Section S8D - Stormwater Characterization

Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit
Permit No.: WAR04-4003

Revision: S8D-003 (Final)

Revision Date: 08/16/2009

Prepared by:
City of Tacoma
Tacoma, Washington

This page intentionally left blank.

1 Title and Approval Sheet

Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit

Internal Review and Approval

Asst. Division Manager Surface Water (Lorna Mauren, P.E.)	8/17/09 Approved On:
NPDES Permit Manager (Lorna Mauren, P.E.)	8/17/09 Approved On:
Program Manager (Dana de Leon, P.E.)	8/17/09 Approved On:
QA Coordinator (Chris Burke)	8/17/09 Approved On:

"I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for willful violations."

Date: 8-17-09

Dan C. Thompson, Ph.D.
Acting Asst. P. W. Director/Environmental Services

This page intentionally left blank.

2 Distribution List

Title:	Name (Affiliation):	Telephone No./email address:	No. of copies:
Regional Contact	Kurt Fremont (Ecology)	360.407.6364 kufr461@ECY.WA.GOV	2 (paper) 1 (electronic)
QA Coordinator	Chris Burke (ESSE EC)	253.502.2247 cburke@cityoftacoma.org	1
Laboratory QAO	Chris Getchell (Tacoma Laboratory)	253.502.2130 cgetchel@cityoftacoma.org	1
Program Manager	Dana de Leon, P.E. (ESSE SW)	253.502.2109 ddeleon@cityoftacoma.org	1
Field Supervisor	Rick Fuller (ESSE EC)	253.502.2129 rfuller@cityoftacoma.org	1

ACRONYMS

BMP	Best Management Practice
CAR	Corrective Action Report
COC	Chain of Custody
DQI	Data Quality Indicator
DQO	Data Quality Objective
EMC	Event Mean Concentrations
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
MDL	Method Detection Limit
MH	Manhole
MLLW	Mean Low Low Water
MLS	Milliliters
MQO	Measurement Quality Objective
MS4	Municipal Separate Storm Sewer System
NCR	Nonconformance Report
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
OF	Outfall
QA/QC	Quality Assurance/Quality Control
QAC	Quality Assurance Coordinator
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure

2 TABLE OF CONTENTS

List of Tables

List of Figures

Abstract

This Quality Assurance Project Plan (QAPP), prepared by City of Tacoma with assistance from Anchor Environmental LLC, describes management of the *stormwater characterization monitoring study* required under Section S8D of the Phase I Municipal Stormwater Permit, permit number WAR04-4003.

The permit requires S8D stormwater characterization, which is intended to characterize stormwater runoff quantity and quality to allow analysis of loadings and changes in conditions over time and generalization across the Permittees' jurisdiction. This QAPP is the second of four that will be submitted to the Washington Department of Ecology (Ecology) to meet the permit requirements of Section S8 and covers the *stormwater characterization monitoring study* component of Section S8D. This document is a companion to the Section S8 Program QAPP.

The City of Tacoma submitted a proposal to Ecology on July 12, 2007 to monitor the following stormwater characterization basins:

- Outfall 237B, representing residential land use,
- Outfall 245, representing industrial land use, and
- Outfall 235, representing commercial land use.

This QAPP further defines each basin and its characteristics.

The primary goal of this QAPP is to define procedures that assure the quality and integrity of the collected samples, the representativeness of the results, the precision and accuracy of the analyses, the completeness of the data, and ultimately delivers defensible products and decisions for stormwater characterization monitoring described in Section S8D.

3 BACKGROUND

The National Pollutant Discharge Elimination System (NPDES) Phase I permits required development and implementation of stormwater management programs to reduce the discharge of pollutants to the maximum extent practicable (Ecology 2007). Section S8D requires to characterize stormwater runoff quantity and quality to allow analysis of loadings and changes in conditions over time. Ecology intends for the combination of intensive monitoring from all Phase 1 Permittees throughout the state to provide them with a sufficient data set from which to draw conclusions about the effectiveness of programs on a region-wide basis.

3.1 The Problem

Stormwater quality is difficult to manage because discharges are not continuous, and storm events can be unpredictable. Rather, discharges are intermittent and weather-dependent (i.e., rainfall and snowmelt). There is a wide range of pollutants in stormwater, and concentrations vary depending on storm events. Further difficulty in controlling municipal stormwater discharges comes from the large number of outfalls where stormwater is being discharged. These features of stormwater runoff make it difficult to apply conventional end-of-pipe treatment options to existing discharges.

Stormwater management is expensive. Knowledge of pollutant loads and of average event mean concentrations from representative areas drained by the municipal storm sewer systems may help Ecology gauge whether the comprehensive stormwater management programs are making cost-effective progress towards the goal of reducing the amount of pollutants discharged and protecting water quality in the most cost-effective manner.

3.1.1 Driver

Three basic control strategies exist for stormwater. First, prevent pollutants from coming into contact with stormwater by using source control best management practices (BMPs). Second, apply treatment BMPs prior to discharge to surface or ground waters to reduce pollutants in the discharge. Third, control the flow rate of stormwater through flow control BMPs.

The complexity inherent in stormwater discharges and the difficulty of controlling such discharges means that it will take many years for full implementation that adequately mitigates or prevents adverse environmental impacts.

A feedback loop for adaptive management of the City of Tacoma's stormwater management programs and the municipal stormwater permit is needed to determine which strategy, or combination of strategies, is the most cost-effective at managing stormwater.

The permit requires each permittee to select one conveyance within the Municipal Separate Storm Sewer System (MS4) representing residential, industrial, and commercial land uses and collect and analyze samples that represent: (1) stormwater quality during qualified storm events, (2) annual sediment quality, and (3) stormwater toxicity during a "first flush" event. The MS4 is defined as a conveyance, or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains). All of the City of Tacoma's storm drain systems are fully separated systems that convey only stormwater.

3.1.2 Decision-making

Ecology will use the collected data to detect and monitor regional patterns and trends in stormwater quality and to analyze the relations between observed patterns and trends in stormwater program efforts.

3.2 Study Area

The permit requires each permittee to select three sites within the stormwater conveyance system based on specific land use designations. City of Tacoma is required to choose three monitoring sites with the following land use designations: commercial, high density residential and industrial. The sites selected to meet these requirements are described below in Table 3-1 and presented visually in Figure 3-1.

Table 3-1. Stormwater characterization monitoring proposed sites.

Land Use Category	Catchment Name	Watershed
Residential	Outfall 237B	Thea Foss Waterway
Industrial	Outfall 245	Thea Foss Waterway
Commercial	Outfall 235	Thea Foss Waterway

For a period of six years (August 2001-2007), seven outfalls discharging into Thea Foss waterway were sampled for a total of 354 stormwater samples, 182 baseflow samples and annual – wet weather - stormwater suspended particulate matter samples (stormwater sediments). The purpose of the monitoring program is:

- To measure effectiveness of Tacoma's stormwater management programs
- To identify trends in stormwater quality
- To provide early warning of new sources
- To trace source(s) using sediment traps.

Stormwater, baseflow and stormwater sediments discharging from Outfalls 237B, 245 and 235 have been monitored as part of the Thea Foss Stormwater Monitoring Program. These outfalls were selected for stormwater monitoring under S8D because they not only represent typical residential, commercial and industrial land uses but already have a long monitoring record to measure effectiveness of Tacoma's stormwater management programs.

Outfall 237B (OF237B) was selected as the residential basin for stormwater monitoring because it represents a typical residential area of the City. This basin is located in the southeast portion of Tacoma and discharges to Thea Foss Waterway and then Commencement Bay in the Puget Sound. Single-family detached housing is the main housing structure (Tacoma 2007). There is some multi-family residential development and a few neighborhood businesses concentrated along major corridors.

Industrial uses are concentrated in, Nalley Valley (Highway 16 and Interstate 5), South Tacoma Channel-southwest portion of Tacoma and the majority in the Port of Tacoma-Tideflats area. Outfall 245 (OF245) was selected because it contains business activities typical of industrial land uses in Tacoma. This basin is located on the east side of Thea Foss Waterway.

Commercial land uses vary by type and density in Tacoma. Outfall 235 (OF235) was selected as the commercial basin for stormwater monitoring. This basin is located on the west side of Thea Foss Waterway and represents a mix of commercial uses such as the University of

Washington-Tacoma, St. Joseph Hospital, businesses and a growing retail and multifamily residential area (Tacoma 2007).

Table 3-2 summarizes the estimated basin land use distribution for the selected monitoring sites. Table 3-2 and Figure 3-2 also display residential as a predominant land use category within the City of Tacoma.

Table 3-2. Stormwater characterization monitoring, basin land use distribution.

Land Use Category	**Catchment Name**	**Area (acres)**	**Land Use Category (%)**			
			Residential	**Industrial**	**Commercial**	**Open**
Residential	Outfall 237B	2,147	89%	0%	11%	
Industrial	Outfall 245	38	0%	100%	0%	0%
Commercial	Outfall 235	163	32%	0%	68%	
	City-wide	33,500	67%	19%	13%	5%

Open space overlaps some of the residential space.
Residential includes single-family, and multi-family.

3.3 Parameters of Concern

The stormwater quality analytes identified as parameters of concern by Ecology are those that have a history of association with stormwater discharges and are found in urban environments. Ecology has identified two parameters of concern that will be collected using manual grab sampling procedures from stormwater (Table 3-3).

Table 3-3. Required stormwater quality parameters to be collected by manual grab.

Analyte Group	**Parameter**
Total Petroleum Hydrocarbons (TPH)	Diesel Range Organics (DRO)
	Gas Range Organics (GRO)
Bacteria	Fecal coliform bacteria

Ecology has identified the following parameters of concern that will be collected using flow-weighted composite sampling procedures (Table 3-4).

The sediment analytes identified as parameters of concern by Ecology are those that have a history of association with stormwater discharges, are found in urban environments, have a marine sediment quality standard, or that provide necessary support information (e.g., total organic carbon). The following table contains the required sediment parameters for laboratory analysis (Table 3-5).

Table 3-4. Required stormwater quality parameters to be collected by composite.

Analyte Group	Parameter
Conventional	Biological Oxygen Demand (BOD5)
	Chloride
	Conductivity
	Hardness
	Methylene Blue Activating Substances (MBAS)
	Total Suspended Solids (TSS)
	Turbidity
Metals (dissolved & total)	Cadmium
	Copper
	Lead
	Mercury [1]
	Zinc
Nutrients	Nitrate-nitrite
	Orthophosphate
	Total kjeldahl nitrogen (TKN)
	Total phosphorus
Semi-Volatile Organic Compounds (SVOCs)	Pentachlorophenol (herbicide)
	Phthalates
	Polycyclic aromatic hydrocarbons (PAHs)
Pesticides, Chlorinated	2,4-D (herbicide)
	Dichlobenil (herbicide)
	MCPP (herbicide)
	Triclopyr (herbicide)
Pesticides, Nitrogen	Prometon (herbicide)
Pesticides, Organophosphorus	Diazinon (insecticide)
	Malathion (insecticide)
	Chloropyrifos (insecticide)

[1] Not required at residential sites.

Table 3-5. Required stormwater sediment parameters to be collected by sediment trap.

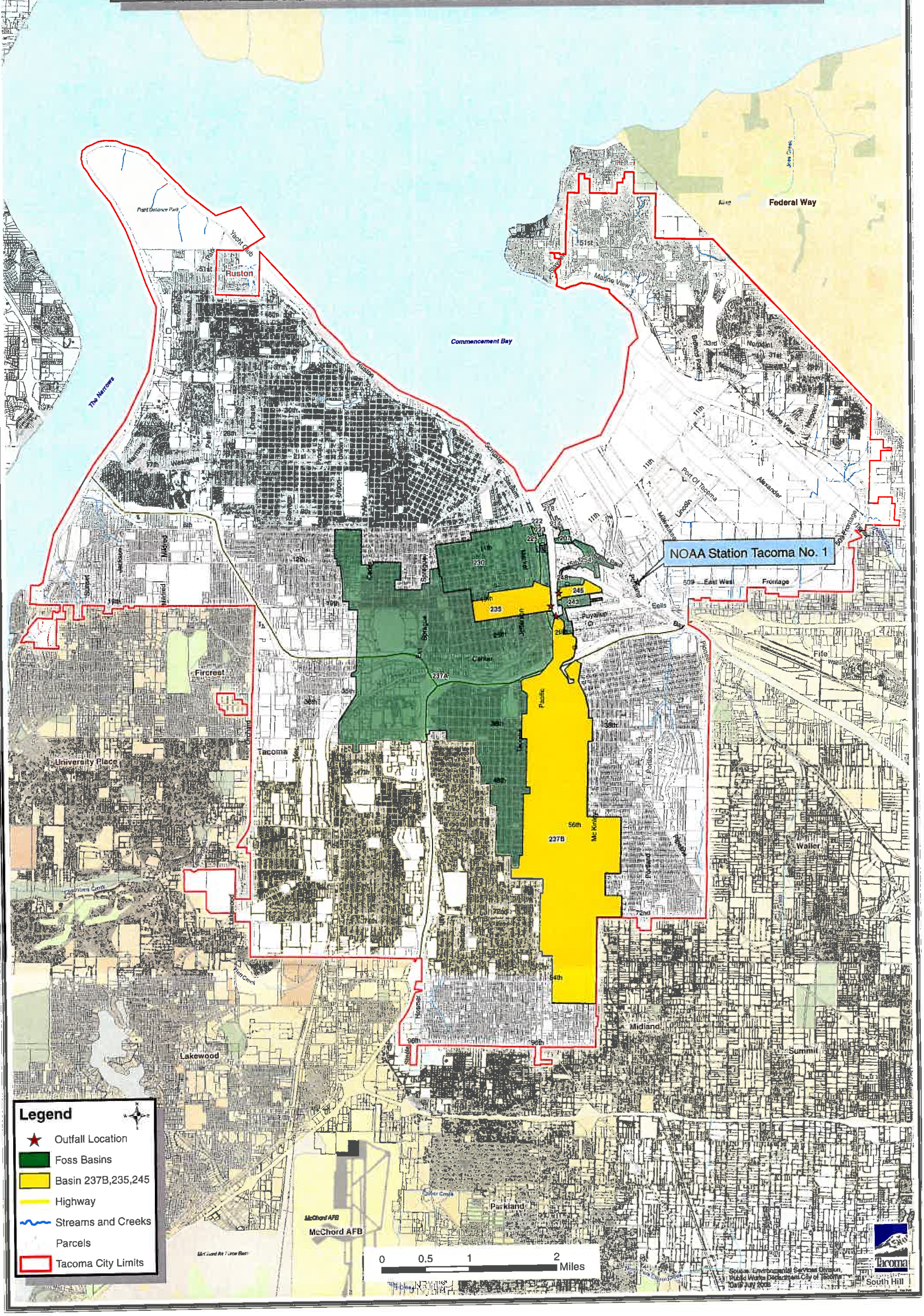
Analyte Group	Parameter
Conventional	Total solids
	Grain size
	Total organic carbon
Metals	Cadmium
	Copper
	Lead
	Mercury[1]
	Zinc
Semi-volatile Organic Compounds	Polycyclic aromatic hydrocarbons (PAHs)
	phthalates
	Pentachlorophenol (herbicide)
	Phenolics
Pesticides, Organophosphorus	Diazinon (insecticide)
	Malathion (insecticide)
	Chloropyrifos (insecticide)
Persistent Organic	Polychlorinated biphenyls (PCBs) [1]

