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Source Assessment of Fecal Coliform in Anchorage Storm Water: 2002 Data Report

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MUNICIPALITY OF ANCHORAGE
WATERSHED MANAGEMENT PROGRAM

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WATERSHED MANAGEMENT

Office of Planning, Development & Public Works

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Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
BMP	best management practice
col/100 ml	colonies of fecal coliform per 100 milliliters of water
DPW	Department of Public Works
EPA	United States Environmental Protection Agency
GIS	geographic information system
ml	milliliter
MOA	Municipality of Anchorage
MPN/gm	most probable numbers per gram
SWMM	storm water management model
WMP	Watershed Management Program
WMS	Watershed Management Section

Introduction

The information described in this data report was collected by MWH, under the Department of Public Works (DPW) WMS. Data collection was performed to meet design parameters defined in the Source Assessment of Fecal Coliform in Anchorage: 2002 Design Report, located in Appendix A. Background information is also available in Municipal Assessment Documents Apr01005 and Apr01006 (WMS, 2001a, 2001b). The following subsections summarize the project background, purpose, primary data collection objectives, limitations of data collected, and report organization.

Project Background

The presence of some types of pathogens or microbes may indicate a potential risk for water contamination, while other microbes are pathogens themselves (i.e., they are known to cause disease). Analytical methods for determining the presence of harmful microbes and pathogens commonly rely on the fecal coliform family of bacteria. This family includes total fecal coliform, fecal coliform, and *Escherichia coli* (E. coli). Although each of these can indicate the presence of fecal wastes in surface waters, fecal coliform is the most commonly used indicator for detecting the presence of harmful bacteria, protozoa, and viruses. Fecal coliform is traditionally used to set standards for drinking water, aquatic food consumption (e.g., shellfish), and water contact recreation. Fecal coliform studies encompass a large body of literature, most of which indicates that fecal coliform bacterium are ubiquitous in watersheds (EPA, 2001; EPA, 1983; FHA, 1985).

Fecal coliform exhibit extreme variability both spatially and temporally. Unlike other conventional water quality parameters, fecal coliform bacteria are living organisms. They multiply quickly when conditions are favorable for growth and die in unfavorable conditions. Fecal coliform bacteria are not homogeneous in the water column or sediments. Because bacterial concentrations depend on specific conditions to remain viable, survive, and grow, and these conditions may change rapidly, fecal coliform bacteria counts are not easy to predict.

In the urban environment, fecal coliform bacteria are produced from sources such as waterfowl, wildlife, pets, humans, soils, and plants (Schueler et. al, 2000). Some urban areas can concentrate fecal coliform, causing potential water quality concerns (EPA, 2001).

Fecal coliform may be mobilized during snowmelt or in rainfall runoff from landscaped areas. Runoff from these events may mobilize fecal coliform or fecal coliform adsorbed to sediment, washing the coliform into the storm drain system. A portion of the fecal coliform load may be washed into receiving waters entrained in storm water runoff; however, catch basins and obstructions within the storm drain systems may concentrate fecal coliform, which can then be mobilized during higher intensity runoff periods.

In addition to the daily loading of fecal coliforms from animal and pet defecation, fecal coliform can remain viable or grow colonies in storm drain systems under favorable conditions. Conditions favorable for bacterial survival or growth include:

- Dark areas
- Moist/wet areas
- Favorable temperatures
- Areas with nutrient availability or that are nutrient rich

Anchorage storm drains have dark, moist, and nutrient rich areas. A literature search was conducted to determine if they also have favorable temperatures for coliform viablity. According to the EPA, a temperature of 5 ^{o}C (41 ^{o}F) will stop fecal coliform from growing but will not prevent re-growth, kill, or inactivate the bacteria if temperature is increased (Almodovar, 2002). Additionally, nutrient availability may increase or decrease the temperature at which fecal coliform can form colonies or re-grow (Smith et al., 1994). Potential for fecal coliform growth in Anchorage storm drains exists primarily when warmer summer temperatures are present or when groundwater temperatures can reach a maximum of 9 ^{o}C (48 ^{o}F). Studies of ground water temperatures in Anchorage indicate temperatures can range from 3-9^{0}C (37-48 ^{o}F), with a median value of 4.5^{0}C (40 ^{o}F) (Glass, 1999). Given the available literature information, Anchorage storm drain temperatures are likely to be at a temperature that can maintain the viability of fecal coliform but may not be able to sustain significant fecal coliform growth.

Project Purpose

This study is intended to build on work documented previously in the Fecal Coliform in Street Sediments Design Report and Data Report (MOA, 2001a). Data collected from street sweepings showed that fecal coliform concentrations were generally very low in street sweepings, with the overall median value below detection limits. The majority of samples with detectable concentrations were located in residential areas (MOA, 2001a).

This source assessment data report was conducted to quantify fecal coliform concentrations in residential outfall discharge and estimate contribution from select source areas. Specific data collection objectives were to characterize and assess concentrations of fecal coliform 1) in pipe and ditch system runoff, including curb-gutters and system outfalls, and 2) to collect data by season, in both spring snowmelt runoff and summer rainfall runoff.

Problem Statements

This data report is intended to present information critical to answering the following watershed management questions about fecal coliform in residential outfall basins:

- What are the sources and concentrations of fecal coliform during snowmelt runoff in Anchorage?
- What are the sources and concentrations of fecal coliform during rainfall runoff in Anchorage?
- How do these concentrations vary?

Data Limitations

This project was performed at an exploratory level, and focused only on fecal coliform sources from residential streets, landscaped areas, and storm drain systems.

Data acquired in this study pertain to fecal coliform concentrations in Anchorage storm water runoff in spring and summer of 2002. Collected data represent unique climate conditions during spring and summer of 2002, and can be calibrated only approximately to average Anchorage conditions. Similarly, these data can be extrapolated only to areas with similar climatic conditions, street maintenance practices, and pet and wildlife populations. Given the limitations of the study, however, it is believed that the results of the investigation are reasonably representative and useful in meeting WMS needs.

This data report is meant to describe the quality and character of the collected data only, in the context of the 2002 design document (Appendix A). The data report contains validated data (data that have been determined to be reasonably free of error) that can be used, as appropriate, in analysis to answer watershed management questions. The specific intent of the data report is to summarize the history of data collection and validation efforts and to graphically present principal data characteristics. The data report also makes available the collected, validated data.

This investigation was conducted with the participation and funding of the WMS Project Management and Engineering Division of DPW. WMS provided review and oversight of the sample collection process; MWH and CH2M Hill performed data collection and reporting.

Report Organization

This document is organized in the following manner:

Introduction. Summarizes the context of the 2002 data report, discusses data limitations, and describes the organization of this document.

Data Collection. Briefly describes the methods and logic used in the 2002 data collection effort.

Data Summary. Describes data collected.

References. Contains the references cited in this report.

Appendix A. Contains the Source Assessment of Fecal Coliform in Anchorage: 2002 Design Report.

Appendix B. Presents a tabulated account of the validated data by sample station, land use data, and a photo log.

Appendix C. Presents a brief description and results of modeling Anchorage rainfall.

Appendix D. Presents a annotated bibliography and data results from previous storm drain investigations of fecal coliform in Anchorage.

All figures and tables follow the written text where they are mentioned. Selected field observations and data tabulations are attached.

Data Collection

This section summarizes the purpose for data collection, and how the data were reported and used to represent fecal coliform source area, and concentrations in snowmelt and rainfall runoff.

Data Purpose

MOA intends to use project data to potentially define fecal coliform source areas and track fecal coliform through residential outfall basins. Identifying potential fecal coliform source areas and loading characteristics will help understand the contribution of fecal coliform discharging from the storm drain system into receiving waters. Project data will be used as a basis for developing guidance for storm water management model (SWMM) use and defining areas that could potentially benefit from implementing BMPs.

Data collection design and parameters were chosen to address critical system elements within a systematic context. Identified critical system elements include the following:

- Land use characteristics (e.g., pipes/ditches, streets, landscaped uplands, outfall basin presence) of residential areas
- Physical characteristics (e.g., slope, infiltration rates, detention storage,) of land use characteristics
- Climatic conditions between and during a sampling event (e.g., number of days of dry and wet weather, and rainfall intensity and duration).
- Order of magnitude, mean concentration, and source area contributions of fecal coliform in snowmelt discharge (outfall)
- Order of magnitude, mean concentration, and source area contributions of fecal coliform in rainfall runoff discharge (outfall)
- Order of magnitude and source area contributions of fecal coliform from streets and landscaped residential areas (curb-gutter)
- Order of magnitude and mean concentration of fecal coliform in the piped systems sediment (catch basins)
- Order of magnitude and mean concentration of fecal coliform in groundwater baseflow

These elements may be representative of the magnitude of storm drain contribution to fecal coliform levels in area streams and the sources of those concentrations.

Sampling Locations

Figure 1 shows the sampling stations used during data collection and Table 1 tabulates sampling performed at each of these sites.

