CITY OF KALISPELL

MPDES Permit # MTR04005

Evaluation of Stormwater Quality Monitoring 2019 Sample Results

Introduction

The City of Kalispell operates its storm drainage system under the authorization of the Montana Pollution Discharge Elimination System (MPDES) General Permit for Storm Water Discharges Associated with Small Municipal Separate Storm Sewer Systems (MS4s). The current MS4 General Permit, issued by the Montana Department of Environmental Quality (MDEQ), is effective from January 1, 2017 through December 31, 2021. Part IV of the MS4 General Permit requires semi-annual monitoring (self-monitoring).

The City has selected self-monitoring Option 2 (see Part IV of the MS4 General Permit). Stormwater grab samples were collected semi-annually from four stormwater discharge locations within the City of Kalispell. Four discharge sample locations were chosen to represent stormwater runoff (1) from a primarily commercial/industrial area, (1) from a primarily residential area, (1) from a large drainage area combining both commercial and residential areas, and (1) upstream, outside the MS4 boundary to evaluate water quality entering the MS4 (Table 1).

Table 1. Self-monitoring sample locations

Name	Watershed	Receiving Waterbody	Location	Drainage Area (Acre)	Frequency	Sample Parameters
001	SWR-4	Stillwater River	48°11’40.14”N 114°17’55.76”W	266	Semi-annual	▪ Total Suspended Solids ▪ Chemical Oxygen Demand ▪ Total Phosphorus ▪ Total Nitrogen ▪ pH ▪ Copper ▪ Lead ▪ Zinc ▪ Estimated Flow ▪ Oil and Grease
002	SWR-7	Stillwater River	48°12’26.98”N 114°18’49.81”W	100	Semi-annual	
003A	AC-A	Ashley Creek	48°11’43.49”N 114°22’23.71”W	NA	Semi-annual	
004	AC-11	Ashley Creek	48°11’10.01”N 114°19’17.46”W	294	Semi-annual	

Methods

Sample Collection

Grab samples were collected once in the spring (4/9/19) and once in the fall (9/9/19) of 2019. Field personnel collected samples during rainfall events that produced a measurable volume of runoff flowing past/through the monitoring locations that allowed a sample to be collected. Clean, labeled bottles provided by the laboratory, on an extension pole, were used to obtain stormwater samples. Field logs were used to document the date, time, location, personnel, weather, conditions observed, samples collected, estimated duration of the storm event, and total rainfall of the storm event.

Sample Parameters and Analytical Methods

Stormwater samples were analyzed for the parameters listed in Table 1. Table 2 shows the parameters and the standard analytical methods used. Montana Environmental Labs processed all the samples and uses a combination of blanks, laboratory control spikes, surrogates, and duplicates to evaluate analytical results. Chain of custody forms accompanied all samples.

Sample Analysis

Due to new sample locations being designated in 2017, statistical analyses are not appropriate because of the low number of samples. The City of Kalispell is required to calculate the long-term median concentration of all known monitoring results at an individual location of each parameter in Table 1 Par IV.A. of the MS4 General Permit issued by MDEQ.

To compare individual parameters across locations, bar charts were created to visually represent observed sample values of 2019 in comparison to the long-term median. To compare parameters at one location, parameter values were standardized and graphed over time by location.

The MS4 General Permit requires monitoring results to be used to evaluate measures taken to improve the quality of stormwater discharges. This includes an evaluation of the results relative to the long-term median, comparisons between monitoring locations, discussion of trends and outliers compared to the long-term median, discussion of pH values outside the range of 6.0 to 9.0, and a schedule and rationale for BMPs planned to improve water quality of stormwater discharges based on monitoring results.

Table 2. Parameters and standard analytical methods

Parameter	Analytical Method	Reporting Limit (mg/L)	Sample Container	Preservative	Holding Time (days)
Total Suspended Solids	SM 2450 D	1	1 L plastic[2]	None[2]	Analyze immediately[2]
Total Phosphorus	E365.1	0.01			
Nitrogen – Kjeldahl, total[1]	E351.2	0.2			
Nitrate & Nitrite, total[1]	E353.2 E300A	0.01			
Chemical Oxygen Demand	E410.1 E410.4	1			
Total Recoverable Copper	E200.8	0.01			
Total Recoverable Lead	E200.8	0.001			
Total Recoverable Zinc	E200.7 E200.8	0.01			
Oil and Grease	E1664A	1	1 L glass (2)	H2SO4 to pH<2 Cool to 4°C	28
Estimated Flow	NA	NA	NA	NA	Analyze onsite[3]
Dissolved Oxygen	SM 4500-OG	0.1	NA	NA	Analyze onsite[3]
Temperature	NA	0.1°C	NA	NA	Analyze onsite[3]
pH	E150.1	0.1 unit	NA	NA	Analyze onsite[3]

[1] Total Nitrogen is calculated from Nitrogen – Kjeldahl, total and Nitrate & Nitrite, total.
[2] Samples will be immediately delivered to the Montana Environmental Lab in Kalispell. The lab staff will separate the 1L samples so that each parameter can be analyzed. Preservatives will be added by the lab staff, if necessary.
[3] The City analyzes estimated flow, dissolved oxygen, temperature, and pH, onsite.

Results

Sample Comparison and Median Concentration

Table 3 is a summary of the 2019 sample parameter comparisons with the long-term median concentrations for each. Long-term median concentrations are calculated from all known monitoring results for each parameter at a monitoring location. **Please note, as monitoring locations were new in 2017, median concentrations have been calculated only with samples taken since 2017 (6 total samples per site).**

Figures 1-9 depict observed and median parameter concentrations by site location. Many of the sites had higher recorded parameter values in spring than fall.

Zinc was greater for all stormwater sampling locations collected in the spring (zinc was not detected at AC-A/003A, the in-stream sample).

Total phosphorus (TP), pH, chemical oxygen demand (COD), total nitrogen (TN), copper, and lead were greater in the spring for all locations except for AC-A/003A (TP, COD, TN, copper, lead) and AC-11/004 (pH).

Total suspended solids (TSS) was greater in the spring for all locations except AC-A/003A where it was equivalent for both sampling events.

Oil and grease values were greater in spring at both locations discharging to the Stillwater River (SWR-4/001, SWR-7/002), not detected in spring and fall at AC-A/003A, and greater in fall at AC-11/004.

Flow was greater in fall for all locations.

In the spring, observed parameter values somewhat to notably elevated include TSS, oil/grease, and COD at SWR-4/001 and TSS and COD at SWR-7/002.

Table 3. 2019 Parameter Comparison

Name	Watershed	Receiving Waterbody	Type	Date	TSS (mg/L)	COD (mg/L)	TP (mg/L)	TN (mg/L)	pH	Copper (mg/L)	Lead (mg/L)	Zinc (mg/L)	Oil & Grease (mg/L)	Flow (GPM)
001	SWR-4	Stillwater River	Residential 30%, Commercial 70%	4/09/19	549	329	0.47	2.67	8.77	0.0297	0.0169	0.269	16	3162
001	SWR-4	Stillwater River	Residential 30%, Commercial 70%	09/09/19	48	68	0.13	0.81	8.24	0.0065	0.00258	0.054	1	4325.26
				Median	**72**	**105**	**0.41**	**1.56**	**8.14**	**0.0105**	**0.00444**	**0.091**	**2.5**	**1695**
002	SWR-7	Stillwater River	Commercial/ Industrial	4/09/19	377	297	0.33	2.06	8.83	0.03	0.0134	0.241	2	265
002	SWR-7	Stillwater River	Commercial/ Industrial	09/09/19	20	76	0.11	0.88	8.37	0.0065	0.00157	0.034	1	278.78
				Median	**252.5**	**242.5**	**0.36**	**1.71**	**8.155**	**0.023**	**0.00825**	**0.1925**	**3.5**	**152.5**
003	AC-A	Ashley Creek	In-stream Outside MS4 Boundary	4/09/19	8	8	0.02	0.77	8.84	ND	ND	ND	ND	37,553
003	AC-A	Ashley Creek	In-stream Outside MS4 Boundary	09/09/19	8	71	0.03	0.96	8.46	0.0009	0.00027	ND	ND	42481.38
				Median	**8**	**29.5**	**0.025**	**0.785**	**8.11**	**0**	**0**	**0**	**0**	**33,229.5**
004	AC-11	Ashley Creek	Residential	4/09/19	160	204	0.36	2.68	8.3	0.019	0.0107	0.158	0	67
004	AC-11	Ashley Creek	Residential	09/09/19	108	76	0.19	2.11	8.52	0.0072	0.00456	0.067	2	265.63
				Median	**89.5**	**167**	**0.435**	**2.63**	**7.6**	**0.0106**	**0.00423**	**0.0775**	**1.5**	**71**

