2016 Stormwater Outfall Monitoring Report

APDES Permit No. AKS-052558

FINAL REPORT

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MUNICIPALITY OF ANCHORAGE

WATERSHED MANAGEMENT PROGRAM

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1.0 Introduction

1.1 Background

The U.S. Environmental Protection Agency (EPA) issued the Municipality of Anchorage (MOA) and the Alaska Department of Transportation and Public Facilities (ADOT&PF) a Municipal Separate Storm Sewer System (MS4) permit under the National Pollutant Discharge Elimination System (NPDES) in 1999. EPA re-issued the permit (Permit No. AKS-052558) in October 2009 (EPA 2009). The new permit included a requirement to conduct stormwater outfall monitoring at 10 priority outfalls. The MOA has taken the lead role in implementing the monitoring requirements of the permit. Since permit issuance, EPA has delegated the NPDES stormwater program for Alaska to the Alaska Department of Environmental Conservation (ADEC) who now oversees its implementation and administration under the Alaska Pollutant Discharge Elimination System (APDES). The 2009 permit expired in January 2015 and was reissued in June 2015 with an effective date of August 1, 2015 (ADEC 2015a). The stormwater outfall monitoring requirements in the 2015 permit are, for the most part, identical to those contained in the prior permit, which require continued monitoring at the 10 priority stormwater outfalls.

The APDES MS4 permit establishes minimum control measures requiring the co-permittees to develop programs and policies, and implement actions designed to prevent and control contaminants entering publicly owned storm sewer systems. The permit also identifies a number of objectives for monitoring of which the stormwater outfall monitoring is one component. The objective most relevant to stormwater outfall monitoring is to broadly identify fecal coliform and petroleum product loading from stormwater. To accomplish this objective, a variety of land uses must be examined to ensure representative water quality conditions across the MS4 area are included in the monitoring program. This report and the data collected during the monitoring program fulfill the annual outfall monitoring objectives of the APDES Permit. The stormwater sampling conducted during 2016 is the second year of monitoring that was performed for the reissued permit, but the sixth year of monitoring for the 10 outfalls.

1.2 Stormwater Definition

The EPA has recognized urban stormwater as a major contributor to pollution of the nation’s streams, rivers, and lakes. EPA and delegated states are using the NPDES MS4 permit to control pollutants from urban stormwater to the maximum extent practicable. Urban stormwater can contribute to the degradation of the quality of water bodies. Runoff from precipitation and snowmelt events can transport contaminants from impervious surfaces such as driveways; sidewalks; and roads and semi-pervious surfaces such as lawns, into the local water bodies. Most stormwater runoff flows into a storm sewer system or directly to a water body, often without receiving treatment to remove the pollutants.

In issuing the Anchorage MS4 permit, EPA recognized that a number of water bodies in the greater Anchorage watershed were categorized as impaired under section 303(d) of the Clean Water Act. For 14 impaired water bodies (13 for elevated concentrations of fecal coliform and one for petroleum hydrocarbons) ADEC has developed (and EPA has approved) Total

Maximum Daily Load (TMDL) plans to improve water quality to the extent that the waters will meet the current standards. The TMDLs identify stormwater runoff as a contributor of fecal coliform and petroleum hydrocarbon contamination to the water bodies and the TMDLs establish reduction goals for concentrations of these pollutants in stormwater.

1.3 Goals and Objectives of Monitoring Program

The monitoring elements of the MS4 permit are designed to identify sources of stormwater pollution such as fecal coliform and petroleum hydrocarbons, monitor the effectiveness of best management practices (BMPs), and monitor the status of stormwater outfalls and receiving waters. The goal of the stormwater outfall monitoring component of the permit is to obtain sufficient data to characterize the quality of the stormwater runoff for pollutants identified in the permit. By monitoring the same outfalls over a multi-year period, the results should provide a qualitative characterization that meets the objectives identified in the APDES Permit and Fact Sheet (ADEC 2015a and 2015b).

The stormwater outfall monitoring program measured pollutants and pollutant indicators during precipitation events that generated runoff at 10 high priority outfall sites. This monitoring program will allow MOA to meet the ADEC objectives specified in the permit. As specified in the permit, the outfall monitoring should address the following objectives:

- Broadly estimate the annual pollutant loading of fecal coliform and petroleum products discharged to specific watersheds from the MS4s
- Assess the effectiveness and adequacy of existing stormwater controls in reducing fecal coliform bacteria and petroleum products
- Identify and prioritize portions of the MS4 that need additional controls

2.0 Explanation of Report Organization

This report is divided into the following sections:

- Introduction, background information, and goals and objectives of the program
- Summary information about the field phase of the project including project design, site selection and descriptions, parameters to be measured, field and laboratory procedures, deviations from the QAPP, and summary of QA/QC results
- Tabular and graphical summaries of the data along with a discussion of results
- Summary and preliminary conclusions
- References
- Appendices that include: field photographs, laboratory data reports, field and laboratory data validation summary, and completed field log forms

3.0 Monitoring Program

3.1 Sampling Design

Beginning in the summer of 2011 and for the following six years, the 10 priority outfalls were sampled four times each summer when there was sufficient precipitation to generate runoff (typically, 0.1 to 0.25 inches depending upon percent impervious land use within the watershed). For planning purposes, 0.1 inches of rain was the trigger for a potential sampling event. Monitoring of the outfalls included both in situ measurements and discrete grab samples submitted for laboratory analyses. Appendix B (*Stormwater Outfall Monitoring Plan)* of the Quality Assurance Project Plan (QAPP, MOA 2012) stipulates that the following parameters are collected at each outfall: flow, dissolved oxygen (DO), pH, temperature, turbidity, 5-day biochemical oxygen demand (BOD_5), fecal coliform, and total suspended solids (TSS). Outfalls located in predominantly commercial; industrial; or paved collector, arterial streets or parking lots, samples were also analyzed for total aromatic hydrocarbons (TAH) and total aqueous hydrocarbons (TAqH). In addition, the supplemental measurement of specific conductance was obtained with the field parameters. Beginning in 2016, supplemental samples at all 10 outfalls were also collected for dissolved copper (Cu) and water hardness.

3.2 Monitoring Site Selection and Descriptions

The stormwater outfall monitoring prescribed in the permit requires the monitoring of specific water quality parameters and flow four times each year at 10 separate locations. To meet the permit objectives, the outfalls selected represent a diversity of land uses. The MOA developed a selection process for identifying the 10 outfalls as the highest priority locations from a list of 30 medium to high priority outfalls. Criteria identified by the MOA for targeted monitoring within the Anchorage Basin are as follows:

- Include a variety of land uses
- Include storm drains that discharge to water quality impaired (303(d)-listed) streams
- Experience approximately the same annual precipitation
- Be geographically diverse while allowing relatively easy access to all outfalls during a single rainfall event

To meet these criteria, MOA selected a portion of the MS4 that extends from C Street on the west to Lake Otis Parkway on the east, and from the northern portion of the Chester Creek watershed to the southern edge of the Furrow Creek Watershed. The targeted area included substantially urbanized portions of the watershed tributary to Chester Creek, Furrow Creek, Little Campbell Creek, and Campbell Creek. These four streams are impaired for fecal coliform and have an approved TMDL, and therefore meet one of the permit objectives (ADEC 2004a, 2004b, 2005, and 2006, and AWC 2014).

Within the target area, the MOA identified priority outfalls that represent homogeneous land use subbasins, heterogeneous land use subbasins, and subbasins with and without oil/grit separator

(OGS) devices. This diversity of land uses and structures meets the permit objectives of broadly quantifying pollutant loads and assessing effectiveness of existing best management practices (BMPs).

Monitoring data from subbasins meeting the four different conditions (homogeneous land use, heterogeneous land use, with OGS and without OGS) serve different functions.

Conditions for the subbasins with a homogeneous land use:

- Data identify specific pollutants originating from a predominant land use that require additional controls. Controls tailored to a specific land use could be used in those watersheds.
- Data from basins with homogeneous land uses are appropriate for developing loading estimates for fecal coliform and TAH, as described below.
- Fecal coliform, TAH, and TAqH data are appropriate for comparison with receiving water quality criteria. Since water quality criteria do not apply directly to stormwater, the criteria serve as benchmarks.
- Fecal coliform data are appropriate for comparison with TMDL reduction goals for fecal coliform to determine improvement over time.

Conditions for subbasins with heterogeneous land uses:

- Data are useful when developing loading estimates of fecal coliform and petroleum hydrocarbons.
- Data were also to be used to assess pollutants originating across land uses that may require additional controls, and additional BMP controls that could be applied across the basin.
- Fecal coliform and petroleum hydrocarbon data are appropriate for comparison with receiving water quality criteria.
- Fecal coliform data are appropriate for comparison with TMDL reduction goals for fecal coliform to determine improvement over time.

Conditions for subbasins with or without OGS systems:

- Data are used to assess the effectiveness of the OGS systems and determine whether additional OGS systems could be installed to improve stormwater quality.
- Petroleum hydrocarbon data are appropriate for comparison with receiving water quality criteria.

MOA used its hydrogeographic database (HGDB) and other municipal geographic data to select subbasins with the aforementioned characteristics. Application of this selection process resulted in the initial identification of 10 priority outfalls (Table 1). Following the pre-sampling field reconnaissance, it was determined that one of the selected outfalls (Node ID 299-20, highlighted in Table 1) exhibited severe corrosion within the outfall pipe and was not suitable for sampling. An alternate outfall within the Little Campbell Creek Watershed, having the same land use and BMP characteristics (Node ID 847-1), became the tenth sampling site.

To facilitate sample labeling and simplify outfall identification in the field per the *Monitoring, Evaluation and Quality Assurance Plan* (MOA 2012), the outfall stations were sequentially numbered from south to north along the sampling corridor (SWM01 thru SWM10). Table 1 provides the characteristics of each outfall including physical location, geographic location, outfall dimensions, acreage of subbasin, and percent impervious surface of the subbasin. An overview map (Figure 1) shows the 10 monitoring outfall locations along with the subbasins for each watershed. Figures 2-8 are larger scale maps that clearly show land use types for each of the outfalls and subbasins.

Table 1. Top 10 Priority and Replacement Outfalls

Station ID	Subbasin ID	Outfall/ Node ID	Watershed	Contributing Land Use*	OGS Present	Priority Rank	Latitude	Longitude	Outfall Diameter	Drainage Acreage	Percent Impervious
10 Identified Priority Outfalls											
SWM05	805	207-1	Campbell	CI	Yes	1	61° 10.202'	-149° 52.326'	24	58.34	75.41
SWM06	219	314-22	Chester	R	Yes	2	61° 11.996	-149° 50.750'	26	33.81	37.26
SWM03	1224a	1224-1	Campbell	R	Yes	3	61° 09.548'	-149° 52.443'	36	99.99	70.05
SWM09	132	499-1	Chester	CI	Yes	4	61° 12.176'	-149° 52.554'	24	40.04	53.65
SWM10	554	525-2	Chester	M	No	5	61° 12.161'	-149° 52.486'	24	47.51	74.62
SWM08	549	86-1	Chester	M	No	6	61° 12.095'	-149° 52.114'	42	354.62	68.94
SWM04	1224b	1224-2	Campbell	R	Yes	6	61° 09.545'	-149° 52.451'	18	20.10	31.78
NA	133	299-20	Chester	CI	No	8					
SWM07	507	484-1	Chester	CI	No	9	61° 12.100'	-149° 52.114'	24	50.17	87.68
SWM01	1040b	1040-3	L. Campbell	R	No	10	61° 07.526'	-149° 50.196'	18	91.38	35.52
Medium Priority Replacement Outfall											
SWM02	1210	847-1	L. Campbell	CI	No	17	61° 08.665'	-149° 50.797'	18	37.17	81.53

Yellow highlighted Subbasin 133 was replaced with yellow highlighted Subbasin 1210.

R = Residential; CI = Commercial and Industrial; M = Mixed

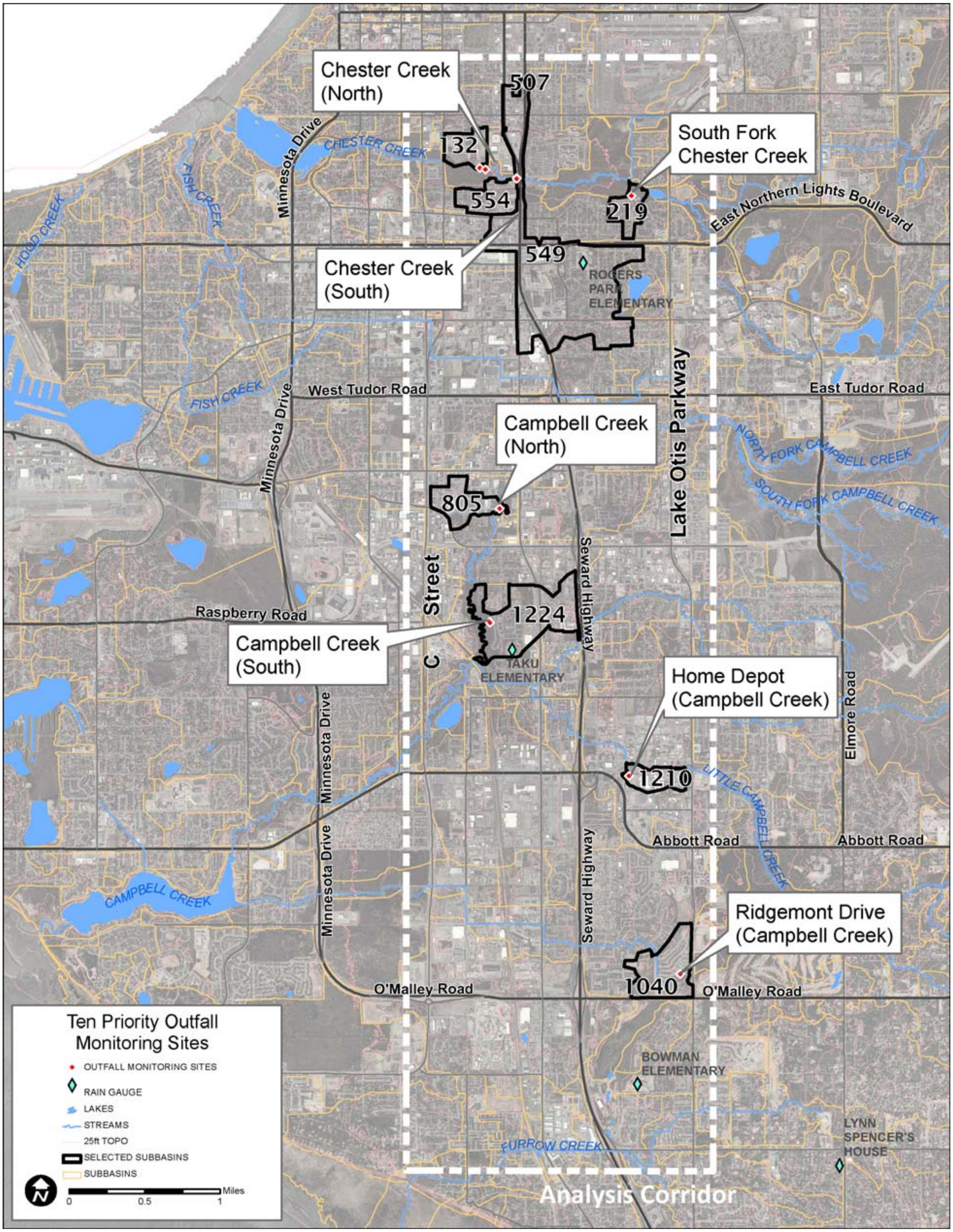


Figure 1. Overview Map of the Ten Final Outfall Monitoring Sites and Subbasins

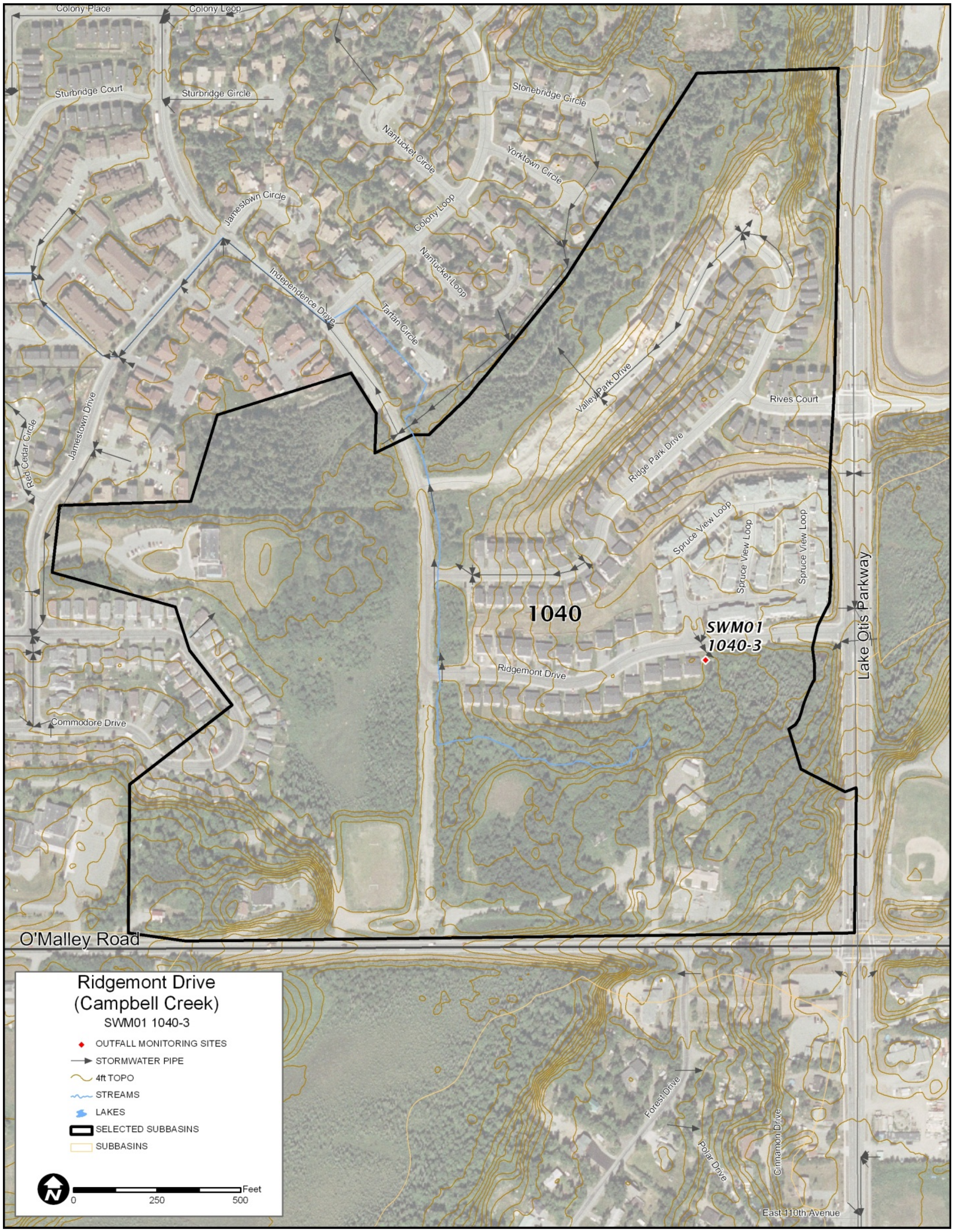


Figure 2. Outfall SWM01, Ridgemont Drive (Little Campbell Creek)

Figure 3. Outfall SWM02, Abbot Road at Home Depot (Little Campbell Creek)

