Technical Memorandum

Date:	Wednesday, December 26, 2018
Project:	MOA MS4 Monitoring Program
To:	Kristi Bischofberger, Municipality of Anchorage Watershed Management Services
From:	Cindy Helmericks, HDR Joe Miller, HDR
Subject:	Municipal Separate Storm Sewer System Water Quality Program Monitoring Program Performance Evaluation – Final

Introduction

The Municipality of Anchorage's (MOA) and Alaska Department of Transportation and Public Facilities (ADOT) Municipal Separate Storm Sewer System (MS4) permit (AK52558) requires the MOA to evaluate the results of the monitoring programs to date and submit the results with the Annual Report.

Section 4.1.8 of the MS4 permit requires that:

> *[w]ithin one year and four years of the effective date of the permit, evaluate the results of the monitoring program to-date and submit the results with the Annual Report. In the evaluation, discuss the effectiveness of street sweeping to reduce turbidity in the outfall, street sweeping and public education to reduce fecal coliform bacteria in the outfall, and other trends or characteristics that may appear as a result of monitoring.*

This evaluation will consist of a review of the Stormwater Outfall Monitoring (SWO) program for the 2011 and 2016 MS4 permits and includes water quality data collected between 2011 and 2018 and a qualitative interpretation of the MOA street sweeping program effectiveness on removing turbidity and fecal coliform bacteria in stormwater runoff.

Street Sweeping Program

According to the current MS4 permit and documentation provided by Watershed Management Services (WMS), street sweeping occurs three to four times a year in Anchorage and is performed by both the ADOT and the MOA, following the sweep schedule presented in Table 1 as described in Section 4.0 of the current MS4 permit. The MOA has at least one sweeper operating after the completion of the spring sweep. In fall, after September 15, crews sweep until freezeup which typically occurs in mid-October.

Table 1. Permit Required Sweeping Schedule

Period in the Year	Residential	Arterial and all other	Public Parking Lots[1]
April 1 – June 15	1 tandem[2]	2 tandem	1 vacuum[3]
June 15 – Sept 15	1 tandem	1 tandem	-
After Sept 15	1 tandem	1 tandem	1 vacuum

Notes:
1. A vacuum sweeper sucks up loosened street particles with a vacuum and sends the directly to a hopper
2. "Tandem" means one mechanical sweeper preceding one vacuum sweeper during the same sweeping event (on the same day). This is equivalent to two sweepers sweeping the same surface; a mechanical sweeper uses a conveyor belt to carry the collected debris to a hopper. Tandem method is relevant for curb and gutter configured streets. Methods may vary for ditched roads as indicated in the Street Sweeping Operations Plan.
3. Threshold size for public parking lots to be swept will be determined as permittees update their street sweeping plan(s).
4. Table 4 of APDES MS4 Permit (AKS052558)

In the spring, the MOA uses 14 mechanical sweepers followed by four vacuum sweepers on arterial roads. In the summer and fall, eight mechanical sweepers followed by two vacuum sweepers clean arterial roads. In spring, summer, and fall, five mechanical sweepers followed by two vacuum sweepers are used on residential roads.

The MOA uses mechanical broom sweepers, mechanical broom sweepers with vacuum assist, and vacuum sweepers. The mechanical broom sweeper collects dirt with one or more brooms that directly sweeps dirt onto conveyors that is then deposited into a hopper. Mechanical broom sweepers are best suited for sweeping heavy dirt loads and streets with rough surfaces under damp to slightly wet conditions. They can also be used to loosen compacted dirt but do not perform well on smaller dirt loads. Mechanical broom sweepers with vacuum assist function like those without but also have an air intake plenum to create a vacuum. These sweepers are more efficient than sweepers without vacuum assist at removing fine particles but do not perform as well under heavy loading or rough road surfaces that can cause vacuum breaks. Best performance is found under dry to damp conditions.

Two types of vacuum sweepers are used: regenerative air and a leaf vac. The regenerative air vacuums recycle exhaust air through an intake plenum that reduces dust and the need for dust suppressing water. These sweepers are effective at removing fine particles. The capital and maintenance costs are high and they don't perform well under heavy street dirt loading or rough road surfaces. Leaf vacuums apply a small high intake velocity nozzle that increases the lifting forces on street dirt. They have a hydraulically articulated boom to allow nozzle placement. Typically leaf vacuums are used to remove leaves and larger debris from curbs but could be effective at removing loosened mineral fines and crushed organic fines.

The operators report annually the average number of passes using the tandem sweeping practice were required to achieve a "visually clean" standard for each sweep event. The tandem sweeping practice is defined as one mechanical sweeper followed immediately by one vacuum sweeper for both curb and gutter and open channel drainage where materials are collected, a process called "Pick-up" sweep practice. For certain streets in the Chugiak/Birchwood/Eagle River Rural Road Service Area (CBERRRSA) with open channel drainage and wide vegetated shoulder, a "Kick Broom" sweep practice is employed where at least one mechanical sweeper is used to “kick” the sediment onto the vegetated shoulder for later collection during shoulder maintenance and ditch dressing.

The ADOT employs contractors to sweep ADOT owned and maintained roads using similar methods as MOA. Their data on sweeping is combined with MOA's for the purposes of this assessment.