ND=Not detected at the reporting limit

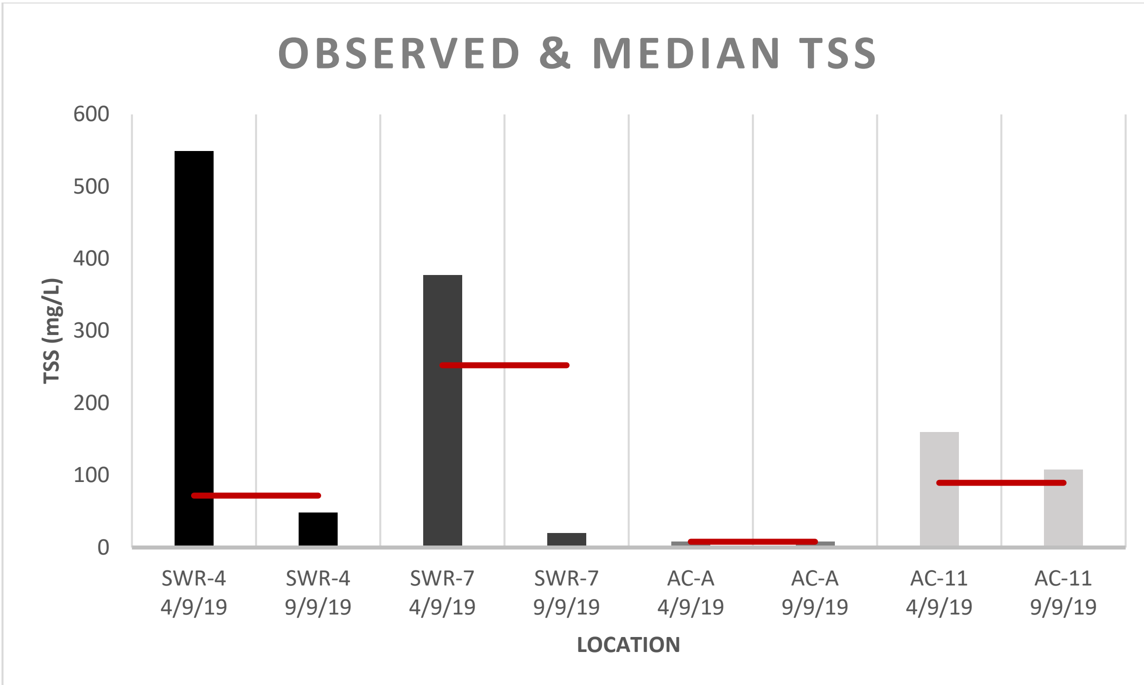

Figure 1. Observed (2019) and median (2017-2019) TSS (total suspended solids) concentrations by location. Horizontal red lines represent median concentrations.

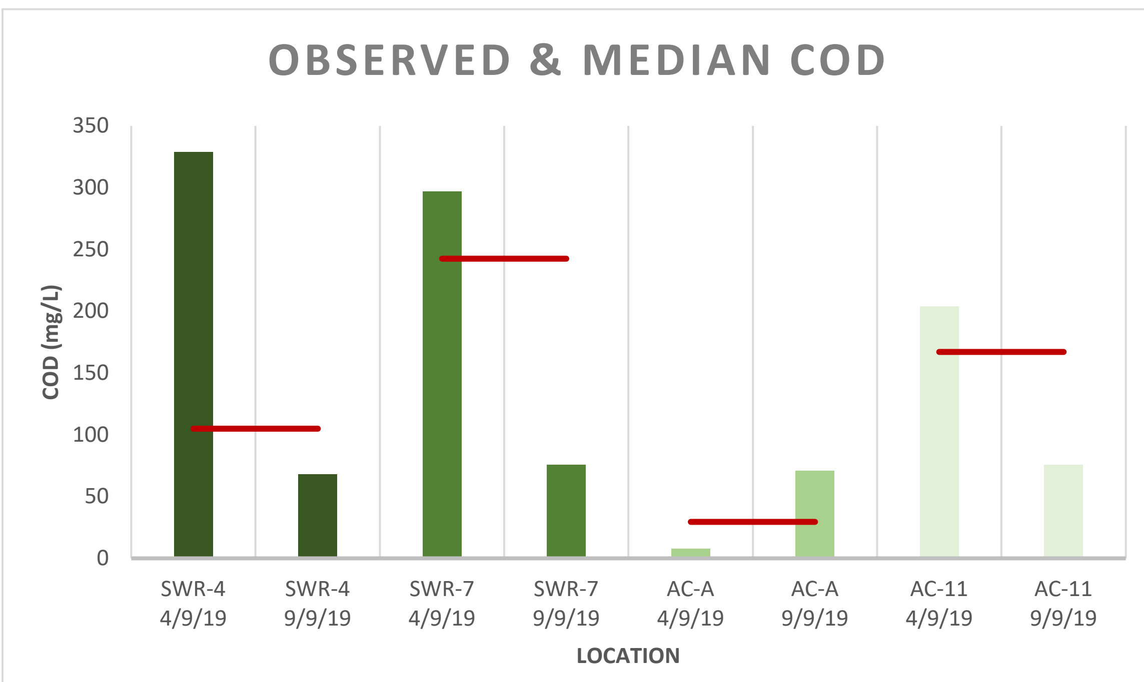

Figure 2. Observed (2019) and median (2017-2019) COD (chemical oxygen demand) concentrations by location. Horizontal red lines represent median concentrations.