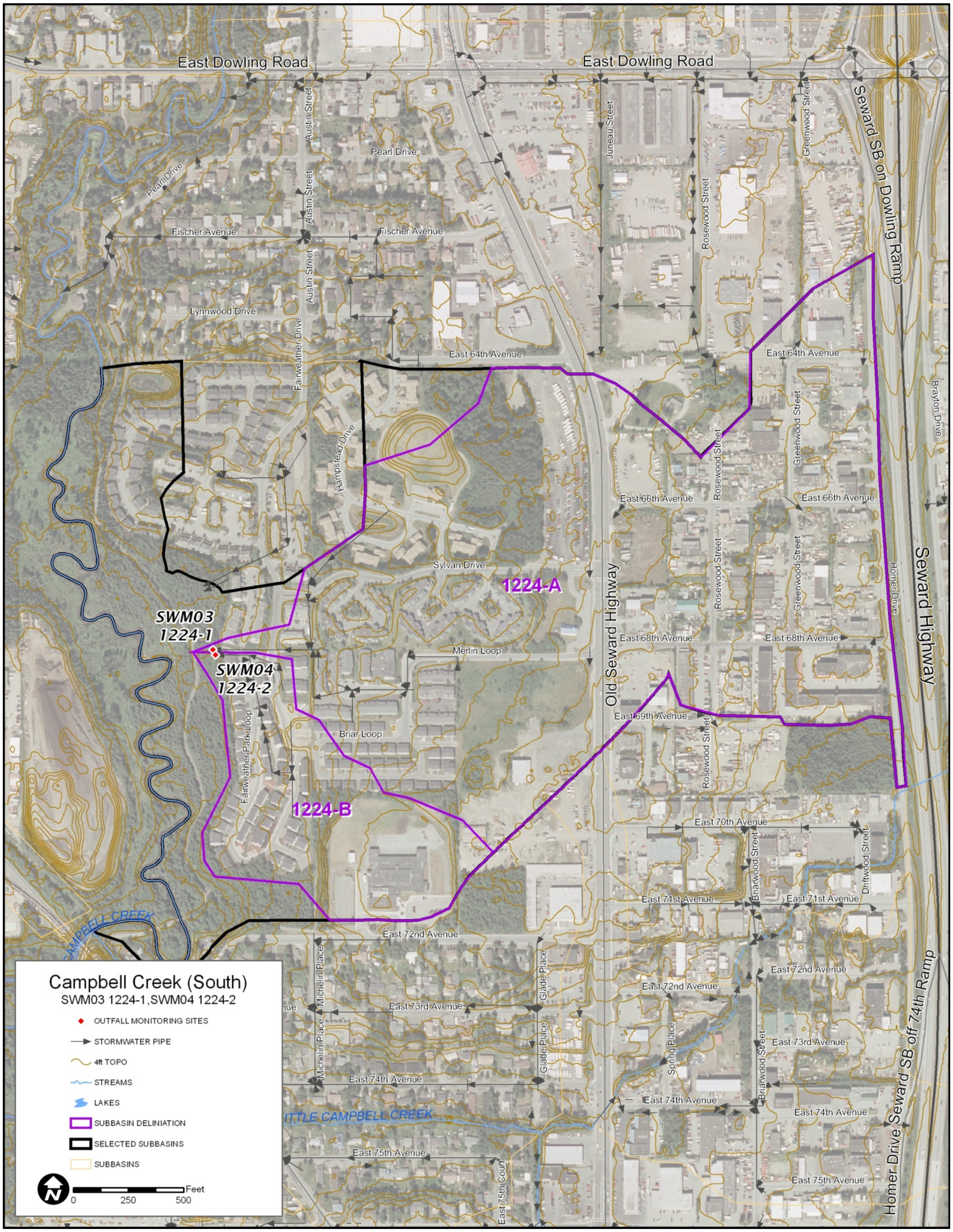


Figure 4. Outfalls SWM03 and SWM04, Fairweather Loop off Sylvan Drive (Campbell Creek)

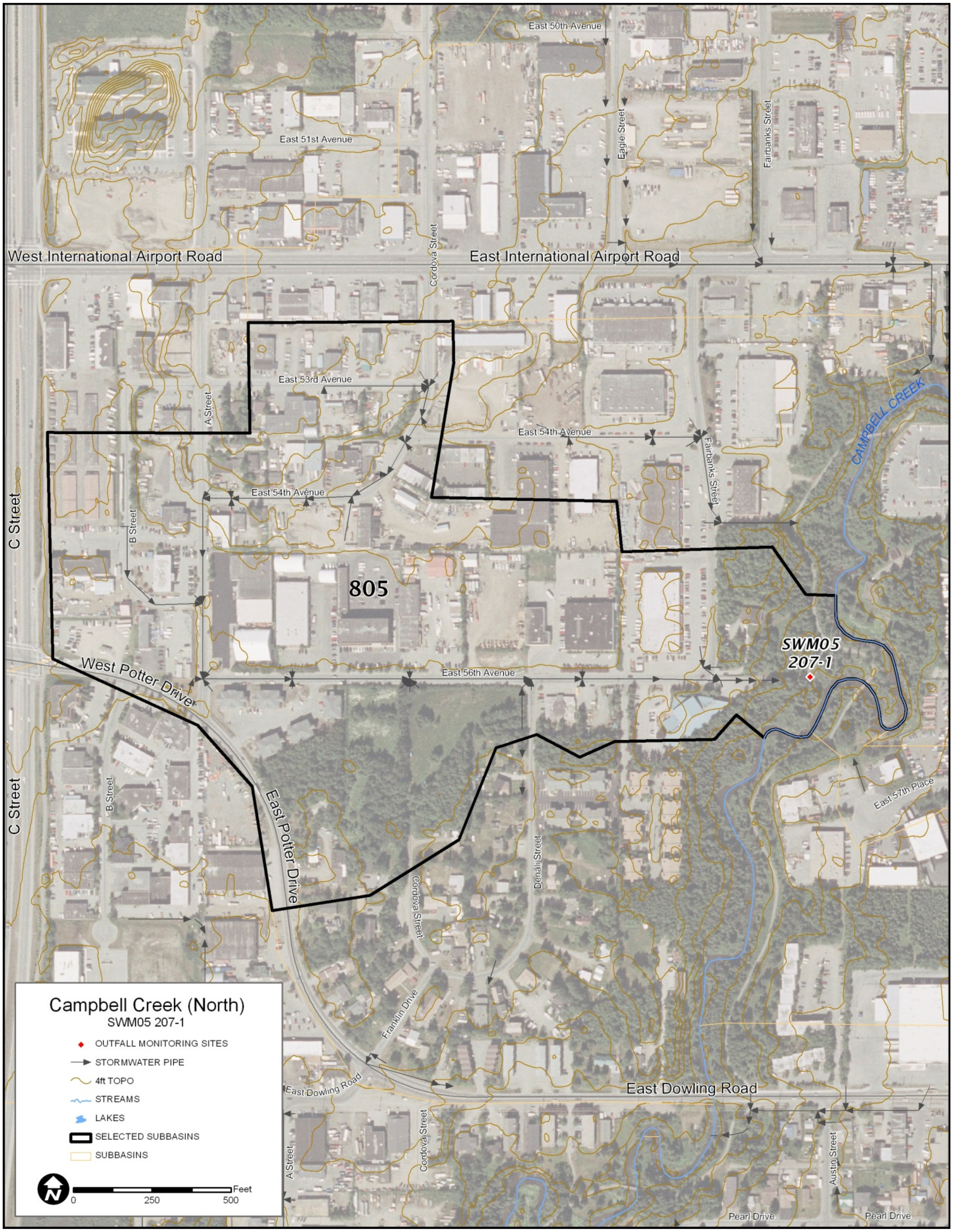


Figure 5. Outfall SWM05, East 56th Avenue (Campbell Creek)

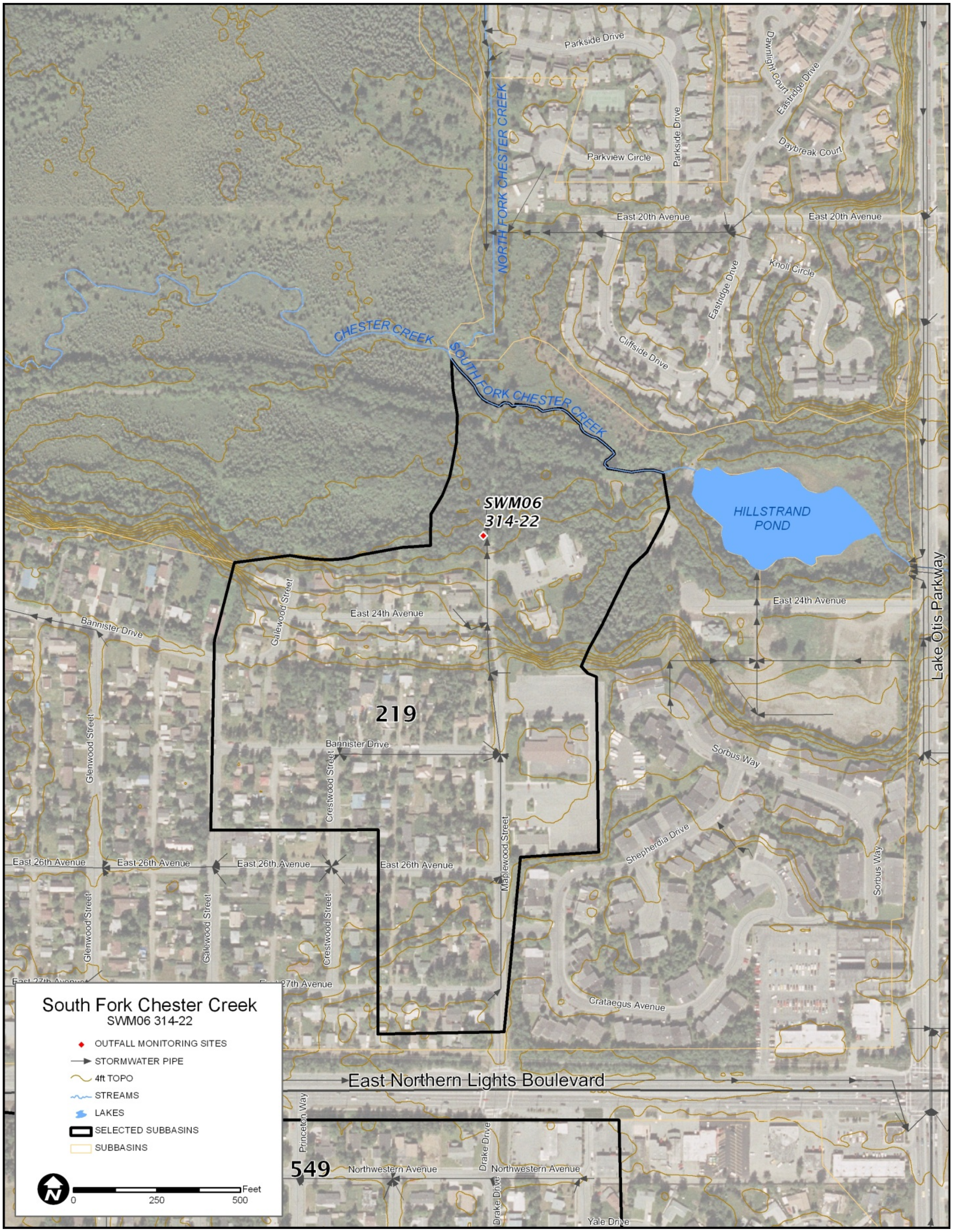


Figure 6. Outfall SWM06, Maplewood Street (South Fork Chester Creek)

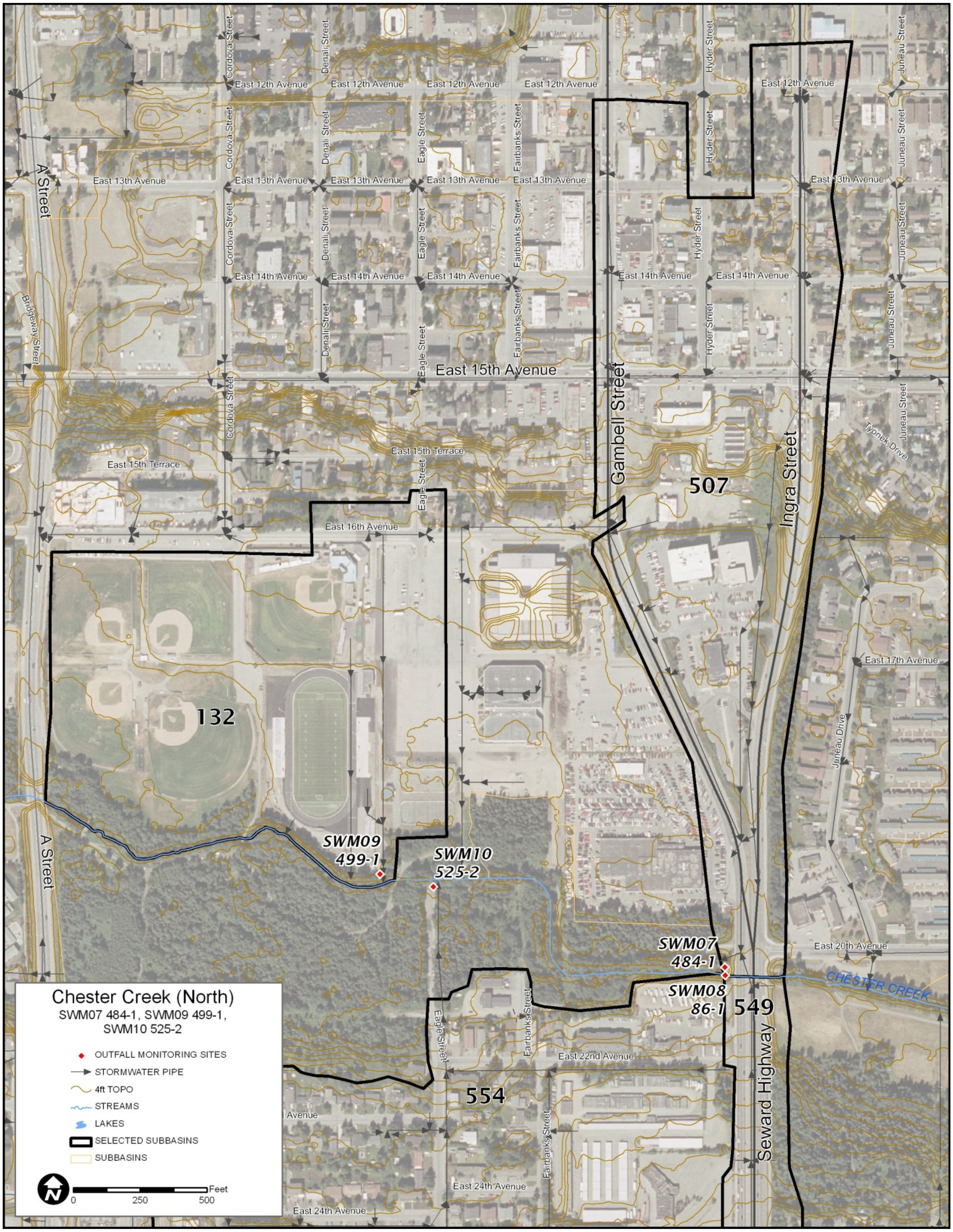


Figure 7. Outfalls SWM07, SWM09, & SWM10 (Chester Creek)

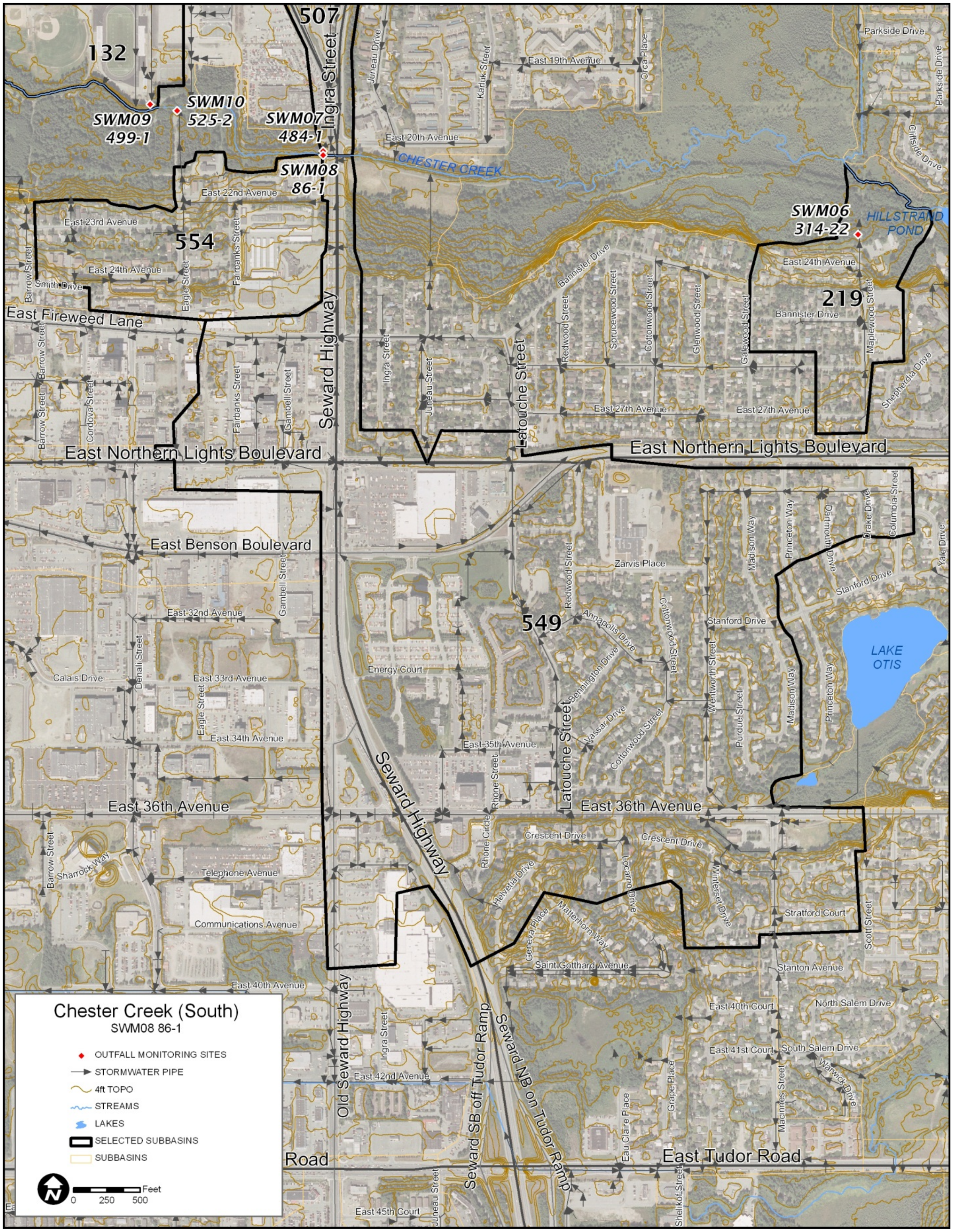


Figure 8. Outfall SWM08, New Seward Highway (Chester Creek)

SWM01 drains a residential area on Ridgemont Drive located between Lake Otis Parkway and Independence Drive just north of O'Malley Road. SWM02 drains the commercial and industrial area by Home Depot and Carrs on Abbott Road. SWM03 and SWM04 are located near Sylvan drive and drain a residential area east of Campbell Creek. Though these outfalls are close together their drainage areas are vastly different. SWM05 is located at the end of East 56th Avenue and drains a commercial and industrial area south of International Airport Road and east of C Street. SWM06 is located at the end of Maplewood Street and drains a residential area north of northern Lights Boulevard. SWM07 and SWM08 are located at the Seward Highway where Chester creek passes under. They drain a commercial industrial area to the north and mixed landuse area to the south. SWM09 is located near the Anchorage Football Stadium and drains the area around Ben Boeke and Sullivan Arenas. SWM10 is located at the end of Eagle Street and drains a commercial and residential area south of Chester Creek.

3.3 Measured Parameters

Parameters measured during stormwater outfall monitoring are shown in Table 2. The table includes measurement type, analysis method, frequency of sampling, purpose of monitoring, and measurement type (field or laboratory). Measurement quality objectives for each parameter including precision, accuracy, sensitivity, and measurement range are in the program's QAPP (MOA 2012). In addition to the parameters listed in Table 2, field observations were recorded at each outfall including any evidence of oily sheen, scum, odor, detritus, floating material, water color and clarity, deposits or stains, vegetation, and any other pertinent observation.

Four tipping bucket rain gauges installed within the monitoring area record precipitation through the monitoring period. The rain gauges were located along the north-south sampling corridor in order to provide a good representation of rainfall within each of the sampled subbasins (refer to Table 1 for rain gage locations).