Table 1 Sampling Stations and Analysis Conducted

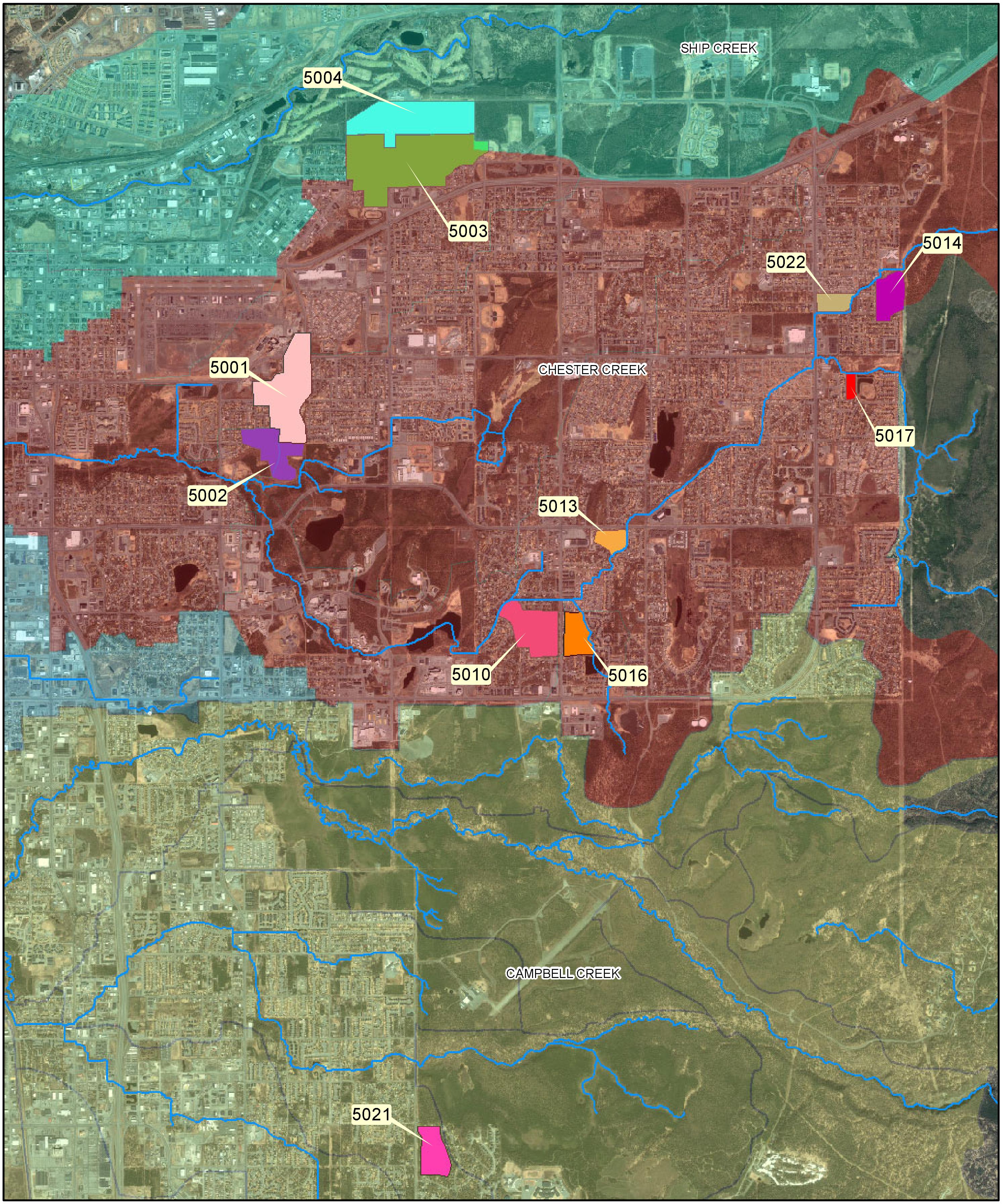
Outfall Basin No. (Figure 1)	Snowmelt Runoff Fecal Coliform	Rainfall Runoff Outfall Fecal Coliform	Rainfall Runoff Curb – Gutter Fecal Coliform	Dry Weather Baseflow Fecal Coliform	Dry Weather Catch Basin Fecal Coliform
5001	√	√	√		√
5002	√	√	√		√
5003	√	√	√		√
5004	Samples collected at site 5004 were discounted after sampling because field conditions did not allow collection of samples from storm drain outfall				
5010				√	√
5013				√	
5014				√	
5016				√	
5017				√	
5021	√				
5022	√				
5023	√				
5024	√				

SPATIAL AND TEMPORAL SELECTIONS

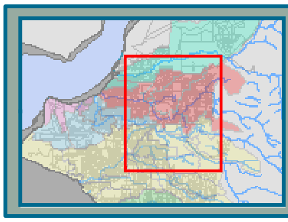
Data were collected to represent spatial variation in fecal coliform loading. Using the 2001 street sediment study, residential areas were targeted because they exhibited detectable concentrations of fecal coliform in street sediment (WMS, 2001a). A general partition was also made spatially between piped versus ditched residential areas to see if different runoff processes resulted in variation of coliform concentrations. Temporal sampling was made between spring melt events and summer storm events. Summer storms were divided between early and late summer rainfall.

LAND USE CHARACTERISTICS

Outfall basin delineation was performed by analysis of existing basin boundaries and adjusting as necessary to reflect field conditions. Land use features within the basins of the selected sites were determined by use of previous geographic information system (GIS) attributes and modeling parameters from 2001 SWMM work for WMS (WMS, 2001b). Selected areas were analyzed using MOA 2000 information on land use. The most current GIS layer for piped systems from MOA determined piped and ditched areas. Areas without piped systems were assumed to be ditched. Landscaped and forested uplands were determined in 2001 using



October 10, 2002



NORTH

4,000 2,000 0 Feet

Anchorage Watershed Management

MOA Watershed Mapping

Anchorage Bowl

Figure 1:
Sample Stations by Outfall Basin

IKONOS satellite imagery. Appendix B, Attachment B-2 contains the specific land use characteristics of each basin.

Data Collection History

All samples were collected between the last week in March and the last week in September, in accordance with the design document (Appendix A). The first snowmelt runoff was observed in mid-March 2002. Data collection began in March. Generally, snow and ice had started to melt from urban streets but significant accumulations of snow still remained on residential streets, and in yards and vegetated areas. Collection efforts began in July to document rainfall runoff, dry weather baseflow, and catch basin sediment concentrations of fecal coliform. Data collection ended September 26, 2002. During spring break-up and summer, snowmelt and rain off samples were collected for flow and fecal coliform. All samples were collected at the selected locations listed in Table 1.

A total of 172 water and 6 soil fecal coliform samples were collected and submitted for laboratory analysis. Collection of 15 duplicate water samples and 6 duplicate catch basin sediment samples brought the total number of samples analyzed for fecal coliform to 187. Particle size distribution and percent moisture samples were analyzed from the catch basin sediment samples. Laboratory and field data are included as an attachment in Appendix B.

Sampling Methods

Sampling methods for collecting water and sediment samples generally adhered to the design (Appendix A). Discussions concerning changes to the design plan and thus the sampling methods are described in detail in the section on Variation to Design.

Sampling was restricted to a limited area of MOA, the Anchorage Bowl, and lower Hillside Area.

Snowmelt Sampling

All snowmelt runoff samples were collected at the basin outfalls. All samples were collected as “grab” samples using a Teflon® dipper cup and then poured into laboratory-provided 100 ml fecal coliform containers.

Snowmelt runoff sampling was also conducted to measure diurnal variability at three sampling stations. Visual observations in addition to discharge measurements were used to determine if increased flow and fecal coliform concentrations are expected as heating occurs over the course of a day. Grab samples were collected at each site three times per hour at 11am –12pm, 1pm-2pm, and 3pm – 4pm. The three samples collected over each hour were then flow-weight composited and submitted to the laboratory for fecal coliform analysis.

Curb-Gutter Sampling

Samples were collected during storm events in laboratory-provided 100 ml fecal coliform containers. During all rainfall runoff events, curb-gutter samples were collected just upstream of six to eight catch basin inlets in each curb-gutter. A single grab sample consisted of a flow-weighted composite of water from the six to eight locations. This technique was employed to ensure that sampling represented street and landscaped area runoff within the outfall basin. Using this technique, sample collection at the curb-gutter could be compared to samples collected at the outfall to help quantify coliform loading and transport characteristics through storm drain systems. At the end of storm events, grab samples were composited or submitted as grab samples, depending on the type of sample submitted for laboratory analysis (see variations from design).

MEASURING DISCHARGE IN THE CURB-GUTTER SYSTEM

To calculate discharge, depth of flow in the gutter was measured perpendicularly at the curb and gutter interface. Figure 2 illustrates the point of the depth measurement. Using the MOA standard specifications (MASS), Design Criteria Manual, specifications for curb and gutter design standards were incorporated in Manning's equation to develop a table that could be used in the field to calculate discharge volume based on the depth of flow in the gutter (Table 2).

Figure 2 Measuring Discharge Within the Curb-Gutter System

Table 2 Depth to Discharge Field Chart

Water Depth in Gutter (inches)	Discharge (gal/s)
0	0.00
0.3	0.02
0.6	0.12
0.9	0.36
1.2	0.78
1.5	1.45
1.8	2.34
2.1	3.99
2.4	6.55
3	14.30
3.6	26.45
4.2	43.72
4.8	66.92
5.4	96.95
6	134.06

Outfall Sampling

Samples were collected during rainfall events in laboratory-provided 100 ml fecal coliform containers. At the end of each storm event, grab samples were composited or submitted as grab samples, depending on the type of sample submitted for laboratory analysis, as discussed in further sections.

MEASURING DISCHARGE AT THE OUTFALL

The study outfalls and ditches were sampled at the same location over the course of this assessment. Discharge was measured at the outfall for all snowmelt runoff grab samples. Discharge was measured and determined for flow weight compositing of collected samples for rainfall runoff. Field flow data were collected using either timed gravimetric, slope-hydraulic radius, or open channel flow methods. The slope-hydraulic radius method consists of using Manning's equation to relate cross-section, water depth, water surface slope, and a roughness factor to flow. Manning's equation is:

$$Q = \frac{KAR^{2/3}S^{1/2}}{n}$$

Where:

Q = Flow

K = A unit constant

A = Cross-sectional flow area

R = Hydraulic radius

S = Slope of the hydraulic radius

n = Manning roughness coefficient

Relating depth measurements in culverts to Manning's equation is common practice in storm water studies and is a practical way to obtain estimates of discharge.

Sample Compositing

Samples for this project were collected as "grab" samples or single point and as composite samples. Composite samples are necessary to effectively obtain event mean concentrations and understand the true loading characteristics of fecal coliform compared to hyetographs or runoff hydrographs.

Collected samples were composited based on discharge and a spreadsheet was used for volume/flow compositing.

The formula for sample compositing was:

$$\text{Quantity of grab sample to add to composite (ml)} = \frac{\Sigma \text{ All Discharge Measurements}}{\text{Individual Discharge Measurement}} \text{ X } 100$$

Variations from Design

Several aspects of the original project design were changed to meet field conditions and to obtain a better understanding of fecal coliform source areas and sampling methods. These variations included what type of samples and where (spatial network), when (temporal), and how many samples were collected. The following sections discuss these changes.

SAMPLE TYPE VARIATIONS

The project design called for composting three to six grab samples representing the rising, peak, and falling limbs of a rainfall runoff hydrograph. Changes in sample type were adjusted to meet project objectives and constraints. After each rainfall runoff sampling event, data were analyzed and the sampling regime was modified to answer questions raised within the existing data set. The following paragraphs briefly describe modifications made to the sampling regime and type of sampling performed during each sampled rainfall runoff event.