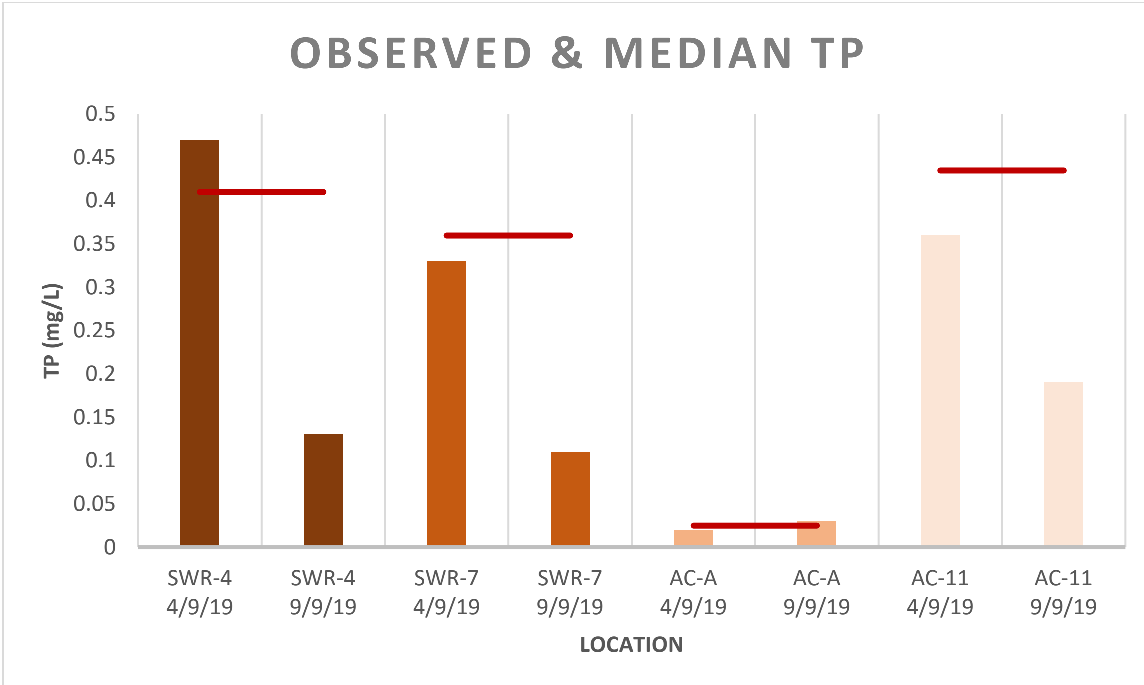

Figure 3. Observed (2019) and median (2017-2019) TP (total phosphorus) concentrations by location. Horizontal red lines represent median concentrations.

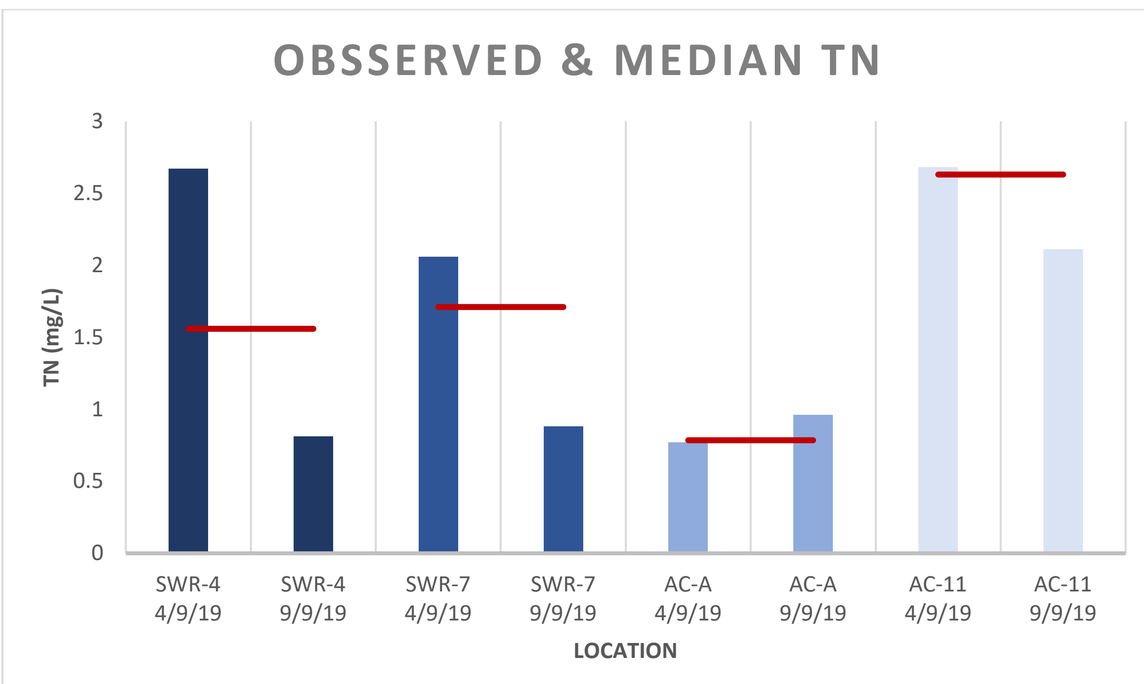

Figure 4. Observed (2019) and median (2017-2019) TN (total nitrogen) concentrations by location. Horizontal red lines represent median concentrations.

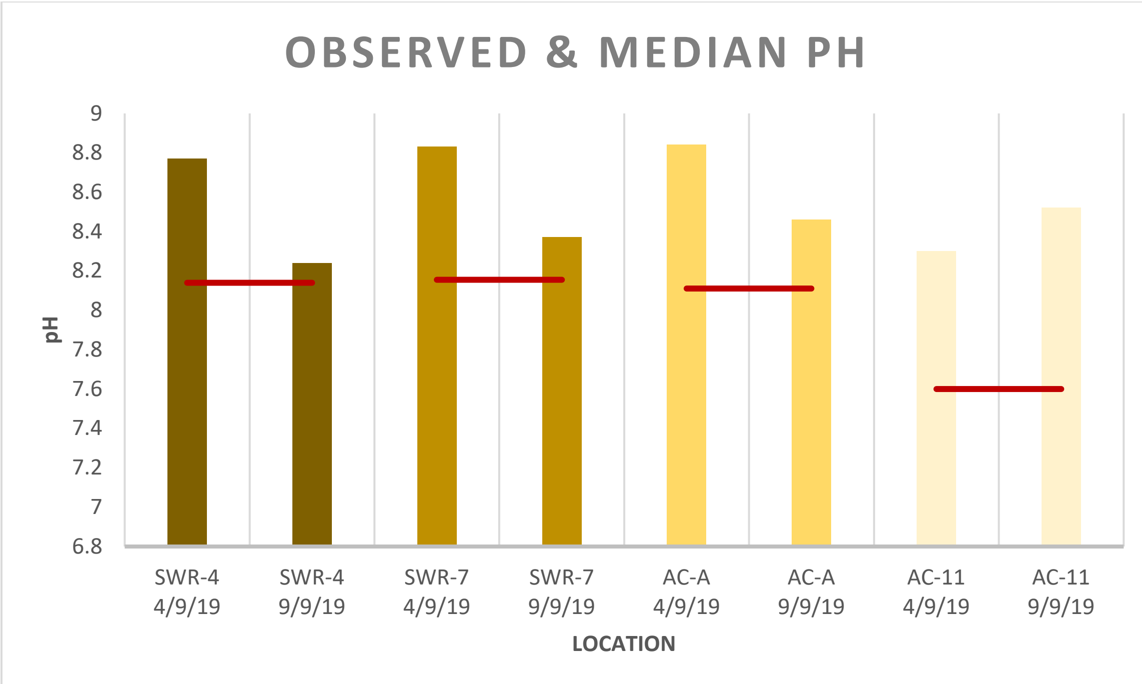

Figure 5. Observed (2019) and median (2017-2019) pH values by location. Horizontal red lines represent median concentrations.