[1]Not required at residential sites.

NPDES S8D-Project Locations

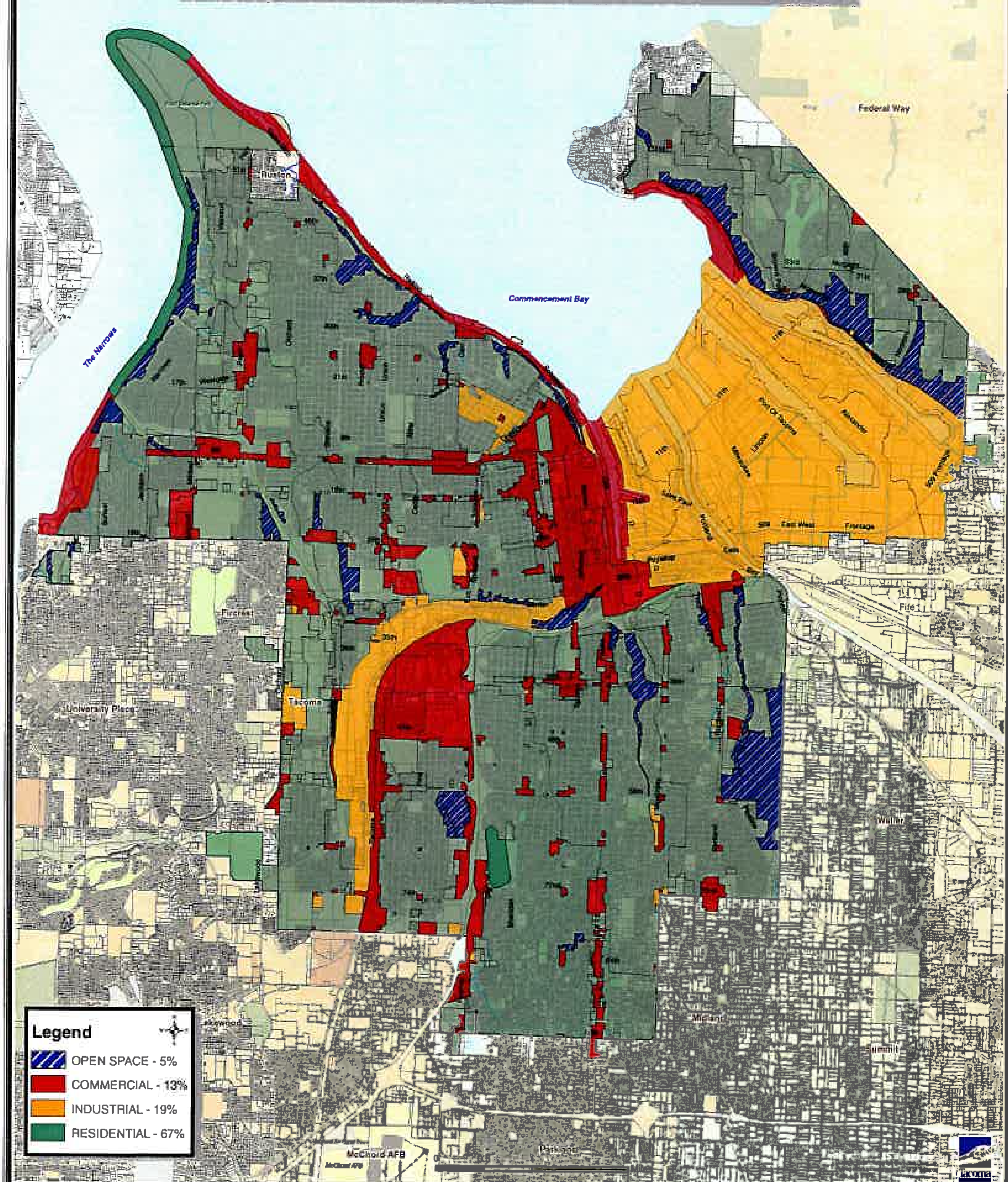
Thea Foss Basins

Figure 3-1



City of Tacoma Land Use (2008)

Figure 3-2



4 PROJECT DESCRIPTION

This section presents the goals and objectives of the project; describes the boundaries, target populations and practical constraints of the study; and specifies the information and data required to meet the study objectives.

4.1 Study Goals

The goal of the stormwater characterization monitoring study is to meet the requirements of Section S8D of the permit. Ecology's purpose is to obtain knowledge of pollutant loads and average event mean concentrations from representative areas drained by municipal storm sewer systems and to gauge whether the comprehensive stormwater management programs are making progress towards the goal of reducing the amount of pollutants discharged and protecting water quality.

4.2 Study Objectives

Ecology's two primary objectives of the stormwater characterization monitoring required under Section S8D include:

1) Estimate concentrations and loads from representative areas or basins to be used in evaluating overall program effectiveness.
2) Provide a feedback loop for adaptive management of the City of Tacoma's stormwater management programs and the municipal stormwater permit. Adaptive management will be implemented through future permits or permit modifications.

Ecology intends this type of monitoring to continue well beyond this permit cycle. Ecology determined the number of samples per year needed coupled with qualifying event criteria to establish a sufficient dataset from which they can discern annual and seasonal loading trends over a long time.

4.3 Information Requirements

The sampling design for stormwater monitoring under S8D contains three primary components that will be conducted at each monitoring site through the remainder of the Phase I Permit cycle:

- Stormwater Sampling
- Toxicity Sampling
- Sediment Sampling

Information required to meet the study objectives is described below.

Stormwater Sampling Automatic flow-weighted composite and manual grab sampling methods will be used to collect stormwater samples from qualifying storm events (Table 7-10) throughout each water year. Sampling will be distributed throughout the year, approximately reflecting the distribution of rainfall between the wet and dry seasons (60-80 percent of the samples collected during the wet season). Section 7.4.1 Parameters and Analytical Methods and Table 7-7 includes a list of the parameters to be analyzed and associated volumes.

Manual grab samples will be collected at each stormwater monitoring site during qualifying storm events as early in the storm event as possible. If it is not possible to collect a sample during the same storm event as a composite sample, a grab sample will be collected from a separate event. Information on parameters and volumes for grab samples can be found in Section 7.4.1 Parameters and Analytical Methods and Table 7-7.

Continuous flow data will be collected at each selected site during all storm events and for one year to establish rainfall and runoff relationships at each basin. Rainfall data will be collected continuously to characterize the antecedent dry period, total rainfall distribution during the sampled events, inter-event dry period, and rainfall intensity during the sampled storm events.

Event Mean Concentrations (EMCs), total annual pollutant loads and seasonal pollutant loads will be calculated for each required parameter at each monitoring site.

Toxicity Sampling Toxicity sampling representing the seasonal first flush will be conducted using automatic flow or time-weighted composite sampling equipment at each stormwater monitoring site. A sample shall be collected during the seasonal first flush in August and September. If toxicity sampling is unsuccessful during this time, a sample can be collected in October irrespective of antecedent dry period.

Up to two attempts will be made to collect a toxicity sample successfully. If the first attempt is unsuccessful or results in invalid or anomalous results a second attempt is required. Further information regarding invalid or anomalous tests can be found in Section 9 Measurement Procedures.

In addition to collecting a stormwater sample for toxicity testing, stormwater must also be collected for associated chemical analyses. The purpose of the chemical analysis for toxicity testing is to determine the presence of toxic substances that could reduce viability of salmonid embryos. Further, the chemical analysis can also indicate the presence of interferences to the 7-day toxicity test. Information on parameters and volumes for toxicity testing can be found in Section 7.4.1Parameters and Analytical Methods and Table 7-7.

4.4 Study Boundaries

This section describes spatial and temporal boundaries of the problem, the scale of decision-making when appropriate, the characteristics that define the population of interest, and any practical constraints on data collection.

4.4.1 *Spatial Boundary*

The spatial boundary defines the geographic area within which all decisions will apply and the physical area to be studied and from where the samples will be taken. Ecology may apply any decisions resulting from this study within the Phase I permittees' jurisdictions.

Three basins were selected based on the permit criteria that each site must represent a discernible type of and use, but not a single industrial or commercial complex. Ideally, to represent a particular land use, no less than 80 percent of the area served by the conveyance will be classified as having that land use. Table 4-1 summarizes the selected monitoring basins. The basins are presented visually in Figure 3-1.

Table 4-1. Stormwater characterization monitoring proposed sites.

Land Use Category	Catchment Name	Temporary Station Names
Residential	Outfall 237B	OF237B
Industrial	Outfall 245	OF245
Commercial	Outfall 235	OF235

4.4.2 *Temporal Boundaries*

The temporal boundary defines the timeframe to which the decision applies and when data will be collected. Ecology intends that this monitoring program will extend well beyond the current permit cycle (February 2007 – February 2012).

Flow discharge rates will be monitored continuously at stations OF237B, OF235, and OF245 for the first year and continuous during the targeted sampling event thereafter. For stormwater characterization monitoring, flow-weighted composite samples will be collected for 67 percent of the forecasted qualifying storms, which result in actual qualifying storm events up to eleven storm events per water year. Approximately 60-80 percent of the samples will be collected during the wet season. Figure 4-1 shows the monthly daily average precipitation for Tacoma's 59-year record with 83 percent of precipitation falling in the wet season. Additionally, up to three samples will be analyzed that are collected as a result of attempts to sample the eleven required storms events and do not meet the rainfall volume storm event criterion but do meet the other storm event and sample criteria.

For each individual sampling event, samples will be collected over at least 75 percent of the storm's hydrograph for storm events lasting less than 24 hours and 75 percent of the hydrograph of the first 24 hours of the storm event for storms lasting greater than 24 hours. In addition, the automatic flow-weighted composite sampler will be programmed to begin sampling as early in the runoff event as practical and to continue sampling past the longest estimated time of concentration for the tributary area.