July 23-24, 2002 – This event was sampled primarily by MWH staff. Project scientists at MWH noted the importance of sampling this event due to its potential to be the highest energy event that had occurred after an extended period of dry weather. All samples collected at outfalls were submitted as grab samples for laboratory analysis. All samples collected at the curb-gutter were a composite of six to eight curb-gutters as they discharged to catch basin inlets. Each composite was submitted as a grab sample representing street and lawn to street runoff from the entire basin at a single point in time.

August 8, 2002 – Due to the long duration of precipitation events in Anchorage, physically sampling an event that can last over 24 hours was impractical and confounded by budget limitations. A brief analysis was performed to determine the probability of sampling the peak hour of a storm event, assuming that sampling commences with the first hour of rainfall measuring 0.01 inch in August or September (Appendix C). This was done to investigate the potential for setting sample duration for an event while still capturing the peak of the storm event. Discrete storms were generated from precipitation records for Anchorage International Airport using the EPAs SYNOP model with a specified inter-event time of 14 hours. Hourly precipitation data were available for 19 years for August and September. For all storms, peak intensity occurs within the first hour in 34 percent of the storms and over 50 percent of the storms experience their peak hourly intensity within the first 4 hours. Based on this analysis, the sampling was to commence within the first hour after rainfall intensity measured 0.01 inches and was to continue for 6 hours (the time frame when approximately 60% of all storms experience their peak intensity).

The August 8 rainfall runoff event was sampled for 6 hours at all selected piped storm drain outfall basins. Results from the initial sampling event in July implied that an increased effort should be placed on sample frequency and more care in flow-weighting and composting samples. Additions to the original design scheme included:

- A total of 6-hours sampling despite storm length
- Increased sample frequency, with completion of 1 sample round per 30 minutes
- Grab samples collected randomly to compare results from composite sampling

September 24 and 26 – To test variability detected in the first two sampling efforts on July 23-24 and August 8, and to continue to capture seasonal and source area information, the sample regime was reconstructed for the last two storm events as part of a variability study. The purpose of the variability study was to identify and compare fecal coliform concentrations at 1) the curb-gutter inlets to the outfall and 2) composite sampling to grab sampling. Previous data implied that the concentration at the curb-gutter was greater than the outfall (combined flow) of the basin. The data also suggested that grab samples were subject to greater variability then true composite sampling and were less predictive of the influence of the hyetographs and hydrographs on sampled concentrations of fecal coliform.

Outfall Basin 5001 was used to test variability. Sampling was conducted during a 2-hour high intensity period on September 24 (0.11 inches/hour) and a 2-hour low intensity period on September 26 (0.03 inches/hour). Samples were collected synchronously and continuously at the curb-gutter and outfall to compare fecal coliform concentrations between grab and composite sampling and to compare fecal coliform concentrations between curb-gutter sampling and outfall sampling.

Composite samples consisted of continuously collected grab samples poured into a 1-gallon bucket over a 10-minute period. At the end of the 10-minute period, a well-mixed 100-ml sub-sample was collected from the 1-gallon bucket. This method of compositing had a higher resolution than the method used on August 8, when discrete grab samples were collected at 30-minute intervals, flow-weighted and combined in a 100 ml sample bottle. The objective was to provide continuous concentrations of fecal coliform over time at both the curb-gutter and the outfall. At the mid-point (5-minutes) of each 10-minute composite interval, a discrete grab sample was collected to compare sample techniques. Each grab and composite sample was then submitted to the laboratory for fecal coliform analysis.

SPATIAL NETWORK VARIATIONS

Snowmelt Runoff – In the project design, snowmelt runoff was selected to be sampled at the outfall of four-piped storm drain systems and two ditched storm drain systems. Sample site 5004 could not be sampled at the outfall because it could not be located and was assumed to be buried under snow or draining to military property. Therefore, the sample was collected on the street surface. Samples collected at this site are not considered representative for comparison with other sample sites and are not presented as part of the data summary.

Rainfall Runoff – In the project design, both piped and ditched sites were selected for sampling rainfall runoff. When field activities were underway, collection of samples from piped systems demanded the use of all the available personnel.

Sampling locations were originally intended to represent a random distribution of residential outfall basins throughout the Anchorage area for both piped and ditched storm drain networks. However, no samples were collected at site 5003 during the July 23-24 storm because the outfall was submerged and a representative water sample could not be collected.

Temporal Variations

Prediction of the magnitude and duration of a precipitation event is the limiting factor when conducting a rainfall runoff assessment. Deciding when conditions are representative to begin sampling, the day or hour when the event occurs, the duration of the event, and the availability of personnel to adequately perform the sampling regime requires careful coordination and best professional judgement. These factors caused several adjustments to be made with respect to when sampling took place.

In the design plan, two low-energy (<0.3 inches) and two high-energy (>0.3 inches) events were intended to be sampled. All of the events sampled during this assessment are considered high-energy events, having a total volume greater than 0.3 inches. However, within an individual event, there was periodic high intensity and low intensity rainfall. Observations made from field and laboratory data suggest that climatic conditions leading up to the sampled events and conditions present when sampling an event had a greater bearing on the fecal coliform concentration than overall storm volume.

SAMPLE NUMBER VARIATIONS

Sample numbers varied from the design plan because of adaptations made throughout the course of the project. Table 3 presents the actual sample numbers and period of record at specific sample sites.

Table 3 Samples Collected by Station

Station No. (Figure 1)	Location	Period of Record	No. of Samples
5001	Outfall	3/2002-9/2002	60
5001	Curb-gutter	7/2002-9/2002	52
5002	Outfall	7/2002-8/2002	10
5002	Curb-gutter	7/2002-8/2002	12
5003	Outfall	3/2002-8/2002	10
5003	Curb-gutter	8/2002	4
5004	Outfall	3/2002	1
5010	Outfall	7/2002-8/2002	2
5013	Outfall	7/2002-8/2002	2
5014	Outfall	7/2002-8/2002	2
5016	Outfall	7/2002-8/2002	2
5017	Outfall	3/2002	1
5021	Outfall	4/2002	7
5022	Outfall	4/2002	5
5023	Outfall	4/2002	1
5024	Outfall	4/2002	1

Note: Baseflow and Sediment Catchbasin sampling data are not included in this table.

Catch Basin Sediment – In the project design, storm drain sediments were selected for two sampling rounds. When field activities were underway, collecting the second sampling round of sediment samples was deleted from the sampling program. This change was made as information gained during the first round of sampling prompted more attention to be placed on rainfall events and baseflow sampling.

SAMPLE HANDLING AND ANALYSIS

Composite and grab samples were obtained for laboratory analysis. Laboratory samples were collected using procedures and containers specified in Attachment A. Table 4 contains the constituents analyzed and analytical methods used. All laboratory data, including practical quantification limits for each sample, are documented in Attachment B. At the end of each sampling day, samples were immediately cooled for best preservation and were taken to the laboratory within 24 hours of the sampling event.

Samples were tracked by standard chain-of-custody protocols, and data were reviewed and compiled in a format that would allow refinement of sampling procedures based on updated information. All analytical and field data were compiled and validated, and derived values were calculated at the end of the project.

Table 4 Constituents Analyzed and Laboratory Methods

Constituent	Matrix	Analysis Method
Fecal Coliform	Water	SM9222D
Fecal Coliform	Sediment	SM18 9221E
Particle Size Analysis	Sediment	ASTM D422

Key:
SM – Standard Methods

CT&E Environmental Services, Inc., a local, state-certified analytical testing laboratory, performed all sample analyses. Analytical results were reviewed by CH2M Hill for precision, accuracy, representativeness, comparability, and completeness. The Data Quality Assessment is included as an attachment in Appendix B. The following quality control samples, indicators, and associated documentation were also reviewed: field and laboratory duplicates, method reporting limits, and sample handling documentation.

Data for this project met all validation criteria contained in the Data Quality Assessment, including sample handling, hold-time compliance, and sample preservation (Appendix B). However, project objectives were not met for samples collected on August 8, 2002 and are flagged as suspect. This sample set was cooled and stored for approximately 12 hours after sampling occurred but, samples were found to exceed the temperature objective of 4 °C established for this project, when the associated temperature blank was submitted to the laboratory. According to the EPA, a temperature of 5 °C (41°F) will stop fecal coliform from growing but will not prevent re-growth or kill or inactivate the bacteria if the temperature is increased (Almodovar, 2002). Samples were stored and not taken immediately to the laboratory, therefore, the concentration of fecal coliform for these samples are flagged as suspect.

Data Summary

The data summary presented in this section provides source and data characteristics important for understanding critical system elements and answering watershed management questions. Detailed field reports and validated laboratory data are presented in Appendix B.

Snowmelt Runoff

Samples were collected primarily from five locations during snowmelt runoff and analyzed for fecal coliform (Table 5). Results from 9 of 11 samples from piped storm drains had detectable levels of bacteria, ranging from 3 to 900 colonies/100 ml and with a geometric mean of 40 colonies/100 ml. Results from 7 of 8 samples from ditched storm drains had detectable levels of bacteria, ranging from 10 to 16,000 colonies/100 ml and with a geometric mean of 170 colonies/100 ml.

Table 5 Concentration of Fecal Coliform in Snowmelt Runoff

Date	Piped Storm Drain Site No.			Ditched Storm Drain Site No.	
	5001	5002	5003	5021	5022
3/29/02	0	*	*	*	*
4/2/02	*	*	40	*	*
4/14/02	*	3	*	640	*
4/15/02	100	46	0	440	100
4/17/02	80	*	*	10	*
4/20/02	900	600	700	0	16,000
4/30/02	14	**	**	773	160

Notes:
* – No sample collected because flow was frozen.
** – Sites not sampled on April 30, 2002

Snowmelt runoff in spring is typically a low-energy event, with streets melting first followed by upland areas, such as lawns. Initial melt samples represented the fecal coliform contribution of streets only. Samples collected after April 17, 2002 (mid/late-melt period), represent additional contribution from landscaped upland areas. Data from 2002 snowmelt sampling during street and then lawn-to-street snowmelt runoff are summarized in Table 6.

Data collected from snowmelt runoff show that fecal coliform concentrations were generally low when snowmelt runoff was strictly from streets. Higher concentrations of fecal coliform were collected toward the later part of spring break-up when the origin of snowmelt runoff observed to be primarily from landscaped surfaces (Figure 3). The data generally reinforces the idea that spring fecal coliform sources are primarily from pet and wildlife waste deposited daily on and built up in the snowpack. As the snow melts on landscaped areas the ground thaws and becomes saturated, resulting in runoff from the landscaped areas to the street. From the street the runoff may flow to the stormdrain system, and either deposits a portion of fecal coliform in the catch basins, at obstructions in the stormdrain system, or transports the load to the outfall.