For 2017, CBERRRSA reported an average of 6 passes for streets swept with “Kick Broom” sweep practice and 5-6 passes for streets swept with a “Pick-up” sweep practice for both the spring and fall sweep period. For the spring 2017 period, Anchorage Road and Drainage Service Area (ARDSA) reported an average of 4 passes with 2 tandem trains for arterial type streets and 2 passes with 2 tandem trains for Residential streets, and an average of 2 passes for all street types for the fall period. For all operators and sweep periods, streets are swept until a supervisor deems that they have met the “visually clean” standards. ADRSA and CBERRRSA both reported sweeping “as necessary” to maintain a “visually clean” standard for the summer sweep period.

Data was not collected regarding the weight or sediment characterization during street sweeping before 2013. From 2013 through 2018, volumetric and residual data were collected, and shown combined for all maintenance groups, in Table 2 and Table 3, respectively.

Table 2. Combined Street Sweep Total Volume Based on Season and Road Category

Season	Road Category	Pick Up Miles[1]	Total Volume (cyds)
Spring 2017	Arterial	504	7836
	Residential	1778	4774
Summer 2017	Arterial	504	1201
	Residential	617[2]	441[3]
Fall 2017	Arterial	504	1682
	Residential	1794	1077

Notes:
1. “Pick Up Miles” are used as a generic term to refer to both Curb Miles and Pick Up Miles defined earlier for curb and gutter and open channel drainage types, respectively
2. ARDSA and CBERRRSA Residential roads were swept on an "as-needed" basis to maintain a "visually clean" standard during the summer sweep period
3. Some data not reported

Table 3. Combined Street Sweep Residual Sampling Averages

Sweep Period and Category	2013 Residential[1] (lbs/pu mile[4])	2013 Proposed[2] (lbs/pu mile[4])	2016 Residential[3] (lbs/pu mile[4])	2017 Residential[3] (lbs/pu mile[4])
Post Spring Arterial	2238	313	508	250
Post Spring Residential	1189	252	974	376
Post Summer Arterial	791	175	286	282
Post Summer Residential	925	218	550	72

Notes:
1. Values from Table 3, *Anchorage Street Sweeping and Storm Water Controls: 2013 Performance Evaluation*
2. Proposed is defined as the permittee's streets and parking lots (that have been designated for sweeping that year) proposed sweeping frequency relative to the frequencies specified in the Anchorage MS4 Street Sweeping Report
3. Values from 2017 residual sampling
4. "pu mile" is short for "pick up mile"

Overall, sweeping efficiencies studies have found high removal rates during the spring sweep period and are likely due to the high sediment loadings on the street surfaces, representing traction sanding loads accumulated over the entire winter. As a result, spring sweeping efficiencies historically exceed 90 percent removal rate. During the 2013 spring sweep period, residual sampling reflected a removal rate of approximately 95 percent for arterial streets and 70 percent for residential streets. Results from the 2016 residual sampling reflect a removal rate of approximately 99 percent for ARDSA arterial roads and 86 percent for ARDSA residential roads. Results from the 2017 residual sampling reflect a removal rate of approximately 99 percent for ARDSA arterial roads and 93 percent for ARDSA residential roads. These higher removal rates suggest that changes to sweep practices over time have increased the efficiency of sweeping operations.

Stormwater Outfall Monitoring

MS4 performance can be measured using water quality data collected from MOA stormwater outfall monitoring program. Outfall monitoring occurs during storm events between June and October each year. Data discussed herein was collected from 2011 through 2018. Between 2011 and 2018, no outfall sample events occurred during the first sweep period (Table 2, no stormwater samples collected before June 15). Four storm events were sampled each year between 2011 and 2018, and sample collection events occurred in summer and fall, with the earliest sample collection event on June 21 and the latest sample collection event on October 16. An evaluation of the outfall monitoring is provided in the Stormwater Outfall Monitoring Report; however the turbidity and fecal coliform data from these events is discussed herein for the purpose of determining the relationship between street sweeping performance and outfall monitoring results to comply with Section 4.1.8 of the MS4 permit.

Ten outfall locations, described in Table 4 and shown on Figure 1, are monitored for stormwater pollution and the effectiveness of best management practices such as street sweeping. For the years 2011 through 2016, sites SWM01, SWM03, SWM04, and SWM06, serviced residential areas; sites SWM02, SWM05, SWM07, and SWM09 serviced industrial areas; and sites

SWM08 and SWM10 serviced mixed residential and industrial areas. For years 2017 through 2018, sites SWM03, SWM04, SWM06, and SWM11 serviced residential areas; sites SWM05, SWM07, SWM09, and SWM12 serviced industrial areas; and sites SWM08 and SWM10 serviced mixed residential and industrial areas.

SWM02 was sampled from 2011 thru 2016, but was subsequently replaced by SWM12 in 2017 as it was found that the original site was not truly representative of the land use as stream flow from Little Campbell Creek was influencing the outfall (Table 4). SWM01 was also replaced in 2017, which was discontinued due to inconsistent flow and the small size of the drainage area. The replacement outfall, SWM11, is located within the Furrow Creek drainage area, has a larger drainage area, and represents the residential land use category. Locations of the outfall stations and catchment areas are displayed on Figure 1.