Table 2. Measured Parameter, Type, Purpose, and Method of Analysis

Parameter	Type of Sample	Measurement Type	Method	Purpose
Flow	IR	Field	Flow meter, or bucket	Characterize flow
Specific Conductance	IR	Field	EPA 120.1/ YSI 556	Stormwater quality
DO	IR	Field	EPA 360.1/ YSI 556	Stormwater quality
pH	IR	Field	EPA 150.2/ YSI 556	Stormwater quality
Temperature	IR	Field	SM2550B/ YSI 556	Stormwater quality
Turbidity	IR/G	Field	EPA 180.1M/ Hach 2100	Stormwater quality
BOD_5	G	Laboratory	SM 5210 B	Stormwater quality

Parameter	Type of Sample	Measurement Type	Method	Purpose
Fecal Coliform	G	Laboratory	SM 9222D	Stormwater quality & loading
TSS	G	Laboratory	SM 2540D	Stormwater quality
TAH	G	Laboratory	EPA 624	Stormwater quality & loading
TAqH	G	Laboratory	EPA 625 + EPA 624	Stormwater quality & loading
Dissolved Copper	G	Laboratory	EPA 200.8	Stormwater quality
Total Hardness	G	Laboratory	EPA 200.8	Stormwater quality

IR = instantaneous recording of field analysis; G = grab sample for analysis; M = modified for field use

Table 3 identifies the parameters monitored at each outfall location. The commercial industrial (CI) land use categories in the table represent predominantly commercial and industrial areas with paved collectors, arterial streets and parking lots. Outfalls with watersheds dominated by these land uses are those most likely to contribute petroleum hydrocarbon pollutants to stormwater. TAH and the TAqH were collected at these locations in addition to the remaining parameters collected at every location. For this monitoring program, two CI subbasin categories were selected that had existing OGS systems and two others were selected that did not have OGS systems.

Table 3. Parameters Measured at each Subbasin Outfall

Station ID	Outfall ID	Watershed	Contributing Land Use*	OGS Present?	Field Parameters						Lab Samples						
					Flow	Cond	pH	Temp	DO	Turb	BOD	FC	TSS	Hardness	Diss. Cu	TAH	TAqH
SWM01	1040-3	L. Campbell Cr	R	No	x	x	x	x	x	x	x	x	x	x	x		
SWM02	847-1	L. Campbell Cr	CI	No	x	x	x	x	x	x	x	x	x	x	x	x	x
SWM03	1224-1	Campbell Cr	R	Yes	x	x	x	x	x	x	x	x	x	x	x		
SWM04	1224-2	Campbell Cr	R	Yes	x	x	x	x	x	x	x	x	x	x	x		
SWM05	207-1	Campbell Cr	CI	Yes	x	x	x	x	x	x	x	x	x	x	x	x	x
SWM06	314-22	Chester Cr	R	Yes	x	x	x	x	x	x	x	x	x	x	x		
SWM07	484-1	Chester Cr	CI	No	x	x	x	x	x	x	x	x	x	x	x	x	x
SWM08	86-1	Chester Cr	M	No	x	x	x	x	x	x	x	x	x	x	x		
SWM09	499-1	Chester Cr	CI	Yes	x	x	x	x	x	x	x	x	x	x	x	x	x
SWM10	525-2	Chester Cr	M	No	x	x	x	x	x	x	x	x	x	x	x		

*R-Residential, CI-Commercial/Industrial, M-Mixed

3.4 Field Sampling Procedures

Monitoring of precipitation throughout the summer and fall rainfall season was done in order to capture four storms that were representative of typical Anchorage rainfall conditions. Water sampling was conducted during storm events that were both expected to create runoff in the MS4 area and that met antecedent dry weather conditions. Typically, rain events yielding greater than 0.1 inch within a 24-hour (hr) period were sufficient to generate runoff at all sites. Therefore, a minimum of 0.1 inches of rain was required before targeting an event. In addition, all storm events were to be preceded by a relatively dry period. A dry period is defined as rainfall of ≤ 0.1 inches in the preceding 24-hr period.

Once a storm event was identified for sampling, the field crew prepared field sampling equipment and laboratory bottles for sampling. All portable water quality measurement instrumentation were calibrated immediately prior to going in the field for each event per the manufacturer's recommendation as outlined in Appendix H of the QAPP. Prior to departing for the field all bottles were labeled with station location, sample number, number of bottles, and analysis type and method. Date, time, and sampler's initials were added in the field.

The field sampling team consisted of two people to address safety concerns and to allow one-person to be the designated recorder while the second person performed measurements and conducted the grab sampling. Upon arriving on site at the outfall, the field team took flow measurements and placed the YSI 556 multi-probe into the outfall flow in order to allow the probes to equilibrate for at least three minutes prior to taking any measurements.

An acoustic Doppler flow meter and staff gauge were used to collect flow measurements. The flow meter measures the average velocity of the outfall pipe. The average velocity was used in conjunction with the water depth and pipe diameter to calculate the instantaneous flow of each outfall.

After measuring flow, the field crew measured dissolved oxygen (DO), specific conductance, pH, and temperature with a YSI 556 multi-probe system. Turbidity was measured in the field by collecting a discrete sample that was analyzed on site with a portable Hach 2100P/Q turbidimeter. All water quality measurements were obtained from the water flowing out of the end-of-pipe prior to any mixing with the receiving water body. All field measurements were recorded on project specific field log forms that were bound in the project field log books along with field instrument calibration logs (refer to Appendix D).

The field crew obtained the water samples for BOD, TSS, fecal coliform, dissolved copper, total hardness, TAH, and TAqH in laboratory provided bottles. The water quality samples were collected from the water flowing out of the end-of-pipe. Sample crews took extra care not to disturb any accumulated sediment when collecting a water sample. To avoid having to perform decontamination procedures, all samples, with the exception of TAH, were collected directly into their respective sample containers. In the case of TAH, the sample was first collected into a pre-cleaned and certified TAqH (PAH) bottle that was then used to carefully fill the 40-ml vials for TAH analyses. The TAqH bottle was then topped off with additional water from the outfall discharge. Since the TAqH bottles were pre-cleaned and certified, it was unnecessary to perform equipment rinsate analyses. Once the water samples were collected, the field crew recorded visual observations at each outfall location.

The field crew conducted replicate field measurements and laboratory analyses at a rate of 15 percent per sampling event. This resulted in two additional measurements for all parameters except TAH and TAqH. TAH and TAqH required only one additional field measurement since they are collected at fewer outfalls. Additional water for TAH and TAqH was collected at one station to allow the laboratory to perform matrix spike/ matrix spike duplicate (MS/MSD) analyses. TAH analyses also included a trip blank sample, provided by the laboratory, that accompanied the sample bottles in the field.

Precipitation was recorded using a tipping bucket rain gauge and data logger recording in 0.01 inch increments. During precipitation events, the collection cup in the gauge collects precipitation until it reaches the equivalent of 0.01 inches of precipitation where upon the bucket tips, triggering a reed switch and recording an event with a time stamp. These events are stored in the data logger and downloaded into a computer program where they are summarized over different time intervals or graphed as a time series. Three rain gauges installed for this program were located at Rogers Park Elementary School, Taku Elementary School, and Bowman Elementary, which represent the northern, middle, and southern portions of the study area respectively. In addition, a supplemental fourth rain gauge was installed at “Spencer’s House” in the southern portion of the study area (refer to Figure 1 for rain gage locations).

3.5 Sampling Handling and Chain of Custody Procedures

BOD, TSS, fecal coliform, dissolved Cu, hardness, TAH, and TAqH samples were collected, preserved, and packed for shipment to the laboratory as described in the QAPP. SGS North America, Inc., is located in Anchorage, so no special sample shipping or packaging was required. Upon sample collection, all samples were kept chilled to 6 °C with gel ice and delivered to the laboratory by the field crew following the sample collection effort. All samples were transferred to the laboratory under chain of custody (COC) procedures as outlined in the QAPP. Copies of all completed COCs are included with the laboratory data reports in Appendix B. When necessary, fecal samples were taken to the laboratory in two batches during the storm event to ensure the 6-hr holding time requirement was met.

3.6 Laboratory Analyses

The water quality constituents selected for this program were established based upon the requirements of MOA’s APDES Stormwater Permit (AKS-052558). All analyses were conducted by SGS North America, Inc. SGS is certified to conduct such analyses. All analytical methods (refer to Table 2) were based upon approved EPA methodology and included all necessary Quality Assurance/Quality Control (QA/QC) procedures and analyses as outlined in the methodology and detailed in the QAPP.

The laboratory QA/QC activities provide information needed to assess potential laboratory contamination, analytical precision and accuracy, and representativeness. Analytical quality assurance for this program included:

- Employing analytical chemists trained in the procedures and analytical methods to be conducted
- Adherence to documented procedures, EPA methods, and laboratory SOPs
- Calibration of analytical instruments
- Use of quality control samples, internal standards, surrogates, and standard reference material (SRMs)
- Complete documentation of sample tracking and analysis

Internal laboratory control checks included the use of internal standards, method blanks, MS/MSDs, duplicates, laboratory control spikes, and SRMs as required by the sample analysis methodology. For additional detail on laboratory QA/QC procedures, refer to the QAPP.

3.7 Deviation from the QAPP

The QAPP called for flow measurements by either of two methods; installation of a temporary portable weir or by timing the collection of flow in a bucket of known volume. After performing the pre-sampling reconnaissance in 2011 it was determined that only one of the ten outfalls was amenable to collection of the flow in a bucket. For most outfalls, a vertical drop did not exist at the end of the outfall pipe where the discharge could be collected with a bucket. Likewise, due to the varying outfall sizes, condition of the outfall pipes, and corrugated nature of most outfall pipes, that a temporary weir sized properly for the variable flow and that would seal properly to the end of pipe would be difficult and impractical to install in a timely manner. For these reasons, an acoustic Doppler flow meter and staff gauge were used to collect flow measurements.

3.8 QA/QC and Data Validation Results

Quality Control and Quality Assurance (QA/QC) procedures were followed according to the QAPP (MOA 2016). The procedures included analytical checks (field replicates, trip blanks, matrix spikes and matrix spike duplicates); instrument calibration; and procedures to assess data for precision, accuracy, representativeness, comparability, and completeness.

Verification analyses for laboratory parameters were conducted by SGS. The data review focused on criteria for the following QA and QC parameters and their overall effects on the data:

- Sample handling (chain of custody)
- Temperature blank
- Holding time compliance
- Matrix spikes and matrix spike duplicates
- Field replicate comparison

- Data validation

SGS is certified by the EPA and the Alaska Drinking Water Program and has an approved QA/QC program. Analytical methods and testing procedures were in adherence with EPA-approved protocols and guidelines. The analyses for the fecal coliform, biological oxygen demand (BOD), total suspended solids (TSS), dissolved copper, total hardness, total aqueous hydrocarbons (TAqH), and total aromatic hydrocarbons (TAH) were reported with appropriate method detection limits and report detection limits.

Sample custody was maintained for the samples. The coolers transporting the samples remained at temperatures of less than 6 °C, or were delivered within a few hours of the sampling event. The holding times for all parameters tested were met and were analyzed before the hold time expirations with the exception of one fecal sample as a result of a laboratory error.

The QA/QC officer validated all data reported by the laboratory. Data that was determined to be a biased low estimate was flagged based on low recovery rates from laboratory control samples. Any data that was considered suspicious was also rejected and flagged as such. For a more detailed summary of field and laboratory data validation results, refer to Appendix C. Other QA/QC procedures included a field audit of the sampling in 2011 to ensure that all field protocols were followed and that protocols being used were sufficient. The field audit concluded that all protocols were followed and were sufficient. The field team was also required to QC all data at the end of each event to insure all data was collected and complete.

4.0 Results and Discussion

The 2016 stormwater monitoring at the 10 long-term monitoring sites was initiated in August and comprised the sixth year of monitoring for the program. Approximately 6.6 inches of precipitation (including snow) had been measured in 2016 at the National Oceanic and Atmospheric Administration (NOAA) National Weather Service's PANC weather station located at the Anchorage International Airport (AIA) before the first event was sampled on 4 August (Figure 9). Four stormwater outfall monitoring events were conducted in 2016 as required by the *Stormwater Outfall Monitoring Plan* (MOA 2012) and the APDES Permit. Sampling events took place on 4 August, 22 August, 15 September, and 22 September and included attempts to sample at all ten outfalls during each storm event. However, due to lack of flow at SWM01 on 22 August, no samples were obtained at this location for this stormwater sampling event. Rainfall for both June and July in 2016 were slightly above the long-term average but still substantially less than the historic maximum monthly measured precipitation for those two months (Figure 9). The total rainfall in August was also above average (5.45 inches) when compared to the long-term average of 3.25 inches and the long-term maximum of 9.77 inches, and was the highest monthly precipition for the year. For September, the recorded rainfall was below average (2.35 inches) when compared to the long-term average of 2.99 inches (Figure 9).

4.1 Precipitation

A total of four events were sampled in 2016 starting on 4 August and ending on 22 September. Total rainfall as measured at PANC and the four stations in the monitoring area during each monitored event ranged from 0.04 to 0.36 inches during the third event to 0.66 to 0.93 inches during the fourth event. Rainfall during the first and second events were similar in size ranging from 0.34 to 1.02 inches at the five rain gauges with a fair amount of variability seen across the Anchorage watershed (Table 4 and Figure 10). With the exception of SWM09, the highest outfall flow rates occurred during the fourth and largest rainfall event.

Daily rainfall records are illustrated in Figure 10 for three rain gauges located along the sampling corridor. Since recording issues were encountered at two of the four project rain gauges, two additional rain gauges records were obtained from Merrill Field and the Campbell Creek Science Center (CCSC) to supplement those collected by the project. As in past years, rainfall data from the PANC weather station at the AIA were used to supplement the other rain gauges to provide a time series for the entire year and a comparison to the long term historic record (Table 4).

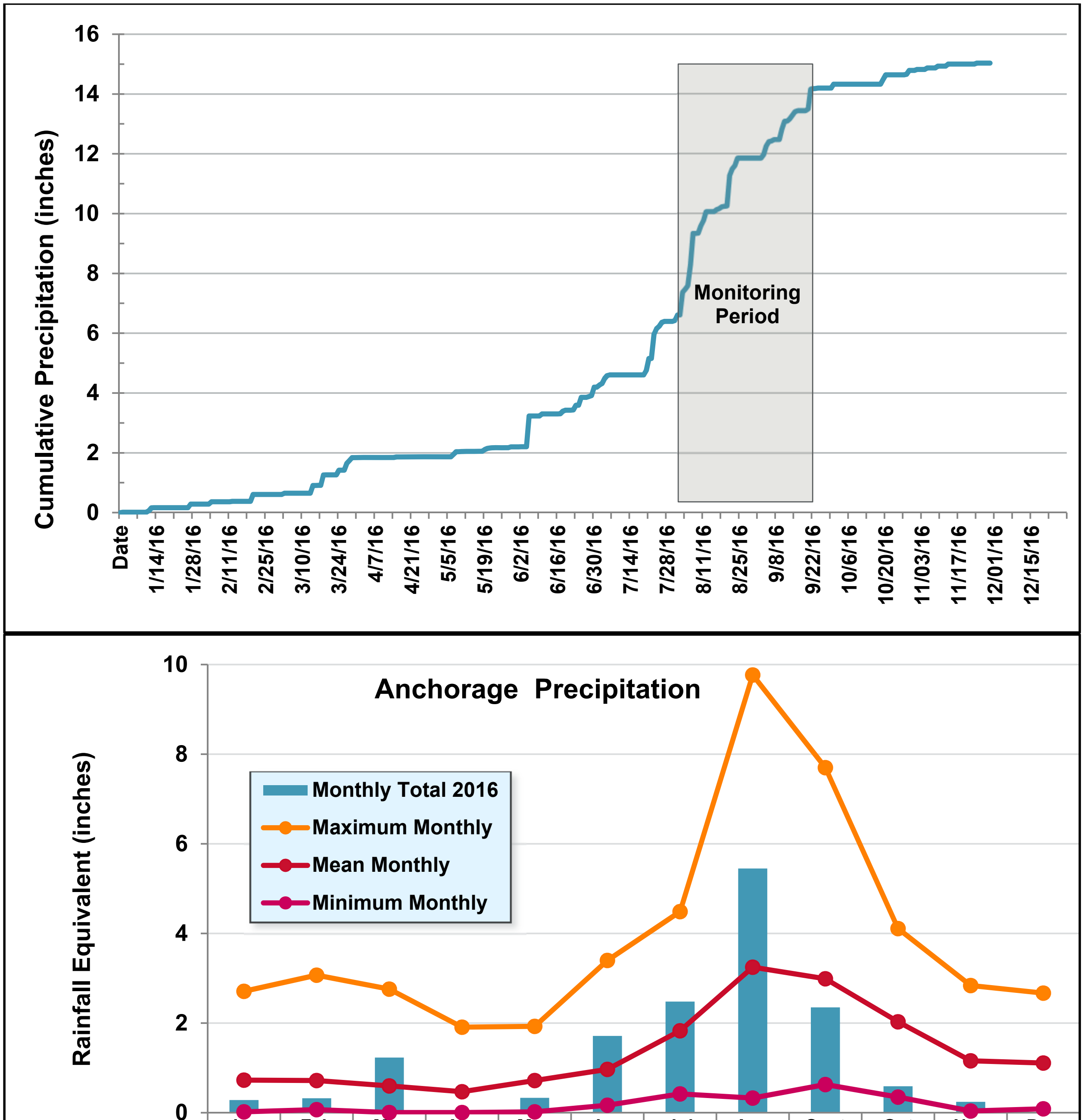
The first storm event took place on 4 August with rainfall ranging from 0.44 inches at Merrill Field to 0.76 inches recorded at PANC for that calendar day. Other than 0.02 inches recorded at CCSC, no rain was recorded within the study area during the preceding calendar day. Since none of the four project rain gauges had been installed prior to the first storm event, rainfall records are only provided for the three non-project gauges. Sampling was initiated in 12:50 approximately 6 hrs after the beginning of the storm. Based on the recorded precipitation, the rainfall appeared to be higher in western portion of the Anchorage Bowl as seen at PANC.

The second storm event occurred on 22 August with recorded rainfall ranging from 0.34 inches at Spencer’s to 1.02 inches at PANC. Rainfall that was recorded within the study area during the preceding calendar day ranged from 0.0 to 0.08 inches which is within the < 0.1 inch dry weather criteria. Sampling for the second event was initiated at 13:30 approximately 4-5 hrs after the beginning of the storm during a period when the rainfall was fairly heavy and corresponding flow rates at most stations were elevated.

Table 4. Anchorage Precipitation Data for 7 Days Prior to Each Sampling Event.

Date	PANC NOAA Airport (in)	PAMR Merrill Field (in)	Campbell Cr. Science (in)	Bowman (in)	Spencer's (in)
7/28/16	0.03	0.05	0.04	NR	NR
7/29/16	0	0	0	NR	NR
7/30/16	0	0	0	NR	NR
7/31/16	0	0	0	NR	NR
8/1/16	0.03	0.05	0.03	NR	NR
8/2/16	0.18	0.19	0.25	NR	NR
8/3/16	0	0	0.02	NR	NR
8/04/16 (Event 1)	0.76	0.44	0.52	NR	NR
8/15/16	T	0.01	0.03	0.03	0.04
8/16/16	0	0	0	0	0
8/17/16	0.07	0.07	0.08	0.16	0.1
8/18/16	0.03	0.04	0.05	0.08	0.04
8/19/16	0.06	0.01	0.01	0.08	0.01
8/20/16	0.02	T	0	0	0.01
8/21/16	0.01	0.08	0.03	0.01	0
8/22/16 (Event 2)	1.02	0.55	0.35	0.37	0.34
9/8/16	0.05	0.05	0.07	0.07	0.09
9/9/16	0	0	0	0	0
9/10/16	0	0	0	0	0
9/11/16	0.36	0.31	0	0.55	0.6
9/12/16	0.25	0.35	0.26	0.32	0.36
9/13/16	0	0.02	0.03	0	0.01
9/14/16	0.08	0.04	0.03	0.09	0.09
9/15/16 (Event 3)	0.12	0.36	0.21	0.09	0.04
9/16/16	0.12	0.12	0.13	0.11	0.05
9/17/16	0.03	0.11	0.2	0.09	0.13
9/18/16	0	0.07	0	0	0
9/19/16	0	0	0	0	0.01
9/20/16	T	T	0	0	0
9/21/16	0.06	0.03	0.03	0.09	0.16
9/22/16 (Event 4)	0.66	0.91	0.91	0.92	0.93

T = Trace level measurement, NR = No record



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Monthly Total 2016	0.28	0.325	1.23	0.02	0.33	1.71	2.48	5.45	2.35	0.59	0.24	
Maximum Monthly	2.71	3.07	2.76	1.91	1.93	3.40	4.49	9.77	7.70	4.11	2.84	2.67
Mean Monthly	0.73	0.72	0.60	0.47	0.72	0.97	1.83	3.25	2.99	2.03	1.16	1.11
Minimum Monthly	0.02	0.07	0.005	0.005	0.02	0.17	0.42	0.33	0.63	0.35	0.04	0.09

Note: Data for 2016 is incomplete at this time and includes only the period of 1/1/15 through 11/30/15.