Table 6 Street and Lawn-to-Street Fecal Coliform Values in Snowmelt Runoff in Anchorage–2002

Runoff Source	Collection Period	Piped Storm Drain (col/100 ml)		Ditched Storm Drain (col/100 ml)	
		Geometric Mean	Median	Geometric Mean	Median
Street	3/29 – 4/17	10	40	130	270
Lawn to Street	4/18 – 4/30	270	650	210	470

Snowmelt runoff sampling was also conducted to measure diurnal variability at three sampling stations. Results of this sampling effort are shown in Table 7 and show a general increasing trend of coliform through the afternoon and evening.

Table 7 Diurnal Concentrations of Fecal Coliform in Snowmelt Runoff

Date: 4/30/02					
Time	5001 (col/100 ml)	Time	5021 (col/100 ml)	Time	5022 (col/100 ml)
1200	4	1135	165	1100	74
1430	7	1415	108	1400	123
1630	14	1615	773	1600	160

Fecal Coliform in Snowmelt Runoff-Modeling

To augment the WMS 2001 street sediment study data with the data collected above, a washoff model for fecal coliform in Anchorage snowmelt from landscaped and street lancovers was developed using the 2002 MWH SWMM model.

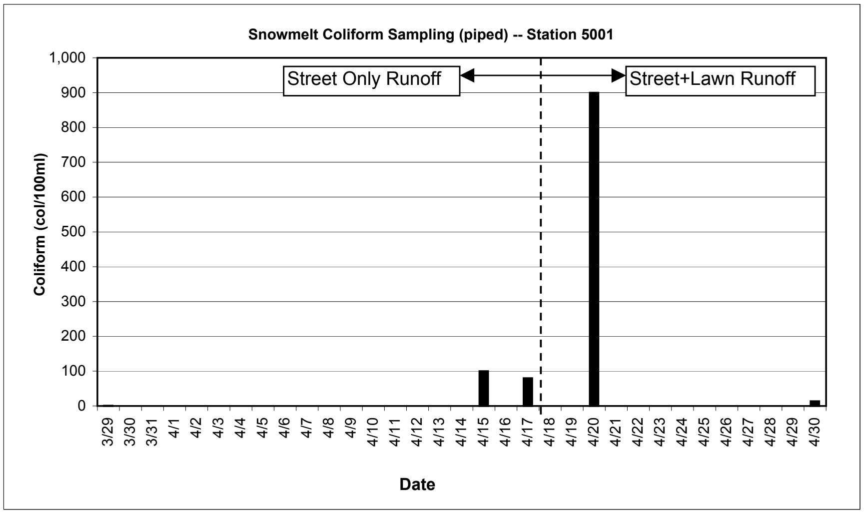
Using data collected in 2001, street fecal coliform were calculated with three street sediment sizes currently modeled in SWMM by using the values in Table 8.

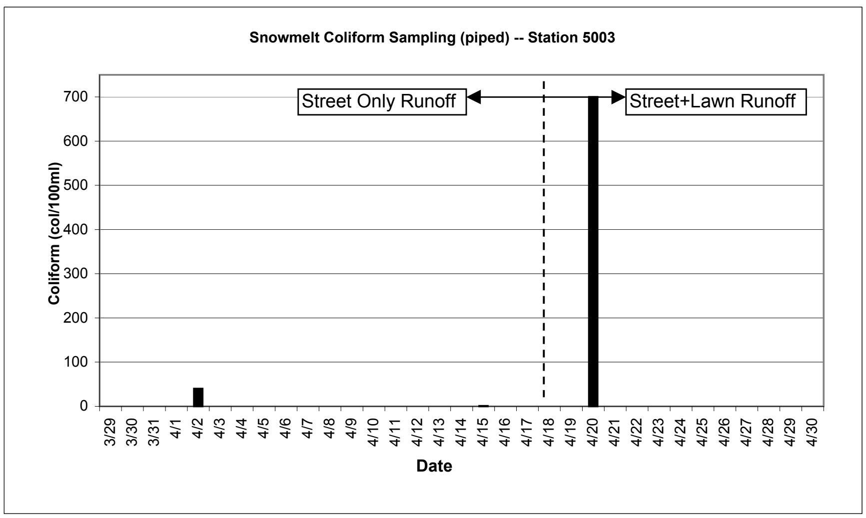
Table 8 Colonies of Fecal Coliform in Relation to Sediment Size

Sediment Size	SWMM Code	Colonies/Gram of Sediment
<100 µm	SED_SML	220
>100 µm < 400 µm	SED_MED	144
>400 µm	SED_LRG	36

Key:
µm – microgram
SWMM – storm water management model

Figure 3
Source Assessment of Fecal Coliform in Anchorage Storm Water: 2002 Data Report
Fecal Coliform Levels in Snowmelt Runoff





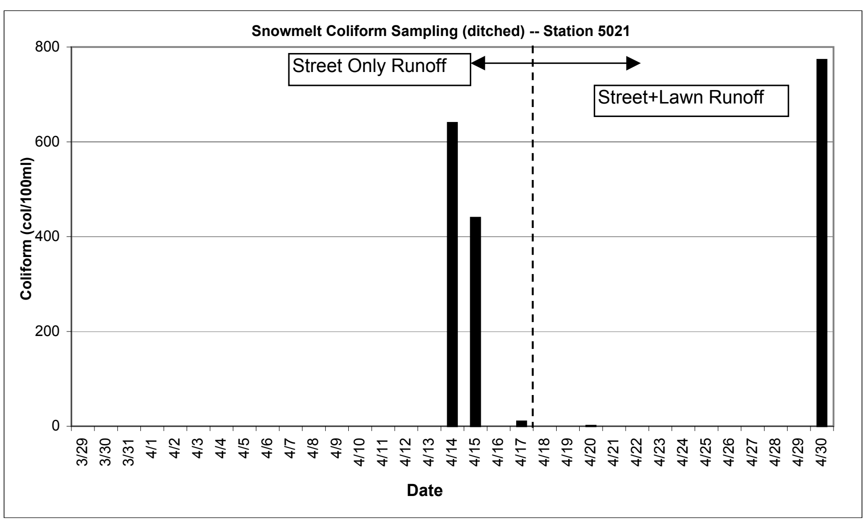
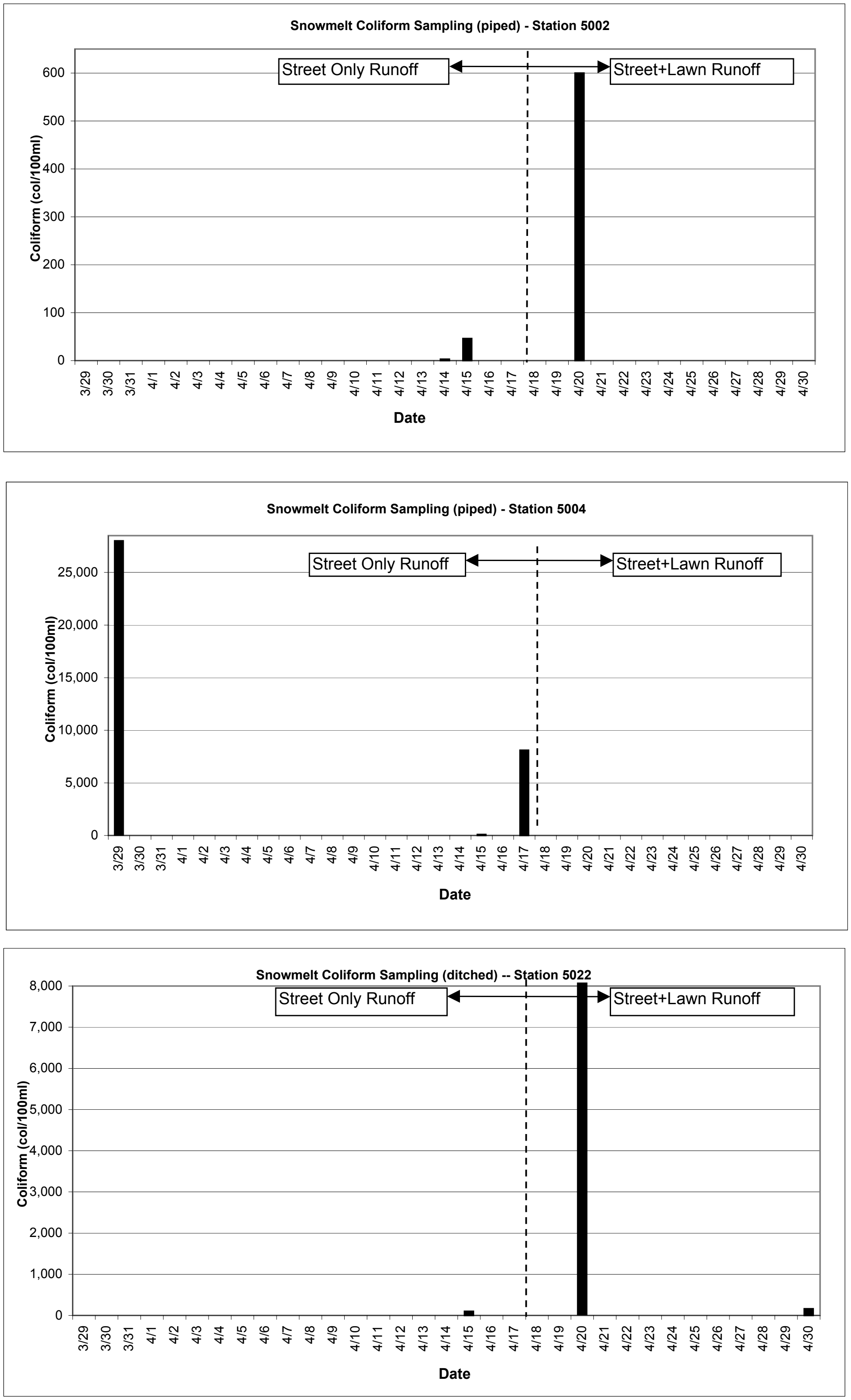


Figure 3
Source Assessment of Fecal Coliform in Anchorage Storm Water: 2002 Data Report
Fecal Coliform Levels in Snowmelt Runoff



The fecal coliform load was not modeled explicitly in SWMM, but rather by using the statistics block of SWMM to produce individual time-step discharge and sediment data for the snowmelt period for street snowmelt runoff only. Fecal coliform concentrations were then applied to this time-step data. For the spring snowmelt period, modeled results for street landcover had a median value of 105 colonies/100 ml.