Table 4. Stormwater Outfall Sample Locations and Contributing Area Characteristics

Station ID	Subbasin ID	Outfall/Node ID	Watershed	Contributing Land Use	Outfall Diameter	Drainage Acreage	Percent Impervious
SWM01	1040b	1040-3	L. Campbell	Residential	18	91.38	35.52
SWM02	1210	847-1	L. Campbell	Industrial	18	37.17	81.53
SWM03	1224a	1224-1	Campbell	Residential	36	99.99	70.05
SWM04	1224b	1224-2	Campbell	Residential	18	20.10	31.78
SWM05	805	207-1	Campbell	Industrial	24	58.34	75.41
SWM06	219	314-22	Chester	Residential	26	33.81	37.26
SWM07	507	484-1	Chester	Industrial	24	50.17	87.68
SWM08	549	86-1	Chester	Mixed	42	354.62	68.94
SWM09	132	499-1	Chester	Industrial	24	40.04	53.65
SWM10	554	525-2	Chester	Mixed	24	47.51	74.62
SWM11	1103	348-3	Furrow Cr.	Residential	36	86.32	38.58
SWM12	1449	1454-1	Campbell	Industrial	24	111.68	59.51

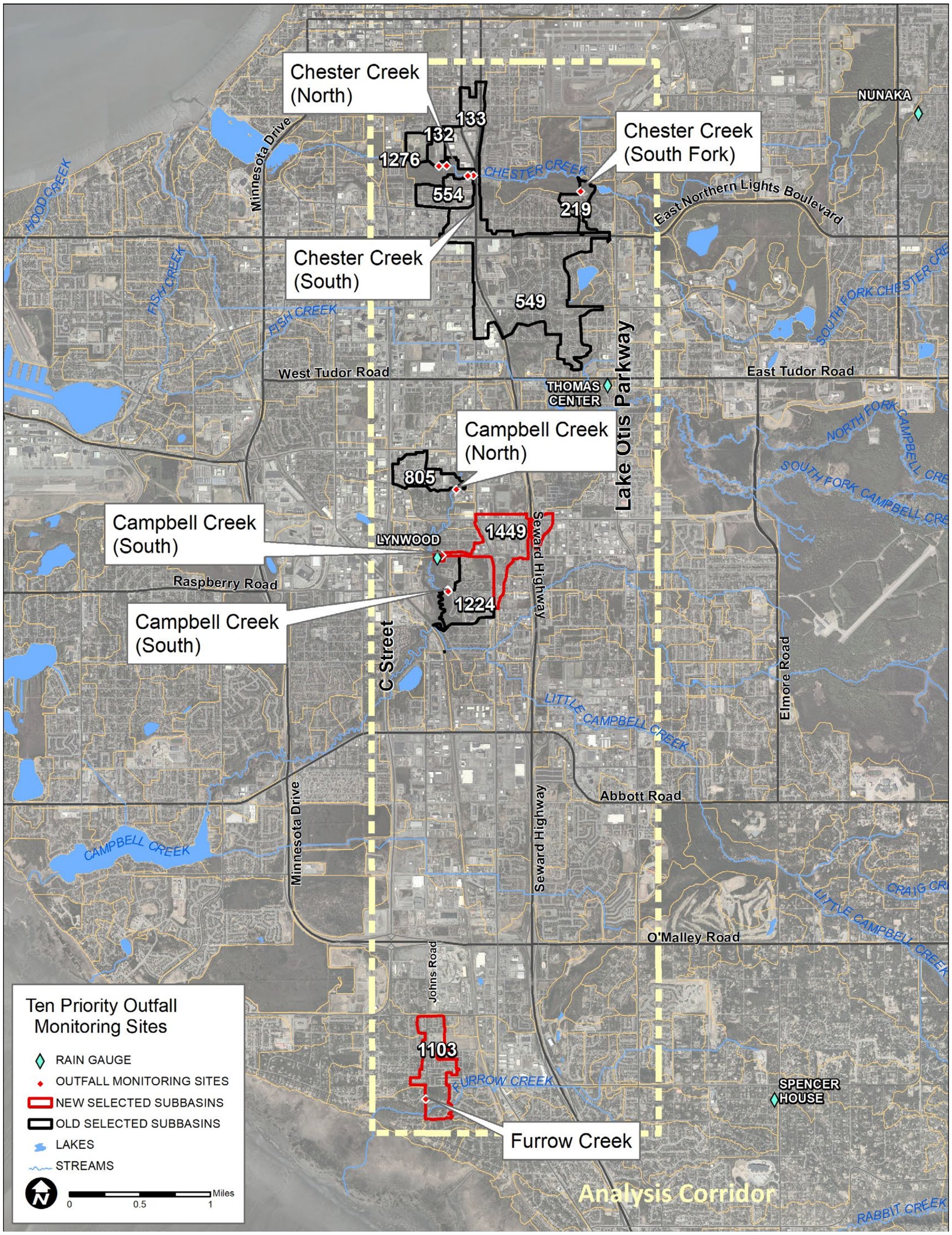

Figure 1: Outfall Monitoring Sites and Contributing Drainage Areas

For years 2011 through 2016, the residential outfall catchment areas were generally larger than the industrial outfall catchment areas. However, the industrial outfall catchment areas had generally higher percent of impervious surface than residential locations; therefore the average acreage of impervious surface was relatively similar between residential and industrial type catchment areas. For years 2017 and 2018, the residential outfall catchment areas are similar to the industrial outfall catchment areas based on drainage area. However, the industrial outfall catchment areas have generally higher percent of impervious surface than residential locations. These values can are listed in Table 5.