Figure 9. **Cumulative, Monthly, and Historic Rainfall Measured at the PANC NOAA Weather Station. Snowfall Has Been Converted to Rain Equivalent.**

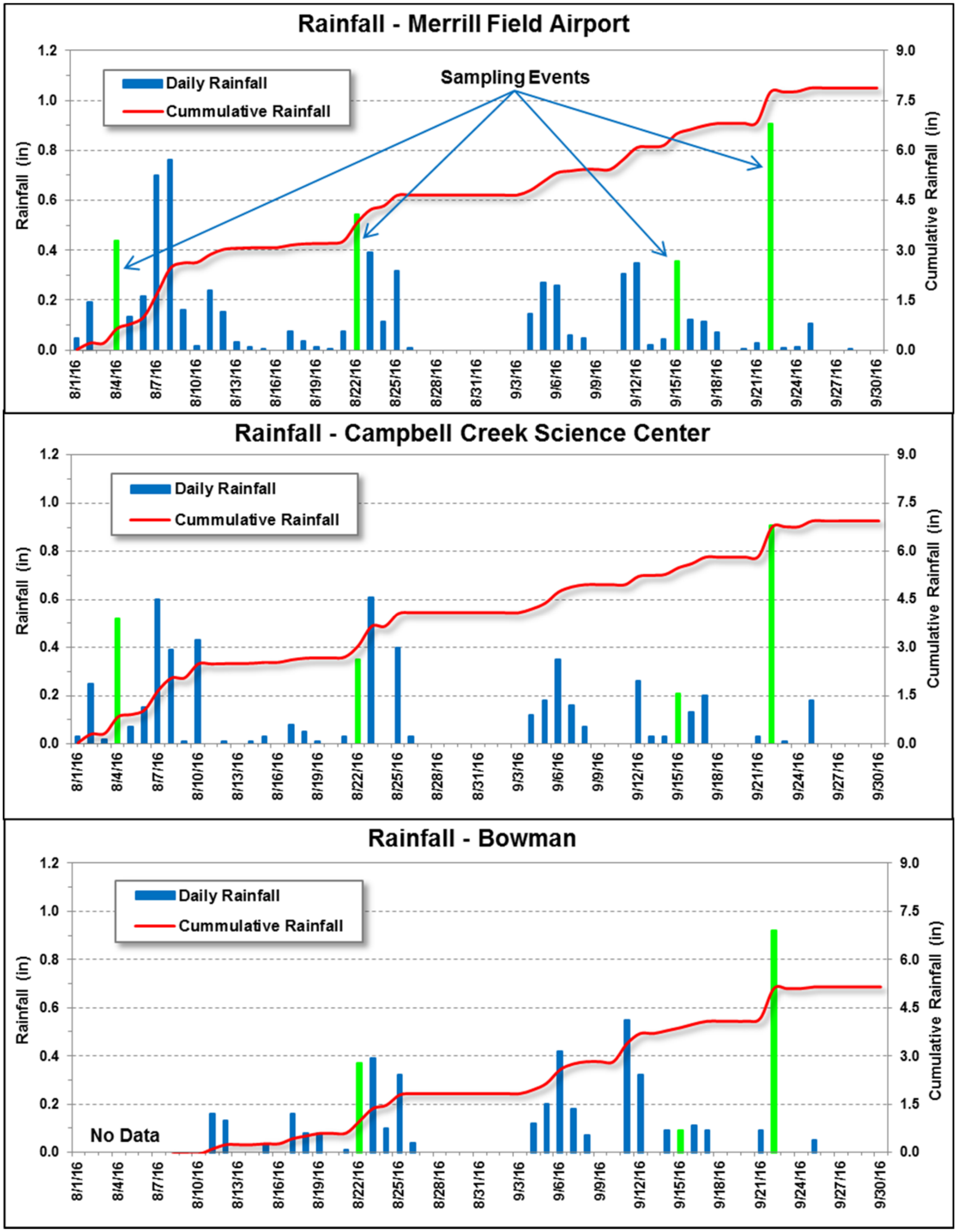


Figure 10. **Rainfall Measured at the Three Anchorage Rain Gauges.** **(Note: sampling days highlighted in green.)**

The third event took place on 15 September. On the day of sampling, precipitation ranged from 0.04 inches at Spencer's to 0.36 inches recorded at Merrill Field. Precipitation during the preceding day was part of the same rain event with rainfall beginning at approximately 22:30 hours on 14 September. Sampling was initiated within 12 hrs of the beginning of the storm event and sampling occurred after a 24-hr period of no rain when the storm's starting time is taken into account.

The fourth monitoring event took place on 22 September. Precipitation for this event ranged from 0.66 inches at PANC to 0.93 inches at Spencer's with fairly consistent rainfall across the Anchorage watershed. Precipitation on the preceding day ranged from 0.03 inches at Merrill Field and CCSC to 0.16 inches at Spencer's with most of the rain occuring late on the prior evening as part of the same storm event. Outfall monitoring for the fourth storm event began approximately 12 hrs after the beginning of the storm event with rainfall being fairly heavy prior to and during the sampling effort.

4.2 Field Measurements

The results of field measurements for flow, turbidity, DO, conductivity, pH, and temperature are shown graphically in Figure 11-16 and in Table 5. Where appropriate, field and laboratory measurements were compared against the most stringent Alaska Water Quality Standard (AWQS) numeric criteria for each parameter (refer to Table 9 for AWQS benchmarks used for comparisons). Most of these parameters exhibited similar trends to those observed for other stormwater programs in cooler climates.

Flow rates were highly variable between sites and storm events with SWM08 having the highest flow rates for two of the four storm events. Flow rates ranged from zero discharge at SWM01 during the second storm event to 2,640 gpm at SWM08 during the fourth storm event. The highest flows for nine of the ten locations occurred during the fourth event on 22 September. The one remaining location (SWM09) had the highest flow during the second storm event.

Mean turbidity levels ranged from a low of 0.72 Nephelometric Turbidity Units (NTU) at SWM02 to a high of 351 NTU at SWM05 that occurred during the fourth storm event. SWM05 also had the highest turbidity levels for the two of the remaining three storm events. The elevated turbidity concentrations were also evident in total suspended sediment (TS*S*) samples taken for laboratory analysis at the same location. Overall, large differences between outfalls are expected for turbidity since this parameter is highly dependent on the drainage area and is a function of the type of useage, percent impervious surfaces, amount of disturbed land from construction and other activities, drainage slope, flow rate, and other factors.

Although not required by the monitoring plan, specific conductivity was recorded at each site since it was available on the portable multi-parameter field instrumentation and is considered useful for interpretation of the stormwater data. Specific conductance was then converted to total dissolved solid (TDS) concentrations so that comparisons could be made with AWQS criteria. Water from SWM04 and SWM10 tended to have notably higher TDS levels than the other locations. Mean TDS concentrations ranged from 11.1 milligrams/liter (mg/L) at SWM01 to 234.0 mg/L at SWM02. Although elevated conductivity and TDS can be indicative of contaminants, the highest concentrations measured were well within expected ranges for stormwater (EPA 1983). Also, no TDS concentrations were found that exceeded the most restricive AWQS criteria of 500 mg/L (Figure 13).

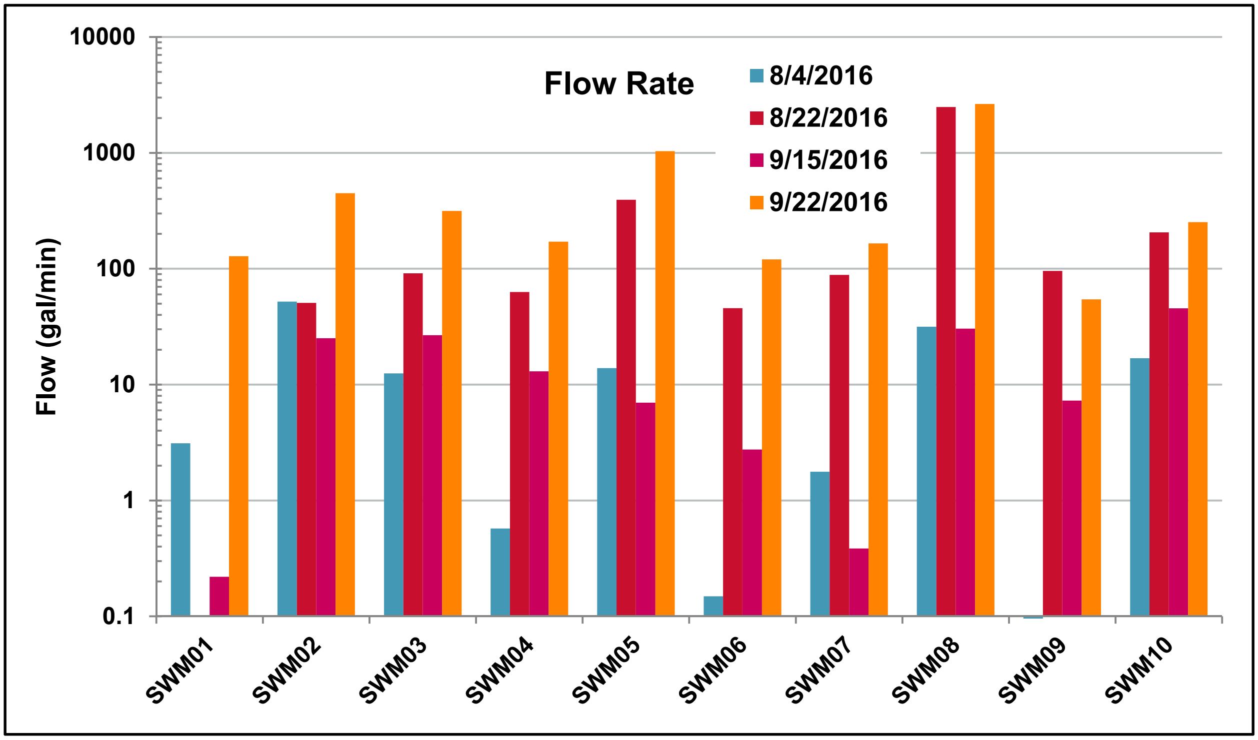


Figure 11. **Flow Rates Measured at Monitoring Sites During all Four Events.**

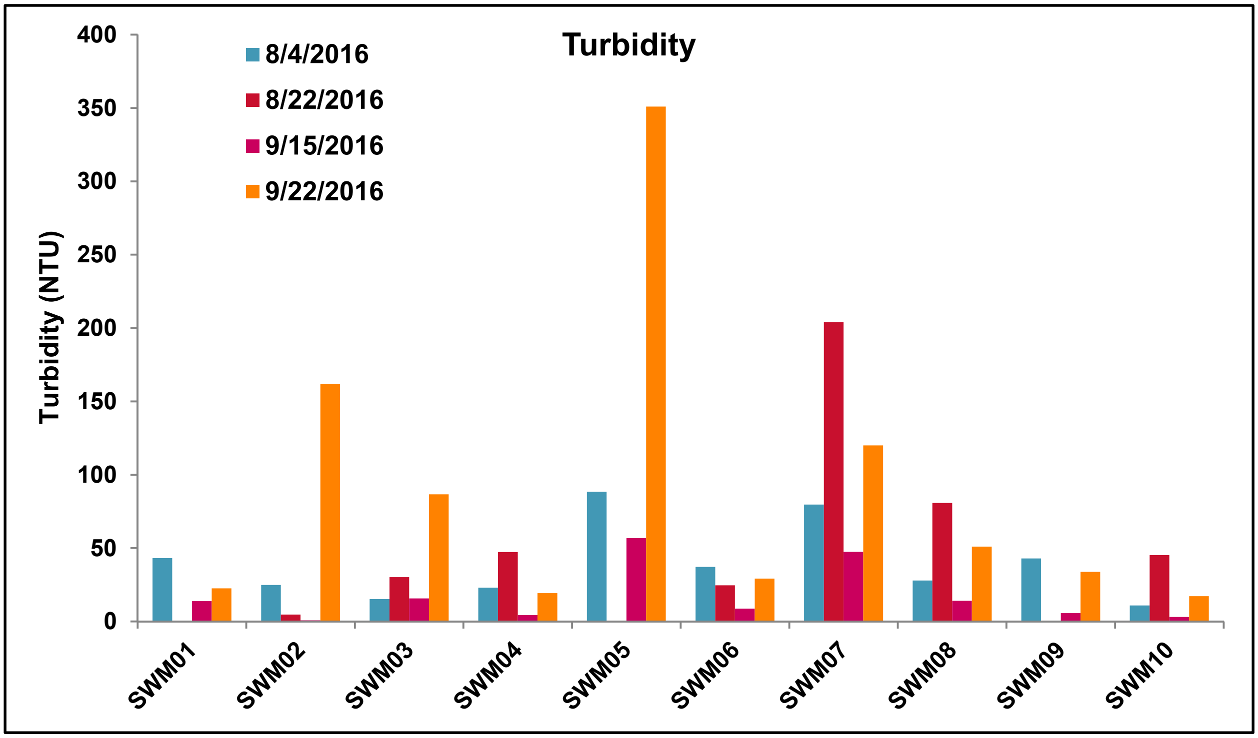


Figure 12. **Turbidity Measured in Stormwater Sampled at Monitoring Sites During all Four Events.**

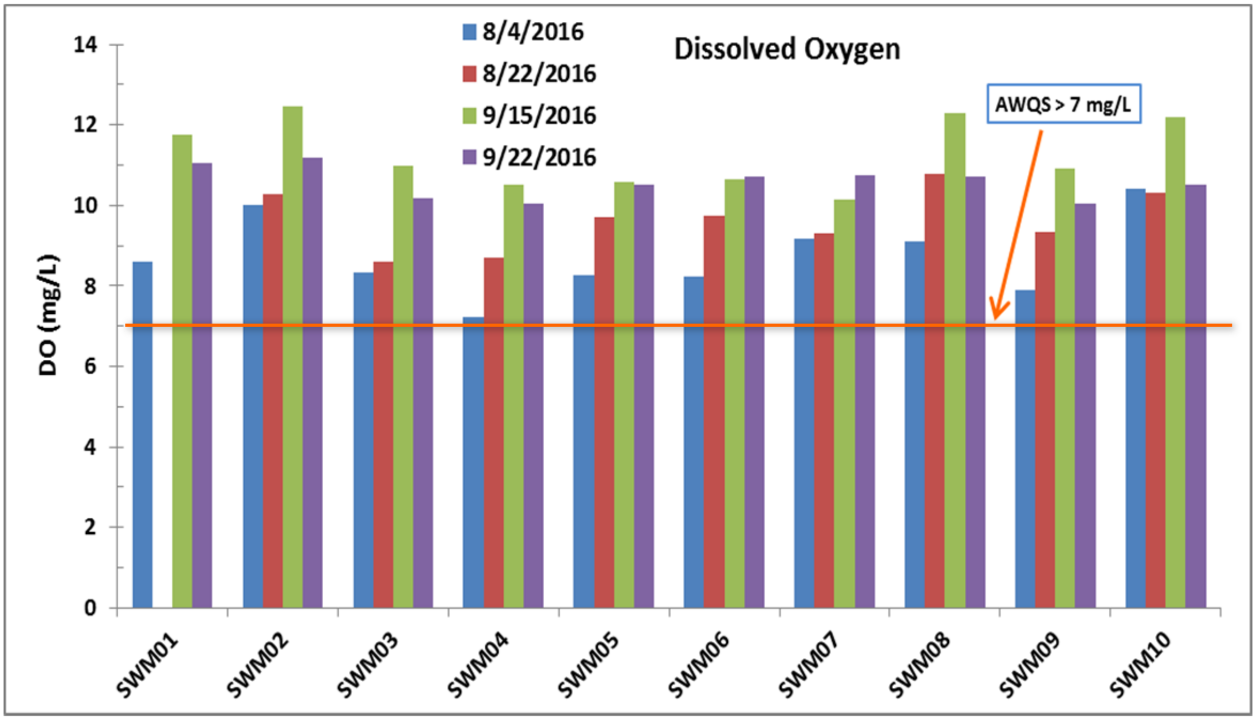


Figure 13. Dissolved Oxygen Measured in Stormwater Sampled at Monitoring Sites During all Four Events. (AWQS Criteria > 7 mg/L).

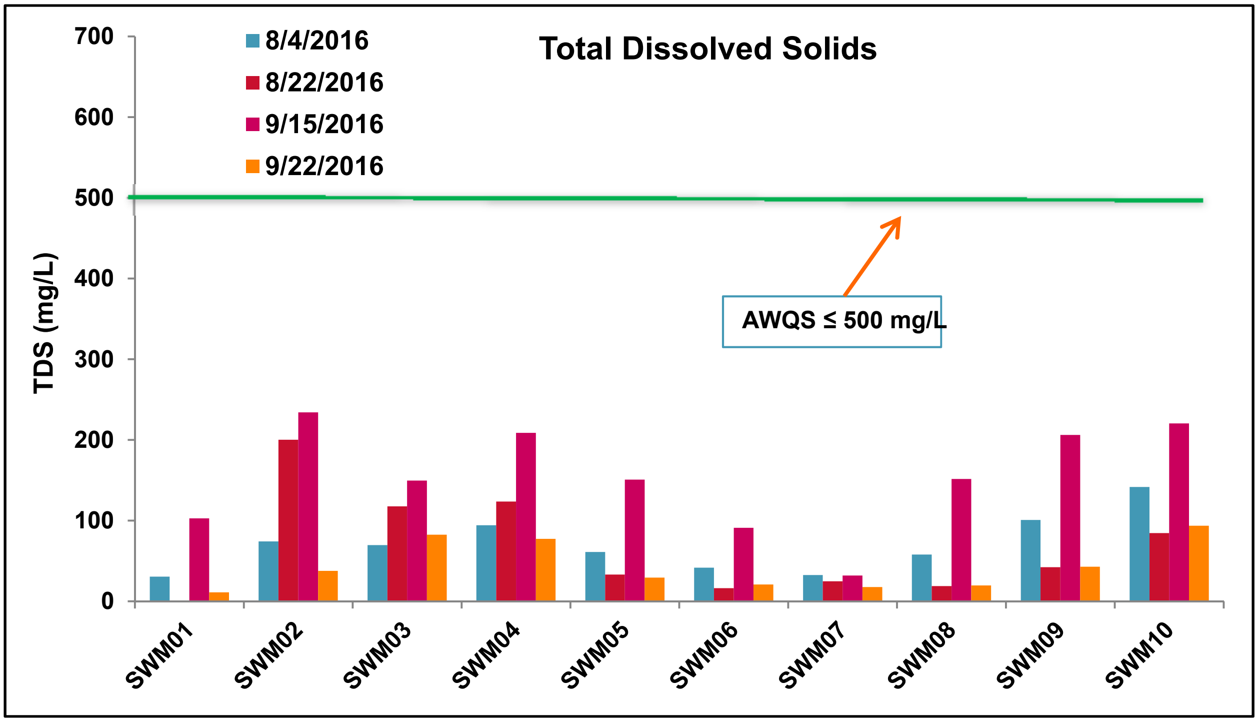
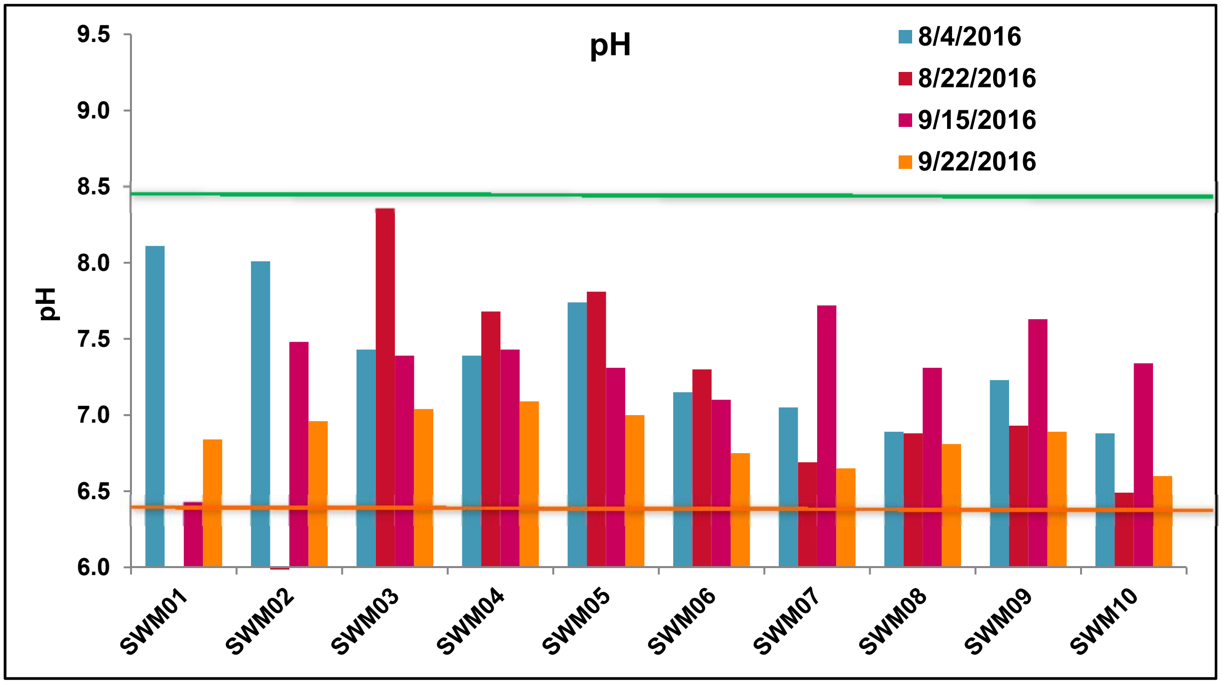
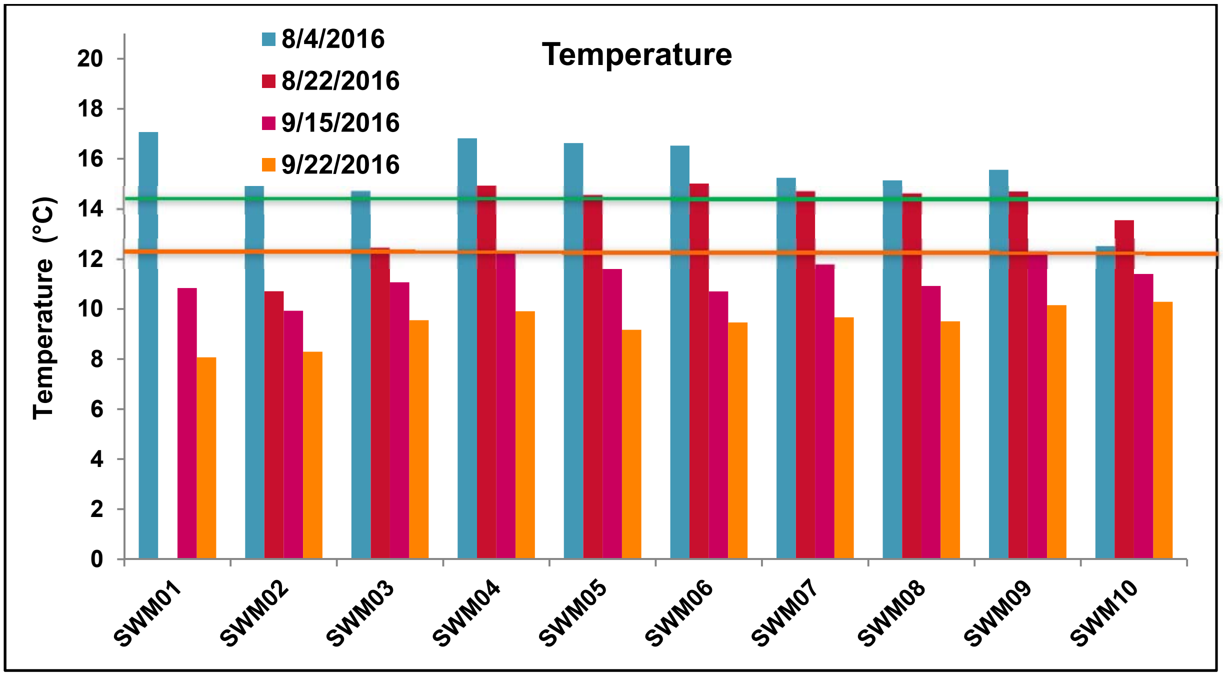