For landscaped landcovers, fecal coliform was not modeled as being associated with sediment. Therefore, an event mean concentration of 1,000 colonies/100 ml runoff was used. This value was chosen based on snowmelt data collected after April 17, 2002.

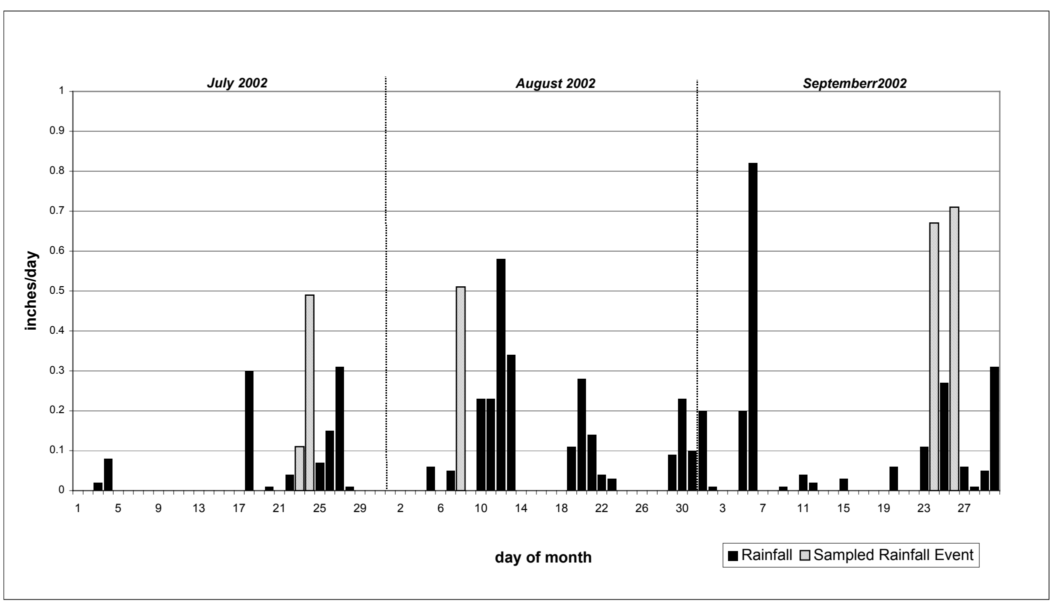
Addition of street and lawn modeled discharge values indicated a similar order of magnitude concentration compared to actual snow sample results.

Rainfall Runoff

As discussed in the Data Collection section, samples include 25 collected from outfalls and 28 collected from curb-gutters within piped storm outfall basins 5001, 5002, and 5003 on July 23-24 and August 8, 2002. In addition, 42 samples were collected from the outfall and 40 samples were collected from curb-gutters within outfall basin 5001 during a variability study on September 24 and 26, 2002. All rainfall runoff sampling took place on piped systems only.

Summer rainfall events for 2002 were typically low-energy events, resulting in only street washoff. Only two or three events per month between July and September resulted in runoff from both landscaped urban areas and streets. The volume of each rainfall event varied and their amounts were calculated by observations made at Merrill Field (Figure 4). Details of each sampled rainfall event are presented in Figure 5.

Figure 4 Precipitation at Merrill Field: Anchorage, Alaska, July – September 2002



Precipitation totals in July were approximately average (1.59 inches). August (3.02 inches) and September (3.58 inches) precipitation totals were higher then average. Generally, all events sampled during this project were considered high energy events (> 0.3 inches).

Typically, seasonal conditions prior to or during each storm event appeared to drive fecal coliform levels obtained when sampling. Most rainfall events were of low intensity and were not observed generating runoff from upland areas such as lawns. Low-energy environment storms may deposit a portion of existing fecal coliform into the storm drain system. A high-intensity rainfall event, assumed to be 0.3 inches or more, occurred two to three times a month from July through September. These high-energy events have a greater potential to transport fecal coliform from upland areas to the street and to the storm drain system. These events also may scour a portion of the deposited fecal coliform and sediment within the storm drain system.

Properties include antecedent conditions before the storm, infiltration, detention storage, and surface roughness of the source sub-areas. Properties of the physical environment appear to have a bearing on the magnitude of fecal coliform concentration observed. Table 9 presents important variables that contribute to the concentrations of fecal coliform found in rainfall runoff.

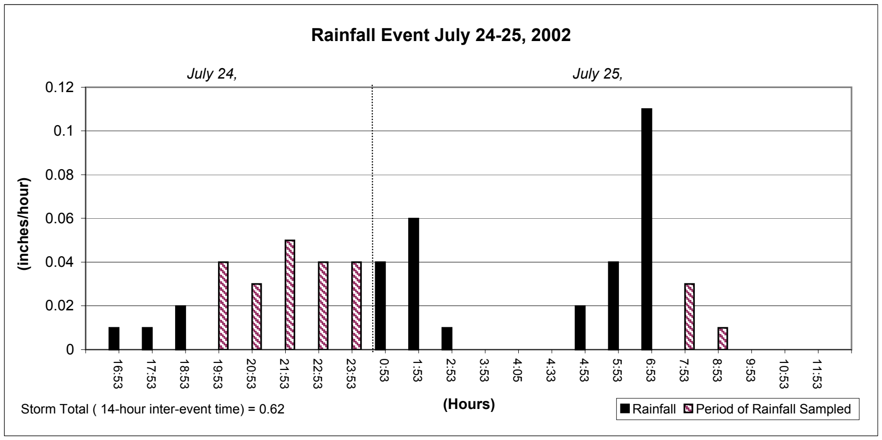
Table 9 Physical Conditions Occurring Between Sampled Rainfall Runoff Events

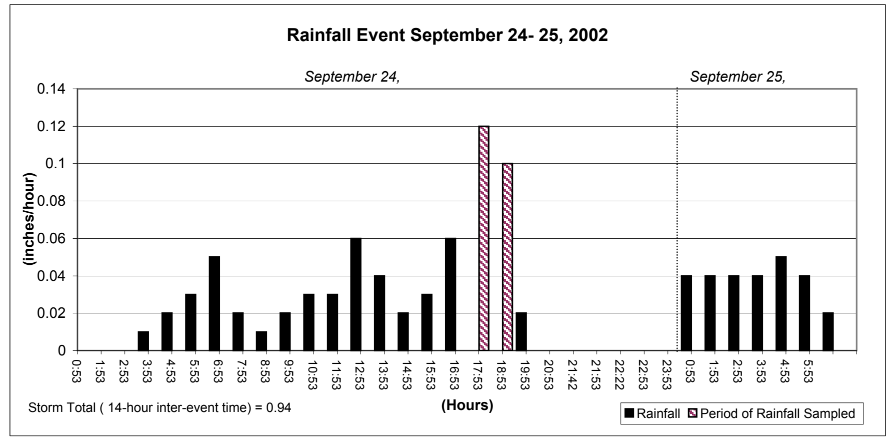
	Units	23-24 Jul-02	08-Aug-02	24-25 Sep-02	26-Sep-02
Total No. of Days between events	Days	1st event	14	45	1
No. of days of build-up prior to sampled event (precip 0-.05 inches)	Days	21	12	33	0
No. of days of washoff prior to sampled event (precip > .05 inches)	Days	1	2	12	2
Precipitation prior to event (inter-event)	Inches	0.45*	0.66	3.90	0.27
High-energy rainfall event prior to sampled event	Inches	0.3	0.31	0.82	0.27
Number of days between high-energy rainfall and storm sampled	Days	5	11	17	1

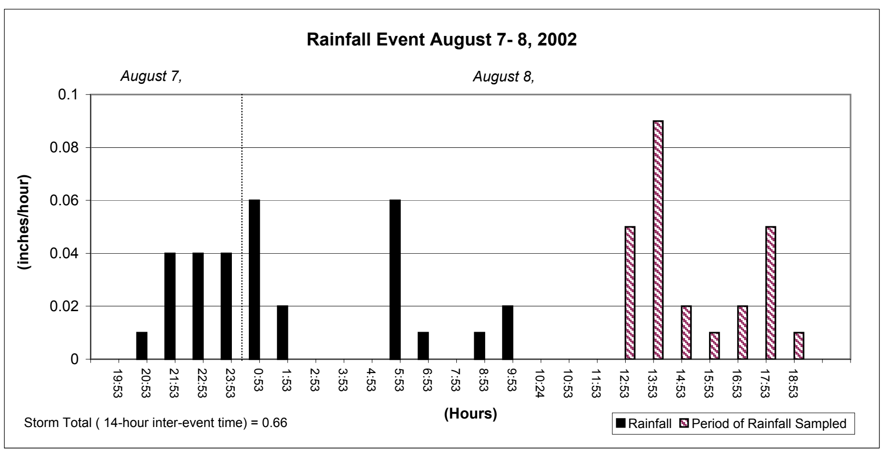
Note:
* – Includes cumulative precipitation for July only.

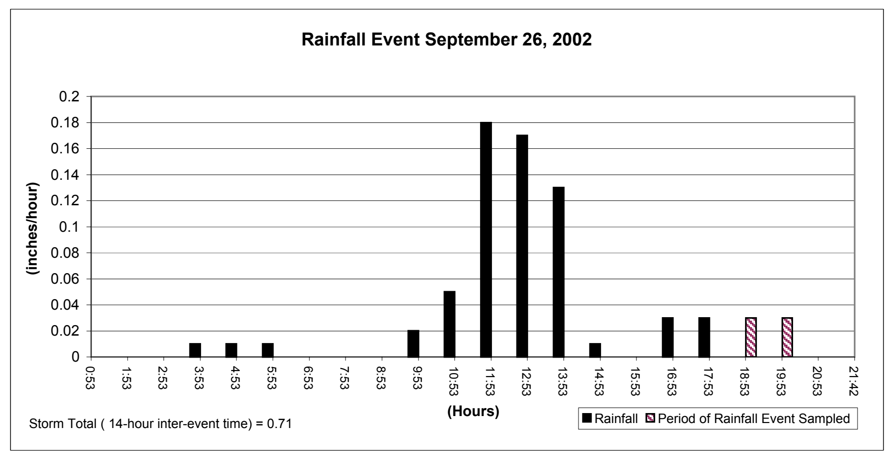
Rainfall runoff sampling was conducted on July 23 and 24, which was the first high-energy rainfall event of the summer, occurring after a period of extended dry weather. Antecedent soil moisture was also assumed to be very low at the time of this storm event. On August 8, antecedent soil moisture conditions had presumably increased due to an increased frequency of rainfall events. Connectivity (overland flow) between lawn and street is apparent during high-intensity rainfall. Frequent rainfall events also increase the antecedent moisture of landscaped areas and thus connectivity to streets. The last two storms were sampled during a period of

Figure 5
Source Assessment of Fecal Coliform in Anchorage Storm Water: 2002 Data Report
Detail of Sampled Rainfall Events









high-antecedent moisture from frequent rainfall events, may have caused the wash off of the majority of fecal coliform load available, or dispersal fecal coliform throughout the outfall basin.