Table 5. Stormwater Outfall Types with Average Drainage Area and Average Impervious Area

Years	Outfall Type	Outfall Sample Station IDs	Number of Locations	Average Drainage Area (ac.)	Average Impervious Area (Ac.)
2011 - 2016	Residential	SWM 01, 03, 04, 06	4	61	30
	Industrial	SWM 02, 05, 07, 09	4	46	35
	Mixed	SWM 08, 10	2	201	140
2017 - 2018	Residential	SWM 03, 04, 06, 11	4	60	31
	Industrial	SWM 05, 07, 09, 12	4	65	44
	Mixed	SWM 08, 10	2	201	140

For years 2011 through 2018, using the respective outfall sample locations, the following information is true: given that arterial roads are swept an additional time over residential roads, a comparison between industrial catchment area land use types and residential land use types is presented; however, the specific industrial catchment area outfall sample sites may not include the arterial roads that are swept twice between April 15 and June 15.

TURBIDITY

The turbidity concentrations at outfall sample locations SWM01 and SWM02 were reviewed from 2011 through 2016, SWM3 through SWM10 were reviewed from 2011 through 2018, and SWM11 and SWM12 were reviewed from 2017 through 2018. The mean annual turbidity concentration for each outfall location is shown in Figure 2. The mean turbidity concentration for each outfall sample event by contributing area land use type is provided in Figure 3. The turbidity data from outfall monitoring is provided in Attachment 1. Specific dates of street sweeping are not available to compare with the dates of outfall sampling.