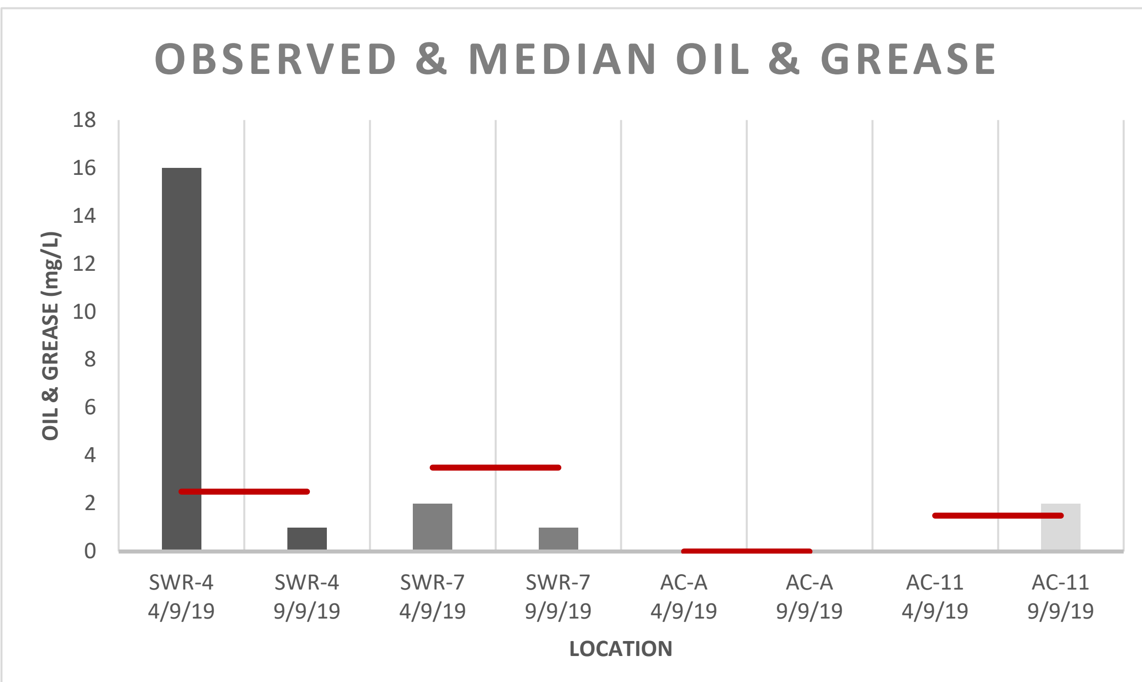

Figure 6. Observed (2019) and median (2017-2019) oil and grease concentrations by location. Horizontal red lines represent median concentrations.

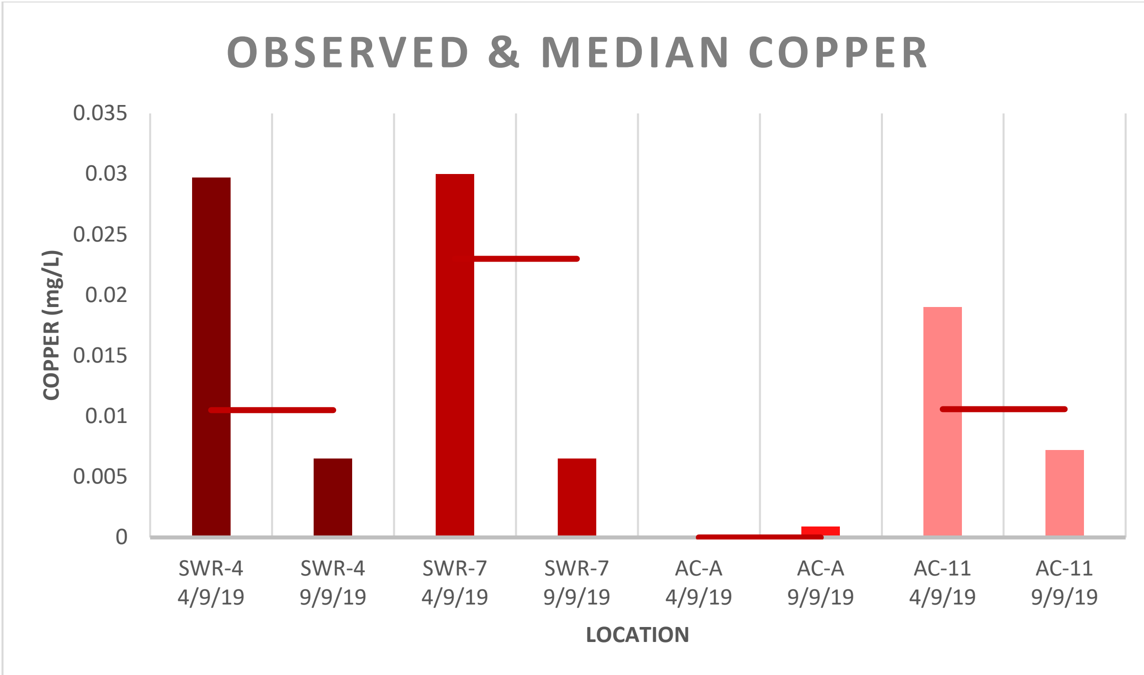

Figure 7. Observed (2019) and median (2017-2019) copper concentrations by location. Horizontal red lines represent median concentrations.

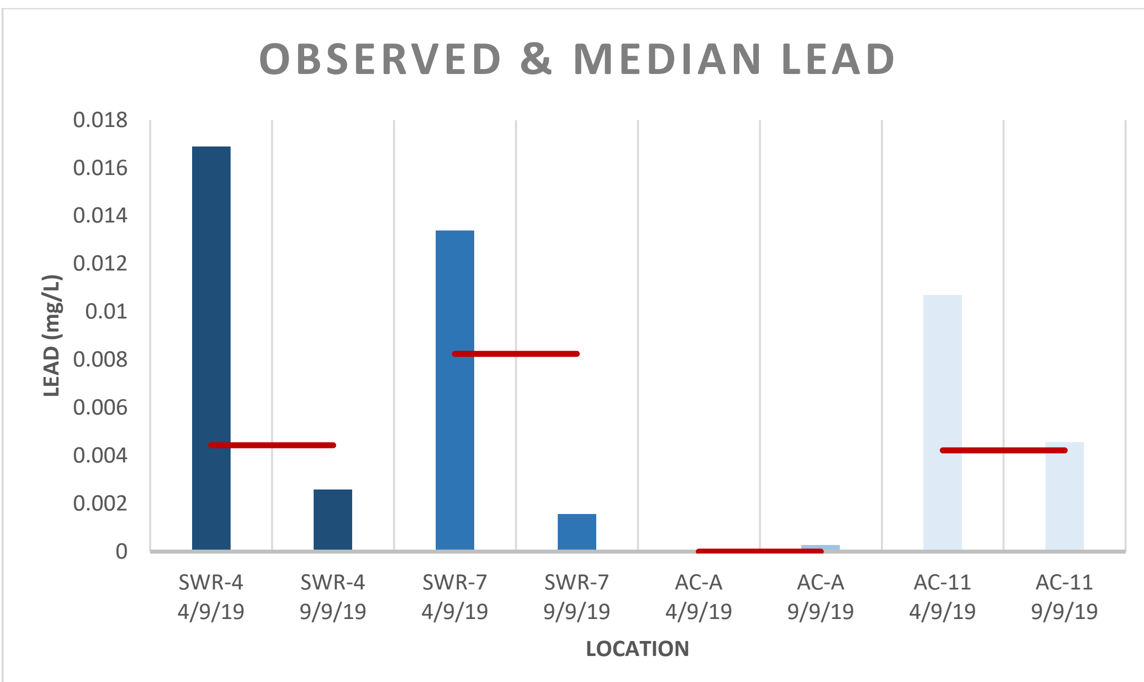

Figure 8. Observed (2019) and median (2017-2019) lead concentrations by location. Horizontal red lines represent median concentrations.