Conditions occurring during a sampling event appear to have an important effect on sampling results similar to conditions that occur between sampled events (Table 10). Data presented below reflect the unique conditions present at the time each rainfall runoff event was sampled.

Table 10 Sampled Rainfall Event Data

	Units	24-Jul-02	8-Aug-02	24-Sep-02	26-Sep-02
Total storm precipitation*	Inches	0.62	0.66	0.94	0.71
Storm duration based on 14-hour inter-event time	Hours	17	24	36	18
Cumulative total precipitation before sampling	Inches	0.53	1.46	7.05	8.92
Amount of precipitation which fell during sampling	Inches	0.25	0.35	0.22	0.06
Length of time storm sampled	Hours	5	6	2	2
Average intensity	In/Hr	0.03	0.03	0.03	0.02
Maximum intensity	In/Hr	0.11	0.09	0.12	0.18
Maximum intensity sampled during storm event	In/Hr	0.05	0.09	0.12	0.03

Key:
In/Hr – inches per hour

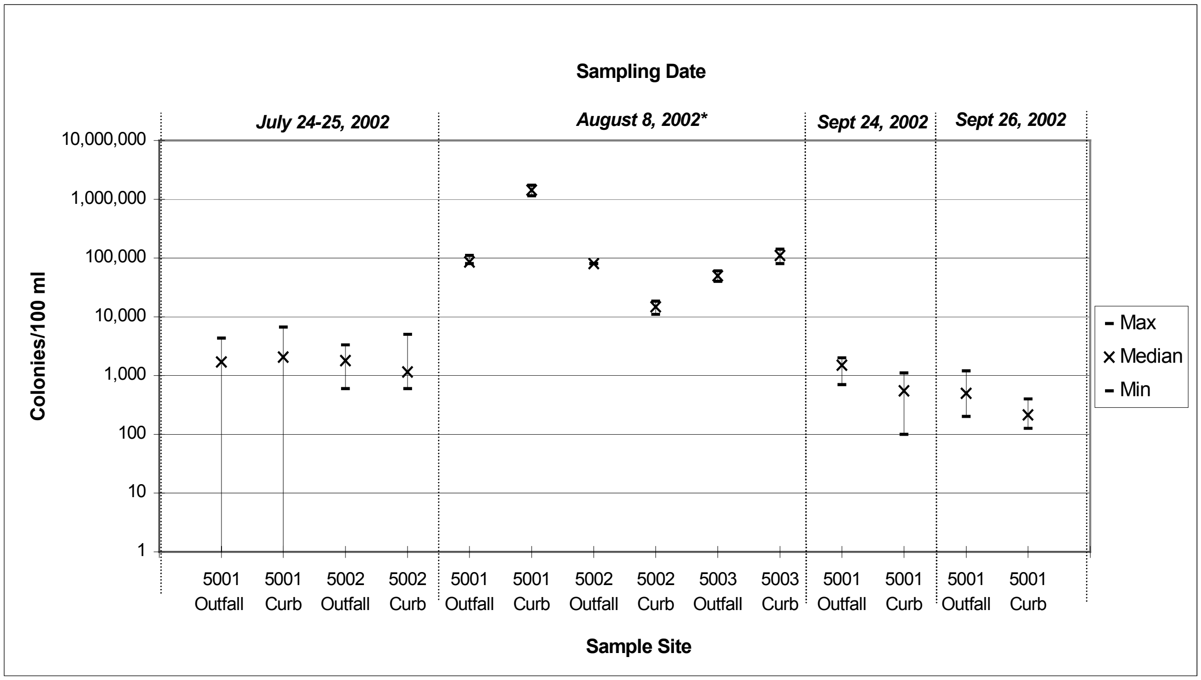
Note:
* – Total storm precipitation is based on a 14-hour inter-event time.

Data collected from rainfall runoff show that fecal coliform concentrations were highly variable with the overall median of 1,100 colonies/100 ml. Figure 6 illustrates basic statistics for all sample locations by storm event. All sample data with the exception of data for July, are presented using results from composite samples. Table 11 presents the type of sampling, number of samples collected, and range for each rainfall runoff event.

As shown in Table 12, geometric mean fecal coliform concentrations in the August samples were two to three orders of magnitude greater than the mean of sampling values reported from July and September.

On a seasonal scale, fecal coliform levels in rainfall runoff emulated historical stream fecal coliform trends. Figure 7 presents the median and geometric mean for all outfall sampling (discharge point of the outfall basin) from April through September 2002. Four years of fecal coliform counts at selected urban water quality monitoring stations in Chester Creek are depicted in Figure 8. The plot indicates that relatively high levels of bacteria (10^{-3} colonies/100 ml) occur during high rainfall periods in late summer. Lesser peaks in late winter correspond to spring breakup. Winter low-flow periods and dry weather periods after breakup and in late fall typically have lower fecal coliform levels.

Figure 6 Fecal Coliform Levels in Anchorage Urban Storm Water by Rainfall Runoff Event



Note:
* – Samples collected on August 8, 2002 are flagged as suspect based on project objectives.

Table 11 Fecal Coliform Levels in Anchorage Urban Storm Water by Rainfall Runoff Event

- **Rainfall Runoff Event: July 23-24,2002**

Sample Type/Method	No. Samples	Range (colonies/100 ml)
Outfall/Grab	11	0-4,300
Curb-gutter/Grab	11	600-6,700

- **Rainfall Runoff Event: August 8, 2002**

Sample Type/Method	No. Samples	Range (colonies/100 ml)
Outfall/Composite	6	40,000-110,000
Outfall/Grab	4	8,850-50,000
Curb-gutter/Composite	6	11,000-1,560,000
Curb-gutter Grab	4	4,100-90,000

- **Rainfall Runoff Event: September 24, 2002**

Sample Type/Method	No. Samples	Range (colonies/100 ml)
Outfall/Composite	12	700-2,000
Outfall/Grab	12	500-2,900
Curb-gutter/Composite	12	200-1,100
Curb-gutter Grab	12	100-1,000

- **Rainfall Runoff Event: September 26 2002**

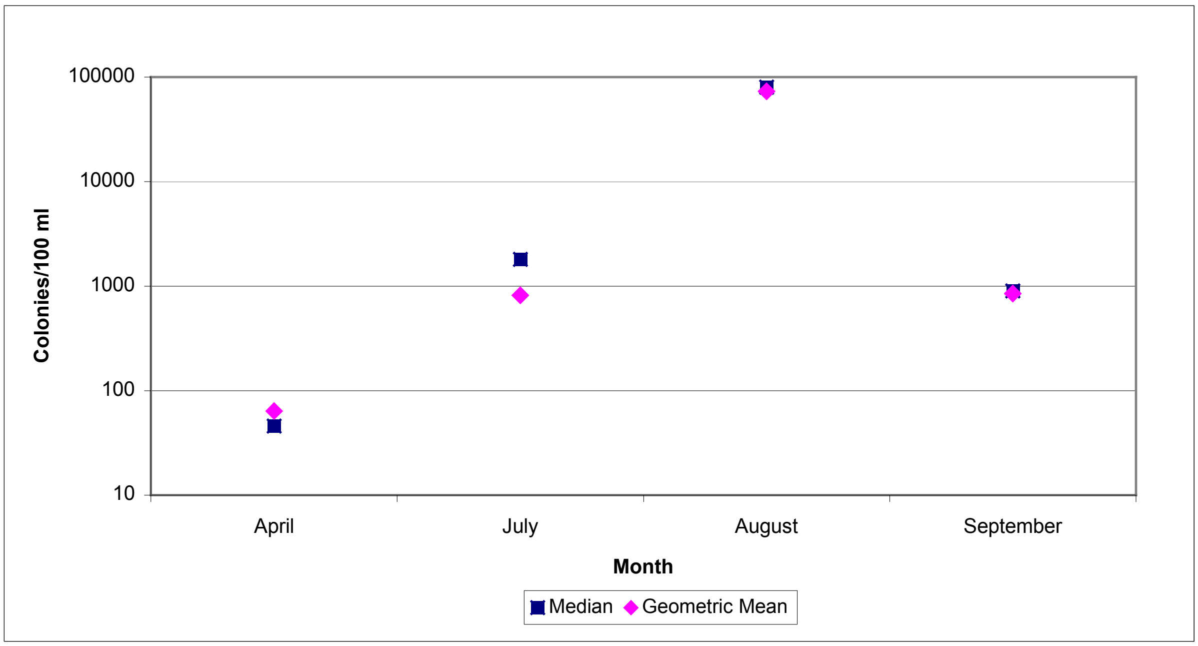
Sample Type/Method	No. Samples	Range (colonies/100 ml)
Outfall/Composite	9	200-1,200
Outfall/Grab	9	400-1,100
Curb-gutter/Composite	8	126-400
Curb-gutter Grab	8	100-500

Table 12 Fecal Coliform Values in Anchorage Rainfall runoff

Rainfall Runoff Event	Outfall Geometric Mean	Curb-Gutter Geometric Mean
July 23-24, 2002	820	1,890
August 8, 2002*	73,060	151,400
September 24, 2002	1,275	450
September 26,2002	490	240