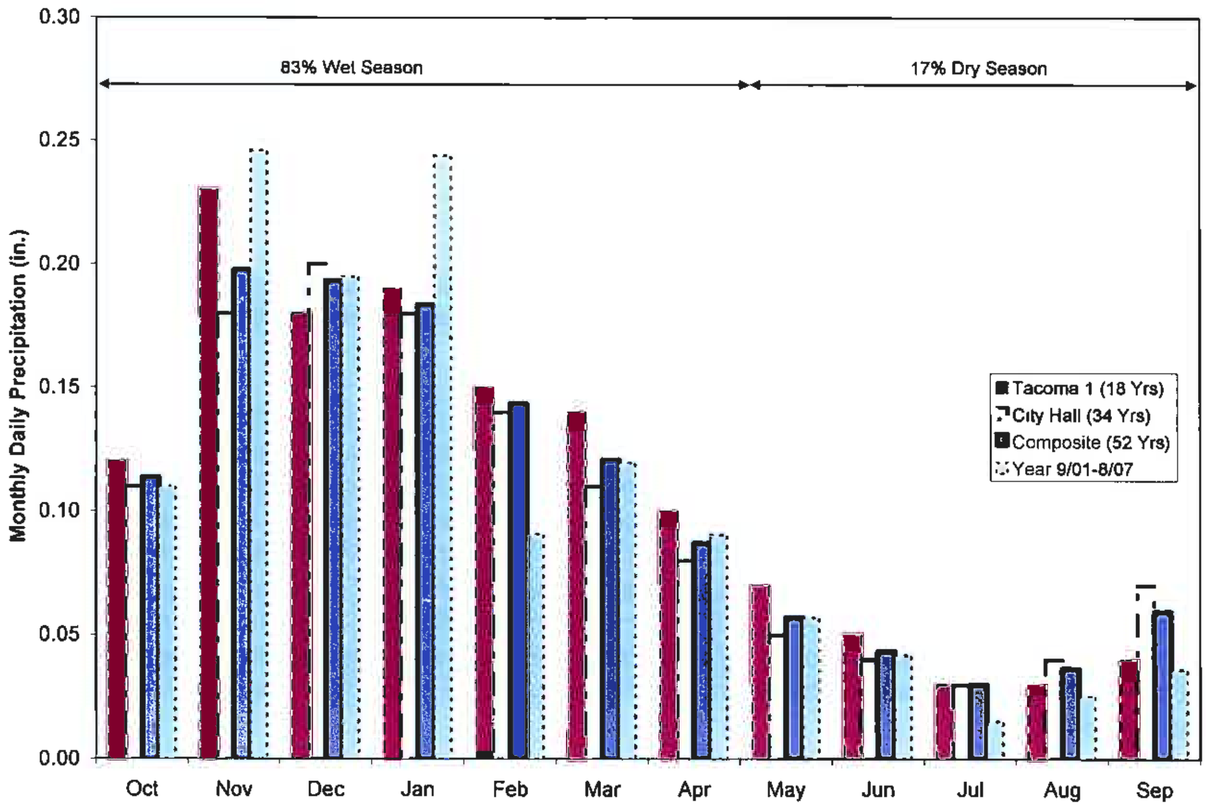


Figure 4-1. Monthly daily precipitation at NOAA Tacoma No. 1 Station.

4.4.3 *Target Populations*

The characteristics that define the population of interest are wet and dry season and annual pollutant loads in the stormwater conveyance system from selected basins within the City of Tacoma.

4.4.4 *Practical Constraints*

Please refer to S8 Program QAPP, Section 4.1 "*Practical Constraints*" for general information related to stormwater sampling. Site-specific constraints are discussed in the following paragraphs.

The sampling design permit requirements are very ambitious and assume a high success rate. Local experience with flow-weighted composite stormwater sampling indicates that the probability of meeting the following sampling requirements is low:

- The ability to successfully track and sample 11 qualifying storm events per year;
- The ability to precisely distribute successful sample collection between wet season (60-to-80 percent of samples to be collected) and the dry season; and
- The ability to successfully track and successfully collect a first flush toxicity sample of the appropriate volume, cool during collection, and deliver to the laboratory within the specified temperature criterion.

Specific logistical considerations for each selected site are described further below.

4.4.4.1 Residential Site (OF237B)

This site is located in City of Tacoma's Dock Street Pump Station Yard, 2300 block E. "C" Street. The yard is fenced and locked. The equipment is cited within MH122. MH122 is located in the southeast section of the asphalt-paved yard. A confined space entry is needed at MH122 to maintain the sample line and flow sensor (see Section 7.5.1). Traffic control is used during work in this active yard where City maintenance vehicles are constantly coming and going during work hours.

4.4.4.2 Industrial Site (OF245)

This site is located in Johnny's Restaurant private parking lot, E. 19th and "D" Street. The equipment is sited in MH390. A parking stall is designated for City of Tacoma use only where MH390 is located. Tacoma coordinates with the owner of the private parking lot on access to this location. Confined space entry is needed to maintain the sample line and flow sensor (see Section 7.5.1). While working, two parking lot stalls are closed off.

4.4.4.3 Commercial Site (OF235)

The commercial site is located at E.21st and Dock Street in a fenced vacant gravel lot along Thea Foss Waterway. The equipment is sited in MH465. The manhole is located in the middle under the State Route (SR) 509 bridge. Confined space entry is needed to maintain the sample line and flow sensor (see Section 7.5.1). The sediment-trap sampling device is located in the next upstream manhole, MH463. Traffic control will be used during work in this area.

The property is owned by Foss Waterway Development Authority, which is a parking area and a park. MH465 manhole is located in the paved area. Tacoma will continue to coordinate with Foss Waterway Development Authority to have access to the manhole.

5 Organization and Schedule

This section describes the roles and responsibilities of the study team, the study timeline and schedule. Please refer to S8 Program QAPP, Section 5.0 "Organization and Schedule" for roles, responsibilities and study timeline/schedule.

5.1 Study Deliverables

This section describes the project deliverables for S8D. Section 14.2 provides additional details describing the procedure and method for developing the deliverables. Refer to Section 11 of the S8 Program QAPP for documentation and records supporting development of the deliverables and Section 15 of this QAPP for a discussion of the content.

Each annual report will include all monitoring data collected during the preceding water year (October 1 – September 30). The first annual monitoring report submitted will include data from a partial water year, August 16, 2009 through September 30, 2009. Each report shall also integrate data from earlier years into the analysis of results, as appropriate. Reports shall be submitted in both paper and electronic form and shall include:

- A summary including the location, land use, drainage area size, and hydrology for each site,
- A comprehensive data and QA/QC report for each component of the monitoring program, with an explanation and discussion of the results of each monitoring study,
- The annual pollutant load based on water year for each site expressed in total pounds, and pounds/acre, and
- The wet and dry season pollutant loads based on water year, expressed in total pounds, and pounds/acre.

The study results will be presented in an annual report. Table 5-1 presents the study timeline, the number of events to be sampled each season, and the study deliverables schedule.

Table 5-1. Study deliverable schedule and events sampled timeline.

Activity	Deliverable	Partial Water Year One (2009)	Water Year Two (2010)		Water Year Three (2011)	
		Dry	Wet	Dry	Wet	Dry
		8/16/2009 to 9/30/2009	10/01/2009 to 4/30/2010	5/01/2010 to 9/30/2010	10/01/2010 to 4/30/2011	5/01/2011 to 9/30/2011
Continuous Flow Recording	Establish a baseline rainfall/runoff	Yes	Yes	NA	NA	NA
Stormwater Sampling 1	Stormwater Monitoring Report	1	9	2	9	2
Toxicity Sampling (First flush event) [2]	Stormwater Monitoring Report and Follow-up Actions (if applicable) [3]	1	NA	1	NA	NA
Sediment Sampling	Stormwater Monitoring Report	NA	1		1	
Deliverable Due Date [4]		03/31/2010	03/31/2011		03/31/2012	

Notes:

Water year is designated by the calendar year in which it ends.

1) The storm events in this table are based on capturing 11 storms per water year with 80 percent of the storms sampled occurring in the wet season. Wet season extends from October 1 through April 30 the next year and Dry season extends from May 1 each year through September 30. For water year 2009, 1.5 months out of 5 months are available for sampling.

2) If a successful toxicity sample is not collected in August and September attempts will be made to collect the sample in October. Toxicity samples will be reported in the water year they are taken.

3) Follow-up actions (if applicable) will follow the timeline presented in Section 9.1.2. If follow-up actions are completed prior to the calendar year the report is issued in, they will be submitted at that time. If not completed, they will be submitted with the next annual report.

4) Submitted with Annual Report

6 Quality Objectives

This section describes the study data quality and measurement quality objectives, which describe the type and quality of data needed to meet the study goals and objectives. Please refer to S8 Program QAPP, Section 6 "Quality Objectives" for method quality objectives.

6.1 Data Quality Objectives

The Data Quality Objectives (DQOs) specify how good a decision must be, but do not directly set criteria for the quality of the data or express data quality characteristics. The outputs of a Decision (or Data) Quality Objectives (DQO) Process are needed to determine the number of samples that must be taken and analyzed.

Ecology has specified the number of samples to be collected annually to meet their objectives and goals over the long-term.

6.1.1 *Representativeness*

The representativeness of the data is dependent on 1) the sampling locations, 2) the flow regime during sample collection 3) the number of years sampling is performed, and 4) the sampling procedures. Site selection and sampling of pertinent media (i.e., water) and use of only approved analytical methods will assure that the measurement data represents the population being studied at the site.

6.1.1.1 Stormwater Quality

Stormwater representativeness is achieved by selecting sample locations, methods and times so that the data describes the characteristics of stormwater runoff over the range of land use conditions in the drainage basins, the varying hydrologic conditions within an individual storm event (i.e., rising and falling portions of the hydrograph), and a representative cross-section of storm types. Additional details regarding representativeness of sample location, collection of storm flows, and the criteria used for sampling are presented in Sections 7.3 and 7.4.3.

Representativeness of land use – The permit calls for each permittee to select three sites representing different land uses. To "represent" a particular land use, no less than 80 percent of the area served by the conveyance should be classified as having that land use. There is some risk in designating so few numbers and types of sites for this long-term monitoring. T he sites selected may not be adequately "representative" of what is being achieved throughout the municipal storm sewer system. Results at these sites can over-estimate or under-estimate what is happening system-wide.

To reduce that error, Ecology will consider extending this type of monitoring to Phase II municipal stormwater permittees in the second round of their permits. The second round is scheduled for issuance in 2011. The combination of intensive monitoring at a number of sites through out the state may provide a sufficient data set from which Ecology can draw conclusions about the effectiveness of programs on a region-wide basis.

Representativeness of individual storm events – Stormwater samples will be flow-weighted composite samples representing the range of discharge conditions during the sampling event, including where possible the rising and falling portions of the runoff hydrograph. Stormwater samples will be flow-weighted composite samples representing 75 percent of the hydrograph for storms less than 24 hours. For storms greater than 24 hours, the flow-weighted composite sample will represent 75 percent of the hydrograph from the first 24-hours of the storm. However, the sampling of tidally influenced drains is necessarily limited to those periods when the drains are not affected by tides, and may therefore include only a portion of the runoff hydrograph. The City acknowledges that sampling tidally influenced drains is difficult and could limit the ability to collect representative samples given the necessity to limit sampling to only those periods when the drains are not affected by tides.

Under the current Thea Foss Stormwater Monitoring Program, tidal effects were excluded from the automatic samplers based on *in-situ* velocity monitoring (i.e., near zero during tidal inundation), height, and/or conductivity, and confirmed in the laboratory using conductivity (salinity) measurements prior to compositing the sample bottles from different portions of the storm (Tacoma 2001).

Over the course of the year and multi-years, it is expected that the tidal sampling windows will randomly overlap with different portions of the runoff hydrograph, and that a representative range of rising, peak, and falling runoff conditions will be captured during multiple sampling events, if not during a single event. As shown in Table 6-1, an evenly distributed range of rising, peak, and falling runoff conditions was captured during multiple sampling events. A majority of these events did capture most of the storm hydrograph (Years 1-6, August 2001-2007, Tacoma 2008a).

Table 6-1. Portion of storm event sampled in tidally influenced drains.

Portion of storm sampled	OF235	OF245
Rising limb	0	2
Rising and peak limb	3	7
Peak	2	2
Peak and falling limb	3	7
Falling limb	0	0
Most of the storm	47	35
Total Number	55	53

Representativeness of storm types – Storm events are variable in nature by runoff volume, flow rate, antecedent rainfall, and season. Storm event criteria have been selected to consider the variation in storm event runoff volume, flow rate, antecedent rainfall conditions, and season. In addition, monitoring will be conducted over a sufficient length of time to ensure that data are collected during representative climatic conditions for the region. Each year, this variability will be evaluated by comparing the magnitude and intensity of the runoff hydrographs, where samples were collected on the hydrographs, time between storm events, and time of year the samples were collected to determine whether a representative range of storm types was included in the monitoring program.

Over the course of Tacoma's six-year monitoring record for Thea Foss Waterway Program, a representative range of storm types have been sampled. Each storm is characterized by the following hydrologic variables:

- Total rainfall
- Runoff hydrograph
- Intensity
- Antecedent period; and
- Season

The ranges of average flow rates, magnitude and intensity of the runoff hydrographs were variable for over the course of Years 1-6 (Table 6-2). In addition, a wide variety of storms were sampled during Years 1-6 including rainfall amounts, duration, intensities and antecedent conditions.

Table 6-2. Ranges of magnitude and intensity - Years 1 to 6 stormwater runoff hydrographs.

Outfall	Runoff Volume Sampled (cf) Min-Max	Event Average Flow Rate (cfs) Min-Max	Maximum Flow Rate (cfs)
YEAR 1 - August 2001-2002			
237B	308,000 - 6,305,000	23 - 87	186
235	15,000 - 339,300	3 - 12	52
245*	43,200 - 187,000	1.3	3.4
YEAR 2 - August 2002-2003			
237B	337,514 - 1,858,007	16 - 27	154
235	43,381 - 234,063	1.4 - 4	26.9
245*	5,654 - 60,984	0.6 - 2.8	8.1
YEAR 3 - August 2003-2004			
237B	183,431 - 1,526,854	8.2 - 48	187
235	32,390 - 142,119	1.6 - 3.3	14.2
245	4,641 - 23,892	1.1 - 4.4	7
YEAR 4 - August 2004-2005			
237B	267,243 - 1,537,388	16.2 - 51	172.2
235	37,913 - 163,159	1.9 - 5.2	21.7
245	12,185 - 45,869	0.5 - 2	6.3
YEAR 5 - August 2005-2006			
237B	259,048 - 1,069,716	15.1 - 36.9	99.7
235	52,074 - 208,197	2.0 - 4.1	29.8
245	16,106 - 63,754	1.1 - 2.7	6.1
YEAR 6 - August 2006-2007			
237B	375,780 - 846,670	14.5 - 59.6	80.9
235	81,980 - 176,350	2.4 - 6.5	25.2
245*	11,790 - 72,630	0.9 - 3.1	6.9

Rainfall amounts sampled were 0.2 inches up to 1.4 inches and whose distributions were representative of the historical distribution of rainfall in Tacoma. The largest numbers of the storms sampled were less than 0.29 inches. Forty-nine percent of the total storms sampled were less than 0.4 inches in Years 1-6, followed by 28 percent of the total storms sampled were between 0.4-0.59 inches and 23 percent of the total storms sampled were between 0.6-1.99 inches. The historic distribution is 52 percent for storms less than 0.4 inches, 24 percent for storms between 0.4-0.59 inches, and 24 percent for storms between 0.6-1.99 inches.