Figure 14. Total Dissolved Solids Measured in Stormwater Sampled at Monitoring Sites During all Four Events. (AWQS Criteria ≤ 500 mg/L).



Green line indicates the upper limit of 8.5 and red line indicates the lower limit of 6.5.

Figure 15. **pH (units) Measured in Stormwater Sampled at Monitoring Sites During all Four Events. (AWQS Criteria ≥6.5 and ≤8.5).**



Green line indicates the upper limit of 13°C for spawning and green line indicates the upper limit of 15°C for migration.

Figure 16. **Temperature (°C) Measured in Stormwater Sampled at Monitoring Sites During all Four Events. (AWQS Criteria ≤13°C for spawning and egg/fry incubation and ≤15°C for migration routes and rearing areas).**

Table 5. In Situ Parameters Measured at Monitoring Sites During All Four Sampling Events.

Station	Event-01 4-Aug-2016	Event-02 22-Aug-2016	Event-03 15-Sept-2016	Event-04 22-Sept-2016	Mean
Flow Rate (gpm)					
SWM01	3.12	0.0	0.22	128	32.9
SWM02	52.1	50.8	25.1	449	144
SWM03	12.5	91.3	26.7	315	111
SWM04	0.57	62.9	13.0	171	62.0
SWM05	13.9	394	6.98	1034	362
SWM06	0.15	45.7	2.76	120	42.2
SWM07	1.77	88.4	0.38	165	64.0
SWM08	31.6	2486	30.5	2640	1297
SWM09	0.03	95.9	7.27	54.3	39.4
SWM10	16.9	206	45.5	252	130
Turbidity (NTU)					
SWM01	43.2	NT	13.9	22.6	26.6
SWM02	24.9	4.64	0.72	162	48.1
SWM03	15.3	30.2	15.7	86.7	37.0
SWM04	23.0	47.3	4.36	19.3	23.5
SWM05	88.4	NA	56.8	351	165.4
SWM06	37.2	24.6	8.72	29.2	24.9
SWM07	79.7	204	47.4	120	112.8
SWM08	27.9	80.8	14.1	51.0	43.5
SWM09	43.0	NA	5.68	33.8	27.5
SWM10	10.9	45.2	3.07	17.2	19.1
Dissolved Oxygen (mg/L)					

Station	Event-01 4-Aug-2016	Event-02 22-Aug-2016	Event-03 15-Sept-2016	Event-04 22-Sept-2016	Mean
SWM01	8.59	NT	11.75	11.06	10.47
SWM02	10.02	10.28	12.45	11.18	10.98
SWM03	8.32	8.60	10.98	10.19	9.52
SWM04	7.23	8.70	10.53	10.05	9.13
SWM05	8.28	9.72	10.58	10.53	9.78
SWM06	8.22	9.74	10.66	10.71	9.83
SWM07	9.17	9.32	10.15	10.75	9.85
SWM08	9.11	10.79	12.31	10.72	10.73
SWM09	7.89	9.33	10.92	10.06	9.55
SWM10	10.43	10.30	12.18	10.53	10.86
Total Dissolved Solids (mg/L)					
SWM01	30.6	NT	102.7	11.1	48.1
SWM02	74.1	200.2	234.0	37.7	136.5
SWM03	69.6	117.7	149.5	82.6	104.8
SWM04	94.3	123.5	208.7	77.4	125.9
SWM05	61.1	33.2	150.8	29.3	68.6
SWM06	41.6	16.3	91.0	20.8	42.4
SWM07	32.5	24.7	31.9	17.6	26.7
SWM08	57.9	18.9	151.5	19.5	61.9
SWM09	100.8	42.3	206.1	42.9	98.0
SWM10	141.7	84.5	220.4	93.6	135.0
pH					
SWM01	8.11	NT	6.43	6.84	6.43 – 8.11
SWM02	8.01	SR	7.48	6.96	6.96 – 8.01
SWM03	7.43	8.36	7.39	7.04	7.04 – 8.36

Station	Event-01 4-Aug-2016	Event-02 22-Aug-2016	Event-03 15-Sept-2016	Event-04 22-Sept-2016	Mean
SWM04	7.39	7.68	7.43	7.09	7.09 – 7.68
SWM05	7.74	7.81	7.31	7.00	7.00 – 7.81
SWM06	7.15	7.30	7.10	6.75	6.75 – 7.30
SWM07	7.05	6.69	7.72	6.65	6.65 – 7.72
SWM08	6.89	6.88	7.31	6.81	6.81 – 7.31
SWM09	7.23	6.93	7.63	6.89	6.89 – 7.63
SWM10	6.88	6.49	7.34	6.60	6.49 – 7.34
Temperature (°C)					
SWM01	17.07	NT	10.84	8.07	11.99
SWM02	15.02	10.71	9.93	8.29	10.99
SWM03	14.72	12.46	11.07	9.55	11.95
SWM04	16.82	14.93	12.35	9.91	13.50
SWM05	16.63	14.56	11.63	9.17	13.00
SWM06	16.53	15.01	10.70	9.46	12.93
SWM07	15.24	14.70	11.81	9.67	12.86
SWM08	15.14	14.62	10.92	9.51	12.55
SWM09	15.56	14.69	12.32	10.15	13.18
SWM10	12.52	13.55	11.40	10.29	11.94

Footnotes: NT = Not tested due to no flow at outfall, SR = QC sample rejection due to equilibration issue

NA = Not available.

Dissolved oxygen (DO) levels were generally fairly high and near saturation. The highest concentrations at eight locations were seen during the third storm event. Many of the outfalls had fairly turbulent flows which tend to raise DO levels. Mean DO concentrations ranged from 9.13 to 10.98 mg/L. The lowest DO level for any of the surveys was seen at SWM04, with a concentration of 7.23 mg/L measured during the first storm event. This level is still above the minimum AWQS criteria of 7.0 mg/L for the growth and propagation of fish, shellfish, and other aquatic life and wildlife (Figure 14).

Except for two samples with low values, measurements of pH were within AWQS criteria for all storm events and locations (Figure 15). pH ranged from a low of 6.43 pH units at SWM01 to a high of 8.36 at SWM03. Rainfall is often slightly acidic but exposure to minerals in soils typically mitigates any brief depressions. The National Atmospheric Deposition Program (NADP) indicates that rainfall in Alaska is typically in the range of 5.2 to 5.5 pH units.

In 2016, all ten locations were coolest during the last storm event. The coolest outfall discharge temperatures were seen at SWM02 for two of the four storm events with a mean temperature of 10.99°C, and the warmest temperatures were seen at SWM04, which drains a small residental area, with a mean temperaure of 13.50°C. Temperature values were generally found to be less than the AWQS of 13°C for spawning and egg/fry incubation areas and, except for eight sites during the first storm event and one site during the second storm event, temperatures were below the AWQS criteria of 15°C for migration routes and rearing areas (Figure 16).

In addition to the standard field measurements, the field crew also recorded visual observations of any odor, water color, clarity, floatables, deposits or stains, sheens, and debris. Observations for petroleum odor and sheen are noted under hydrocarbons. A hydrocarbon odor was noticed at SWM08 during all four of the sampling efforts which receives runoff from a large mixed use area. A slight hydrocarbon odor was also observed at SWM09 and SWM10 during the second storm event. No oily sheens were observed at any location or event during 2016. Observations of water color and clarity were consistent and matched those outfalls where high turbidity and TSS were observed. Floatables consisted of some suds, vegetative material, and other small pieces of organic material that were noted at a few locations (refer to field logs in Appendix D). Some stains (rust) were observed at SWM10 which may be an indication of corrosion of the stormwater piping or simply the result of high iron content that is often seen in Anchorage area streams. Other observations included a small amount of scum at several sites, some garbage-type debris, sediment deposits, and algae. Other than hydrocarbons, no attempt has been made to correlate any of the visual observations with the conventional or pollutant measurements.

4.3 Conventional Parameters (BOD_5 and TSS)

The 5-day biological oxygen demand (BOD_5) during 2016 was found to be fairly low at all locations for all four storm events with no clear seasonal pattern (Table 6 and Figure 17). Concentrations ranged from a low of not detected (ND) (< 2 mg/L) at many sites to a high of 14.0 mg/L measured at SWM07 during the second storm event. The highest overall BOD_5 concentrations was also seen at SWM07 with mean concentration of 6.0 mg/L. The next highest mean concentration was 3.8 mg/L which was seen at SWM06. Outfall SWM02 exhibited the lowest BOD_5 overall with no detectable concentrations during any of the four sampling events.

As noted earlier, it is expected that TSS levels would be highly correlated with turbidity. SWM05 had the highest mean TSS in 2016 and also exhibited some of the highest turbidity levels (Tables 5 and 6, Figures 12 and 18). TSS concentrations ranged from ND (< 1 mg/L) at SWM02 and SWM10 during the third event to a high of 380 mg/L at SWM05 seen during the fourth storm event. The station mean concentrations ranged from 12.8 mg/L at SWM06 to 137.0 mg/L at SWM05. Large differences can occur for TSS since this parameter is highly dependent on the drainage area and is a function of the type of useage, percent impervious surfaces, slope, flow rate, and other factors.

4.4 Fecal Coliform

Fecal coliform measurements were found to often exceed the 200 fecal coliform (FC)/100 milliliter (mL) AWQS criteria. Overall, concentrations were found to be elevated when compared to those seen in 2015 but were similar in range to those seen historically (Table 6 and Figure 19). Although the AWQS do not directly apply to stormwater, the limit of 200 FC/100 mL was used as a benchmark comparison since most applicable beneficial use criteria are based on this numeric limit (refer to Table 9). One site, SWM02, had concentrations below the standard during all four surveys. Another site with a low geometric mean fecal coliform level was SWM10. Overeall, only six individual samples from 2016 were less than the 200 FC/100 mL criteria. The geometric mean of fecal coliform ranged from a low of 45 FC/100 mL at SWM02 to a high of 3,550 FC/100 mL measured at SWM06. Studies conducted by EPA in the early 1980s (EPA, 1983) indicated that fecal coliform levels in warm climates were typically in the range of 10s to 100s of thousand FC/100 ml with a median of 21,000 FC/100 mL. In colder climates, the median concentration of fecal coliform was in the range of 1,000 FC/100 mL which is similar to concentrations seen at most locations and storms during 2016.

Despite the fact that established fecal coliform standards were exceeded at nine of the ten sites, overall concentrations were not alarming. The highest mean concentrations were seen at SWM04, SWM05, SWM06, SWM07, and SWM08 with geometric means of 2428, 2318, 3550, 3204 and 1079 FC/100 mL, respectively, although elevated individual samples were also seen at a number of other locations (Table 6). An earlier analysis of fecal coliform in Anchorage streams indicated that highest loads would most likely occur in August/September in association with peak runoff and rainfall (MOA 2003). This analysis appeared to agree with what was seen during both 2011 and 2013 when the highest levels of fecal coliform tended to occur in July and August with somewhat lower levels seen in September. However, in 2016 the highest levels at each site were spread across all four storms. There did appear to be a slight seasonal pattern in 2016 with lower levels seen in late September particularily during the third storm event. The high variability of fecal coliform measurements between both storm events and locations suggests the need to continue monitoring this parameter over a relatively extended time period to better assess performance of control measures.

Table 6. Concentrations of Microbiological and Conventional Parameters.

Station	Event-01 4-Aug-2016	Event-02 22-Aug-2016	Event-03 15-Sept-2016	Event-04 22-Sept-2016	Mean
Fecal Coliform (CFU/100 ml)					
SWM01	1900	NT	320	225	515
SWM02	118	13	33	78	45
SWM03	330	1150	126	446	382
SWM04	4100	2200	530	7270	2428
SWM05	13000	1500	909	1630	2318
SWM06	34200	8000	440	1320	3550
SWM07	3900	9900	718	3800	3204
SWM08	4100	782	350	1210	1079
SWM09	7300	700	114	360	677
SWM10	230	390	1.64U	360	92
Biological Oxygen Demand (mg/L)					
SWM01	5.8	NT	2U	2.4	3.1
SWM02	2U	2U	2U	2U	1.0
SWM03	2U	2.4	2U	2.2	1.7
SWM04	2.2	2U	2U	2U	1.3
SWM05	4.1	3.3	2U	3.6	3.0
SWM06	2.3	2.9	2.0	7.8	3.8
SWM07	4.0	14.0	2U	5.1	6.0
SWM08	2.4	3.9	2U	4.4	2.9
SWM09	2.7	3.1	2U	3.7	2.6
SWM10	2U	2.6	2U	4.6	2.3
Total Suspended Solids (mg/L)					

Station	Event-01 4-Aug-2016	Event-02 22-Aug-2016	Event-03 15-Sept-2016	Event-04 22-Sept-2016	Mean
SWM01	12.2	NT	8.9	42.5	21.2
SWM02	14.2	2.4	1.04U	78.4	23.9
SWM03	4.1	16.2	5.6	47.3	18.3
SWM04	9.6	31.4	17.1	11.3	17.4
SWM05	21.6	129.0	17.2	380.0	137.0
SWM06	11.6	24.8	3.7	11.2	12.8
SWM07	14.2	129.0	10.0	72.2	56.4
SWM08	9.4	60.0	9.8	36.9	29.0
SWM09	28.0	48.6	5.3	20.2	25.5
SWM10	2.3	59.8	1U	21.4	21.0

Footnotes: U = not detected at the associated detection limit that is shown. Mean calculations used geometric mean for fecal coliform and utilized 1/2 the reporting limit where analyte was not detected.
NT = Not tested due to no flow at outfall.

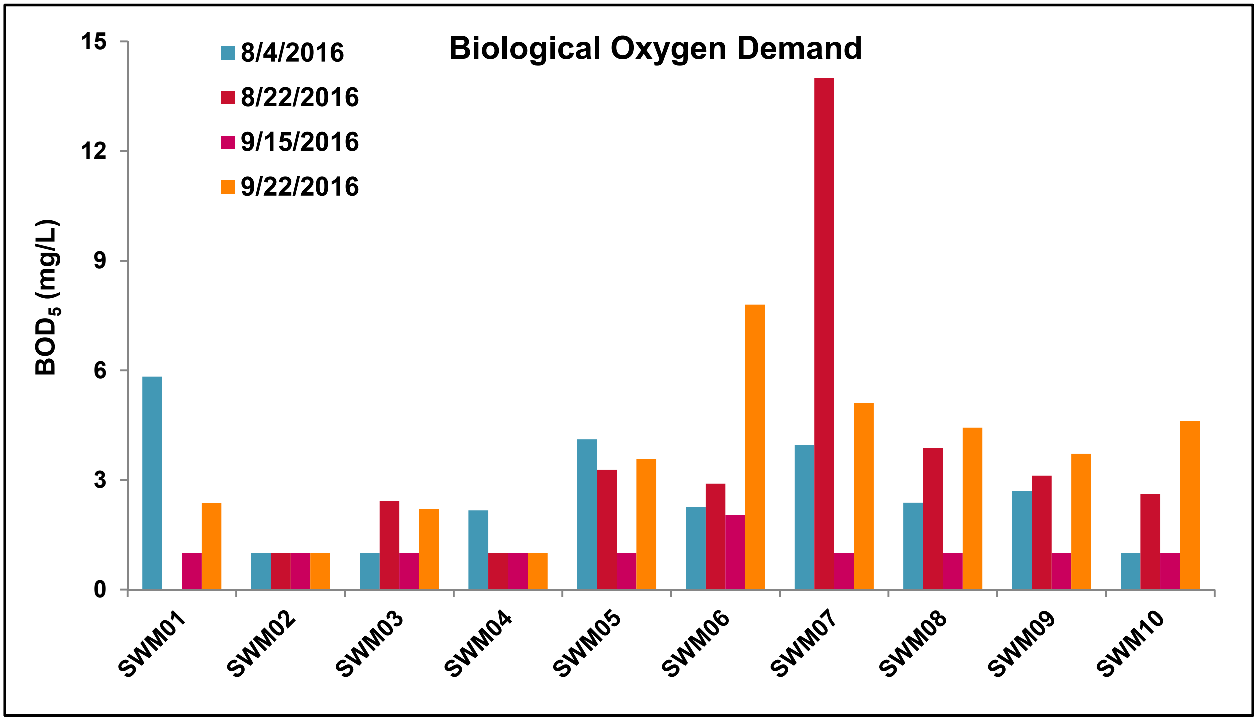


Figure 17. **BOD_5 (mg/L) Measured in Stormwater Sampled at Monitoring Sites During all Four Events.** **(Note: ND ≤ 1mg/L)**