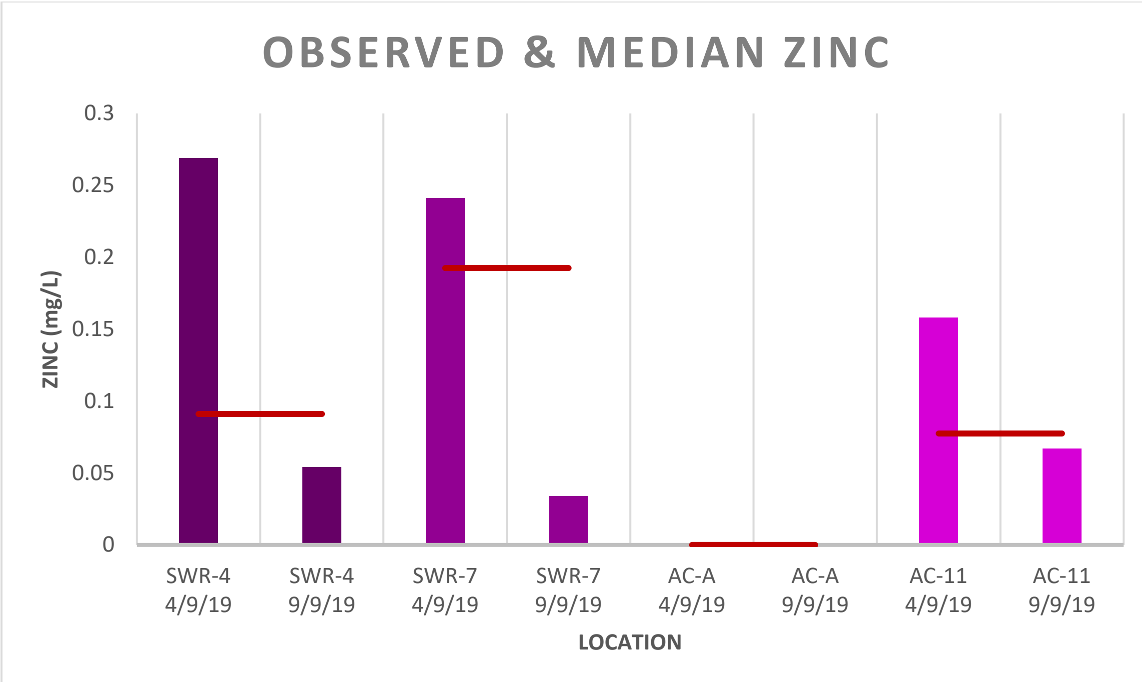

Figure 9. Observed (2019) and median (2017-2019) zinc concentrations by location. Horizontal red lines represent median concentrations.

Standardized Parameter Concentrations by Location

Figures 10-13 compare sample parameters at one site over time. Parameters have been standardized to make the variables comparable.

At most locations, many parameters co-vary together. Stormwater sample locations (SWR-4/001, SWR-7/002, AC-11/004) appear to have elevated values in spring and lower values in fall. The parameter values at the in-stream location (AC-A/003), generally, do not fluctuate as much as the stormwater samples.

The elevated TSS and oil and grease at SWR-4/001 on 4/13/18 appear to strongly co-vary, while the elevated TP at AC-11/004 on 4/13/18 does not strongly co-vary with any other parameters. Standardized parameters in 2019 did not see as large of fluctuations as 2018.

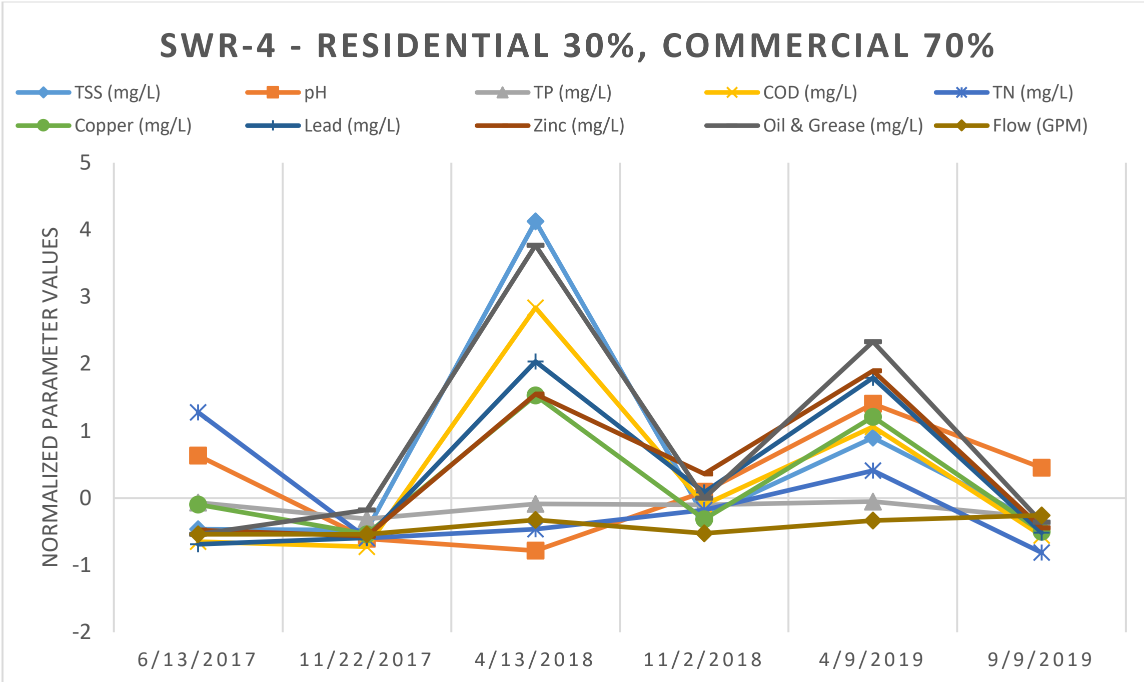

Figure 10. Standardized parameter values over time at SWR-4/001.

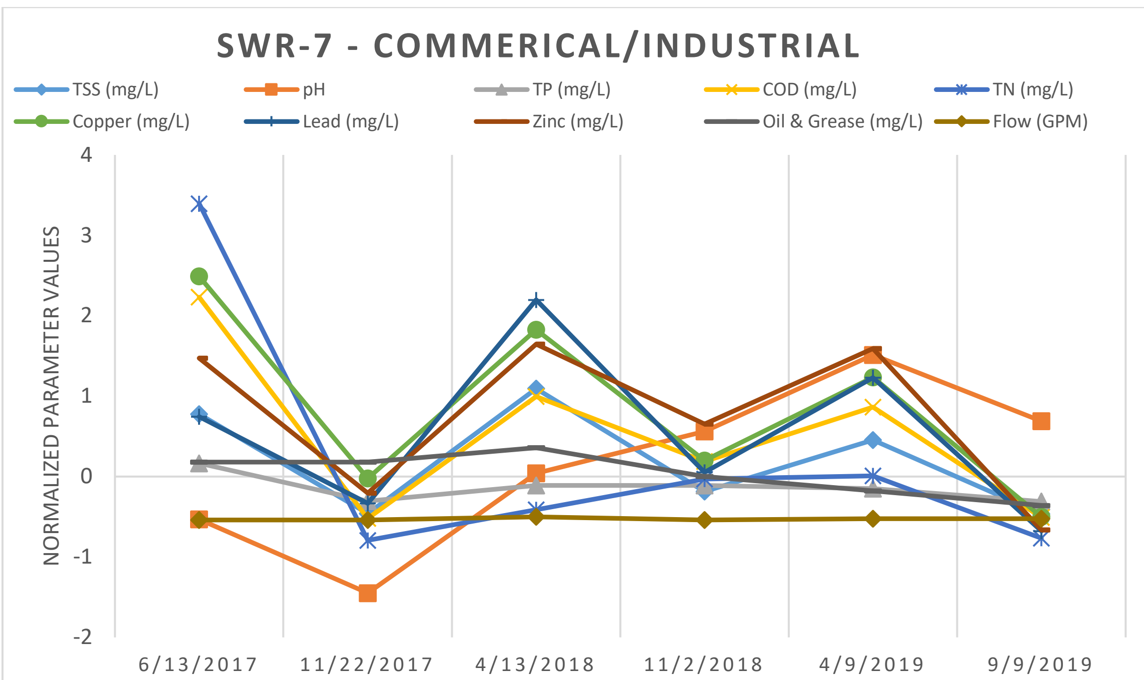

Figure 11. Standardized parameter values over time at SWR-7/002.