Durations ranged from three to greater than 24 hour storms with little difference from year to year. Antecedent periods for all six years broke out the following way:

Antecedent Periods	No. of Storms for Yrs 1-6
24 hours	6
25 to 75 hours	43
76 to 99 hours	6
100 hours and greater	25

Average rainfall intensities were 0.01 to 0.13 inches per hour with a majority of the storm events sampled less than 0.02 inches per hour.

As anticipated, more precipitation events were sampled during the wet season. Seasons are appropriately represented by the number of events sampled (i.e., more samples during the wet season when there is more rain events and fewer samples during the dry season when there are fewer storm events). Representation of storm types was achieved under the Thea Foss Waterway Program (Tacoma 2008a).

Representativeness of toxicity results – Toxicity analyses will be performed on stormwater samples collected from the conveyance system. This does not necessarily represent conditions to which aquatic life may be exposed.

6.1.1.2 Sediment Quality

Sediment traps are useful monitoring tools to help identify chemical concentrations in suspended sediments in stormwater. There are several issues relevant to the representativeness of sediment trap samples. It is difficult to predict potential sampling biases that may occur during sediment trapping, but considering the perturbations in the flow field that the bottle creates, certain grain size fractions in the suspended load could be preferentially trapped.

In addition, the physical characteristics of each sediment trap sampling location vary such that a different range and/or type of flows, and therefore, storm conditions may be sampled. Because there is a minimum height at which the sediment trap is over topped and starts to collect sample, some sediment traps may not be collecting sample during smaller storms, and the frequency of such occurrence will vary from location to location.

7 Sampling Process Design (Experimental Design)

The sampling design strategy was developed by Ecology to increase the knowledge of pollutant loads and average event mean concentrations from representative areas drained by the municipal storm sewer systems. Ecology will use this information to gauge whether the permittees' comprehensive stormwater management programs may be making progress towards the goal of reducing the amount of pollutants discharged and protecting water quality.

This section describes the overall sampling design for the study to support the program objectives identified in Section 4.2. The general sampling process design is summarized in Table 7-1.

Table 7-1. Sampling design summary.

Matrix	Sample Technique/ Type	Analytes	Temporal Boundaries	Annual Frequency per Site[1]
Stormwater	Manual grab	Water chemistry	Qualifying storm event (or as soon as possible thereafter)	11
	Automatic flow-weighted composite	Water chemistry	Qualifying storm event[3]	11
		Water chemistry	First-flush qualifying storm event	1 only
		Toxicity		1 only
	Manual grab	Water chemistry	Base flow qualifying event	4[2]
	Automatic time-weighted composite	Water chemistry		4[2]
Sediment	Manual sediment trap	Sediment chemistry	Composite over sample deployment	1

1) This total does not include QC samples.
2) These samples are not required and are collected under the Foss 2001 SAP.
3) Additionally, up to a maximum of three samples that are collected and do not meet rainfall volume criterion shall be analyzed for a total of14 samples per year

Three steps are generally specified prior to the initiation of any stormwater field collection activities. They include:

- Selection of the monitoring locations,
- Development of the stormwater sampling strategy, and
- Selection of the equipment to meet the study objectives and the site specific needs of the selected locations.

These steps are discussed below:

7.1 Monitoring Location Selection Methodology

Ecology has determined that three basins, each representing a different land use, are to be monitored. The number of locations to be monitored generally depends on specific program objectives, the size and complexity of the drainage watersheds and conveyance system, and the budget allocated to monitoring. In addition, the frequency of sampling at each location should be considered.

The City's preferred stormwater characterization monitoring sites are presented below (Tables 7-2 and 7-3) and graphically (Figure 3-1). Additional details for each site are presented below.

Table 7-2. Monitoring site basin characterization summary.

Represented Land Use	Residential	Industrial	Commercial
Basin	OF237B	OF245	OF235
Surface Area Distribution			
Total Area (acres)	1,821	36	180.7
Impervious Estimate (%)	Approx 65%	Approx 85%	Approx 80%
Land Use Distribution Estimate [18]			
Residential (%)	83	0	32
Industrial (%)	1	100	0
Commercial (%)	10	0	68
Open Space (%)	Approx 5	0	0
Hydrologic Information			
Time of Concentration (minutes)	129	18	11
Rain Gauge	NOAA Station Tacoma No. 1 RG10 RG03		
Rain Gauge Location (latitude/longitude)	47.2472/ 122.4122 47.5000/ 122.2600 47.6481/122.3081		
Mean Annual Precipitation (in) [19]	38.09 34.3 35.6		

[18] City of Tacoma Zoning, Street, and Parcel Data using ESRI ArcGIS 9 for calculations – April 2007
[19] NOAA Station Tacoma No. 1 52-year record: 1948-1998 (2003).

Table 7-3. Monitoring site outfall characterization summary.

	Residential	Industrial	Commercial
Basin	OF237B	OF245	OF235
Pipe size	60 "	18"	42"
Baseflow	Continuous	Tidal	Continuous
Flowrate (cfs)	4.3	0.1	0.4
Outfall Pipe Elevation	6.8	2.8	4.5
Water Monitoring Elevation, MLLW ft.	13.56	3.15	9.79
Tidal influence	No	Yes	Yes
Sediment Trap Elevation	16.5	3.5 (sump)	9.5
Tidal influence	No	Yes	Yes

All elevations are estimated based on review of plans and visual observations. Baseflow was measured in January and February 2001 for Outfalls 235 and 245. Baseflow for 237B was measured in October to December 1995 and site is tidally influenced when tide elevation is above the water monitoring location elevation.

0 feet MLLW tidal Datum is equal to -6.32 feet City of Tacoma Datum

Thea Foss Waterway is an estuarine waterway in Commencement Bay, Tacoma, WA. In Commencement Bay and the Thea Foss Waterway, average tidal fluctuations vary from 0 feet Mean Low Low Water (MLLW) to 11 feet MLLW. Extreme tides, which occur in June and December, range from approximately –4.0 feet MLLW to 14.5 feet MLLW. These outfalls are tidally influenced and portions of the pipes are inundated with marine water twice a day depending on the pipe elevations and the tide height. Table 7-3 lists each outfall, the invert elevation, and whether the pipe is tidally influenced.

7.1.1 *Land Use Estimate Methodology*

The method to determine the land use area to meet the goal: "ideally, to represent a particular land use, no less than 80 percent of the area served by the conveyance will be classified as having that land use" is presented below.

Land use data is derived from the City of Tacoma zoning, street and parcel data, which provides data in six general categories: low intensity, single family, medium intensity, medium intensity mixed use, mixed use centers, and manufacturing/industrial centers. Each category is a mix of one or many of the following:

- Residential – one family, two family, and low density multifamily
- Commercial – residential commercial, community commercial, downtown commercial, hospital medical
- Manufacturing/Industrial – light and heavy industrial and port maritime/industrial

ESRI ArcGIS was used to estimate percent land use based on the City of Tacoma zoning, street and parcel data. Land use is generally grouped into four categories: (1) residential which includes one family, two family, and low density multifamily and may include other/NA; (2) commercial which includes residential commercial, community commercial, downtown commercial, hospital medical, schools, government/public facility and may include other/NA; (3) industrial which includes light and heavy industrial and port maritime/industrial and may include vacant; and (4) open which includes parks/open space and may include vacant residential lots.

7.1.2 *Drainage Area Confirmation Methodology*

This section describes the methodology used to confirm the tributary conveyance system and drainage areas. Mapping and documenting the MS4 is an ongoing project, which was initiated by incorporating preliminary drainage system information using as-built and design drawings, both paper and digital. Since the 1990s as part of the Superfund Program, Thea Foss Watershed drainage areas were defined using existing information. The drainage areas have been field verified by walking surveys and observations in the field during business/source control inspections. Drainage area maps are corrected when changes are found.

In 2005 and again in 2008, OF245 drainage was field verified and mapped using a field-based global positioning system (GPS) that allowed staff to determine locations and collect attribute information regarding the MS4 components. OF235 drainage basin was field verified and mapped using GPS in 2007. All catch basins in the City of Tacoma have been mapped using GPS. GPS mapping of OF237B drainage basin is being completed quadrant by quadrant starting at the southern end of the basin. In addition, the City's watershed drainage areas including the Thea Foss basins were defined ARC-GIS hydrologic analysis and the known MS4 components in 2007 (Figure 3-1).

7.1.3 *Times of Concentration Methodology*

Section S8D, Paragraph 2b of the permit, requires that automatic flow-weighted composite samplers be programmed to begin sampling as early in the runoff event as practical and to continue sampling past the longest estimated time of concentration, Tc, for the tributary area. The Tc provides a measure to ensure the pacing is set to obtain a representative sample and to ascertain if sampling of contributions from the entire basin are represented, (i.e. sampling at or near the Tc may not be representative of the entire basin). Estimated Tc's for the selected basins are 11 minutes for OF235, 18 minutes for OF245, and 129 minutes for OF237B (see Table 7-2). For this project, the minimum time the automatic sampler will be programmed for sample collection in order to meet this permit requirement is 2 times the time of concentration.

The times of concentration were estimated using SBUH methodology (Tacoma 2000). This method is described in the City's *Surface Water Management Manual* (Tacoma 2003). The Time of Concentration, Tc, is defined as:

$$T_c = L \div k \times s^{1/2}$$

Where:

T_c = time of concentration (minutes)
L = flow length (ft)
k = velocity factor (ft/s) (value for sheet, shallow and channel flow)
s = slope of flow path (ft/ft)

Estimated flow lengths are 27,900 feet, 2,600 feet, and 4,430 feet for the residential, industrial, and commercial basins respectively.

7.2 Summary of Long-term Rainfall Data

This section summarizes the collected and in-progress statistical evaluations for long-term rainfall data for NOAA Tacoma No. 1 rain gage CTP01, which is located at 2201 Portland Avenue, City's Central Wastewater Treatment Plant (CTP) (Building E). 15 minute data is also collected using an ISCO Model 675 rain gage (tipping bucket), STP01, which is also located on the STP-1 Digester at the CTP. These rain gauges are located roughly 1 mile east of the monitoring stations OF237B and OF235 and roughly 0.9 mile east of OF245.

Figure 3-1 shows the location of the rain gage. The total monthly, annual and seasonal precipitation for September 2001: August 2007 Thea Foss monitoring program and historical statistics are shown in Tables 7-4 and 7-5.

Based on a 52 year rainfall record, the Thea Foss 2001 Sampling and Analysis Plan (Tacoma 2001, Foss SAP) defines a region specific stormwater monitoring year from August 27 to August 26 of the following year (Tacoma 2001). This analysis was presented in the 2001 SAP, Appendix G. These annual rainfall patterns for Tacoma were subdivided into four seasons:

1. **Dry-to-Wet Transition**. One and one-half months dry to wet transitional period from August 27 to October 15
2. **Wet**. Three and one-half months wet period from October 16 through January.
3. **Wet-to-Dry Transition**. Three months wet to dry transitional period from February through April.
4. **Dry**. Four months dry period from May to August 26.

Table 7-4. CTP rain gage historical monthly totals.

Month	Tacoma 1 Mar 82-Dec 99 Average Monthly Rainfall (inches)	Tacoma City Hall June 48-Dec 81 Average Monthly Rainfall (inches)	Tacoma 1 Average Sept 2001-Aug 2007 (inches)
September	1.16	2.02	**1.07**
October	3.61	3.32	**3.42**
November	6.88	5.34	**7.35**
December	5.45	6.09	**6.07**
January	5.82	5.46	**7.59**
February	4.12	4.02	**2.55**
March	4.22	3.43	**3.76**
April	3.13	2.4	**2.73**
May	2.05	1.46	**1.74**
June	1.64	1.35	**1.22**
July	0.87	0.82	**0.52**
August	0.78	1.21	**0.67**
TOTAL	39.73	36.92	**38.69**

Rainfall data from Tacoma 1 - NOAA Station at Central Wastewater Treatment Plant, Tacoma, WA

50.00	Above historical monthly average
20.00	below historical monthly average

The four seasons were selected based on periods where consistent trends were observed. The transitional periods consist of a steady decline (wet to dry transition) or increase (dry to wet transition) in daily precipitation. The dry and wet periods show little change in monthly average or 21-day average precipitation data.

Historically several significant rainfall events occurred on or after August 27 such that this date was selected as a marked change from dry to transitional rainfall pattern. October 16 was also selected as a marked change from transitional to a consistent 21-day average pattern.

For this project, water year will be reported as October-September, with wet season as October – April and dry season as May – September.

Table 7-5. CTP rain gage historical seasonal totals.