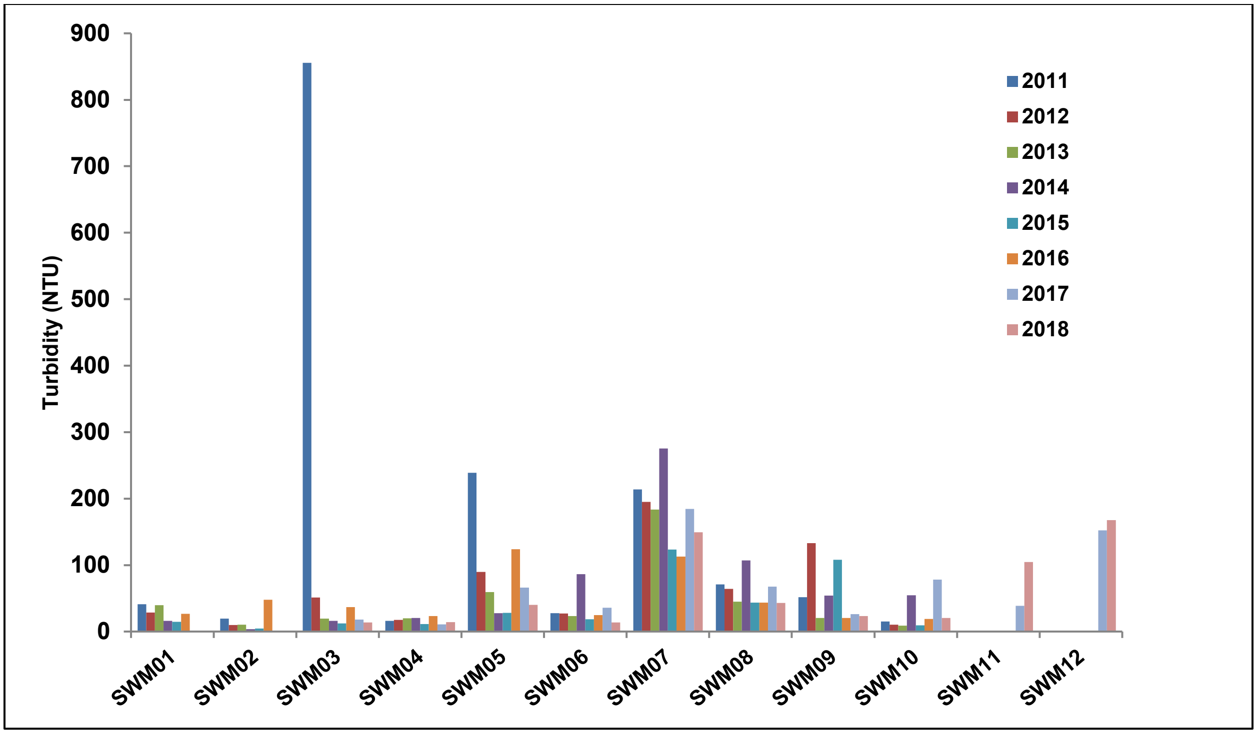

Figure 2. Mean Annual Turbidity in Stormwater at each Outfall Sample Site

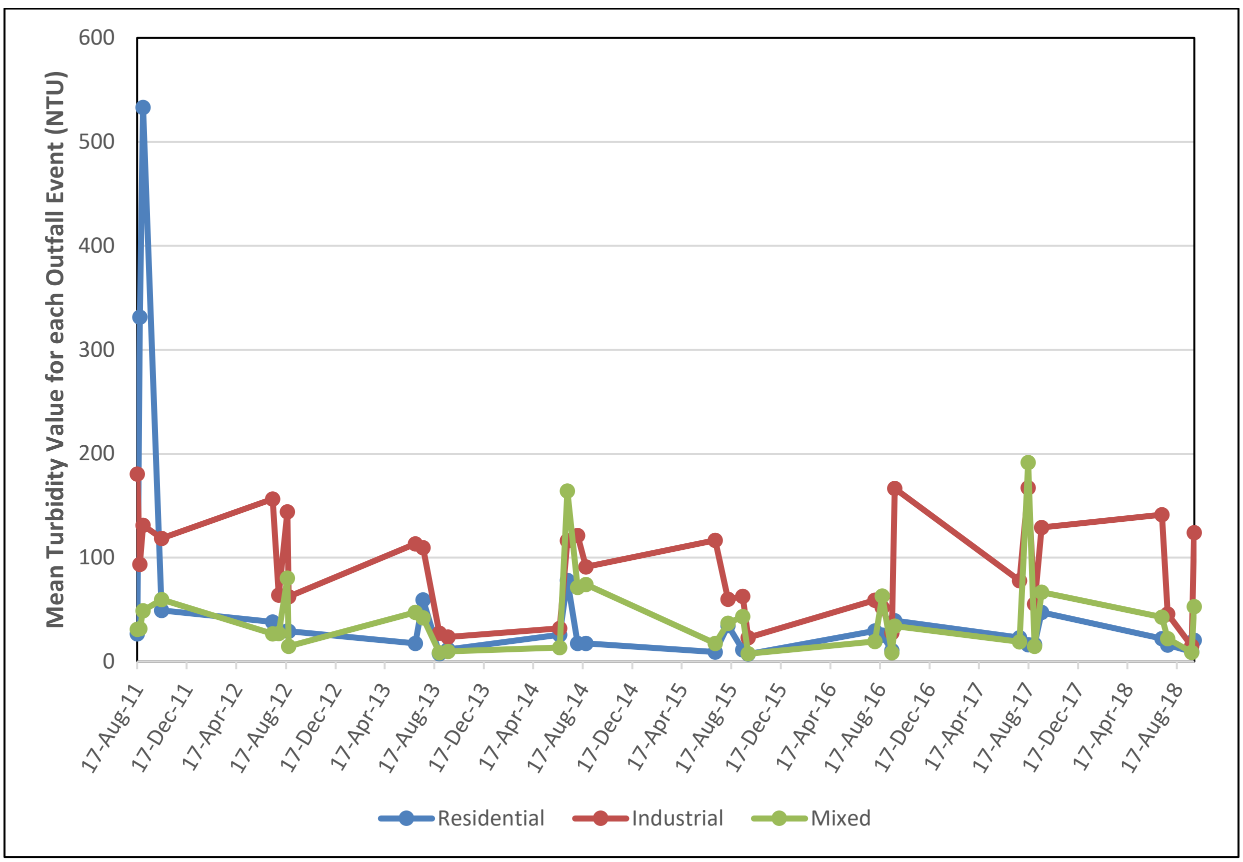

Figure 3. Mean Turbidity for each Outfall Sample Event by Contributing Area Land Use (2011-2018)

For residential sites, SWM03 and SWM04 outfall turbidity values stayed consistently low, aside from two 2013 storm events for SWM03. In 2011, construction occurred near SWM03 that is suspected to have been the source of elevated turbidity levels during that year. When the two anomalous outfall sample events in 2011 for site SWM03 were removed, the annual mean residential turbidity decreases from 127.9 to 26.2 NTU. For SWM04, it is consistently low and contains the lowest average of the residential sites at 16.7 NTU.

For industrial sites, aside from SWM02 that was not truly representative of the land use category, SWM09 had the lowest average and stayed consistently low, aside from one 2015 storm event. According to the 2015 Annual Monitoring Report, construction activities were suspected to be the cause of elevated turbidity at SWM09. When the single anomalous outfall sample event was removed, the annual mean residential turbidity decreases 55.8 to 46.5 NTU.

Overall, residential areas tend to have lower turbidity levels than industrial areas. Figure 3 displays the mean turbidity concentration from area outfalls based on contributing land use for each sampling event. Industrial outfalls tend to have higher turbidity than residential and mixed use outfall catchments in 2011 to 2018. However, four storm events sampled had turbidity values higher for mixed and residential outfalls: a peak in residential outfalls in 2011, one event in 2016 with the mixed outfall turbidity value being slightly higher than industrial, and two peaks in mixed outfalls in 2014 and 2017. If the industrial outfall sample sites do in fact contain arterial roads that are swept more than the residential roads, there is no apparent benefit in turbidity concentrations at industrial outfalls that could be accounted for by the additional sweep of those roads (Figure 3). However, the sample collection timing within the storm hydrograph has a significant impact on the stormwater turbidity concentration. Without an analysis of the data collection within each storm event and paired with street sweeping events, the stormwater turbidity data is of limited use in evaluating street sweeping effectiveness.

SWM07 consistently had the highest turbidity levels but shows decreasing values over time. SWM07 drains the area between north and south-bound lane of Seward Highway near 15th Avenue (Figure 1). During the 2017 and 2018 field seasons crews walked the entire sub-basin looking for activities and/or land uses that could be introducing turbidity into the storm drain system. Inspections were also completed of the catch basins and OGS upstream of the outfall. The only discovery from the inspections was a missing cover for a manhole that was below existing grade. The area around the manhole was reconfigured and the cover replaced.

During the 2017 and 2018 sampling events SWM12 shows similar turbidity values as SWM07 with 2018 values being higher than SWM07. SWM12 drainage area is twice the size of the drainage area of SWM07, but has 27 percent less impervious pavement.

Based on land use areas, there does not appear to be a trend of turbidity in stormwater during each sample season (e.g. higher turbidity earlier in the sample season).