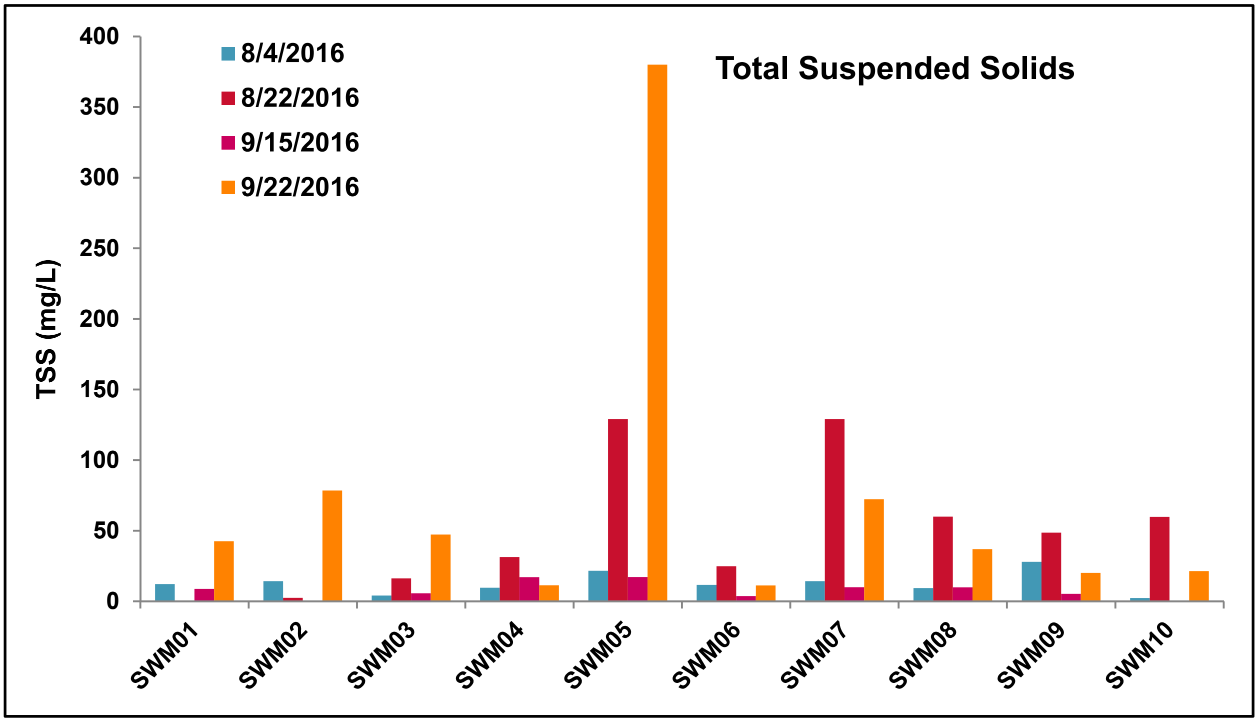


Figure 18. **Total Suspended Solids Measured in Stormwater Sampled at Monitoring Sites During all Four Events**

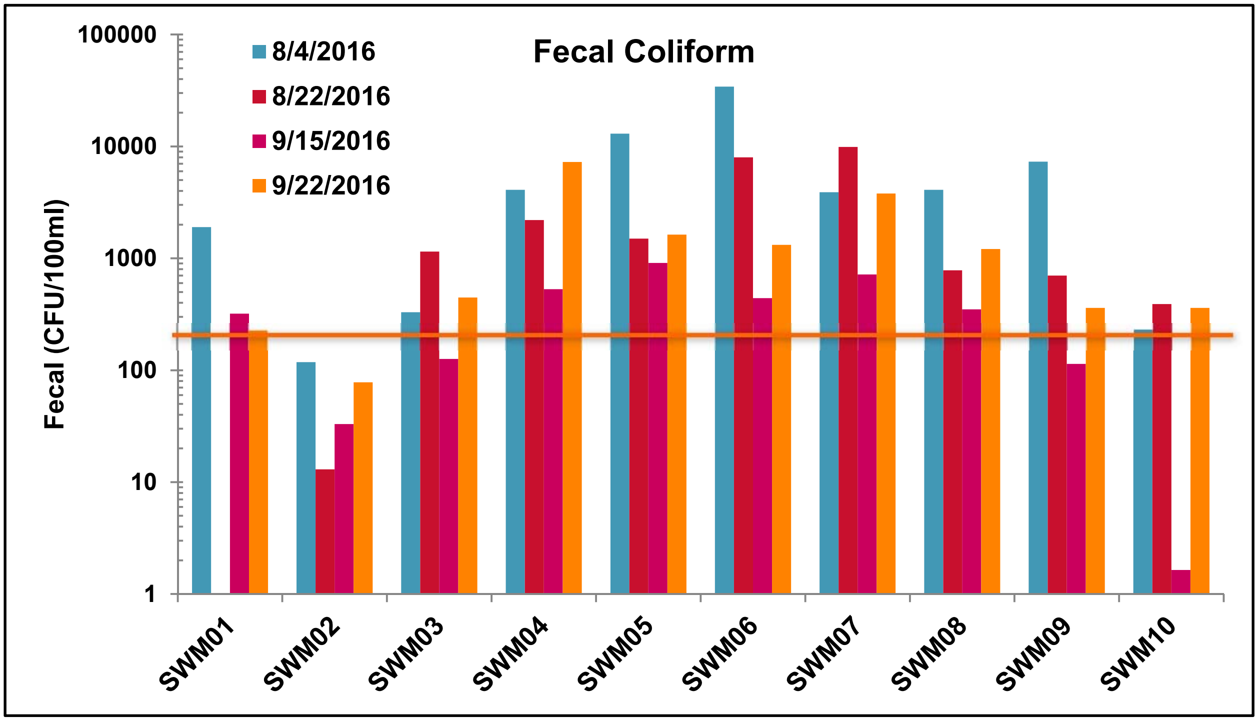


Figure 19. **Fecal Coliform (FC/100 mL) Measured in Stormwater Sampled at Monitoring Sites during all Four Events (AWQS less than 200 FC/100mL).**

4.5 Metals and Hardness

Supplemental monitoring of dissolved copper and total water hardness were added in 2016 for all locations and storms. The Permit requirements and monitoring conducted in prior years did not include these two parameters.

Hardness was found to be highly variable between locations and events. Hardness concentrations ranged from a low of 8.56 mg/L to a high of 131 mg/L (Table 7 and Figure 20). Mean concentrations ranged from a low of 18.7 mg/L at SWM07 to a high of 85.2 mg/L at SWM02. Typically, within the same water body, hardness is inversely correlated to turbidity and TSS. This relationship can be seen in the 2016 data where eight of the ten sites had their highest hardness values during the third storm and nine of ten sites had their lowest turbidity levels during the same storm. Hardness is an important parameter for freshwater since it affects toxicity and it is used to determine both the acute and chronic receiving water criteria for many metals. As hardness increases, so does the corresponding metals criteria. For example for the State of Alaska, the acute water quality criteria for copper range from a concentration of 6.99 µg/L at a hardness of 50 mg/L to a concentration of 13.44 µg/L at a hardness value of 100 mg/L. However, in order to apply this information directly to the metals data collected in this program, hardness data is needed for the receiving waterbody.

Dissolved copper concentrations with few exceptions were generally low. Concentrations ranged from ND (<1 µg/L) to 10.5 µg/L with the exception of one very high anomalous outlier at

950 µg/L that was seen at SWM09 during the second storm (Table 7 and Figure 21). Concentrations at this site during the other three storms were very low with the next highest value at 2.8 µg/L. This high concentration was confirmed by the laboratory and was subjected to a secondary analysis as part of laboratory's QC analysis. This site drains the area around the Sullivan Arena and Ben Boeke Ice Arena parking areas and does not include any known sources that would contribute to a high copper concentration. Mean copper concentrations ranged from 1.3 µg/L at SWM10 to a high of 239 µg/L seen at SWM09 as a result of the one high value. The next highest station mean concentration was seen at SWM07 at 7.2 µg/L. Since this is the first year of dissolved copper monitoring, additional data will be necessary to see if any significant patterns or trends emerge.

Table 7. Concentrations of Hardness and Dissolved Copper.

Station	Event-01 4-Aug-2016	Event-02 22-Aug-2016	Event-03 15-Sept-2016	Event-04 22-Sept-2016	Mean
			Hardness (mg/L)		
SWM01	20.5	NT	52.5	8.6	27.2
SWM02	46.8	124	131	39.0	85.2
SWM03	53.4	84.7	91.2	54.8	71.0
SWM04	29.9	60.0	119	43.4	63.1
SWM05	42.4	32.5	96.4	47.8	54.8
SWM06	28.8	10.4	52.8	12.3	26.1
SWM07	19.8	21.2	18.0	15.7	18.7
SWM08	33.5	13.6	69.2	12.4	32.2
SWM09	62.7	27.8	114	24.4	57.2
SWM10	81.8	43.0	101	44.4	67.6
			Dissolved Copper (µg/L)		
SWM01	6.3	NT	3.3	1.5	3.7
SWM02	3.4	3.1	3.1	1.8	2.8
SWM03	2.6	4.1	2.9	3.8	3.3
SWM04	4.1	3.4	2.8	2.7	3.2
SWM05	10.0	4.9	5.6	6.2	6.7

Station	Event-01 4-Aug-2016	Event-02 22-Aug-2016	Event-03 15-Sept-2016	Event-04 22-Sept-2016	Mean
SWM06	4.5	2.0	2.6	1.8	2.7
SWM07	10.5	7.3	5.7	5.5	7.2
SWM08	4.0	3.0	1.8	3.3	3.0
SWM09	2.8	950	1U	2.4	239
SWM10	1.1	2.1	1U	1.3	1.3

Footnotes: U = not detected at the associated detection limit that is shown. Mean calculations utilized 1/2 the reporting limit where analyte was not detected.
NT = Not tested due to no flow at outfall.

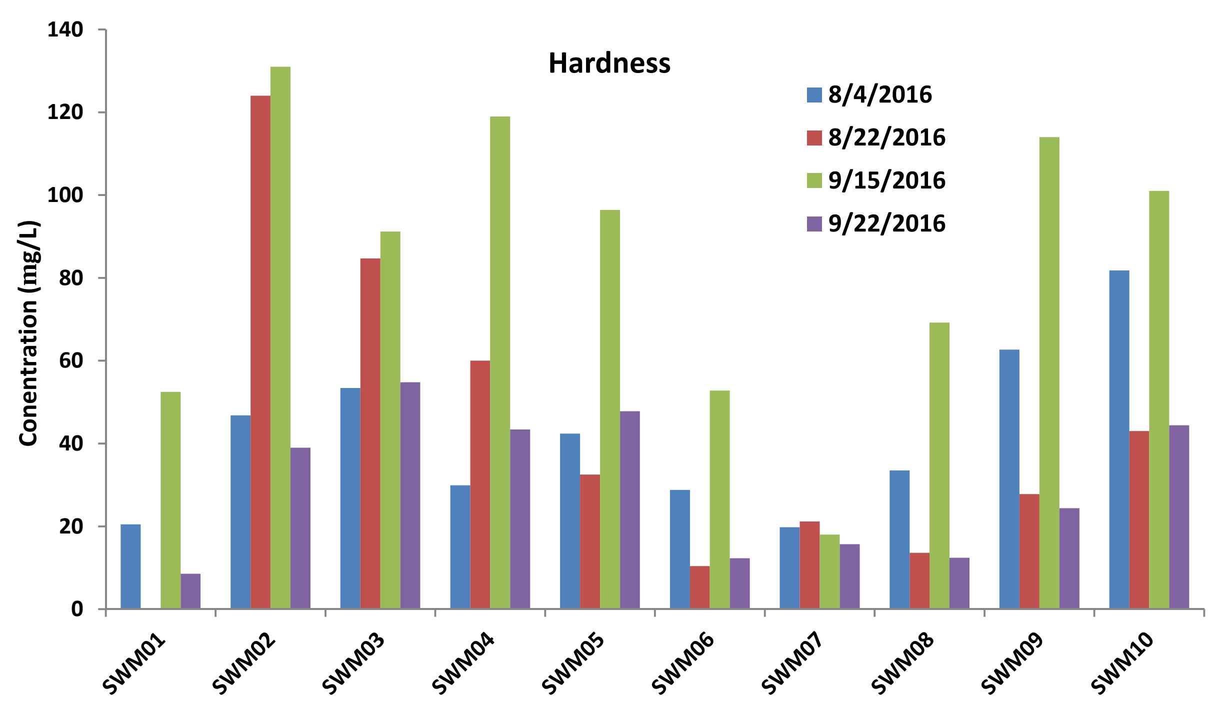


Figure 20. **Water Hardness (mg/L) Measured in Stormwater Samples.**

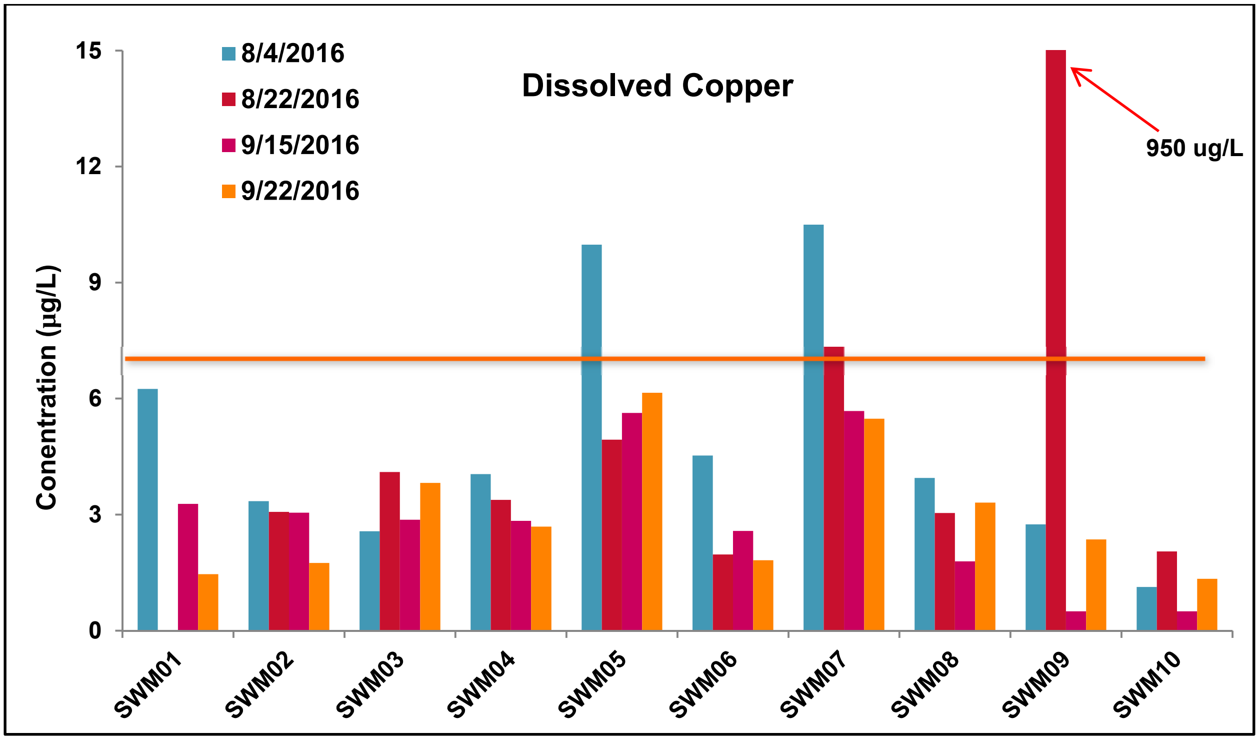


Figure 21. Dissolved Copper (µg/L) Measured in Stormwater Samples (Acute AWQS based on Hardness value of 50 mg/L).

4.6 Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) and total volatile aromatic hydrocarbons (TAH) were measured at four of the monitoring sites: SWM02, SWM05, SWM07, and SWM09. In all cases, total PAH concentrations were low ranging from ND to 3.49 µg/L (Table 8 and Figure 22). TAH concentrations were all below detection limits for all sites and all storms, and all samples were well within the AWQS criteria for both total aqueous hydrocarbons (TAqH) and TAH measured as benzene, ethylbenzene, tolulene, and xylenes (BETX). TAqH is defined in the AWQS as the summation of total PAH and TAH with a criteria of 15 µg/L, whereas TAH alone has an AWQS criteria of 10 µg/L (Table 9). The highest concentration of TAqH was 3.49 µg/L at SWM02 during the fourth stormwater sampling event.

PAHs were the most common compounds found at each site and were typically comprised of combustion-related compounds like pyrene, fluoranthene, chrysene, benzo(a)pyrene, benzo(a)anthracene, benzo(g,h,i)perylene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene although small quanities of dibenzo(a,h)anthracene was seen in one sample and low levels of phenanthrene was also seen in a number of samples. Concentrations of individual PAHs were found to be low and with the exception of three samples were all less than 0.2 µg/L. Some PAHs were seen at all four sites during at least two storm event. PAHs were present at SWM02 and SWM09 during three of the four storms and at SWM05 and SWM07 during two of the four sampled storm events. The highest PAH concentrations at three of the four sites occurred during the fourth storm event which was also the largest storm in terms of outfall flow rates and TSS/turbidity levels at most sites. There did not appear to be any noticeable differences in PAH levels at the two sites with OGS versus the two that were non-OGS.

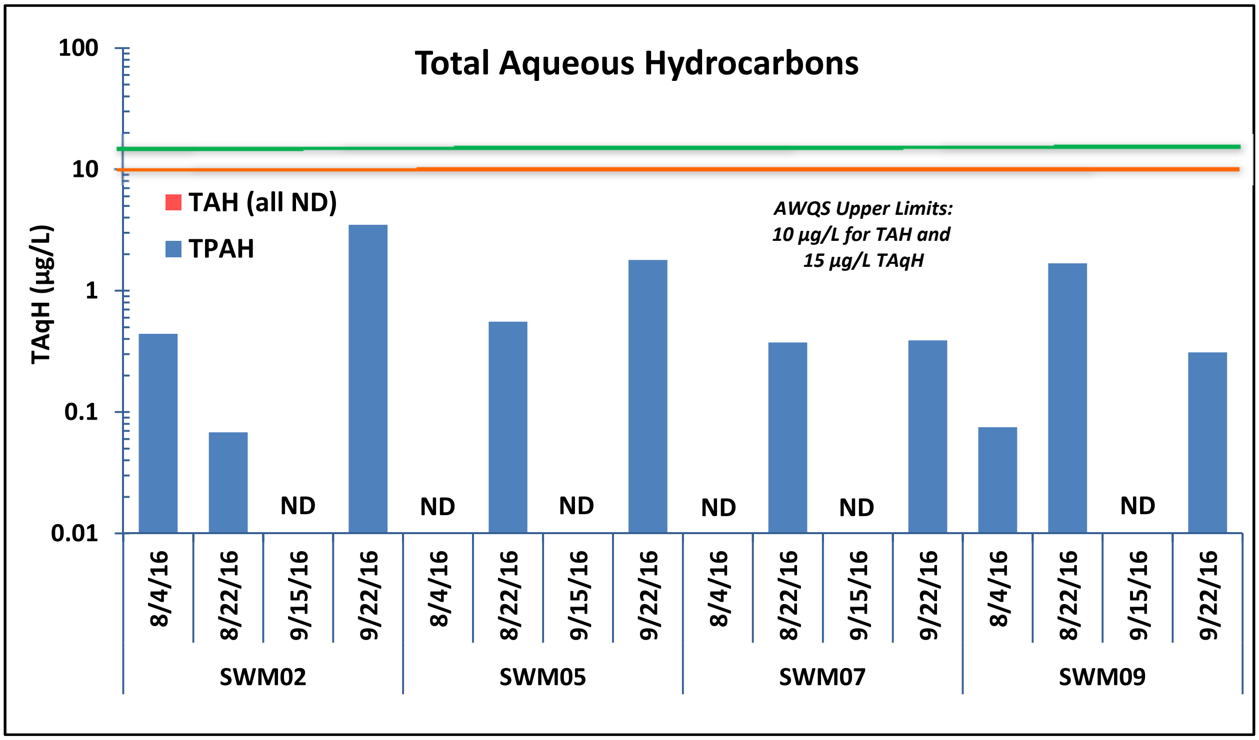


Figure 22. **Total Aqueous Hydrocarbons (TAqH = TAH + TPAH) Measured in Stormwater Sampled at Monitoring Sites During all Four Events (AWQS ≤ 10 µg/L for TAH and ≤ 15 µg/L for TAqH).**

Table 8. Hydrocarbon Concentrations Measured in Stormwater at Four Sites During All Four Storm Events.