	NPDES Water Year Seasonal Totals			
	Wet		Dry	
	10/1 - 4/30		5/1 - 9/30	
Composite - June 1948-Dec 1999	31.34		6.81	
Tacoma No. 1 - March 1982-Dec 1999	33.39		5.59	
Tacoma City Hall - June 1948-Dec 1981	30.25		6.93	
Tacoma No. 1 Aug 27, 2001 to Aug 26, 2007	33.47		5.23	
	Thea Foss Program Seasonal Precipitation Totals			
	Dry-Wet Transition	Wet	Wet-Dry Transition	Dry
	8/27 - 10/15	10/16 - 1/31	2/1 - 4/30	5/1 - 8/26
Composite - June 1948-Dec 1999	3.35	19.42	10.46	4.85
Tacoma No. 1 - March 1982-Dec 1999	2.60	20.59	11.50	5.17
Tacoma City Hall - June 1948-Dec 1981	3.75	18.80	9.91	4.68
Tacoma No. 1 Aug 27, 2001 to Aug 26, 2007	2.06	23.21	8.94	4.20

Rainfall data from Tacoma 1 - NOAA Station at Central Wastewater Treatment Plant, Tacoma, WA

50.00	above historical monthly average
20.00	below historical monthly average

7.3 Monitoring Site Characteristics

A discussion of each selected basin is provided below. The discussion includes:

- Background information,
- Site hydrology, and
- Suitability of long-term monitoring.

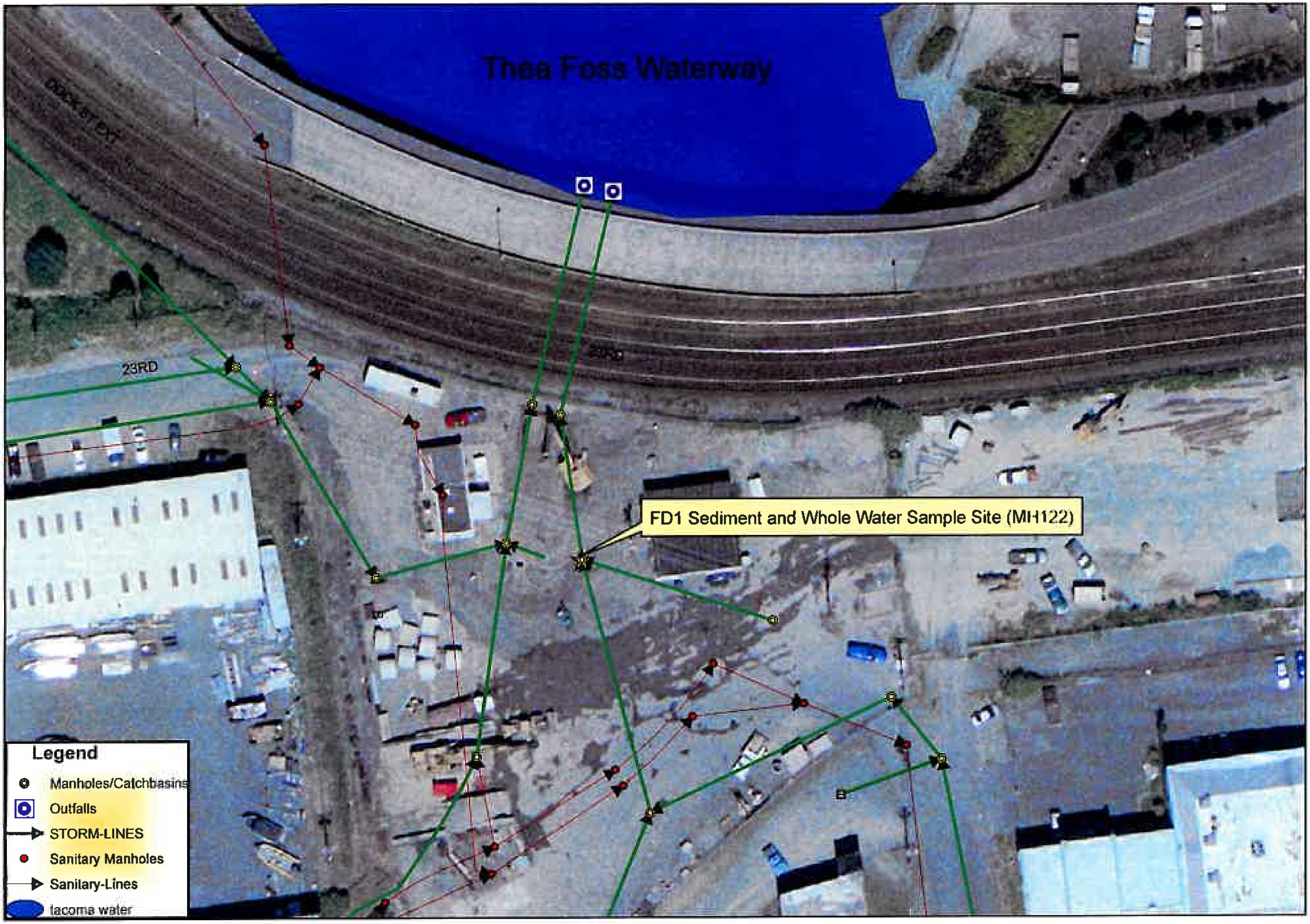
7.3.1 *Residential Basin (OF237B)*

The residential land use site is located in the Thea Foss Watershed at City of Tacoma's Dock Street Pump Station Yard 2300 block E. "C" Street (Figure 7-1). Basin 237B encompasses 1,821 acres of south and east Tacoma. This area drains through a 96-inch outfall pipe located in the block of E. Dock Street at the head of the waterway. The general basin boundaries are East 23rd Street and East Dock Street to the north, East 84th Street to the south, South Fawcett Avenue to the west, and McKinley Avenue to the east. Most of the storm drainage is channeled to the main trunk line, which flows south to north along East "D" Street.

Over 78 percent of the land use in Basin 237B is residential and 5 percent is multi-family (Figure 7-2). Commercial land use accounts for less than 10 percent in this basin. Commercial areas are mostly linear and spread out in strips along Pacific Avenue and McKinley Avenue with some areas from I-5 north to the Thea Foss Waterway. Industrial land use accounts for only one percent in this basin. Freeway right-of-way makes up a small percent of this basin, which includes a portion of the I-5: I-705: Highway 7 interchange and Highway 7. This may increase slightly with the 2005 to 2008 expansions and HOV Lanes on I-5. Streets, parks, and open or undeveloped property account for the remaining land uses.

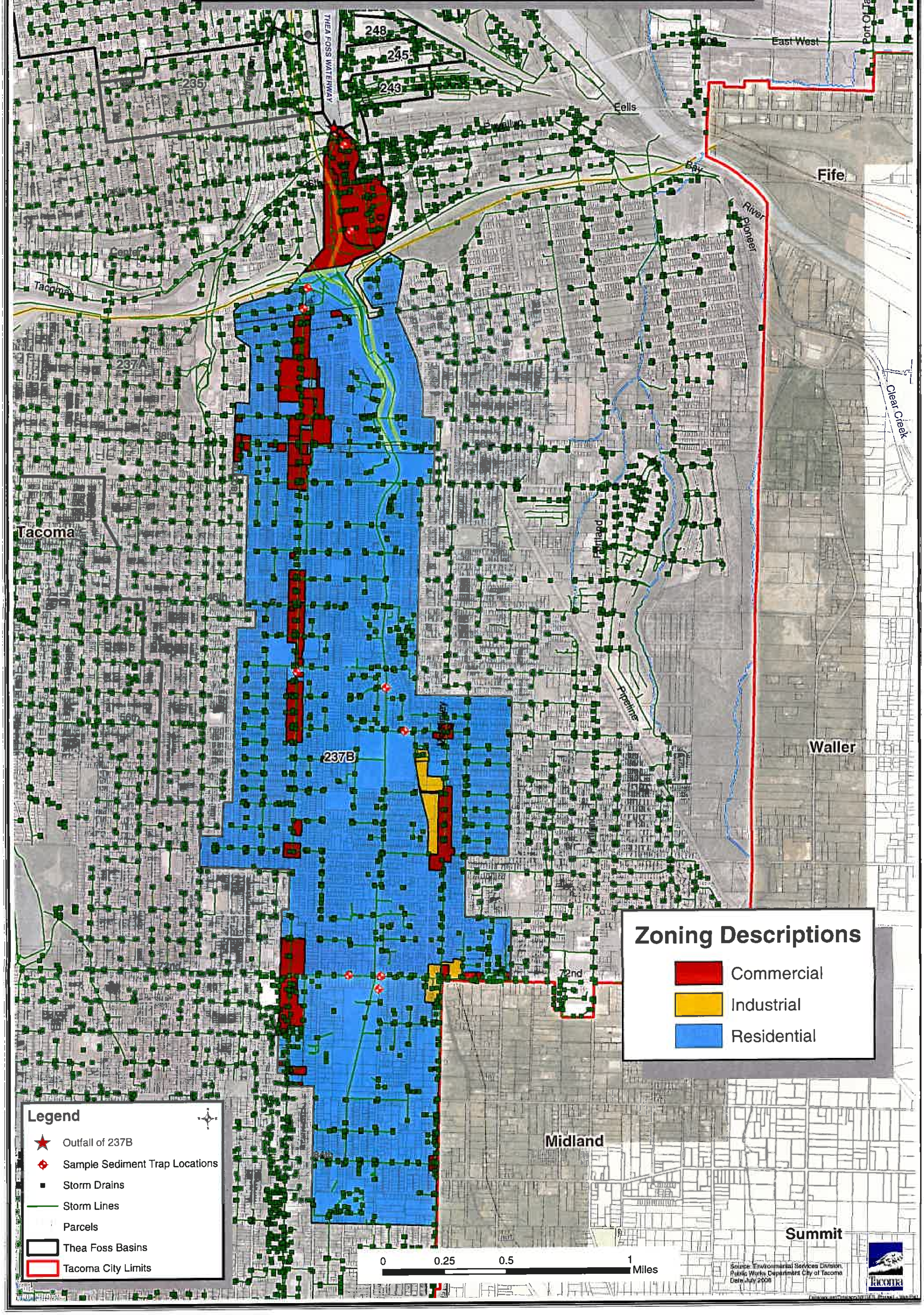
Outfall 237B Whole Water and Sediment Sampling Site

Figure 7-1



Basin 237B

Figure 7-2



7.3.1.1 Site Hydrology

This section contains a brief description of the site's hydrology including any potential or known back-water conditions, whether or not the site is subject to base flow or tidally influenced, or other site-specific conditions that may influence sampling.

Baseflow from OF237B is continuous from former creeks that were piped. The flows originate in two major areas: seeps from the blueberry fields on 72nd and along the railroad tracks by Highway 7, and from an Artesian well on South Tacoma Way in Gallagher's Gulch that discharges into the old 237A pipe, which is 30 feet deep and connects to 237B at Tacoma's Dock Street yard. The baseflow for OF237B is approximately 4.3 cubic feet per second (City of Tacoma 2008).

Stormwater flow rates of events sampled under the Foss 2001 SAP from 2001-2007 varied from 8.2 cfs for small events up to 87 cfs for larger storms. In 1995, a relationship between rainfall data and actual runoff records was developed (Tacoma 1997). A clear and distinct relationship between rainfall and runoff was apparent (Table 7-6). The resulting equations were:

Table 7-6. Rainfall/runoff relationship for OF237B.

	Residential
Basin	OF237B
Baseflow rate, cfs	4.3
Runoff in addition to baseflow, acre-feet per inch of rain	19.63
Lag time between rainfall and runoff, hours	2

The predicted flows based on this equation matched the recorded flows.

This rainfall/runoff relationship will be reevaluated using the continuous flow data.

Runoff from the upper two-thirds of the basin drains down steep slopes to the lower third of the basin. This generates higher velocities and well mixing of the flow regime. The slope of the pipe section at the sampling location is 2.4 percent. The higher velocity at the sampling location is such that the flow regime is well mixed. The outfall pipe is oversized to allow for drainage during even during extreme tidal events.

The selected monitoring site MH122 is located within a relatively straight section of pipe. The straightness of the pipe produces a relatively linear flow path through the pipe. The depth of water in the pipe is about 0.9 feet and the velocities are fairly consistent. The large volume of water discharged during large events and subsequent turbulence has pulled tubing out of its brackets.

7.3.1.2 Suitability for Long-Term Monitoring

This section includes an assessment of the suitability for permanent installation and operation of flow-weighted composite sampling equipment. A discussion of pros and cons associated with the long-term monitoring of flow and water quality at the residential land use site follows.

Pros:

- Capable of collecting accurate flow measurement using existing pipe configuration.
- 24-hour access to the secured Dock Street Pump Station Yard.
- Seven years of existing flow and water quality data.

- Existing institutional knowledge on rainfall/runoff response that contributes to the success of sampling.
- Location is within one mile of City's facility and laboratory, which allows for quick response for storm deployment, grab sampling and retrieval.

The residential site is suitable for long-term monitoring. The secured yard provides plenty of room for the monitoring equipment and as well as easy access to equipment and manhole. Flow in the pipe is relatively linear and smooth and provides the best opportunity to monitor in the entire basin. Monitoring with the flow sensor has been successful the past seven years. However, the flow velocity in steep pipes can pull out the sampler tubing during large storm events.

7.3.2 *Industrial Basin (OF245)*

The industrial land use site is located in the Thea Foss Watershed at East 19th and "D" Street in the Johnny's Restaurant parking lot (Figure 7-3). Basin 245 is located in the tideflats of Tacoma on the southern portion of the east side of the waterway. The outfall is located at E. 19th Street, just south of Johnny's Restaurant.