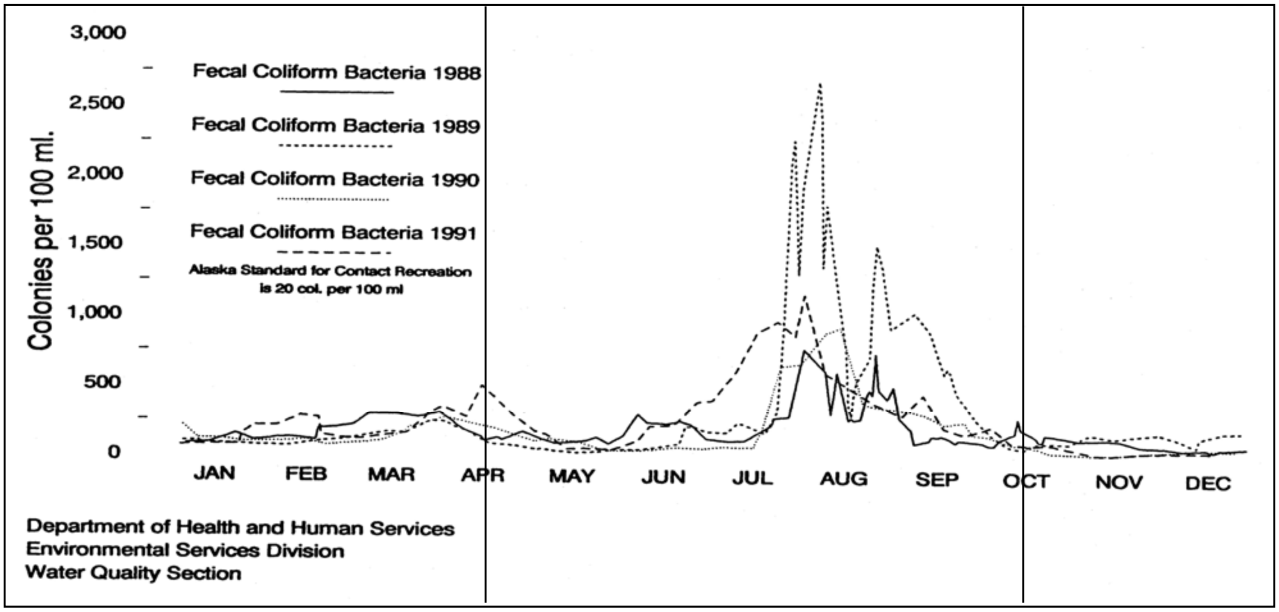
Note:
* – Samples collected on August 8, 2002 are flagged as suspect based on project objectives.

Figure 7 Trend of Fecal Coliform Levels in Anchorage Urban Stormwater: 2002



Note: Samples collected on August 8, 2002 are flagged as suspect based on project objectives.

Figure 8 Trend of Fecal Coliform Loading (Chester Creek Water Quality Monitoring)



Variability Study

As shown in Table 12, differences in coliform levels varied between curb-gutter and composite sample results for the first two storms. Grab and composite samples were varied for the last two storms to verify the differences with more detailed sampling.

For the last two storms sampled results were opposite than the first two storms (Table 12). Curb-gutter grab and composite fecal coliform concentrations were consistently less than outfall grab and outfall composite samples for both storms sampled (Figure 9). Data collection on September 24 was conducted during high-energy rainfall intensity (0.11 inches/hour) while data collection on September 26 was conducted during low-rainfall intensity (0.03 inches/hour).

Instantaneous grab and composite sampling taken by continuously sampling over 10 minute intervals were conducted simultaneously at outfall basin 5001 curb-gutter and outfall sampling sites. Figure 10 presents storm water concentrations of fecal coliform represented as a "grab" samples or single points and as a true composite samples. Comparing the grab sampling technique in to composite sampling resulted in representative event media concentrations. However, composite samples are necessary to effectively understand the true loading characteristics of fecal coliform compared to hyetographs or runoff hydrographs. Grab sample concentrations were up to 500 colonies/100 ml different than their adjoining composite samples. These data reinforce the extreme variability of fecal coliform in runoff, even when using very short sample intervals.

Groundwater Baseflow

Nine composite samples were collected during two rounds of baseflow sampling. Groundwater baseflow was sampled to determine baseline conditions for storm drains with a baseflow component. Storm drains were sampled after a long period of dry weather on July 31, 2002 and August 28, 2002, to characterize fecal coliform concentrations in storm drain baseflow.

Geometric means for fecal coliform concentrations for July 31,2002, and August 28, 2002, were 245 colonies/100 ml and 290 colonies/100 ml respectively. Figure 11 presents results from selected storm water outfalls and illustrates the variability in sampled baseflow waters.

Catch Basins (Dry Weather)

Six composite sediment samples were collected from three catch basins and analyzed for fecal coliform, percent moisture, and particle size distribution. The sample locations included 5001, 5002, and 5010. Catch basin sampling was initially scheduled to be performed within outfall basin 5003, but once in the field, all eight catch basins were found to be free of any sediment buildup. Outfall 5010 was substituted for 5003 to maintain a reasonable sample number.

Catch basin sampling was performed to characterize fecal coliform loading in sediment trapped in piped storm drain systems. Fecal coliform was present, yet highly variable, ranging from 6 to 20,000 colonies/100 ml. The median value for all composite (including duplicate) samples was 1,275 colonies/100 ml.

Sediment samples were analyzed for type of sediment and total solids (Table 13). Any observations of organic or other material were noted from field observations and back-calculated from the solids analysis. Results indicate that the consistency of sediment ranged from poorly graded sand to well-graded sand with silt and gravel. Generally, the sediment appeared to have only minor fines associated with it. The majority of the sediment appeared to be larger size sediment used for winter traction enhancement by the MOA. Field observations of collected sediment samples from catch basins did not reveal visible signs of feces but an odor resembling decomposing organic matter was noticeable (Figure12). All of the samples contained organic material, which made up approximately 40 percent by weight of the samples. Organic matter usually consisted of twigs, leaves, and grass clippings in various states of decomposition; some grass clippings appeared to have been recently introduced.

Figure 9
Source Assessment of Fecal Coliform in Anchorage Storm Water: 2002 Data Report
Results of Variability Study: Curb-Gutter vs. Outfall Fecal Coliform Concentrations

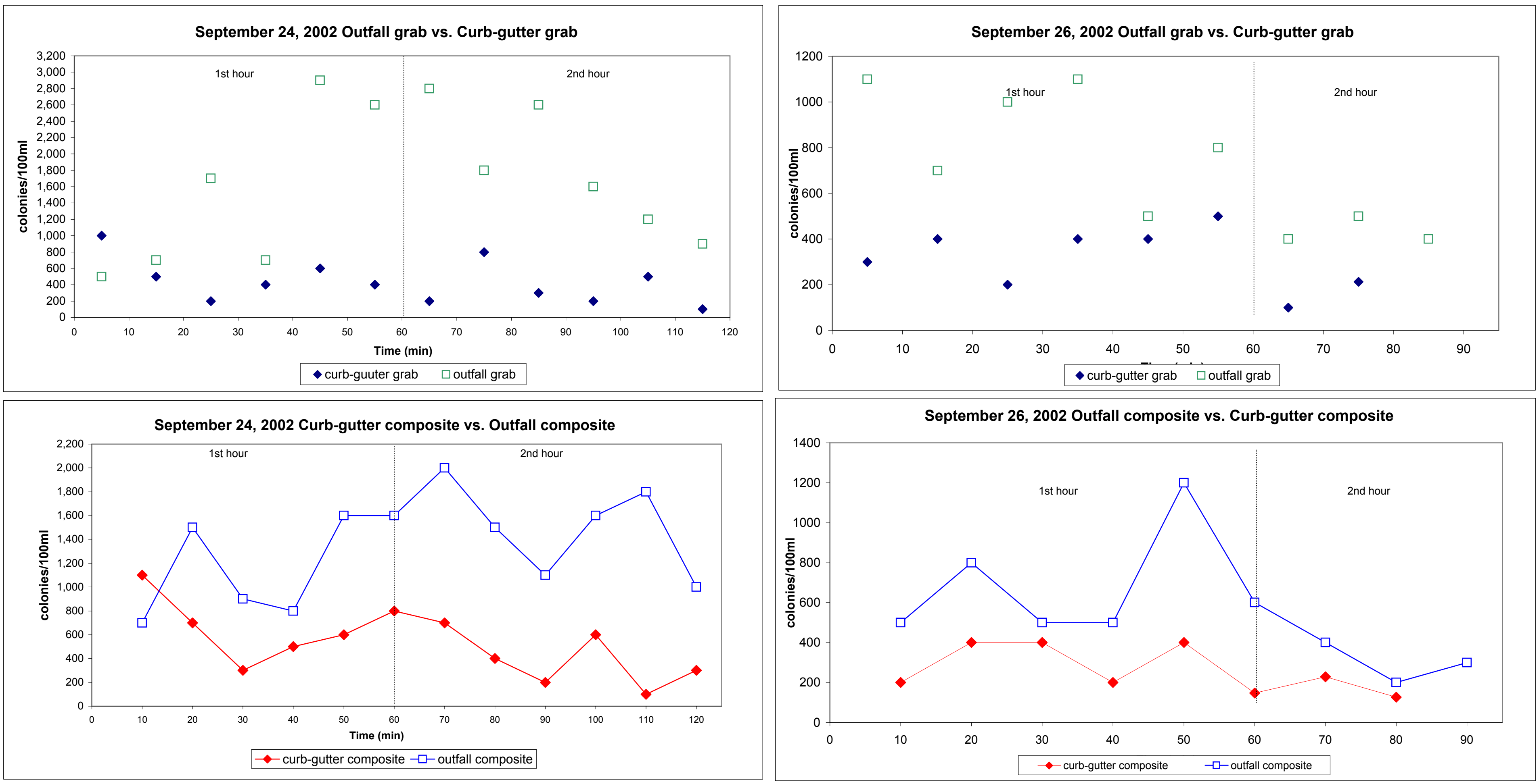
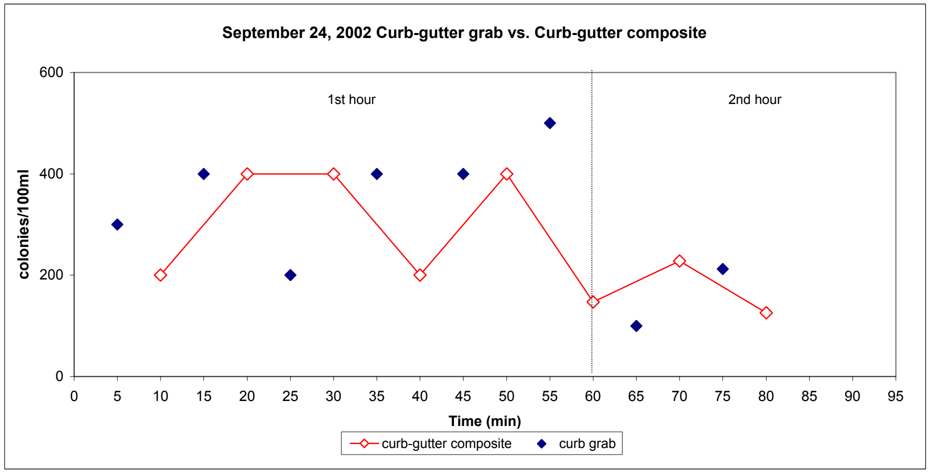
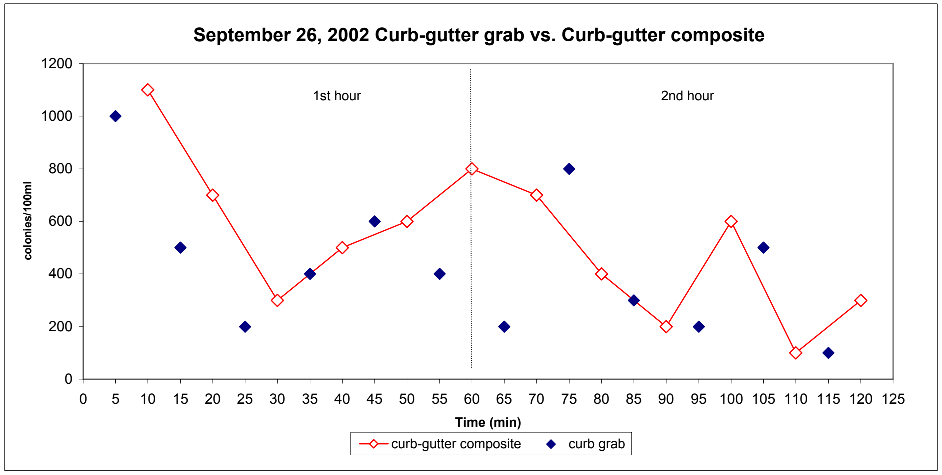
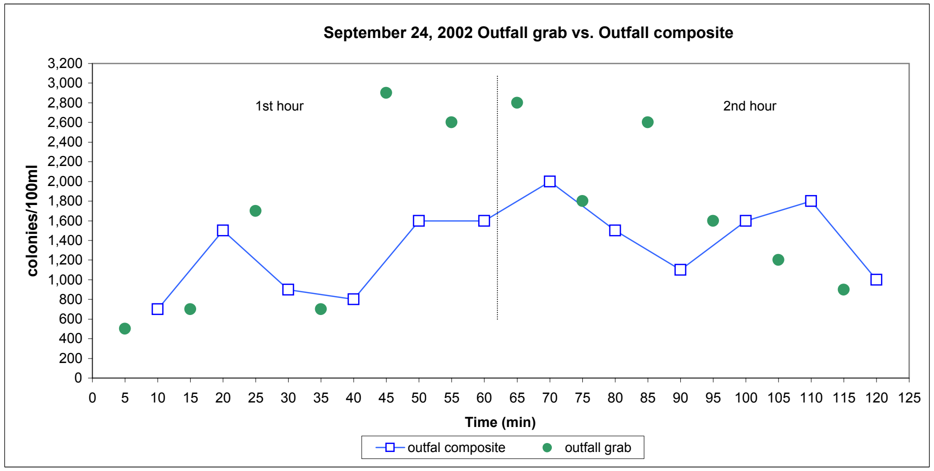