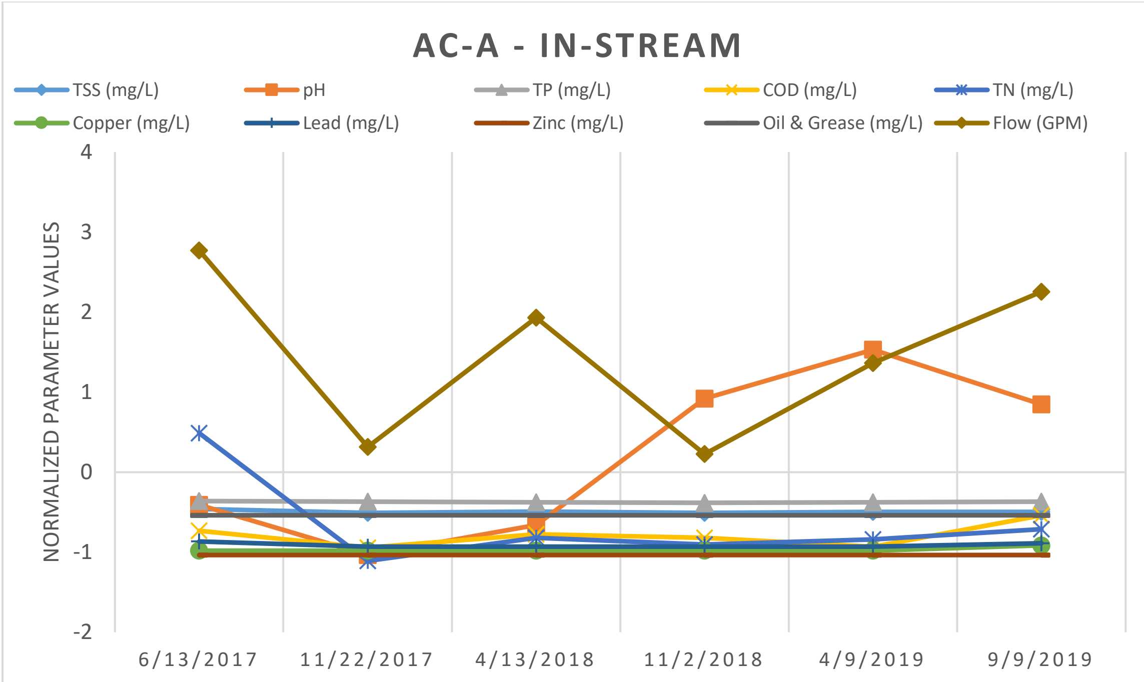

Figure 12. Standardized parameter values over time at AC-A/003 (2017-2018) and AC-A/003A (2019).

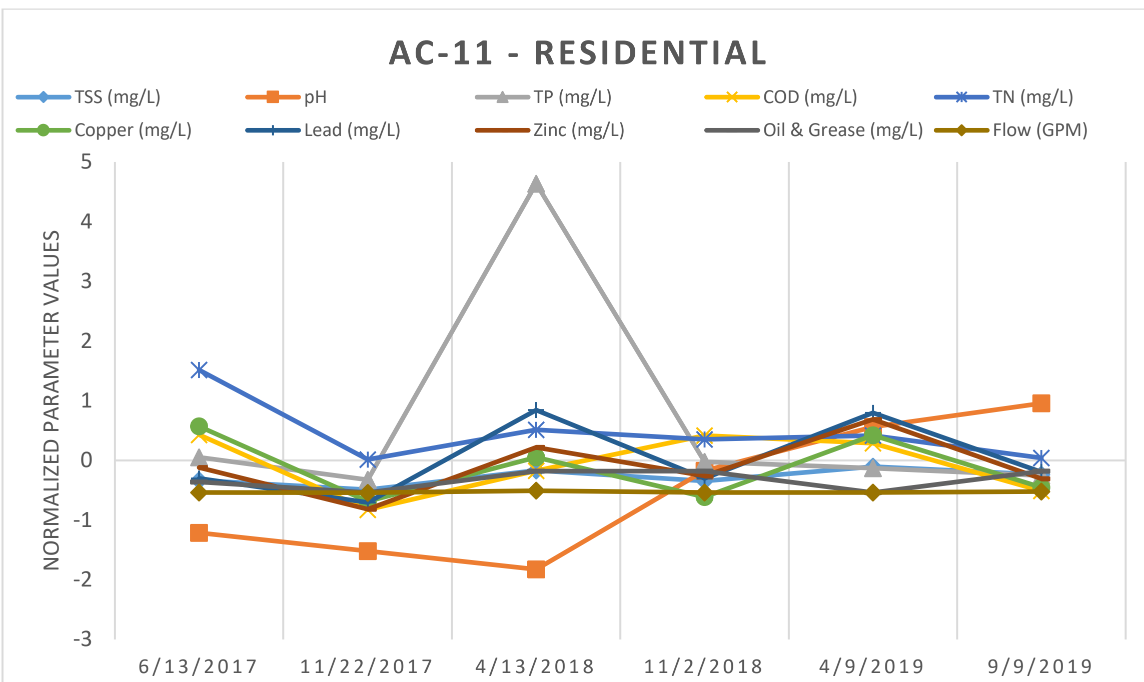

Figure 13. Standardized parameter values over time at AC-11/004.

Discussion: Trends, Outliers, and BMPs

The following analysis reviews the 2019 parameter trends and outliers compared to the calculated long-term median and examines results outside a pH range of 6.0 to 9.0 standard units. Additionally, explained is a schedule and rationale for BMPs planned to improve the water quality of stormwater discharges based on monitoring results.

Sampling Conditions

Spring samples were collected in April 2019. The winter leading up to this sample collection had numerous snow events, which lead to frequent sanding and salt application.

Fall samples were collected in September 2019. Prior to sample collection, the summer was generally cool with some small rain showers. The September event began with heavy rainfall in the very early morning. Samples were collected at the beginning of the workday.

Spring samples generally had higher concentrations of all parameters. This same pattern was observed in the 2017 and 2018 sample results. This may be indicative of winter loading of contaminants. Additional measures to try to reduce spring runoff may be beneficial. Future sampling will help clarify trends and what BMPs will be most beneficial to minimize pollutant discharge.

Stillwater River

Two locations drain into the Stillwater River, which is listed as impaired for sediment. Location 001-SWR-4 is characterized as mixed residential (30%) and commercial (70%) and location 002-SWR-7 is characterized as commercial/industrial.

Mixed Residential (30%) and Commercial (70%) Location

Sample location 001-SWR-4 drains about 266 acres and had elevated total suspended solids, oil/grease, and chemical oxygen demand in the spring samples in 2018 and 2019. However, the 2019 samples all had lower pollutant concentrations per season than 2018.

In 2018, due to the elevated TSS and oil and grease, the surrounding storm system was inspected and cleaned. This sample location is downstream from two mechanical treatment units. Both treatment units were cleaned along with upstream manholes and sumps (if needed). A roll of Ram-Nek/manhole mastic was found in a manhole sump upstream and was removed. This could have been contributing to higher oil and grease and COD readings in spring 2018. The cleaning schedule of the two treatment units was updated to twice a year due to the amount of debris found when they were cleaned, and the biannual schedule has been maintained. After the wide-scale cleaning in 2018, TSS, oil and grease, and COD levels dropped during the next sampling event and have continued to stay below the spring 2018 levels.

Commercial/Industrial Location

At sample location 002-SWR-7, the median of every parameter, except TP and TN, was higher than other locations in both 2018 and 2019. The drainage area of 002-SWR-7 is approximately 100 acres and is comprised mostly of commercial/industrial land use including highway managed by Montana Department of Transportation. Activities in industrial areas and highways, including material handling and storage, equipment maintenance and cleaning, and others, are often exposed to weather and may introduce pollutants into stormwater.