The drainage area is approximately 36 acres. The main trunkline of the storm drainage system extends east from Foss Waterway, down E. 19th Street to E. "I" Street (Figure 7-4). Land use in this basin is entirely industrial. Most facilities are engaged in storage, transloading and warehousing of materials and products, and manufacturing.

Directly upstream of the outfall is a deep bottom sump manhole known as MH390 (Figure 7-3). MH390 is in the restaurant parking lot in a designated no parking space and require closing an adjacent parking space during sampling activities. MH390 is 60 inches (I.D.) approximately 18 feet in depth with the inlet pipe and outlet pipe at 55.5 inches above the bottom. A plastic tide gate (swing valve) is located on the inlet pipe. The tide gate does not securely seal and some tidal water does get into the upper reaches of the system. In the fall 2004, the last 24 feet of pipe from MH390 to the waterway was replaced with HPDE. Drainage from MH390 was improved with the new pipe slope, which replaced the old line that had a sag in it.

In August 2004, Tacoma replaced a 300 feet segment of the stormwater line and associated laterals in East 19th Street. This action sealed this segment from groundwater, sediment and product migration from the surrounding contaminated soil that remains in-place after an interim action remediation project was completed in this area. In the summer and fall of 2008, more contaminated soil will be removed along "D" Street.

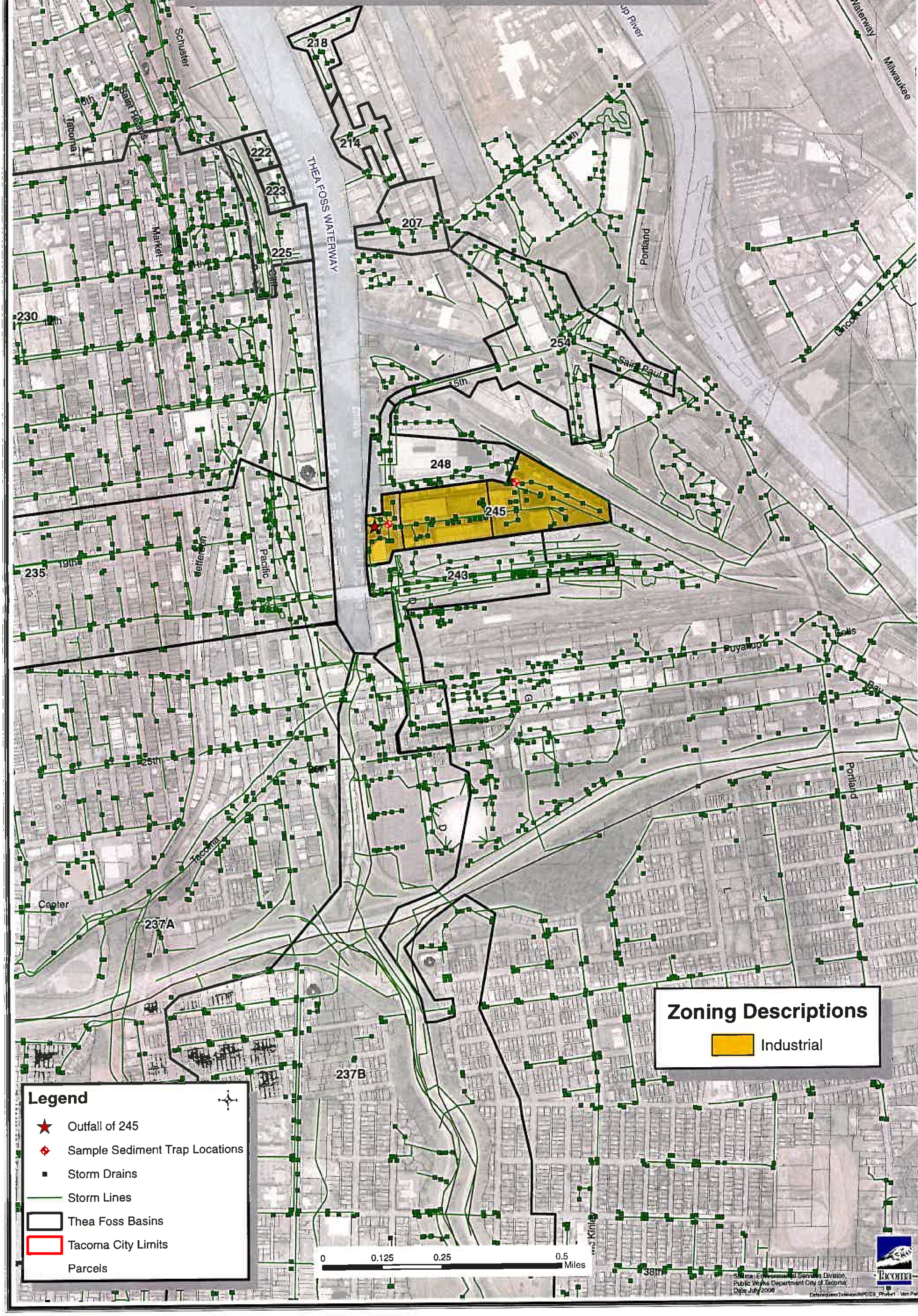
The water monitoring station would be located in the outlet pipe of the MH390 sump.

Outfall 245 Whole Water and Sediment Sampling Site

Figure 7-3

Foss Basin 245

Figure 7-4



7.3.2.1 Site Hydrology

This section contains a brief description of the site's hydrology including any potential or known back-water conditions, whether or not the site is subject to base flow or tidally influenced, or other site-specific conditions that may influence sampling.

The monitoring location at OF245, elevation 3.15 MLLW ft., is tidally influenced and portions of the outfall pipe and sump are inundated with marine water twice a day depending on the tide height. Average tidal fluctuations vary from 0 feet MLLW to 11 feet MLLW. Extreme tides, which occur in June and December, range from approximately –4.0 feet MLLW to 14.5 feet MLLW.

In the Foss stormwater monitoring program, tidal effects were excluded from the automatic samplers using sequential sampling and based on *in-situ* velocity monitoring (i.e., near zero during tidal inundation), height, and/or conductivity, and confirmed in the laboratory using conductivity (salinity) measurements prior to compositing the sample bottles from different portions of the storm. Conductivity measurements of the aliquots composited for OF245 were less, than 2,700 umhos/cm. For comparison purposes, conductivity measurements of 95 percent stormwater/5 percent saltwater is approximately 2,400 umhos/cm and measurements of 50 percent stormwater/50 percent saltwater is approximately 20,000 umhos/cm (Tacoma 2008).

The sampling of tidally influenced drains was necessarily limited to those periods when the drain was not affected by tides, and therefore included only a portion of the runoff hydrograph. The City acknowledged that sampling tidally influenced drains was difficult given the limit of those periods when the drain was not affected by tides.

Over the course of the six years (2001-2007), the tidal sampling windows randomly overlapped with different portions of the runoff hydrograph. An evenly distributed range of rising, peak, and falling runoff conditions was captured during multiple sampling events. Even with the tidal influence, 66 percent of the storms sampled included most of the storm event (Table 6-1). Therefore, a variety of runoff conditions were sampled in this tidally-influenced drain for these individual storm events in an attempt to address the Foss 2001 SAP, which recognizes the fact that storm events are variable by nature (Table 6-2).

The 2001-2007 storm event flow rates in OF245 varied from 0.14 cfs for small events up to 2.8 cfs for larger storms. Prior to 1999, annual flow from OF245 was estimated based on the rational method and flow data. However, the limitations use of the rational method in larger basins was noted (i.e., overestimation of annual flow). In 1999, a flow relationship between rainfall data and annual precipitation was developed based on the OF237B equation and a correlation with the South Tacoma Drainage Basin stormwater management model (SWMM) (Tacoma 1999). For OF245, the estimated annual volume for 37 inches of rainfall is 33 acre-feet. The rainfall/runoff relationship will be reevaluated using the continuous flow data.

7.3.2.2 Suitability for Long-Term Monitoring

This section includes an assessment of the suitability for permanent installation and operation of flow-weighted composite sampling equipment. A discussion of pros and cons associated with the long-term monitoring of flow and water quality at the industrial land use site follows.

Pros:

- Capable of collecting accurate flow measurement using existing pipe configuration.
- Designated no parking space allowing 24-hour access to MH390.

- Seven years of existing flow and water quality data.
- Existing institutional knowledge on rainfall/runoff response that contributes to the success of sampling.
- Location is within one mile of City's facility and laboratory, which allows for quick response for storm deployment, grab sampling and retrieval.

Cons

- Tidal influences limit the use of velocity measurements during high tides.

The industrial site is suitable for long-term monitoring. The designated parking space provides plenty of room for the monitoring equipment and as well as easy access to equipment and manhole. Flow in the pipe is relatively linear and smooth and provides the best opportunity to monitor in the entire basin. Monitoring with the flow sensor has been successful the past seven years.

7.3.3 *Commercial Basin (OF235)*

The commercial land use site, OF235, is located in the Thea Foss Watershed located directly under the SR509 Bridge on the east side of Thea Foss Waterway, East 21st and Dock Street (Figure 7-5).

Basin 235 is the fourth-largest basin in the Thea Foss Watershed. The drainage basin encompasses a section of downtown between Basins 230 and 237A. Basin 235 is heavily developed and covers an area of approximately 180.7 acres, which drains through a 42-inch outfall pipe located on the west bank of the Waterway at 21st and East Dock Street under the SR-509 bridge. The general basin boundaries are South 18th to the north, South 23rd to the south, South "L" Street to the west and E. Dock Street to the east (Figure 7-6).

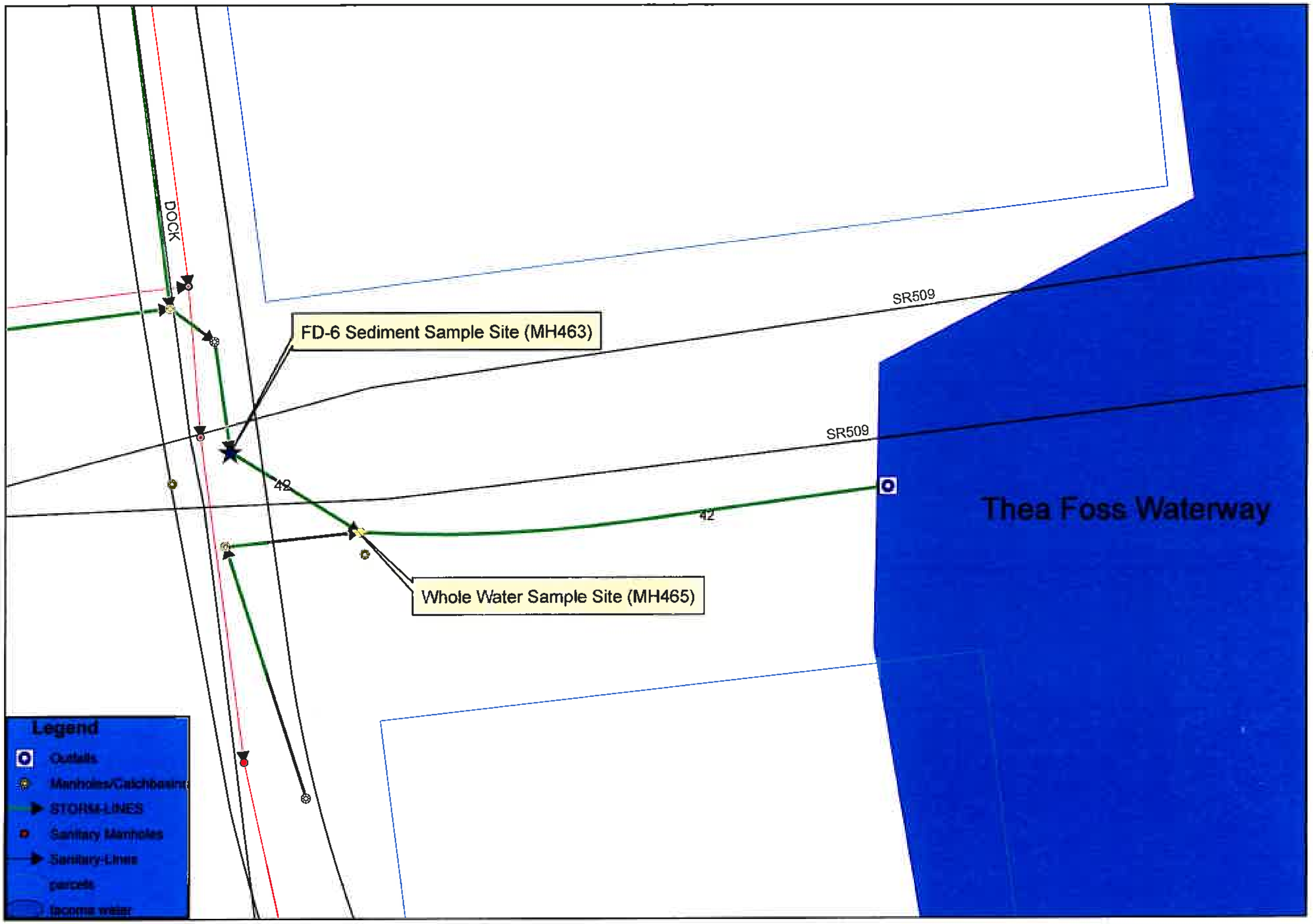
Commercial land use accounts for approximately 68 percent, residential approximately 25 percent, and multi-family at seven percent (Figure 7-6). A small portion of freeway right-of-way is in the lower part of this basin including I-705 and the entire I-705 and I-509 interchange. Most of the stormwater runoff from the freeways discharges to an infiltration pond and not to the city-owned storm drains.