Figure 10
Source Assessment of Fecal Coliform in Anchorage Storm Water: 2002 Data Report
Results of Variability Sampling "Grab" vs "Composite" Techniques







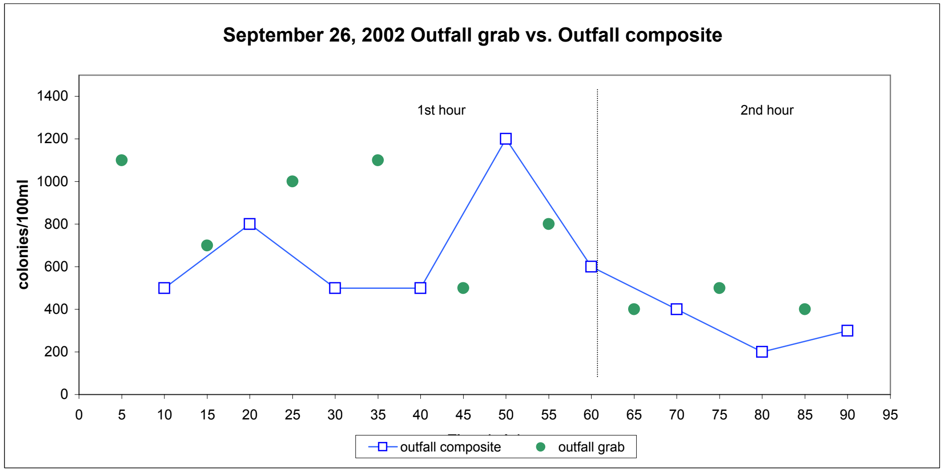
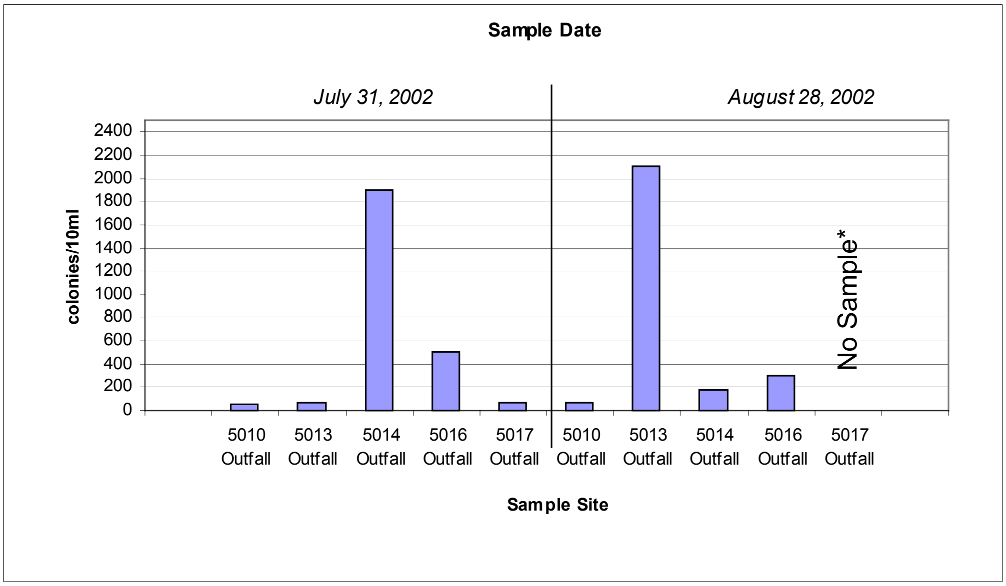


Figure 11 Fecal Coliform Levels in Urban Storm Water Pipes at Baseflow



Note: Outfall 5017 was not sampled in August because the outfall was submerged in ponded water at the discharge point.

Figure 12 Example of Sediment Collected from Catchbasins

Table 13 Catch Basin Sediment Description

Station ID	Sample Number	Date	Sediment Description	Solids (%)
5001	CB5001R1LC072302	7/24	Well-Graded Sand with Silt and Gravel up to ¾ inch	59
5002	CB5002R1LC072302	7/24	Poorly graded sand up to ½ inch	55
5010	CB5010R1LC072302	7/24	Well Graded Sand with Silt up to ¾ inch	56

DUPLICATE SAMPLE RESULTS

Of the 77 water samples collected for snowmelt and rainfall runoff from March through September, 10 were duplicates. No duplicate sampling was performed for the rainfall runoff variability study. Baseflow samples collected on July 31 and August 28 consisted of nine composite samples and five duplicates. Of the three composite sediment samples collected from catch basins, one duplicate sample was collected for each sample site. Table 14 displays analytical results for these duplicates and the associated primary samples.

Table 14 Field Duplicate and Associated Primary Samples

Sample Number	Sample Type	Fecal Coliform
Snowmelt Duplicates		**(colonies/100 ml)**
5003FS	Primary	40
5003FSD	Duplicate	20
5002 FS	Primary	3
5002 FSD	Duplicate	4
5021 FS	Primary	640
5021 FSD	Duplicate	990
5001 FS	Primary	0
5001 FSD	Duplicate	0
Rainfall Runoff Duplicates		**(colonies/100 ml)**
5001OF2	Primary	2,100
SR5001R1LG072302	Duplicate	3,100
5014BF1	Primary	1,900
5014BF1D	Duplicate	1,000
5016BF1	Primary	500
5016BF1D	Duplicate	600
5010BF1	Primary	52
5010BF1D	Duplicate	38
50010F6080802	Primary	110,000
50010F6080802D	Duplicate	80,000
Baseflow Duplicates		**(colonies/100 ml)**
5010BF1	Primary	52
5010BF1D	Duplicate	38
5014BF1	Primary	1,900
5014BF1D	Duplicate	1,000

Table 14 (cont.) Field Duplicate and Associated Primary Samples

Sample Number	Sample Type	Fecal Coliform
5014BF2	Primary	172
5014BF2D	Duplicate	1,000
5016BF1	Primary	500
5016BF1D	Duplicate	600
5013BF2	Primary	2,100
5013BF2D	Duplicate	1,400
Catch Basin Sediment Duplicates		**(MPN/gm)**
CB5002R1LC072302	Primary	9,900
CB5002R1LC072302D	Duplicate	20,000
CB5001R1LC072302	Primary	1,600
CB5001R1LC072302D	Duplicate	950
CB5010R1LC072302	Primary	6
CB5010R1LC072302D	Duplicate	25

Primary and duplicate samples gave variable results, indicating that fecal coliform concentrations are not homogeneous even in well-mixed samples of water or sediment. Using standard sampling methods for obtaining duplicate samples of surface water or sediment did not achieve consistent results.

As shown in Table 14, for one set of rainfall runoff, baseflow, and for two sets of catch basin samples, primary and duplicate results varied by an order of magnitude. For the other sets of samples, results also displayed high variability.

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Appendix A
Source Assessment of Fecal Coliform in Anchorage: Design Report 2002

Appendix B
Data, Data Validation, and Photo Log

Attachment B-1
Field and Laboratory Data and Data Quality Assessment

Attachment B-2
Land Use and Modeling Data

Attachment B-3
Photo Log

Appendix C
SYNOP Rainfall Analysis

Appendix D
Annotated Bibliography: Fecal Coliform in Anchorage Storm Drains