FECAL COLIFORM

The fecal coliform concentrations at each outfall sample location were reviewed from 2011 through 2018. The mean annual fecal coliform concentration for each outfall location is shown in Figure 4. The mean fecal coliform concentration for each outfall sample event by contributing area land use type is provided in Figure 5. The fecal coliform data from outfall monitoring is provided in Attachment 1. Specific dates of street sweeping are not available to compare with the dates of outfall sampling.

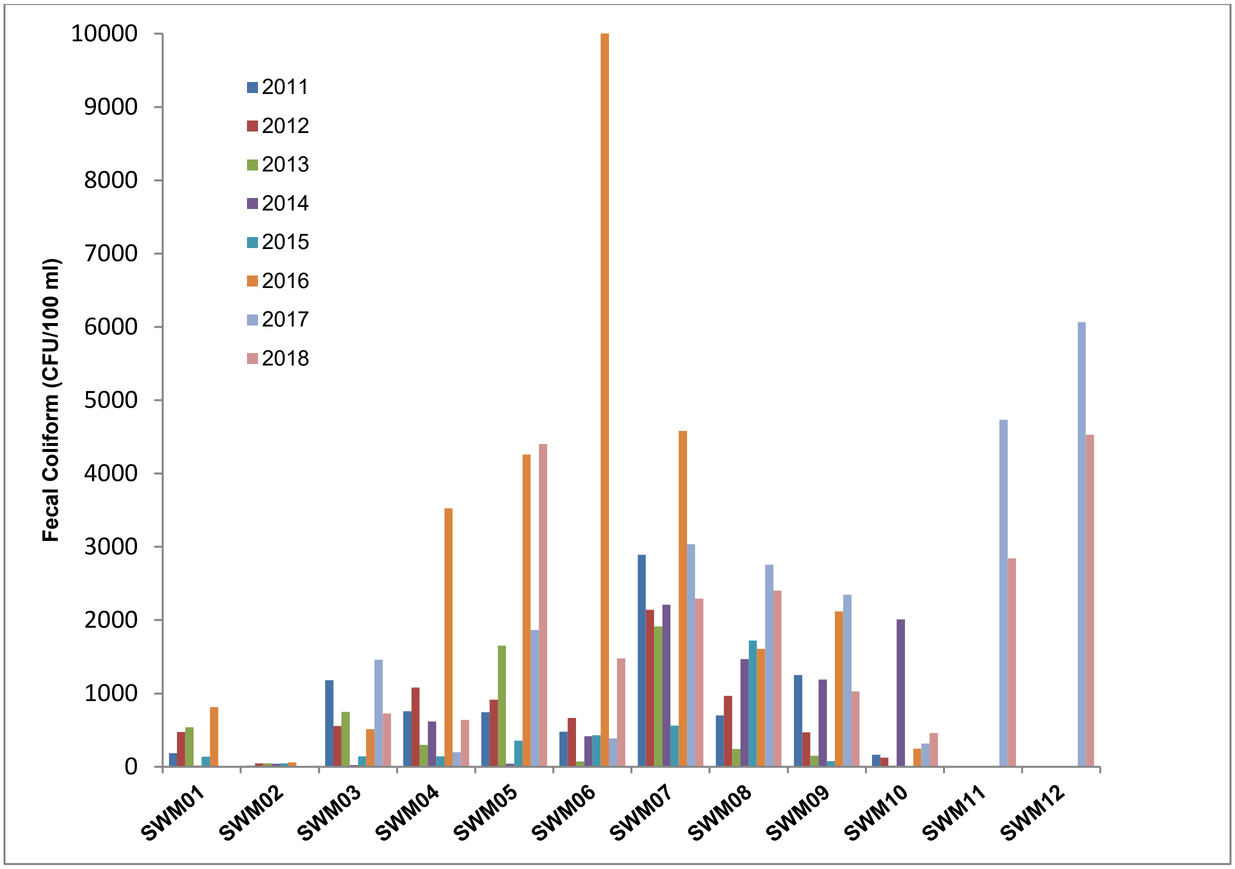

Figure 4. Mean annual concentration of fecal coliform in Stormwater at each Outfall Sample Site