The southern portion of the University of Washington–Tacoma (UWT) and a portion of the Saint Joseph Medical Complex discharges to OF 235. The drainage area for UWT is bounded by Pacific Avenue, South 21st Street, Tacoma Avenue and South 17th Street. Also included in the basin is Tacoma Light Rail – LINK, downtown revitalization, Dock Street redevelopment and The Foss Waterway Public Esplanade from South 21 Street to South 17th Street.

Baseflow in OF 235 is groundwater from an old railroad tunnel located near Jefferson and South 25th (City of Tacoma 2008). The flow is continuous at approximately 0.23 cubic feet per second.

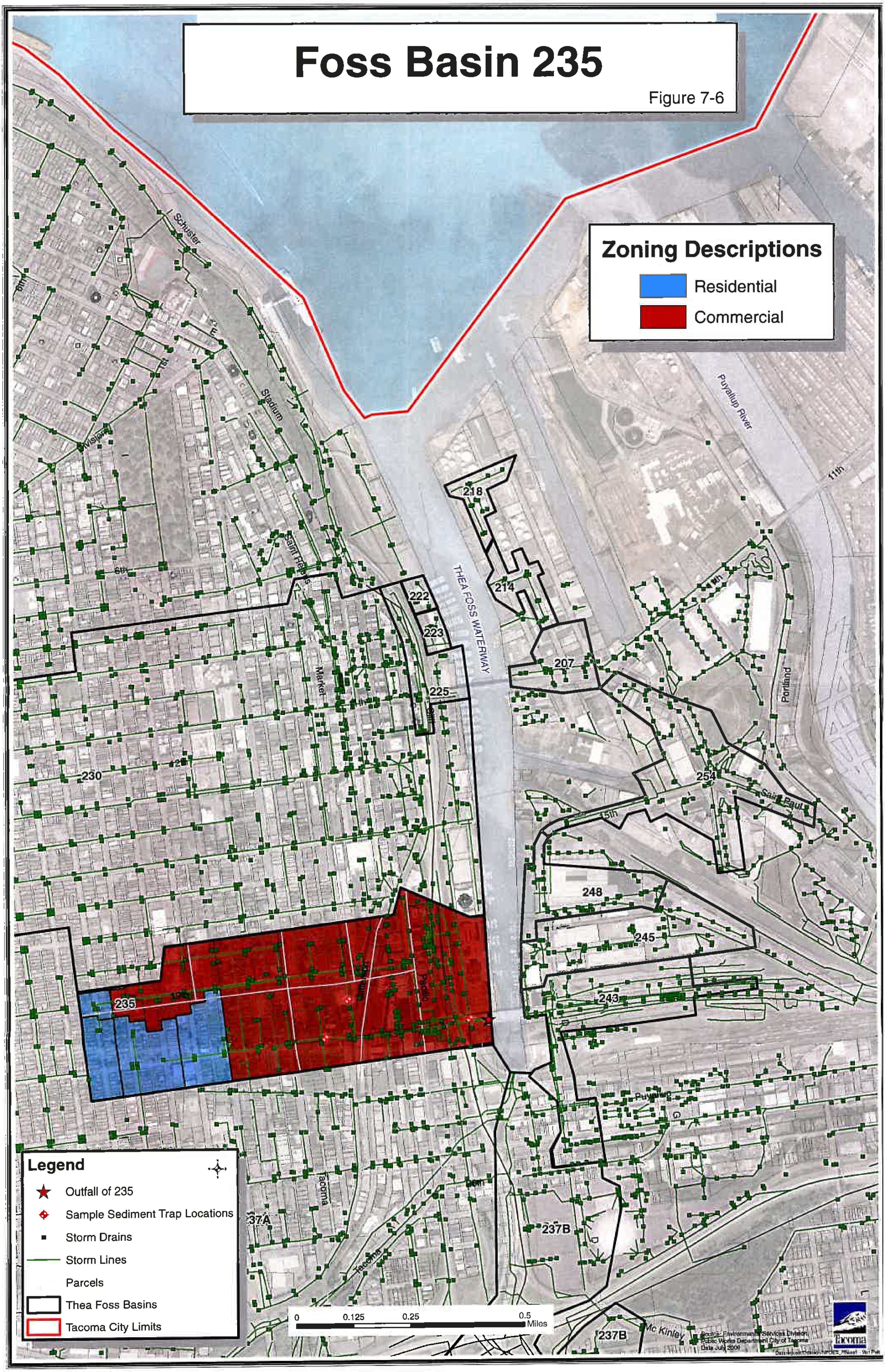
Outfall 235 Whole Water and Sediment Sampling Sites

Figure 7-5



Foss Basin 235

Figure 7-6



7.3.3.1 Site Hydrology

This section contains a brief description of the site's hydrology including any potential or known back-water conditions, whether or not the site is subject to base flow or tidally influenced, or other site-specific conditions that may influence sampling.

The selected monitoring site, the outlet pipe in manhole (MH) 465, is located within a relatively straight section of pipe. The inlet pipe has an estimated slope of 0.7 percent under Dock Street and the outlet pipe has an estimated slope of 2.95 percent. The straightness of the pipe produces a relatively linear flow path through the maintenance hole. The depth in the pipe is shallow and the velocities are high due the steepness of the inlet and outlet pipes. Turbulence and backwater issues are not expected.

Runoff from the upper half of the basin drains down steep slopes to the lower half of the basin. This generates higher velocities and well mixing of the flow regime. The higher velocity at the sampling location is such that the flow regime is well mixed.

The monitoring location at OF235, elevation 9.79 MLLW ft., is tidally-influenced and portions of the pipe are inundated with marine water twice a day depending on the tide height. Average tidal fluctuations vary from 0 feet Mean Low Low Water (MLLW) to 11 feet MLLW. Extreme tides, which occur in June and December, range from approximately –4.0 feet MLLW to 14.5 feet MLLW.

In the Foss stormwater monitoring program, tidal effects were excluded from the automatic samplers using sequential sampling and based on *in-situ* velocity monitoring (i.e., near zero during tidal inundation), height, and/or conductivity, and confirmed in the laboratory using conductivity (salinity) measurements prior to compositing the sample bottles from different portions of the storm. Conductivity measurements of the aliquots composited for OF235 for the most part were less, than 2,000 umhos/cm. For comparison purposes, conductivity measurements of 95 percent stormwater/5 percent saltwater is approximately 2,400 umhos /cm and measurements of 50 percent stormwater/50 percent saltwater is approximately 20,000 umhos /cm (Tacoma 2008).

Over the course of the six years (2001-2007), the tidal sampling windows randomly overlapped with different portions of the runoff hydrograph. An evenly distributed range of rising, peak, and falling runoff conditions was captured during multiple sampling events. Even with the tidal influence, 85 percent of the storms sampled included most of the storm event (Table 6-1). Therefore, a variety of runoff conditions were sampled in this tidally-influenced drain for these individual storm events in an attempt to address the Foss 2001 SAP, which recognizes the fact that storm events are variable by nature (Table 6-2).

The 2001-2007 storm event flow rates in OF235 varied from 1.4 cfs for small events up to 12 cfs for larger storms. Prior to 1999, annual flow from OF235 was estimated based on the rational method and flow data. However, the limitations use of the rational method in larger basins was noted (i.e., overestimation of annual flow). In 1999, a flow relationship between rainfall data and annual precipitation was developed based on the OF237B equation and a correlation with the South Tacoma Drainage Basin stormwater management model (SWMM) (Tacoma 1999). For OF235, the estimated annual volume for 37 inches of rainfall is 118 acre-feet. The rainfall/runoff relationship will be reevaluated using the continuous flow data.

7.3.3.2 Suitability for Long-Term Monitoring

This section includes an assessment of the suitability for permanent installation and operation of flow-weighted composite sampling equipment. A discussion of pros and cons associated with the long-term monitoring of flow and water quality at the commercial land use site follows.

Pros:

- Capable of collecting accurate flow measurement using existing pipe configuration.
- 24-hour access to the manhole under SR509.
- Seven years of existing flow and water quality data.
- Existing institutional knowledge on rainfall/runoff response that contributes to the success of sampling.
- Location is within one mile of City's facility and laboratory, which allows for quick response for storm deployment, grab sampling and retrieval.
- Flow is linear and fairly smooth in pipe-best in-pipe conditions in the area.

Cons:

- Flow is shallow and small events may be too shallow to sample.
- High velocities may cause sampler tubing to pull out during large/intense storm events

The commercial site is suitable for long-term monitoring. The easement under SR509 provides plenty of room for the monitoring equipment and as well as easy access to equipment and manhole. Flow in the pipe is relatively linear and smooth and provides the best opportunity to monitor the entire basin.

7.4 Stormwater Monitoring Strategy

A discussion of the stormwater monitoring strategy developed by Ecology is presented below and includes:

- Selection of parameters and analytical methods,
- Selection of sampling techniques and types, and
- Selection of sampling frequency and criteria to ensure representative samples.

7.4.1 Parameters and Analytical Methods

Ecology selected pollutants to be monitored based upon their known presence in stormwater, their potential for adverse impacts, or their value in providing necessary supporting information (see Section 3.3 for additional information).

A significant sampling design concern is the ability to obtain adequate sample volume to complete the selected analyses. This section discusses the selected parameters, the volumes required to analyze those parameters, and the priority order in which analyses will be done. Table 7-7 summarizes the estimated volumes needed for stormwater analytical chemistry and toxicity samples.

Table 7-7. Volume requirements for stormwater chemistry and toxicity analyses.

Sample Technique/ Type	Analytes	QC Sample Status	First Flush Toxicity Volume (L)		Routine Volume (L)	
			Regular	**With QC**	**Regular**	**With QC**
Manual grab	Water Chemistry	Primary	1	1	1	1
		Duplicate		1		1
	Max Volume per Event		**1**	**2**	**1**	**2**
Automatic flow-weighted composite	Water	Primary	6.4 - 17.3	6.4 - 17.3	6.4 - 17.3	6.4 - 17.3
	Water	Duplicate	--	6.4 - 17.3		6.4 - 17.3
	Toxicity	Primary	16 – 40	16 – 40		
	Volume Range per Event		**Min 23.4**	**Max 76.6**	**Min 7.4**	**Max 36.6**

Three types of analyses may be conducted on samples collected at each site: (1) stormwater analytical chemistry, (2) stormwater toxicity, and (3) sediment analytical chemistry. Each analysis is discussed further in the following sections.

7.4.1.1 Water Analytical Chemistry

Samples collected using automatic flow-weighted composite samplers will be analyzed for the following parameters:

- BOD5
- Hardness
- TSS
- Turbidity
- Conductivity
- Chloride
- Orthophosphate
- Total phosphorus
- Nitrate/nitrite
- Total kjeldahl nitrogen
- Phthalates
- Polycyclic aromatic hydrocarbons (PAHs)
- Methlyene Blue Activating Substances (MBAS)
- Metals (total and dissolved zinc, copper, cadmium and lead. Mercury is required for commercial and industrial land uses only).
- Pesticides (2,4-D, MCPP, Triclopyr, Diazinon, Malathion, Chlorpyrifos, Dichlobenil, Prometon and Pentachlorophenol)

Samples collected using manual grab sampling procedures will be analyzed for the following parameters:

- Fecal coliform bacteria,
- Total petroleum hydrocarbons (TPH) using NWTPH-Dx and NWTPH-Gx.

Table 6-5 in the S8 Program QAPP presents the analytical methods and minimum reporting limits. Adequate volume to perform stormwater analysis of the flow-weighted composite sample will be between 8-to 17 L. If the volume of stormwater sample collected from a qualifying storm is insufficient to allow analysis for all parameters listed in Table 6-5 in the S8 Program QAPP, the sample shall be analyzed for as many parameters as possible in the following priority order (Table 7-8):

Table 7-8. Required composite sample analysis priority order (S8D, Paragraph 2c).

Priority analysis order	
OF237B	OF235 OF245
1. TSS; 2. Conductivity; 3. MBAS; 4. Metals and hardness ; 5. Nutrients; 6. Pesticides; 7. PAHs and phthalates; 8. BOD5; and 9. Chlorides	1. TSS; 2. Conductivity; 3. MBAS; 4. Metals and hardness; 5. PAHs and phthalates; 6. Pesticides; 7. Nutrients 8. BOD5; and 9. Chloride

If insufficient sample exists to run the next highest priority pollutant, that analysis should be bypassed and analyses run on lower priority pollutants in accordance with the remaining priority order to the extent possible.

7.4.1.2 Toxicity Samples

The total volume required for toxicity testing and associated egg analysis is in the range of 24 to 44 liters. In addition, a minimum volume of 8 to 17 liters is needed for associated chemical analyses (see Section 7.3.1.1). Section 9.1.1 discusses the approach to be taken if insufficient volume is present.