Total suspended solids and chemical oxygen demand readings were elevated, though not as high as 001-SWR-4. All parameters will be monitored to try and further understand sources. Future sampling may help clarify trends and outliers at this location and what management practices will provide a reduction of the pollutant loads.

The City's Capital Improvement Program has a stormwater quality treatment facility planned for 2020 to try to reduce the MS4's discharge of sediment to the Stillwater River. Samples collected prior to implementation may provide information on BMP effectiveness in a commercial/industrial location and help plan future BMPs in other commercial/industrial areas.

Ashley Creek

Two locations drain into Ashley Creek, which is listed as impaired for phosphorus, nitrogen, dissolved oxygen, sediment, and temperature. Location 003A-AC-A is characterized as being in-stream and outside the MS4 boundary and 004-AC-11 is characterized as residential.

In-Stream Outside MS4 Boundary Location

Sample location 003A-AC-A did not have notable trends or outliers in monitoring results compared to the calculated long-term median. The in-stream sample results provide background readings of the pollutants in-stream during comparable rain events.

Residential Location

The drainage area of 004-AC-11 is approximately 300 acres, comprised mostly of residential land use.

Sample location 004-AC-11 results showed moderate levels of total suspended sediment, chemical oxygen demand, total phosphorus, and total nitrogen. In 2018, total phosphorus was significantly elevated in the spring sample but was comparable to other sites in 2019. Future sampling may help clarify trends and outliers at this location and what management practices will provide a reduction of the pollutant loads.

The City's Capital Improvement Program has a stormwater quality treatment facility planned for 2023 to try to reduce the MS4's discharge of pollutants to Ashley Creek. Samples collected prior to implementation may provide information on BMP effectiveness in a residential location and help plan future BMPs in other residential areas.

Identified Pollutants

Several pollutants were identified as elevated through this evaluation. As such, this section provides a schedule and rationale of BMPs planned to improve the water quality of the stormwater discharges.

Chemical Oxygen Demand (COD)

Potential Sources

Natural:

- Leaves and woody debris
- Dead plants and animals
- Animal manure

Industrial:

- Oils and grease from transportation and industrial/commercial site activities
- Benzene from gasoline
- Synthetic detergents
- Pesticides
- Herbicides
- Wood preservatives
- Synthetic organic industrial chemicals

Residential:

- Grass clippings and leaves
- Animal waste
- Failing septic systems
- Sugar-containing substances (milk, molasses, juice, vegetables, energy drinks, etc.)

Management Measures and BMPs

Table 4 outlines the potential sources, reasons, and management measures the City has or will implement for the MPDES MS4 permit. Dry weather screening will continue to be utilized to aid in identifying sources of chemical oxygen demand. Additionally, two locations have a planned stormwater quality treatment facility in the City's Capital Improvement Program.

Table 4. COD Evaluation

Potential Sources	Reasons	*Minimum Measure	BMP	Date(s) Implemented
Organic material i.e. leaves, grass clippings	Fallen Leaves Landscaping Pre-Winter Maintenance	1	Public Education Program	2015-Current
		6	Implement Pollution Prevention Good Housekeeping Guidance Manual for Kalispell Municipal Operations. Provide training to City employees.	2015-Current
			Street Sweeping Program	2015-Current
			Leaf Collection Program	2015-Current
			Storm Drainage System Inspection and Cleaning	2015-Current
			Residential Curbside Pickup Services	2013-Current

* Minimum Measures 1) Public education and outreach on stormwater impacts; 2) Public involvement/participation; 3) Illicit discharge detection and elimination; 4) Construction site stormwater runoff control; 5) Post-construction stormwater management in new development and redevelopment; and, 6) Pollution prevention and good housekeeping for municipal operations.

Total Suspended Solids (TSS)

Potential Sources

Natural:

- Erosion

Industrial:

- Land development
- Roadway material deterioration
- Road salt and sand
- Road paint
- Industrial/commercial site activities
- Gravel parking areas

Residential:

- Land development
- Road salt and sand
- Road paint
- Roadway material deterioration

Management Measures and BMPs

Table 5 outlines the potential sources, reasons, and management measures the City has implemented or will implement for the MPDES MS4 General Permit. Additionally, two locations have a planned stormwater quality treatment facility in the City's Capital Improvement Program.

Table 5. TSS Evaluation

Potential Sources	Reasons	*Minimum Measure	BMP	Date(s) Implemented
Construction Site Runoff	Subdivision Development Residential House Construction Municipal Operations Commercial Development	4	Ordinance 1831: Stormwater Regulations. Requires Construction Stormwater Permits for all land disturbance within City limits.	2015-Current
			Provide training for builders, engineers, and developers.	2015-Current
		1	Public Education Program	2015-Current
			Public Education Program 2010 Update to include commercial education.	2010-Current
		6	Implement Pollution Prevention Good Housekeeping Guidance Manual for Kalispell Municipal Operations. Provide training to City employees.	2015-Current
Sand on Roads	Winter condition road sanding	6	Implement Pollution Prevention Good Housekeeping Guidance Manual for Kalispell Municipal Operations. Provide training to City employees.	2015-Current
			Street Sweeping	2015-Current
			Storm Drainage System Inspection & Cleaning	2015-Current
Industrial and Commercial Sites	Generation of solid material from industrial and commercial site activities Dirt/gravel driveways and parking areas	1	Public Education Program	2015-Current
		3	Illicit Discharge, Detection, and Elimination Program	2015-Current
		5	Redevelopment standards implemented through Kalispell Design and Construction Standards	2015-Current
Residential	Yard Waste Management Native Landscaping Better Car and Equipment Washing	1	Public Education Program	2018-Current
		6	Residential Curbside Pickup Services	2013-Current
Commercial Landscaping	Yard Waste Management	1	Public Education Program	2018-Current

* Minimum Measures 1) Public education and outreach on stormwater impacts; 2) Public involvement/participation; 3) Illicit discharge detection and elimination; 4) Construction site stormwater runoff control; 5) Post-construction stormwater management in new development and redevelopment; and, 6) Pollution prevention and good housekeeping for municipal operations.

Oil and Grease

Potential Sources

Natural:

- Petroleum

Industrial:

- Automotive oils

Residential:

- Automotive oils
- Cooking oils

Management Measures and BMPs

Table 6 outlines the potential sources, reasons, and management measures the City has implemented or will implement for the MPDES MS General Permit. Additionally, two locations have a planned stormwater quality treatment facility in the City's Capital Improvement Program.

Table 6. Oil and Grease Evaluation

Potential Sources	Reasons	*Minimum Measure	BMP	Date(s) Implemented
Industrial Site Activities	Common industrial and commercial site activities	1	Public Education Program	2007-Current
			Public Education Program 2010 Update to include commercial education	2010-Current
		3	Illicit Discharge, Detection, and Elimination Program	2008-Current
Restaurants	Common restaurant activities	1	Public Education Program	2013-Current
Residential	Car Maintenance	1	Public Education Program	2018-Current
Mobile Cleaning Business	Common mobile cleaning activities (i.e. pressure washing)	1	Public Education Program	2018-Current
Gas Stations	Common gas station activities	1	Public Education Program	2018-Current

* Minimum Measures 1) Public education and outreach on stormwater impacts; 2) Public involvement/participation; 3) Illicit discharge detection and elimination; 4) Construction site stormwater runoff control; 5) Post-construction stormwater management in new development and redevelopment; and, 6) Pollution prevention and good housekeeping for municipal operations.

APPENDIX A. Monitoring Parameters

The parameters required to be monitored can contribute to stormwater pollution. The following is a description of the potential sources of stormwater runoff contamination.

Total Suspended Solids (TSS)

TSS is a common stormwater pollutant and can be generated from construction sites, bare spots in lawns and gardens, wastewater from washing/trucks on driveways and parking lots, dirt roads and driveways, and sanding roads during winter conditions.