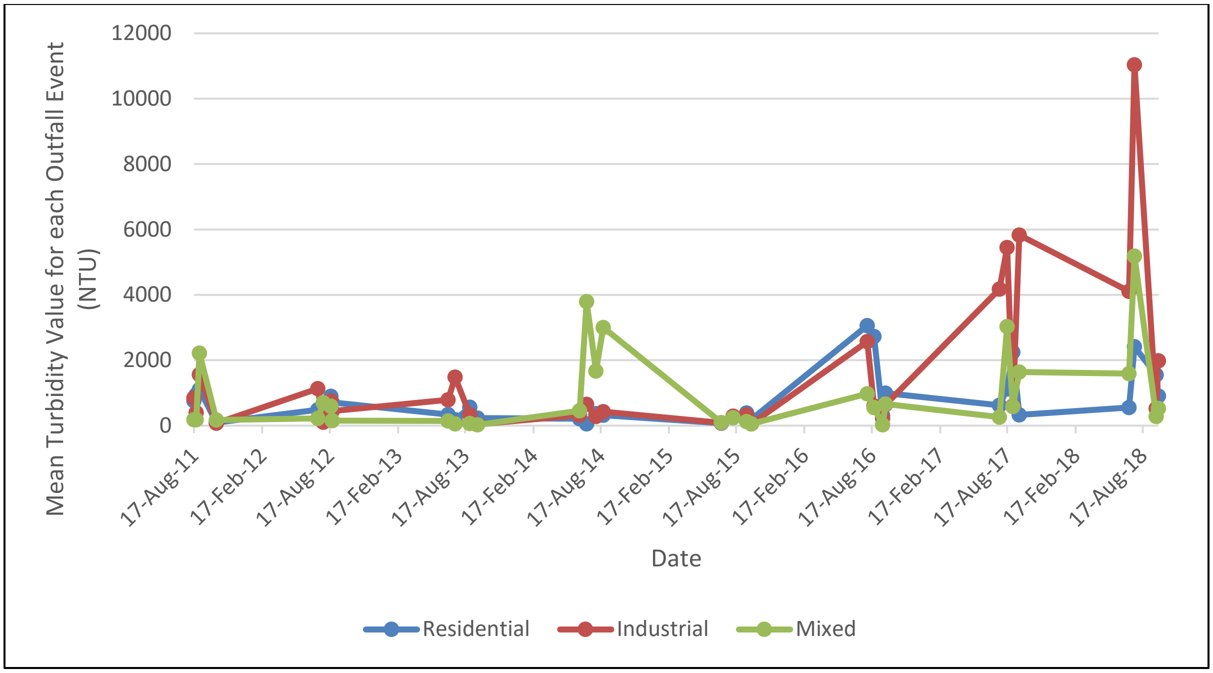

Figure 5. Mean Fecal Coliform for each Outfall Sample Event by Contributing Area Land Use (2011-2018)

For fecal coliform, SWM01 and SWM02, not being considered, due to being discontinued sampling locations, SWM10, a mixed land use outfall, had the lowest mean of 8 CFU/100 ml during 2015, based on means taken each year of the four storm events. The lowest residential mean was 25 CFU/100 ml at SWM04 during the 2014 sampling events. The lowest industrial mean was 41 CFU/100 ml at SWM05 during 2014. Overall, the industrial land use areas had higher fecal coliform levels than residential areas with a mean of 646 CFU/100ml versus 502 CFU/100 ml respectively for all data collected from 2011 to 2018. Outfalls SWM08 and SWM10 represents mixed land use areas and had an overall mean of 377 CFU/100 ml. Outfalls SWM11 and SWM12 have only been sampled for two years (2017 and 2018) but and are fairly consistent in containing high levels of fecal coliform. In 2017, SWM12 contained the highest annual mean concentration at 6065 CFU/100 ml and SWM11 contained the second highest at 4736 CFU/100 ml. In 2018, SWM12 still contained the highest levels at 4529 CFU/100 ml, SWM05 contained the second highest at 4402 CFU/100 ml, and SWM11 contained the third highest at 2846 CFU/100 ml.

Unlike turbidity, mixed land use contains the overall lowest values and industrial contains the highest. SWM10, a mixed land use outfall, had consistently low mean fecal coliform values for all years except 2014 in which it had some of the highest.

Since the *2016 Municipal Separate Storm Sewer System Water Quality Program Monitoring Program Performance Evaluation Technical Memorandum* (HDR, 2016), additional years of data have shown an upward trend of fecal coliform in industrial and mixed use, which can be seen in Figure 5. There is no apparent association with drainage size nor percent impervious surface.

