2	94.6	100	100	100	100
EC-AC	3/5/2019 10:16	11	17	8	270	73	1.36	12.9	30.9	46.9	65.2	74.7	77.4	84.1	89.5	99.1	100	100	100
EC-AC	3/27/2019 4:38	57	35	19	400	132	0.19	1.90	5.20	10.0	18.1	33.5	40.5	77.4	94.0	100	100	100	100
EC-AC	3/29/2019 7:23	12	3	2	210	34	0.05	0.48	1.33	2.59	7.35	18.6	23.1	62.4	85.3	96.7	100	100	100
EC-AC	4/1/2019 18:10	29	18	18	320	88	0.34	3.61	10.3	20.2	36.9	61.2	68.5	91.0	96.6	99.7	100	100	100
EC-AC	5/16/2019 19:10	10	6	2	190	18	0.03	0.33	1.06	2.86	8.65	23.4	30.8	73.5	90.2	97.5	98.8	100	100
EC-AC	5/26/2019 2:25	10	6	3	200	29	0.12	1.25	3.66	7.82	17.1	31.2	37.3	67.2	85.9	95.2	98.9	100	100
EC-AC	6/19/2019 7:51	130	61	12	na	na	0.01	0.09	0.32	0.81	2.79	9.57	13.3	39.3	60.8	85.1	94.8	98.8	100
EC-AC	9/16/2019 12:26	100	95	63	4,870	59	0.49	4.80	12.8	25.4	43.6	62.7	68.7	89.9	97.6	99.8	100	100	100

Appendix C: Data Collection, Management, and Analysis Protocols

C.1 Data Collection Methods, Sampling Protocols, Analytic Methods

Continuous hydrology and stormwater samples are collected using an ISCO brand automated sampler (autosampler) per RSWMP protocols (RSWMP FIG 2015 section 10.2.1, Tahoe RCD et al 2017) to support seasonal [fall/winter (October 1-February 28), spring (March 1-May 31), and summer (June 1-September 30)] volume and load reporting. Autosampler was installed and site was maintained according to protocols outlined in the RSWMP FIG sections 10.1.2.2 and 10.2.1.3 respectively. Continuous turbidity was collected with an FTS DTS-12 turbidimeter. Turbidimeter was 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 maintained following recommendations in the RSWMP FIG sections 10.2.3.1 and 10.2.3.2. Raph's shop meteorological station is maintained by Tahoe RCD, and the Shakori meteorological station is maintained by El Dorado County. 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 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 of every 5 or 10 minutes, depending on the site. 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 the flume was dry, and stage and turbidity should read zero. Visual observations are also used to determine if ice in the flume is causing stage errors that need to be adjusted to zero. Visual observations and field measurements are made frequently throughout the year 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 in-situ turbidimeter with a solution of known turbidity in June 2017 and June 2018. In 2019 turbidimeter was sent into the manufacturing for calibration.

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 15 summarizes the sample type acronyms and their meaning. Table 16 summarizes the analytical methods and detection limits for all analyses. Event summary data is presented in Appendix A and raw analytical data for all samples is presented in Appendix B.

Table 15 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 16 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.

C.2 Data Management Procedure

Continuous data series and sample dates and times are collected through the RSWMP Data Management System (DMS). 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 the monitoring station. All nutrient/sediment samples are sent to analytical laboratories within appropriate holding times for TSS, TN, TP, and PSD analysis. 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. Sample liquid remaining after the event composites have been made is filtered through a 20-micron mesh and particles are allowed to settle for 24 hours. After 24 hours the supernatant is removed, and the remaining water/particle mixture is decanted into conical bottles for source apportionment analysis. All conical bottles are sent to an analytical laboratory for source apportionment analysis. When analytical results are received from the laboratories, they are entered into the same Excel workbook for storing nutrient and sediment data. 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.

C.3 Data Analysis

The raw hydrologic data set includes stage and flow (determined by an equation relating stage in the flume), and turbidity recorded every 5 minutes 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; the DMS then applies these concentrations to each hydrologic measurement for that season. The DMS calculates loads by summing concentrations multiplied by runoff volumes over time as outlined in section 10.1.2.11 of the RSWMP FIG. Turbidity is converted to FSP concentration (in both mass per liter and number of particles per liter) using equations relating turbidity to FSP (2NDNATURE et al 2014) and integrated over time to calculate seasonal and annual load estimates in pounds and number of particles (RSWMP FIG sections 10.2.2.6 and 10.2.2.7).

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