	SWM02 - OGS (No)				SWM05 - OGS (Yes)				SWM07 - OGS (No)				SMW09 - OGS (Yes)			
	8/4/16	8/22/16	9/15/16	9/22/16	8/4/16	8/22/16	9/15/16	9/22/16	8/4/16	8/22/16	9/15/16	9/22/16	8/4/16	8/22/16	9/15/16	9/22/16
Polycyclic Aromatic Hydrocarbons (µg/L)																
Acenaphthene	0.054U	0.057U	0.052U	0.053U	0.052U	0.053U	0.051U	0.051U	0.051U	0.052U	0.051U	0.051U	0.053U	0.054U	0.051U	0.051U
Acenaphthylene	0.054U	0.057U	0.052U	0.053U	0.052U	0.053U	0.051U	0.051U	0.051U	0.052U	0.051U	0.051U	0.053U	0.054U	0.051U	0.051U
Anthracene	0.054U	0.057U	0.052U	0.053U	0.052U	0.053U	0.051U	0.051U	0.051U	0.052U	0.051U	0.051U	0.053U	0.054U	0.051U	0.051U
Benzo(a)anthracene	0.054UJ-	0.057U	0.052U	0.145	0.052UJ-	0.053U	0.051U	0.093	0.051UJ-	0.052U	0.051U	0.051U	0.053UJ-	0.080	0.051U	0.051U
Benzo(a)pyrene	0.025J-	0.023U	0.021U	0.302	0.021UJ-	0.033	0.020U	0.139	0.020UJ-	0.021U	0.020U	0.033	0.021UJ-	0.120	0.020U	0.027
Benzo(b)fluoranthene	0.094J-	0.057U	0.052U	0.651	0.052UJ-	0.107	0.051U	0.321	0.051UJ-	0.052	0.051U	0.054	0.053UJ-	0.247	0.051U	0.060
Benzo(g,h,i)perylene	0.054UJ-	0.057U	0.052U	0.530	0.052UJ-	0.065	0.051U	0.275	0.051UJ-	0.059	0.051U	0.060	0.053UJ-	0.143	0.051U	0.051U
Benzo(k)fluoranthene	0.054UJ-	0.057U	0.052U	0.180	0.052UJ-	0.053U	0.051U	0.091	0.051UJ-	0.052U	0.051U	0.051U	0.053UJ-	0.069	0.051U	0.051U
Chrysene	0.095J-	0.057U	0.052U	0.400	0.052UJ-	0.110	0.051U	0.294	0.051UJ-	0.074	0.051U	0.066	0.053UJ-	0.204	0.051U	0.053
Dibenzo(a,h)anthracene	0.022UJ-	0.023U	0.021U	0.021U	0.021UJ-	0.021U	0.020U	0.020U	0.020UJ-	0.021U	0.020U	0.020U	0.021UJ-	0.027	0.020U	0.020U
Fluoranthene	0.130J-	0.068	0.052U	0.414	0.052UJ-	0.132	0.051U	0.249	0.051UJ-	0.078	0.051U	0.075	0.075J-	0.335	0.051U	0.099
Fluorene	0.054U	0.057U	0.052U	0.053U	0.052U	0.053U	0.051U	0.051U	0.051U	0.052U	0.051U	0.051U	0.053U	0.054U	0.051U	0.051U
Indeno(1,2,3-cd)pyrene	0.054UJ-	0.057U	0.052U	0.383	0.052UJ-	0.053U	0.051U	0.051U	0.051UJ-	0.052U	0.051U	0.051U	0.053UJ-	0.107	0.051U	0.051U
Naphthalene	0.108U	0.114U	0.104U	0.106U	0.103U	0.106U	0.102U	0.102U	0.102U	0.104U	0.101U	0.102U	0.105U	0.108U	0.101U	0.102U
Phenanthrene	0.054U	0.057U	0.052U	0.148	0.052U	0.053U	0.051U	0.086	0.051U	0.052U	0.051U	0.051U	0.053U	0.105	0.051U	0.051U
Pyrene	0.098J-	0.057U	0.052U	0.335	0.052UJ-	0.107	0.051U	0.238	0.051UJ-	0.112	0.051U	0.101	0.053UJ-	0.246	0.051U	0.072
Volatile Aromatic Hydrocarbons (µg/L)																
1,2-Dichlorobenzene	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,3-Dichlorobenzene	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,4-Dichlorobenzene	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U
Benzene	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U
Chlorobenzene	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U
Ethylbenzene	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
o-Xylene	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Toluene	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Xylene, Isomers m & p	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U
Hydrocarbon Summary Parameters (µg/L)																
TPAH	0.441	0.068	ND	3.490	ND	0.555	ND	1.790	ND	0.374	ND	0.389	0.075	1.683	ND	0.310
TAH as BETX	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TAqH (TPAH + TAH)	0.441	0.068	ND	3.490	ND	0.555	ND	1.790	ND	0.374	ND	0.389	0.075	1.683	ND	0.310

Footnotes: U = not detected at the detection limit. ND = no concentration detected in any analyte tested. J- = Estimated value biased low.
All detected concentrations are shown in bold.

Table 9. Pertinent Numeric Alaska Water Quality Standard Criteria.

Designated Use	Description of Standard
Fecal Coliform Bacteria	
(A) Water Supply (i) drinking, culinary and food processing	In a 30-day period, the geometric mean may not exceed 20/FC/100 ml, and not more than 10 of the samples may exceed 40 FC/100 ml.
(A) Water Supply (ii) agriculture, including irrigation and stock watering	The geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml. For products not normally cooked and for dairy sanitation of unpasteurized products, the criteria for drinking water supply, (1)(A)(i), apply.
(A) Water Supply (iii) aquaculture	For products normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml. For products not normally cooked, the criteria for drinking water supply, (1)(A)(i), apply.
(A) Water Supply (iii) Industrial	Where worker contact is present, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml.
(B) Water Recreation (iv) contact recreation	In a 30-day period, the geometric mean of samples may not exceed 100 FC/100 ml, and not more than one sample or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100 ml.
(B) Water Recreation (ii) secondary contact	In a 30-day period, the geometric mean of samples may not exceed 200 FC/100 ml, and not more than 10% of the total samples may exceed 400 FC/100 ml.
(C) Growth and Propagation of Fish, Shellfish, other Aquatic Life and Wildlife	Not applicable.
Dissolved Oxygen (most restrictive shown)	
(A) Water Supply (iii) aquaculture (C) Growth and Propagation of Fish, Shellfish, other Aquatic Life and Wildlife	DO must be greater than 7mg/L in surface waters. The concentration of total dissolved gas my not exceed 110% of saturation at any point of sample collection.
pH	
(A) Water Supply (i) drinking, culinary and food processing	May not be less than 6.0 or greater than 8.5.
(A) Water Supply (ii) agriculture, including irrigation and stock watering, & (iv) Industrial	May not be less than 5.0 or greater than 9.0.

Designated Use	Description of Standard
(A) Water Supply (iii) aquaculture	May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH unit from natural conditions.
(B) Water Recreation (iv) contact recreation	May not be less than 6.5 or greater than 8.5. If the natural condition pH is outside this range, substances may not be added that cause an increase in the buffering capacity of the water.
(B) Water Recreation (ii) secondary contact	Same as (6)(A)(iv)
(C) Growth and Propagation of Fish, Shellfish, other Aquatic Life and Wildlife	May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH unit from natural conditions.
Petroleum Hydrocarbons	
(A) Water Supply (iii) aquaculture & (C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife.	TAqH in the water column may not exceed 15 µg/L. TAH in the water column my not exceed 10 µg/L. Surface waters and adjoining shorelines must be virtually free from floating oil, film, or discoloration.
Dissolved Inorganic Substances (most restrictive shown)	
(A) Water Supply (i) drinking, culinary, and food processing	Total dissolved solids (TDS) from all sources may not exceed 500 mg/L.
Temperature (most restrictive shown)	
(A) Water Supply (iii) aquaculture & (C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife.	The following maximum temperatures may not be exceeded, where applicable: Migration routes and rearing areas: 15°C Spawning areas, egg & fry incubation: 13°C

In addition to the laboratory measurements of PAH and TAH, field observations were recorded for any sheens or odors. No oil sheens were seen during any storm at any location during 2016. Although not sampled for hydrocarbons, a hydrocarbon odor was also noted at SWM08 during all four sampling events during 2016. A slight hydrocarbon odor was also observed at SWM09 and SWM10 during the second storm event.

4.7 Site Trends

This report presents the latest of six years of monitoring for this program. Some general trends between sites were detected that in some cases have persisted across sampling events and between years. General site differences were investigated graphically with boxplots that have been prepared for each field and laboratory parameter (Figures 23, 24 and 25). The boxplots constitute the results from 20–24 samples collected at each location during 2011 through 2016 and depict the minimum, maximum, median, 25-percentile, 75-percentile, and grand median measurements across all locations. In addition, AWQS criteria have been plotted where appropriate for each parameter.

A few locations seem to stand out for each parameter. For pH, SWM06 is consistently lower than the other locations with a few measurements below the AWQS lower limit of 6.5 pH units. Outfall SWM03 had the highest median pH concentration. SWM01 had the most variable and the highest pH concentration with one value exceeding the upper pH water quality criteria limit of 8.5.

Temperature is somewhat lower at three locations (SWM02, SWM03, and SWM10). This may be a function of the duration in which the stormwater flows through a buried storm drain network versus the drainages with more open-channel and overland flow with shorter pipe networks. Water flowing through buried pipes tends to remain cooler than that flowing overland.

TDS appeared to be slightly higher at both SWM04 and SWM10 and may be an indication of other pollutants such as trace metals or salts. Potential sources could be magnesium chloride, which MOA uses on the city streets for de-icing/anti-icing purposes or residential/commercial use of deicing salts on walkways and driveways that could show up as an increase in TDS levels, particularly during the early summer storms. Both of these outfalls drain primarily residential areas. In general, TDS did appear to be higher at most locations during the third storm event during 2016 (Figure 14). USGS (2006) documented increases in TDS, sodium, and chloride levels in the downstream direction within the Chester Creek drainage that indicated influences from urbanization.

Dissolved oxygen was near saturation at all locations. SWM02 had the highest levels potentially due to turbulent flow in the outfall pipe prior to discharge. SWM02 was also one of the locations with the lowest BOD_5 concentration. This potential correlation did not hold true for SWM07, which had a median DO level of ~10 mg/L, slightly above average, but also had the highest BOD_5 concentration. For BOD_5, SWM07 and SWM08 are somewhat higher which may be the result of vehicle cooling liquid inputs (glycols) from streets and driveways. The drainage areas for both of these outfalls include a high percentage of streets, parking lots, and other impervious surfaces.

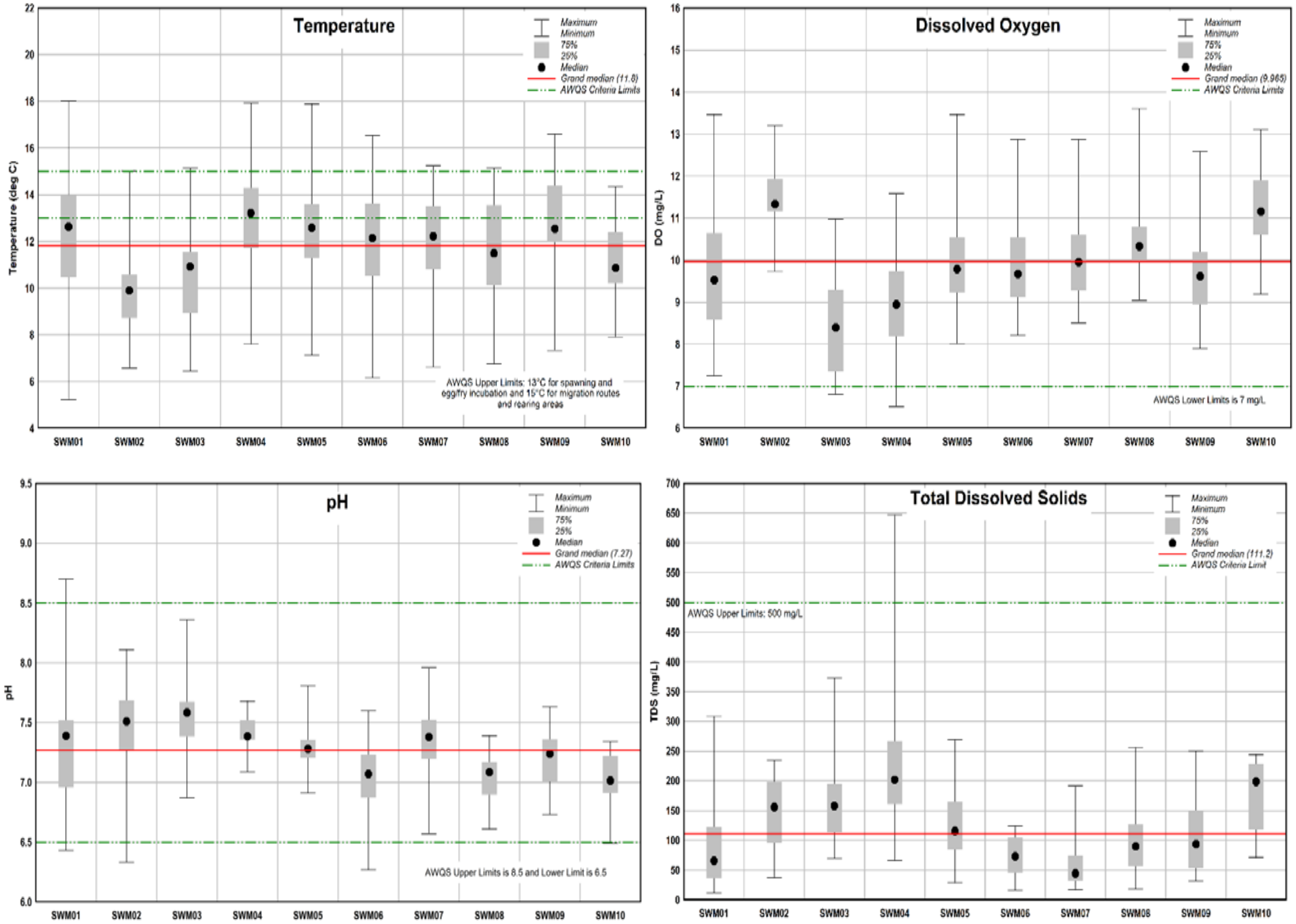


Figure 23. Station Boxplots of pH, Temperature, Total Dissolved Solids, and Dissolved Oxygen for 2011 thru 2016.

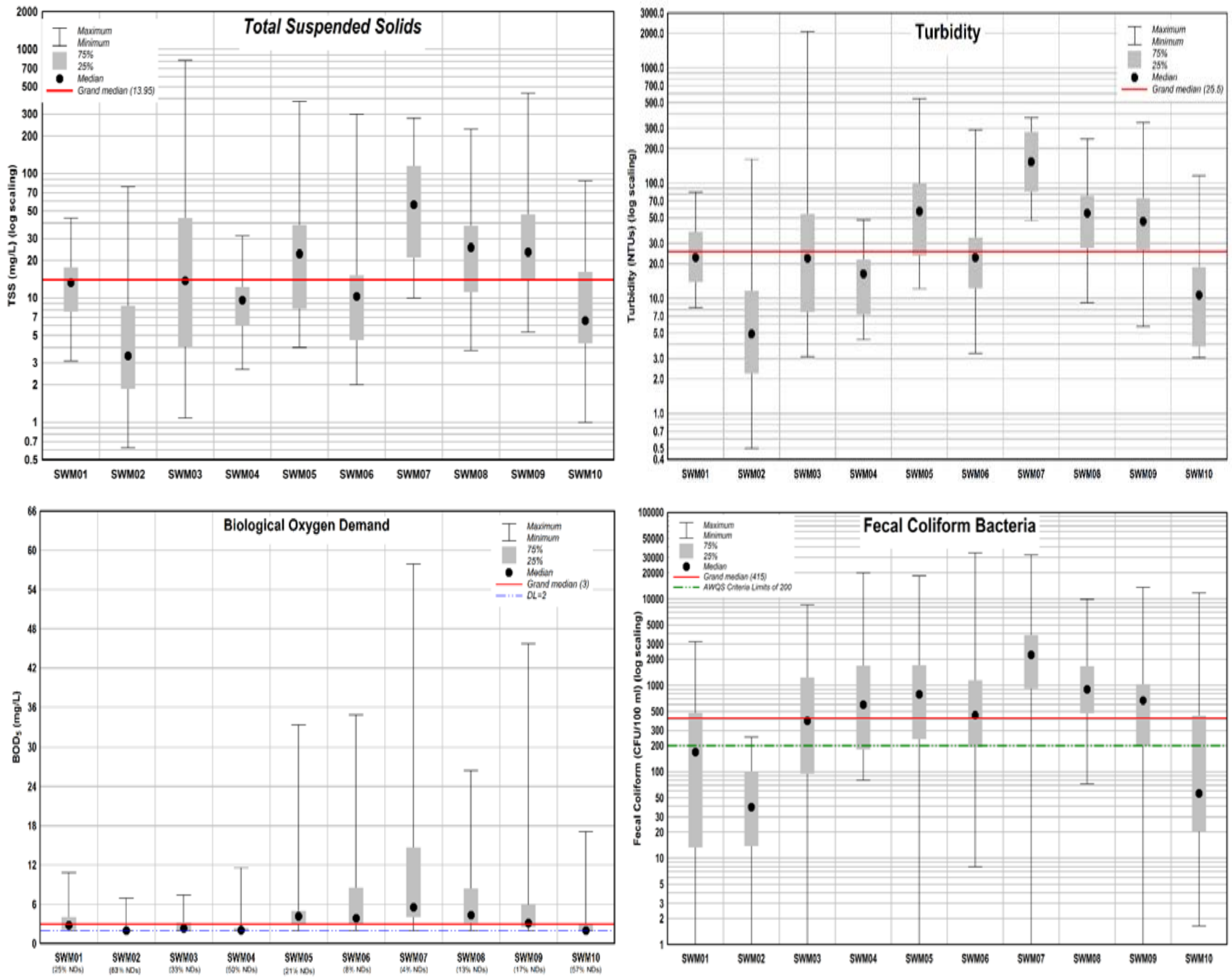


Figure 24. **Station Boxplots of Total Suspended Solids, Turbidity, Biological Oxgen Demand, and Fecal Coliform for 2011 thru 2016.**

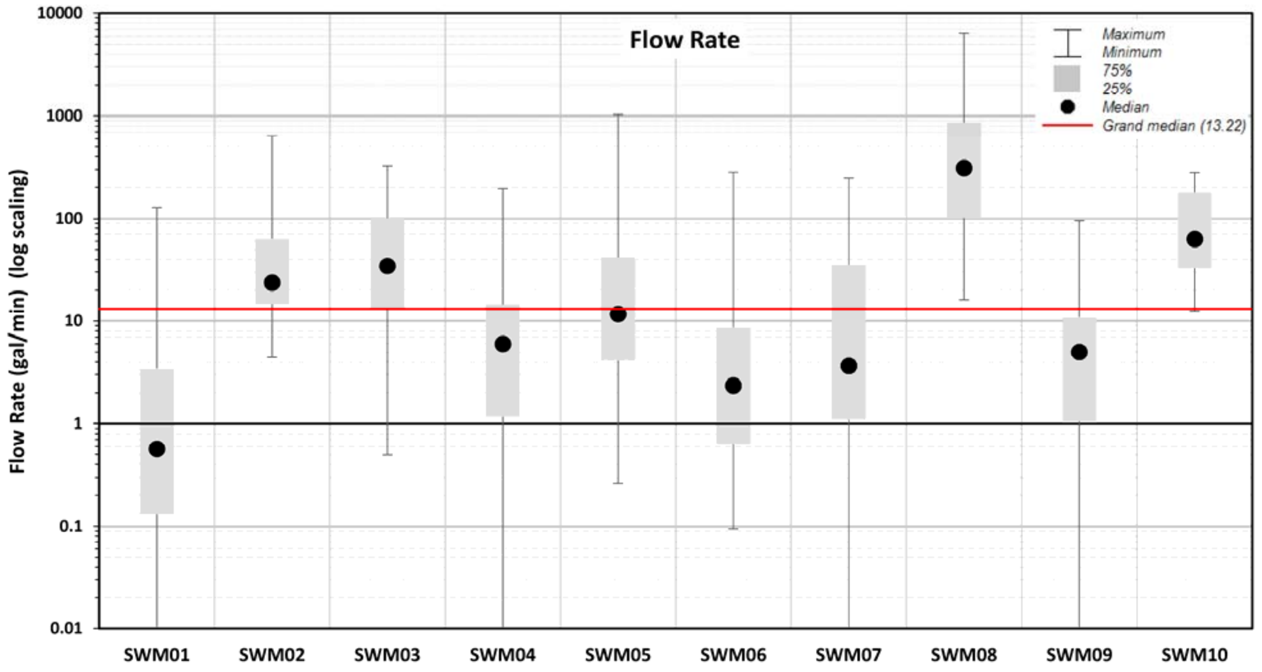


Figure 25. Station Box Plot of Outfall Flow Rate for 2011 thru 2016.