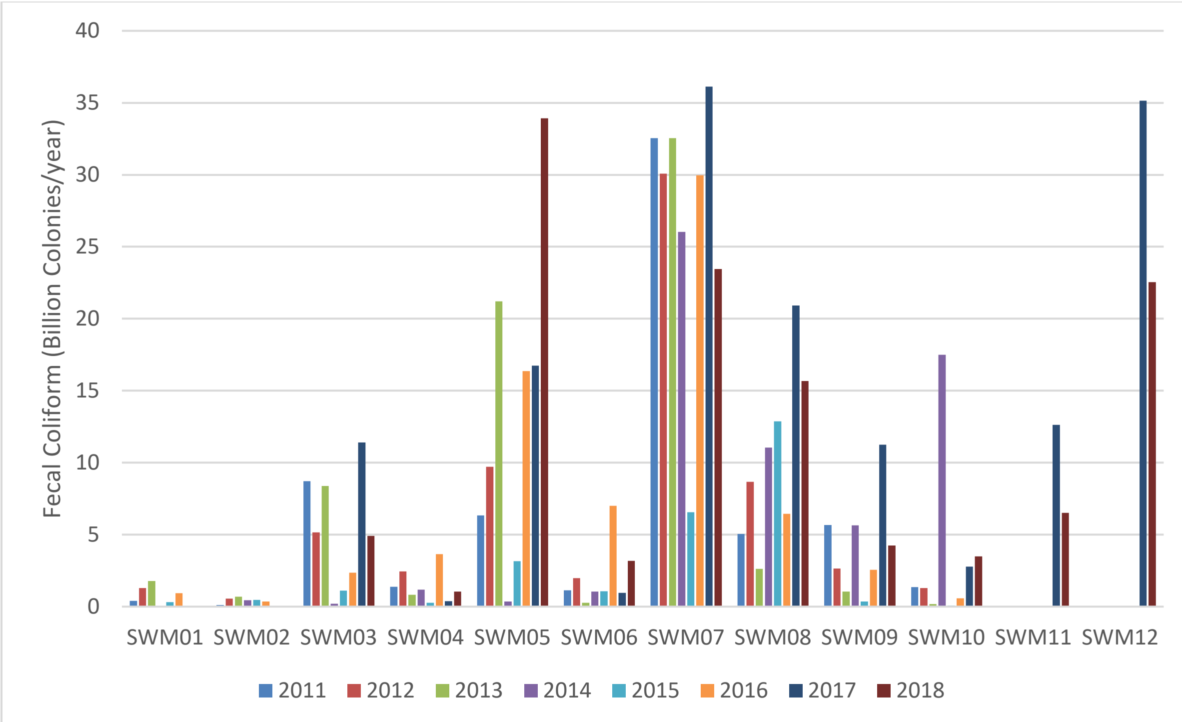

Figure 6. Fecal Coliform Annual Loading by Monitoring Site

An analysis of fecal coliform in 2003 by MOA indicated that the highest loads would occur in August/September in association with peak runoff (MOA, 2003). Peak runoff during the 2011-2018 monitoring occurred mostly in July/August (MOA, 2012; MOA, 2013; MOA, 2014; MOA, 2015; MOA 2016, MOA 2017, MOA 2018). Fecal coliform levels are typically higher in July/August in association with peak runoff and rainfall in urban areas (Figure 5).

SWM07 consistently had the highest fecal coliform loading rates for six of the eight years from 2011 through 2018, except for 2015 and 2018. During the 2017 and 2018 field seasons, the sub-basin draining into the outfall was mapped and field crews sampled from several access points and made visual inspects. The results ranged from non-detect to 6500 colonies per 100 milliliters and visual inspections did not identify a single flow source that looked like a possible cross connect. For years 2017 and 2018, SWM12 also had second and third highest loading rates.

Conclusions

It is well documented that relationships between stormwater outfall data and street sweeping are difficult to correlate (Selbig and Bannerman, 2007). Results of existing studies show there is little probability that street sweeping, regardless of street-sweeper type, had measurable effect on the quality of runoff. Measuring the performance of street sweeping as a stormwater quality management tool appears to be limited by the extreme variability in constituents in stormwater runoff. It is extremely difficult to isolate changes in stormwater quality as a result of street sweeping because other factors may be affecting the movement and supply of constituents (including turbidity and fecal coliform) in catchment areas. Examples of factors that might contribute to the high variability include the amount of sediment delivered from other source areas such as lawns and driveways, the efficiency of sediment delivery in the storm sewer system, and the changes in the amount of gravel applied to enhance vehicle traction each winter. In addition, the stormwater outfall sample collection timing during the storm event hydrograph is not consistent between events, or amongst the outfall stations. There is insufficient data available regarding sweeping schedule to pair sample collection events with street sweeping events; however existing studies have concluded that a much larger number of water samples would have to be collected in order to detect any significant change due to street sweeping. For example, a USGS study using 40 paired stormwater-quality samples estimated that 200 paired stormwater-quality samples would have been required to detect a significant change (Selbig and Bannerman, 2007).

In 2017, street sweeping reported collecting in excess of 17,011 cubic yards of sediment, which provides an observable account of the of sweeping impeding sediment from entering the waterbodies of Anchorage. The amount of residual sediment after sweeping events found on residential streets within the MOA has decreased over time, further preventing sediment from reaching and entering the MS4. While tracking this through to specific turbidity and coliform concentrations is difficult, the sweeping treatment is understood to improve runoff water quality and extend the operational life of stormwater infrastructure.

For future analysis to be of use to determine the performance of street sweeping on the MOA waterbodies it is recommended that the stormwater outfall monitoring continue at the same ten outfalls being currently sampled. Data from the same outfalls needs to be collected over an extended period of time in order to see any statistical trends as stated in Selbig and Bannerman, 2007. Two of the currently tested outfalls have been a part of the study for two years and therefore need further sampling to determine if any trends exist in the respective basins. Furthermore, to better align the stormwater outfall monitoring data with street sweeping data, dates of street sweeping and residual sample studies should be taken into account and if possible stormwater outfall sampling should occur during a storm event as closely as possible to those dates.

References

HDR 2016. Municipal Separate Storm Sewer System Water Quality Program Monitoring Program Performance Evaluation Technical Memorandum, Final Report, January 2017.

MOA 2003. Fecal Coliform in Anchorage Streams: Sources and Transport Processes. Document APg03001, September 2003

MOA 2012. 2011 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Final Report, January 2012.

MOA 2012. 2012 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Final Report, December 2012.

MOA 2013. 2013 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Draft Report, November 2013.

MOA 2014. Anchorage Street Sweeping and Storm Water Controls: 2013 Performance Evaluation. Document Apr14001, January 2014

MOA 2014. 2014 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Final Report, December 2014

MOA 2015. 2015 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Final Report, January 2016.

MOA 2016. 2016 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Final Report, December 2016.

MOA 2017. 2017 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Final Report, December 2017.

MOA 2017. Anchorage MS4 Street Sweeping Report for 2017, Document No. WMP CPr18001, WMS Project No. 95003, Final Report, January 2018.

MOA 2018. 2018 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Draft Report, December 2018.

MOA 2018. 2017 SWM07 Stormwater Outfall Monitoring Report, APDES Permit No. AKS-052558, Interim Progress Report, January 2018.

William R. Selbig and Roger T. Bannerman, 2007. Evaluation of Street Sweeping as a Stormwater-Quality-Management Tool in Three Residential Basins in Madison, Wisconsin. Scientific Investigations Report 2007–5156