Chemical Oxygen Demand (COD)

Organic material such as leaves, grass, oils, grease, and litter become deposited in urban areas and become part of stormwater runoff flows. A COD test can be used to quantify the amount of organics in water. COD is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as Ammonia and nitrite. High COD concentrations lower dissolved oxygen concentration, progressively deteriorating conditions for fish and other aquatic life. Also, the absence of dissolved oxygen could result in the growth of microorganisms that produce by-products which cause foul odors in the water.

Total Phosphorus (TP)

Nutrients such as phosphorus are common constituents of nonpoint source runoff. The introduction of nutrients into receiving waters stimulates the growth of algae and other aquatic plants causing algal blooms and creating turbid conditions. Total phosphorus enters runoff from sources such as fertilizers, pesticides, grass clippings/leaves left on streets and sidewalks, detergents and washing fluids, animal waste, and seepage from septic tanks. Automobile lubricant emissions, food products, and various household cleaners, paints, fabrics and carpets contain phosphates which can also be transported by runoff.

Total Nitrogen (TN)

Plant nutrients, such as nitrogen, are common constituents of nonpoint source runoff. The introduction of nutrients into receiving waters stimulates the growth of algae and other aquatic plants causing algal blooms and creating turbid conditions. Total nitrogen enters runoff from sources such as fertilizers, grass clippings and leaves left on streets and sidewalks, detergents and washing fluids, animal wastes, and seepage from septic tanks.

pH

Most discharge flow types are neutral, having a pH value around 7, although groundwater concentrations can be somewhat variable. pH is a reasonably good indicator for liquid wastes from industries, which can have very high or low pH (ranging from 3 to 12). The pH of residential wash water tends to be rather basic (pH of 8 or 9). Although pH data is often inconclusive by itself, it can identify problem outfalls that merit follow-up investigations using indicators that are more effective.

Heavy Metals: Total Copper (Cu), Lead (Pb), Zinc (Zn)

Metal pollutants can be generated from the operation and maintenance of motor vehicles, the degradation of highway material, and industrial/commercial site activities. Heavy metals in water can cause bioaccumulation in animal tissues, affect reproduction rates and life spans of aquatic species, and ultimately affect recreational and commercial fisheries. Transportation-related sources of Zn include diesel fuel, crankcase and lubrication oils, grease, and decorative and protective coatings.

Copper in stormwater runoff can be generated from wear on brake pads, roofing and gutter runoff, and copper-based fungicides/fertilizers used for controlling algae, fungi, and mildew. Metal finishers, electroplaters, and semiconductor manufacturers may use copper-containing materials in their manufacturing processes. Vehicle services (engine repair and service, fueling, vehicle body repair, replacement of fluids, recycling, cleaning, and outdoor equipment storage and parking through dripping engines) can generate toxic hydrocarbons and other organic compounds, oils and greases, nutrients, phosphates, heavy metals, paints and other contaminants. Radiator repair and flushing operations are the most likely source of copper-containing waste streams.

The principal source of lead in highway and street stormwater runoff as well as soils in urban areas and near highways during the time of the NURP studies i.e., about 1980, was the use of lead as an additive in gasoline. Other sources of lead in stormwater runoff include yellow and white road marking paints used on parking lots, streets, buildings, building cavity dust and other demolition waste from buildings and structures, and vehicular sources including leaded petrol (auto exhaust), auto paint (which can still contain 10% lead), lead-acid batteries, lubricating oil and grease, and bearing wear.

Oil and Grease (O&G)

Oil and grease pollutants can be generated from leaks and spills of oil and gas, used oil dumping, and commercial and industrial activities. These organic pollutants cannot be easily decomposed through biological action and may persist for long periods.

APPENDIX B. Correlation Matrix

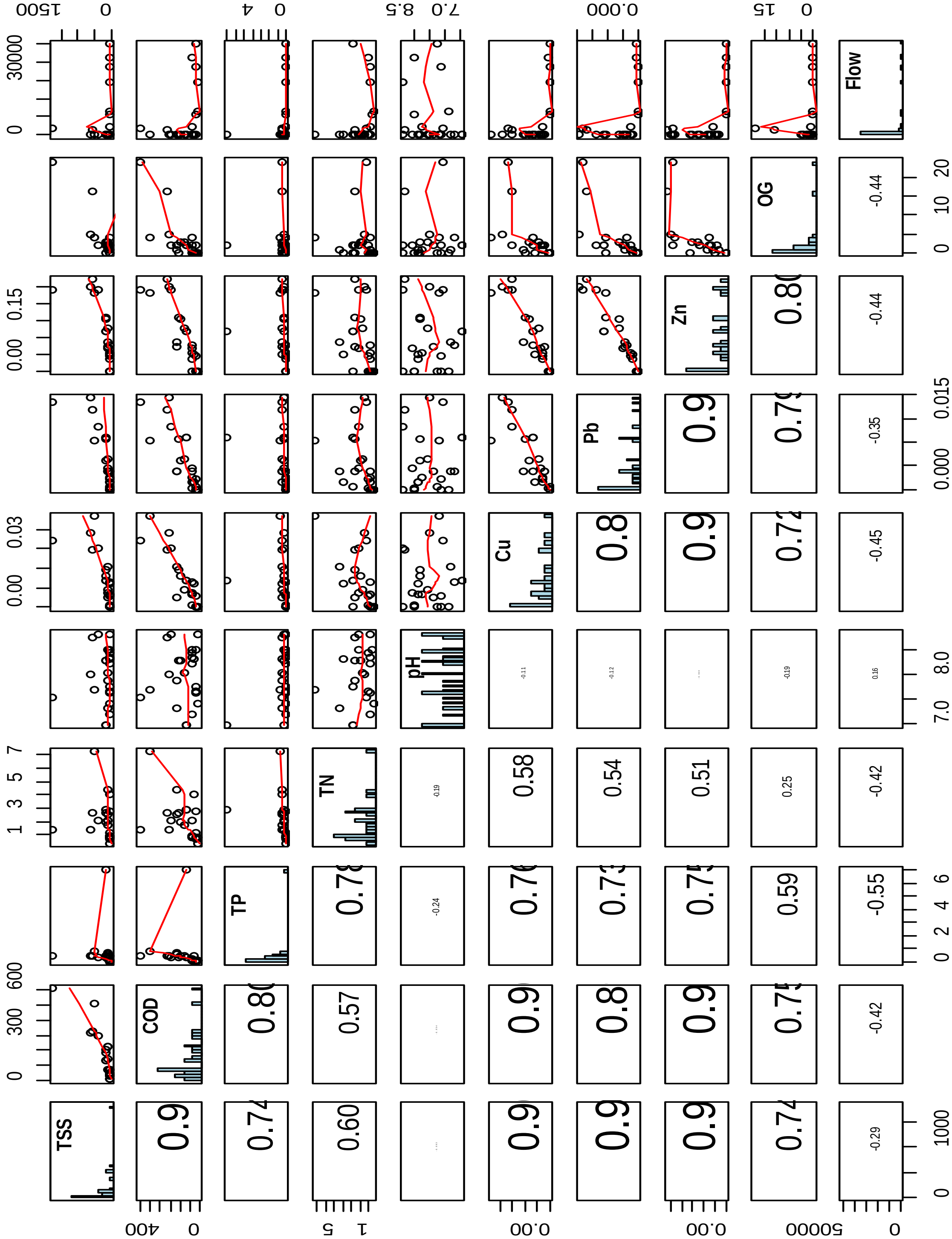

Figure B1. Correlation matrix of water quality variables. Correlations (r) are represented on the lower left, histograms on the diagonal, and x-y plots on the upper right. TSS = total suspended solids, COD = chemical oxygen demand, TP = total phosphorus, TN = total nitrogen, Cu = total copper, Pb = total lead, Zn = total zinc, OG = oil and grease