Both TSS and turbidity were highly variable although there was a general correlation between TSS and turbidity in the boxplot location patterns. The highest median TSS and turbidity concentrations were detected at SWM07. This outfall has been consistently high for each year of the study.

For fecal coliform, SWM02 and SWM10 were consistently lower than other locations, and SWM07 was consistently much higher. Other elevated locations included SWM04, SWM05, SWM08 and SWM09. The sources of the higher concentrations seen at SWM07 are unknown, but these observations should be used to guide future efforts and to focus subsequent analyses.

Flow rate was highly variable between locations and between events. Outfall SWM08, which is a large 42-inch pipe that drains the largest basin, had consistently higher flow rates than the other locations. The lowest flow was at SWM01 which drains a small residential area. Flows at SWM02, SWM03, and SWM10 were relatively high when compared to the other six locations, although some of the other locations exhibited high flows during some storm events. For some outfalls, particularly for those with small drainage basins, flow rates responded rapidly to changes in precipitation.

4.8 Yearly and Seasonal Trends

The data were examined for any yearly or seasonal trends to determine if differences in the concentration of any parameter changed dramatically from one year to the next or if there were differences that could be attributed to seasonal timing. For example, historic studies conducted in the Anchorage watersheds indicated that there were seasonal influences on fecal coliform concentrations, presumably tied to air and water temperatures, where concentrations were generally higher during the summer months and lower during spring and fall (MOA, 2003). Most of the measurements taken over the six years of this study occurred during July and August. Data was collected during one storm event during June and one in October, while five storm events were sampled in September. With a limited number of storm events sampled outside of the peak summer months determining seasonal trends is difficult.

Although many differences occurred between years for various parameters, no clear patterns emerged across multiple locations. For example, fecal coliform was highest at two locations during 2011, three locations in 2012 and 2013, two locations in 2014, one location during 2015, and at four locations in 2016, although SWM07 has stood out each year as having the highest fecal coliform levels. Variability fluctuated between years for other parameters as well. In fact, other than TSS and turbidity, no patterns of multiple parameters correspondingly fluctuating across multiple locations and years emerged.

Even with limited data points outside the peak summer months, some seasonal differences occurred in a few of the parameters. Temperature was higher across all locations in July and August than in early June, September, and October. DO typically fluctuates inversely to temperature with higher DO concentrations during early summer and fall and lower concentrations during mid-summer. This seasonal trend in DO, as plotted against the day of year (DOY), is clear in the regression plot for all sites and years (Figure 26). Although not as consistent or as highly correlated as temperature or DO, fecal coliform followed a similar trend as that seen in temperature. Fecal coliform counts were generally lower during spring and fall and higher during the summer (Figure 26). Seasonal pattern regression values are presented on each plot where the data has been fitted to a second order polynomial. Regression values (R coefficient) were 0.564 for DO, 0.710 for temperature, and 0.173 for fecal coliform.

4.9 Annual Loading

The Simplified Method to calculate loading estimates was used for determining annual loadings for fecal coliform and hydrocarbons for each of the subbasins that was examined in this study. The Simple Method was developed under an EPA grant to provide Phase II communities with tools to protect their local watersheds (SMRC, 2010). This method estimates stormwater runoff pollutant loads for urban areas and requires the following information: subbasin drainage area and percent impervious cover, flow weighted or event mean stormwater runoff pollutant concentrations, and annual precipitation. With the Simple Method, calculations can be based on specific land use areas such as residential, commercial, industrial, and roadway to calculate annual pollutant loads for each type of land use. The method can also be used for more generalized pollutant comparisons by land uses such as new suburban areas, older urban areas, central business districts, and highways. Equations and calculation methodology utilized for the Simple Method are detailed in Attachment B-1 of the QAPP (MOA, 2016).

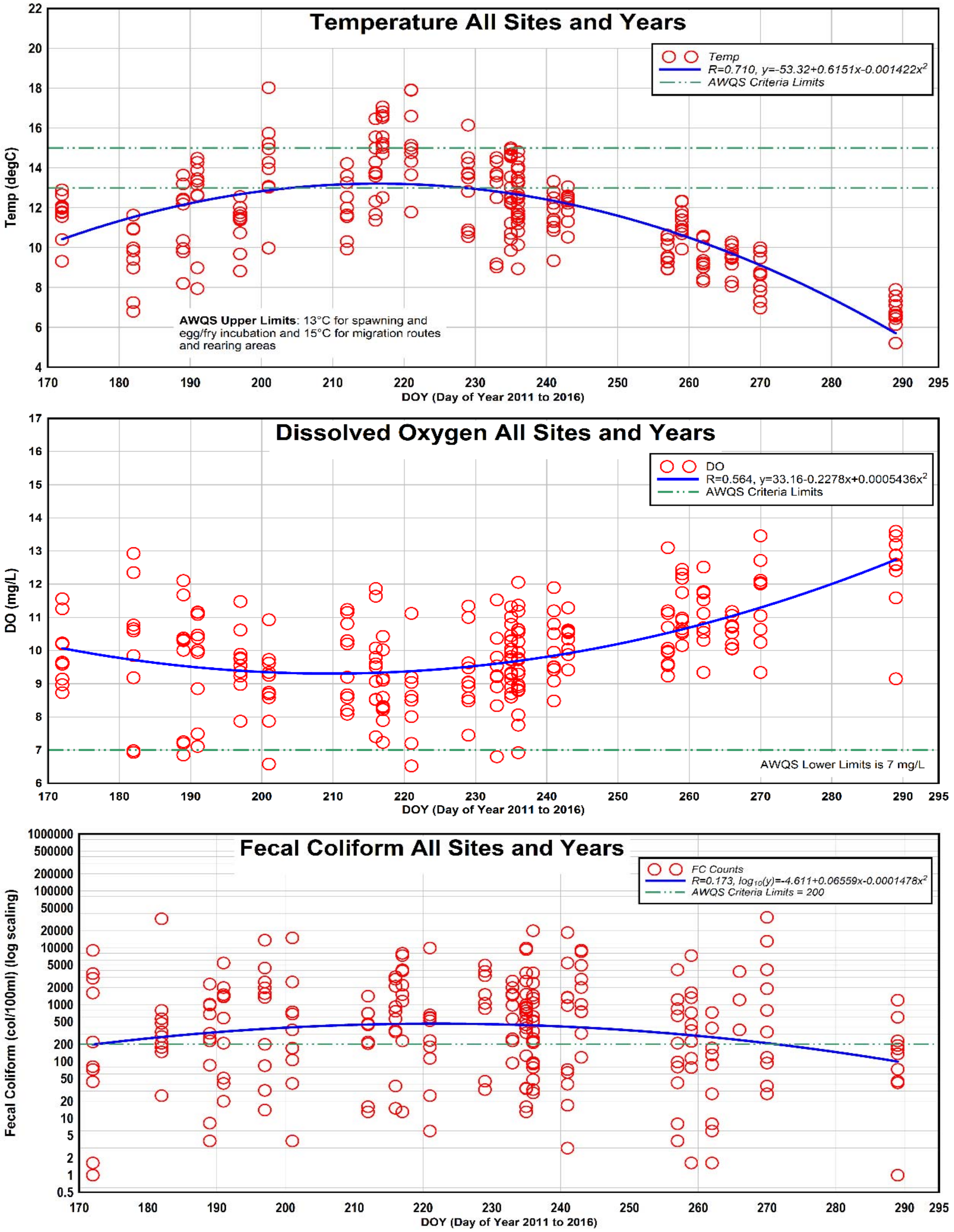


Figure 26. Seasonal Patterns for Temperature, DO, and Fecal Coliform, All Sites and All Years.

A major limitation for this method is applying data collected from a single grab sample for each storm event rather than using flow-weighed data which would help eliminate some of the high variability. Available documentation for this method does not address its applicability to organic compounds such as petroleum hydrocarbons even though comparisons are provided in this report (SMRC, 2010). Loading data are considered estimates that can provide useful information in comparing subbasins and be used as a planning tool, and are not precise enough for comparing similar loading estimates.

Annual loading estimates were determined for hydrocarbons and fecal coliform. For hydrocarbons, only TPAH was examined since all volatile aromatic hydrocarbons were found to be ND except a single sample in both 2011 and 2012. Fecal coliform loading calculations (Figure 27) utilized the annual geometric mean for each location to account for some of the high variability. TPAH loading calculations (Figure 28) utilized the annual arithmetic mean for each location.

SWM07 stands out as the subbasin with the highest annual fecal coliform loading in five of the six years of the study (Figure 27). During 2015, the fecal loading at SWM07 was substantially lower but has since increased to be the highest again in 2016. In 2015, SWM08 had the highest loading estimate. Other areas with relatively high fecal coliform loading were SWM03 (residential), SWM05 (commercial/industrial), SWM08 (mixed), and SWM09 (commercial/industrial). These locations represent all three of the different land use categories examined in the study (refer to Table 1). The lowest fecal loading values were detected at SWM01 (residential), SWM02 (commercial/industrial), SWM04 (residential), SWM06 (residential), and SWM10 (mixed). SWM10 indicated elevated levels of fecal coliform loading during 2014, although three or the four storm events were in line with historic measurements. With the exception of SWM03, the residential areas were lower in fecal coliform loading when compared to the commercial/industrial areas.

Annual hydrocarbon loading, as determined by TPAH measurements, was low at all four locations that were measured (Figure 28). The highest loading was 0.25 lbs/year at SWM02 during 2011. Slightly lower levels were seen at both SWM07 and SWM09 during some years. No clear pattern was noted between the outfalls that contained OGS units (SWM05 and SWM09) versus those that did not (SWM02 and SWM07). SWM05 had some of the lowest loading values while SWM09 had some the highest. Based on these four locations, and given that they were all similar in size in terms of acreage and were from the commercial/industrial land use categories, the efficacy of the OGS units could not be determined. OGS units may be effective in removing oil, grease, and grit but that hydrocarbons as measured by both TAH and TPAH may not be removed. TAH and TPAH measured in these samples are mostly dissolved and likely pass through an OGS. Alternatively, there could just be large differences between the four areas examined that make it difficult to determine the effectiveness of the OGS based on this study. The best way to measure the efficacy of an OGS unit would be to take both up- and down-stream measurements so that a direct comparison could be made on the amount of hydrocarbons removed at a specific location. Hydrocarbon concentrations could also be measured in the oil and grit that is collected within the OGS unit itself to obtain a percent removal estimate.

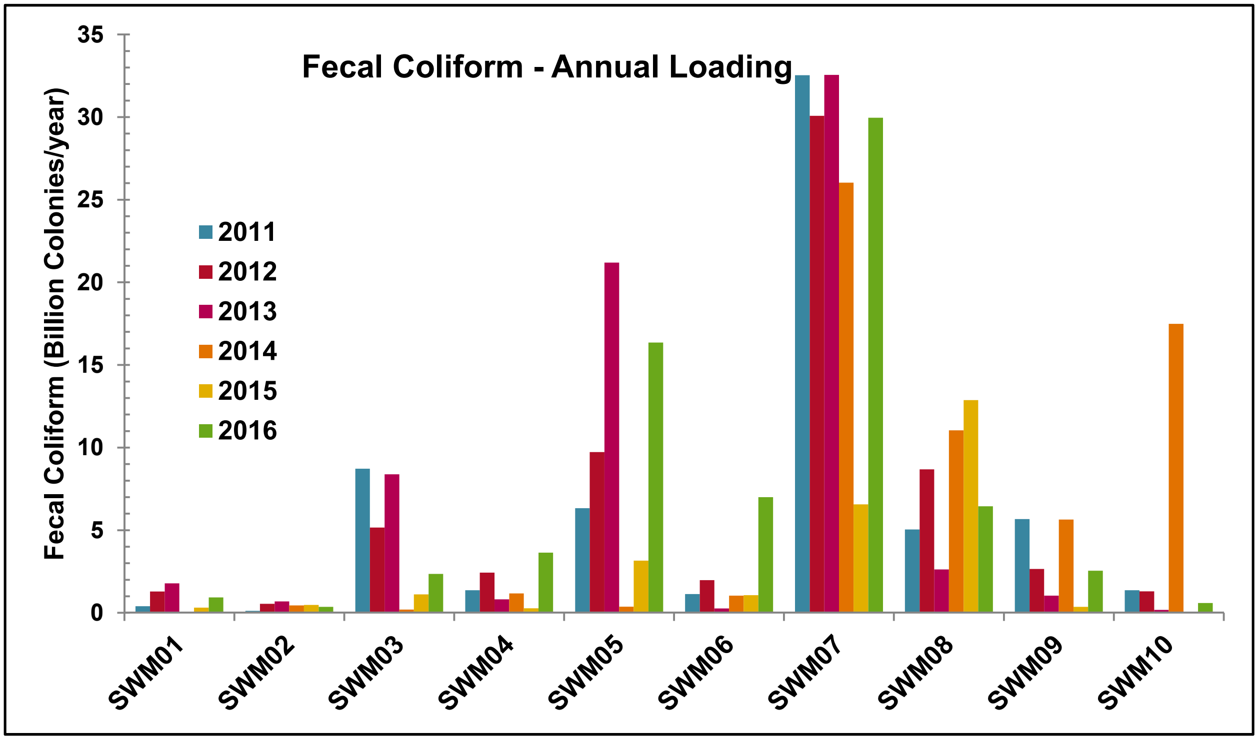


Figure 27. **Fecal Coliform Annual Loading by Monitoring Site.**

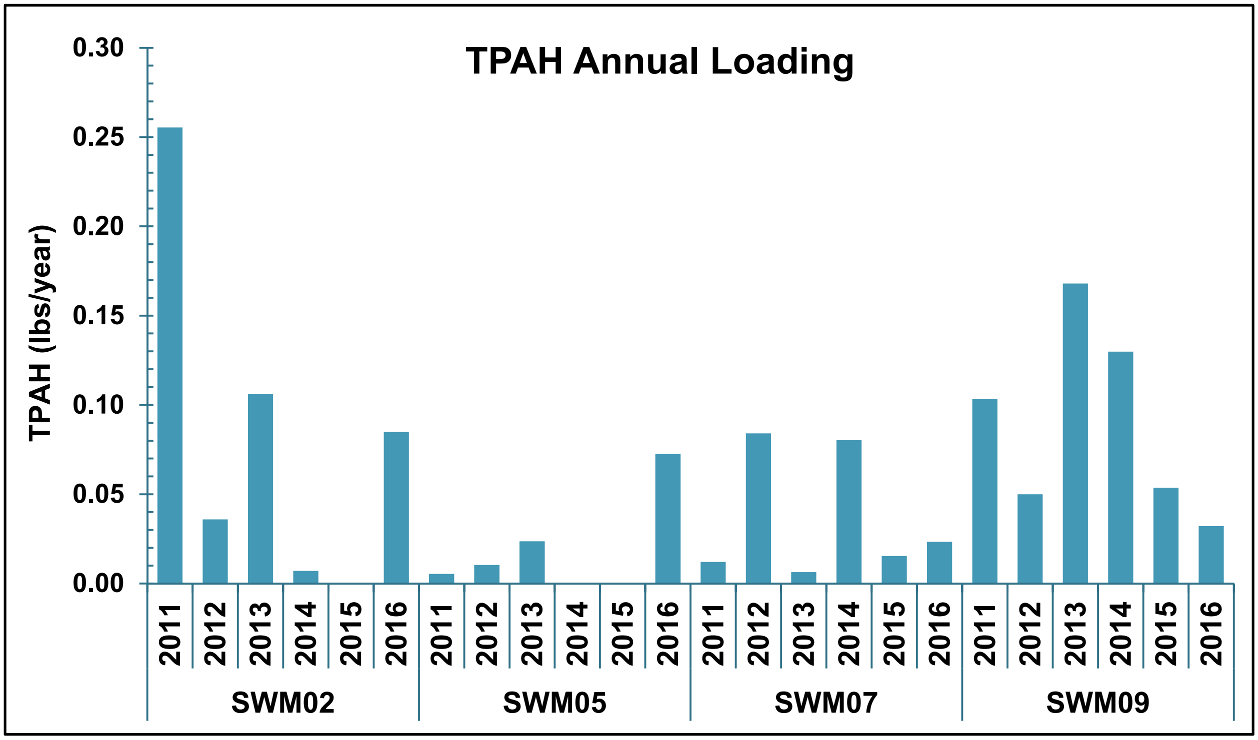


Figure 28. **TPAH Annual Loading by Monitoring Site.**

5.0 Summary and Conclusions

This report presents results from the 2016 monitoring and summaries the results for the entire six years of sampling conducted under the APDES permit-specified monitoring program. The monitoring program began in 2011 and included sampling at ten representative locations during four storm events each year for a total of 24 storms. Results from this sampling effort allow an initial screening by comparison against all available water quality standards. When benchmark exceedances were identified, the intent was that MOA would determine likely causes and take actions if necessary such as education and outreach or implementation of additional BMPs to reduce the pollutant loading.

Exceptions in the 2016 sampling effort included no sample collection at SWM01 during the second storm as a result of zero flow at this outfall during this event. There were also a few minor exceptions where a parameter such as turbidity was run in the field but was not recorded on the field data log form. Other than these exceptions, the sixth year of monitoring successfully sampled all parameters specified for each of the ten selected outfalls during all four monitoring events meeting the permit requirements.

Overall, there were no significant findings from any of the years 2011 through 2016 that would suggest the need for any special investigations to be initiated at this time. With the exception of fecal coliforms; high TSS/turbidity detected at one location in 2011 and a separate location in 2015; and high aromatic hydrocarbons at one location during one storm event in 2012, concentrations of target constituents in the grab samples and in the field measurements were all well within the range of expected values. Although AWQS criteria were commonly exceeded in the fecal samples, concentrations were not considered extraordinary and warranting further investigation at this time. Also, it should be noted that AWQS criteria used in this report were for benchmark comparisons purposes only and that any exceedances noted are not considered water quality or permit violations.

The high TSS and turbidity concentrations that were noted at one location during two storm events in 2011 and at a separate location during one storm event during 2015 were all believed to be due to commercial construction activities within the subbasin at the time of sampling. Since those times, no high turbidity or TSS concentrations have been seen at either location. In 2012, the one high hydrocarbon sample that was collected adjacent to the Seward Highway is believed to have originated from a gasoline-type source as there was no indication that it originated from a combustion source and BTEX levels in diesel fuel are typically much less. A sample taken at the same location three days later during the subsequent storm event did not detect any volatile hydrocarbons. The field crew contacted the MOA as soon as a problematic result occurred to allow the MOA an opportunity to perform a site inspection and potentially identify the source of the problem. In 2016, a high level of dissolved copper was noted at one location during one storm event, but the cause of this anomolous high value could not be determined. Also, it should be noted that monitoring for copper is not a permit requirement, but was added in 2016 to provide supplemental information for each of the outfalls. No anomolous field measurements were noted in 2013 or 2014 that warranted further investigation.

Data were examined for station, yearly, and seasonal trends to determine if particular locations have pollutant problems, whether significant differences were seen on a year-to-year basis, and whether there were seasonal influences that could be discerned in the data. One location that stood out was SWM07. This location consistently had the highest BOD_5, fecal coliform, TSS, and turbidity concentrations. Although BOD_5 was consistently high, the DO levels were higher than a majority of other locations. High fecal coliform levels at SWM07 were reflected in the annual loading estimates for that location. This site exhibited the highest annual loading of fecal coliform for five of the six years of the study. The reason for the high levels of fecal loading at this site is unknown as it drains a commercial use area located between the two lanes of the Seward Highway north of Chester Creek and south of 12th Avenue (refer to Figure 7).

Other trends include a general seasonal trend in temperature, DO, and fecal coliform. Temperature and fecal coliform were highest during the mid-summer months and lower in early summer and fall. DO concentrations had an inverse relationship with lower values in the summer and higher values in early summer and fall as would be expected since colder water has a higher DO saturation level.

Hydrocarbon concentrations were examined in four of the ten subbasins that represented commercial/industrial land use category. Two of the locations had OGS units and two did not, which allowed comparisons to be made on their efficacy for stormwater pollutant control. Based on TPAH levels, no differences could be attributed to an OGS unit, although the measurement of TPAH may not be the best parameter to be used in this examination. In general, with the exception of two samples with elevated BTEX concentrations, all aromatic hydrocarbon concentrations were below detection levels for all six years of monitoring. TAqH concentrations were also very low and, when compared to ADEC’s TAqH water quality standard, were all well below the criteria. Annual hydrocarbon loading was also very low at all four locations.

6.0 References

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