7.4.1.3 Sediment Samples

The following parameters will be analyzed for in sediments:

- Total solids (% solids)
- Grain size
- Total organic carbon
- PAHs
- Phthalates
- Phenolics
- PCBs[1]
- Pesticides (diazinon, chloropyrifos, malathion, pentachlorophenol)
- Metals (total copper, zinc, cadmium, lead and mercury[1])

1 Not necessary for residential land use site.

Table 6-6 in the S8 Program QAPP presents the required analytical methods and minimum reporting limits. Adequate volume to perform sediment analysis will be approximately 1250 to 1600 grams. If the volume of sample collected is insufficient to allow analysis for all parameters listed in Table 6-6 in the S8 Program QAPP, the sample shall be analyzed for as many parameters as possible in the following priority order (Table 7-9):

Table 7-9. Required sediment sample analysis priority order (S8D, Paragraph 2(f)(iii)).

Priority analysis order	
OF237B	OF235 OF245
1) Grain size[1]; 2) Total organic carbon; 3) Metals; 4) Pesticides; 5) PAHs and Phthalates; and 6) Phenolics	1) Grain size[1] ; 2) Total organic carbon; 3) Metals; 4) PAHs and Phthalates; 5) Phenolics; 6) PCB's; and 7) Pesticides

[1] if enough sample is available for all parameters use method in Table 6-6; otherwise characterize grain size qualitatively.

7.4.2 *Sampling Techniques and Types*

Ecology has specified the sampling techniques and types to be used. In addition to those specified, automatic composite sampling will be used to characterize base flow.

7.4.2.1 Automatic Composite Sampling

Automatic composite sampling is required for all parameters, except fecal coliform bacteria or total petroleum hydrocarbons. Automatic flow-weighted composite samples will be collected for water chemistry (Section 7.4.1 Parameters and Analytical Methods) and automatic time-composite samples for toxicity. Automatic time-weighted composite samples will be collected for base flow chemistry (Section 7.4.1 Parameters and Analytical Methods).

7.4.2.2 Manual Grab

Manual grab samples will be collected for total petroleum hydrocarbon and fecal coliform bacteria. Composite samples are not appropriate for these parameters due to their tendency to adhere to sampling equipment (total petroleum hydrocarbon) or change in concentration after a short period (fecal coliform bacteria).

7.4.2.3 Manual Sediment Trap

Sediment samples will be collected with sediment traps. Sediment traps will be deployed for approximately 12-month intervals.

7.4.3 *Representative Sample Criteria*

Ecology has defined "representative" storms that must be monitored and the frequency of monitoring. Storm event criteria are established to: (1) ensure that adequate flow will be discharged; (2) allow some build-up of pollutants during the dry weather intervals; and (3) ensure that the storm will be "representative," (i.e., typical for the area in terms of intensity, depth, and duration).

Collection of samples during a storm event meeting these criteria ensures that the resulting data will accurately portray the most common conditions for each site. Ensuring a representative sample requires two considerations: (1) the storm event must be representative, and (2) the sample collected must represent resulting runoff from the storm event.

7.4.3.1 Representative Storm Event Criteria and Sampling Frequency

Table 7-10 lists the qualifying storm event criteria for dry and wet seasons and the seasonal first flush. Ecology determined that 67 percent of qualifying events, up to a maximum of 11, is needed to establish a sufficient data set from which to discern annual and seasonal loading trends over a long period. In addition, toxicity and annual stormwater sediment sampling are required.

Table 7-10. Representative storm event criteria and sampling frequency.

Criteria	Wet season	Dry season	First Flush	Base Flow[4]
Period	October 1 through April 30	May 1 through September 30	August or September 2010[1]	October 1 through September 30
Rainfall volume	0.20" minimum, no fixed maximum	0.20" minimum, no fixed maximum	0.20" minimum, no fixed maximum	NA
Rainfall duration	No fixed minimum or maximum	No fixed minimum or maximum	No fixed minimum or maximum	Event duration – 24 hours
Antecedent dry period	≤ 0.02" rain in the previous 24 hours	≤ 0.02" rain in the previous 72 hours	≤ 0.02" rain in the previous 168 hours	≤ 0.02" rain in the previous 24 hours
Inter-event dry period	6 hours	6 hours	6 hours	NA
No. of annual chemistry samples per site[2,3]	7-9 (60%-80%)	2-4 (20-40%)	1 only	2 wet season 2 dry season
No. of toxicity samples per site	NA	NA	1	NA

1 Or October, irrespective of antecedent dry period, if unsuccessful in August or September.

2 Includes grab and flow –weighted composite samples. Assumes 60-80 percent of the samples collected during the wet season. Does not include QC samples.

3 additionally, up to a maximum of 3 samples that are collected and do not meet rainfall volume criterion shall be analyzed for a total of14 samples per year

4 Base flow samples are not required under S8D of the NPDES permit and are collected under the Foss 2001 SAP.

Collection of flow-weighted composite water samples will be attempted whenever weather conditions present themselves in order to obtain 11 stormwater samples distributed within the wet-weather and dry weather season during storms that meet the acceptable target storm conditions. Additionally, up to a maximum of 3 samples that are collected as a result of attempts to sample the eleven required storm events and do not meet the rainfall volume storm event criterion but do meet the other storm event and sample criteria.

7.4.3.2 Representative Composite Sampling Criteria

Ecology has defined criteria to ensure the composite sample collected is representative of the storm event sampled (Table 7-11). For storm events lasting less than 24 hours, samples shall be collected for at least 75 percent of the storm event hydrograph. For storm events lasting longer than 24 hours, samples shall be collected for at least 75 percent of the hydrograph of the first 24 hours of the storm. Each composite sample must consist of at least 10 aliquots. Composite samples with 7-to-9 aliquots are acceptable if they meet the other sampling criteria and help achieve a representative balance of wet season/dry season events and storm sizes.

Table 7-11. Representative sampler collection criteria.

Storm event duration	<24 hours	>24 hours	Base Flow
Minimum storm volume to sample	75 percent of the storm event hydrograph	75 percent of the hydrograph of the first 24 hours of the storm	NA
No. of Aliquots	≥10: 7-to-9 accepted	≥10: 7-to-9 accepted	≥10: 7-to-9 accepted
Minimum duration to program ISCO for sampling (hours) 1	2 X time of Concentration	2 X time of Concentration	24

1 Paragraph S8D2(b) requires the sampler to be programmed to continue sampling past the longest estimated time of concentration

7.5 Equipment Monitoring Strategy

The general equipment strategy is to employ a ISCO Model 6712 composite sampler, area/velocity flow module and other sensors (conductivity probes), if necessary, for all selected sites. The recommended strategies for collecting the required volumes include;

1. Standard sequential sample, up to a volume maximum of 12 liters. Where possible, duplicate, matrix spike, and matrix spike duplicates will be obtained from this arrangement. A field blank may be run at the start, middle or end of the sample series.
2. If sequential sampling with a single auto sampler provides insufficient volume for detection limits and QC parameters, then duplicate samplers, in a master-slave configuration, will be used to obtain enough water for field duplicates, matrix spikes and matrix spike duplicates.
3. The toxicity sampling occurs once in the five-year period. For this activity, personnel will be stationed on-site to actuate the sampler, ensuring sufficient volume is obtained.

The QC samples generally follow a 1 QC per 20 samples for…

1. Blanks: Bottle, equipment, transport
2. Duplicates/Replicates: Laboratory and field.
3. Matrix Spike/Duplicate: Laboratory at 1:20, field at 1:40.

Equipment specifications for each site will include: (1) rational for selected equipment strategy, (2) monitoring and communication equipment specifications, and (3) site configuration.

7.5.1 *Thea Foss Waterway Stormwater Monitoring Sampling Strategy*

Since OF235 and OF245 are tidally influenced, it is challenging to coordinate the appropriate tide with the appropriate storm or dry period to collect representative samples. Sampling equipment was selected that was able to determine if the tide is in or out, and activate automatically when rainwater is running off into the storm line outside of tidal influence. An additional safety check was through the use of discrete sampler containers known as sequential sampling. This prevented one aliquot from contaminating an entire composite sample with saltwater. It allowed for compositing of just those samples that are most representative, by reviewing the storm hydrograph and compositing only those samples that best represent the storm criteria.

Currently, the City uses 15 ISCO 6700 samplers with flow monitoring modules, 25 sampler bases, and three conductivity probes along with support equipment (battery chargers, data modules, sampler tubs, strainers, glass jars, etc.). Teflon suction tubing, silicon pump tubing and glass bottles were used in all locations. Sampler probes were attached to a stainless steel plate. The plate was bolted using concrete bolts to the bottom of the pipe. Hoses and electrical cords were attached to the side of the pipe and manhole using concrete bolts and plastic ties. The sampler was hung from the manhole rungs using stainless steel cable and iron hangers.

The samplers are composite samplers with sequential sampling capabilities. Each sampler base contains twelve one-liter discrete sample containers. For the purposes of the Foss project, the samplers were programmed to collect flow proportional discrete samples on the west side outfalls and time composite discrete samples on the east side tidally influenced outfalls.

Within the next year, the ISCO 6700 samplers will all be replaced with the newer model ISCO 6712 at OF237B, OF235 and OF245. Sampler activation and programming protocols were developed for each sampling location (Tables 7-12 and 7-13). These protocols will be evaluated and changed as necessary to meet the required sample volumes for the S8D analytes.

Table 7-12. Sampler enables for OF235, OF237B, and OF245.

LOCATION	ENABLE
235	Level > 0.6 feet Velocity > 1.0 feet per second
237B	Level > 0.950 feet
245	Velocity > 0.40 feet per second

Table 7-13. Sampler pacing for OF235, OF237B, and OF245.

LOCATION	PACING
STORM 0.2-0.3 inches	
235	17,955
237B	300,000
STORM 0.3-0.4 inches	
235	22,610
237B	370,000
STORM 0.4-0.5 inches	
235	29,925
237B	455,000
STORM 0.5-0.6 inches	
235	37,400
237B	560,000
ALL STORMS	
245	10 MINUTES

Under the Foss 2001 SAP, the ISCO samplers at OF237B and OF235 are programmed to calculate storm flow based on area-velocity and to be collected over a 24-hour period. OF245 is collected using time composite and is collected during tidal window when the sampler is enabled.

During OF235 and OF245 baseflow events, the ISCO samplers are programmed to calculate flow using Manning's equation because baseflow depths are too shallow to enable accurate velocity readings. Pacing is adjusted to collect as many aliquots as possible over the tidal window (4-hour minimum and at least 10 aliquots). Baseflow samples are scheduled whenever tidal conditions were suitable (i.e., tides less than one foot). This did not require periods of extreme low tides. i.e., A flow composited sample collected for a minimum of 24 hours where the aliquots represent the non-tidally influence of that period of time.

As previous stated, these protocols will be evaluated and changed as necessary to meet the requirements for S8D.

8 SAMPLING (FIELD) PROCEDURES

This section describes field procedures that will be utilized to ensure that samples are collected in a consistent manner and are representative of the matrix being sampled, and the data will be comparable to data collected by other existing and future monitoring programs. Please refer to S8 Program QAPP, Section 8 Sampling (Field) Procedures for general information related to stormwater sampling. Specific details will be provided in the SOPs.

A general description of field activities is provided below.

8.1 Sample Identification

All samples will be clearly labeled in the field with indelible ink. Each sample will be uniquely identified by its sample location identifier combined with the sample method (type and technique, i.e. manual grab, automatic flow-weighted composite), the event date and time stamp, and the sample matrix. For composite samples, the date and time stamp will reflect the last aliquot collected

8.2 Sample Collection Procedures

A general discussion of sample collections procedures is described below. Specific details will be provided in the SOPs.

8.2.1 *Automatic Flow-weighted Composite Samples*

Automatic flow-weighted composite samples using the ISCO 6712 sampler will be collected for analytical chemistry. Clean hands protocols should be followed during sampler setup, sample collection and handling to avoid sample contamination. Samples should remain on ice during the collection period. For all sampling conditions, the samplers were programmed to perform one pre-flush prior to taking a sample. The sampler purges, rinses with sample water, purges and then samples.

The objective is to collect a flow proportional composite sample that represents 75 percent of the storm event hydrograph for storm events lasting less than 24 hours and 75 percent of the first 24 hours of the storm hydrograph for storms lasting longer than 24 hours.

The goal of composite sampling is to sample representative storm runoff. The samplers will be programmed to sample anytime storm drain conditions indicated that runoff was occurring and there was not tidal influence. This enable is determined based on the velocity of the water in the pipe, height of the water in the pipe, and/or the conductivity of the water in the pipe. Thus, the enable level should be set to discontinue sampling once base flow returns at the end of a storm event or even during intra-event base flow (that is, when flow rate falls to the base flow level between short gaps within one storm event hydrograph) Some intra-event base flow may be sampled if sufficient volume passes to accumulate the pacing volume.

The activation protocols (enables) will be dictated by type of sample to be collected (flow composite) and the site conditions, and were therefore site specific for each location. Site-specific sampler activation and programming protocols are listed in Tables 7-12 and 7-13.

Antecedent conditions and storm predictions will be monitored via the Internet and review of rain gauge data, and a determination will be made as to whether to target an approaching storm for sampling. Once a decision has been made to target a storm event for sampling, field personnel will conduct site visits to deploy clean sample bottles in the automated samplers at each monitoring station, calibrate equipment as necessary, clear any obstructions from the sampler intakes, and check the operational status of the flow monitoring equipment. Field personnel will then fill the automatic samplers with ice and initiate the sampler program. Ice is estimated to keep the interior of the samplers cool for 48 hours; consequently, ice will not be added to the samplers more than 24 hours before a targeted storm event. The speed and intensity of incoming storm events will then be tracked using Internet-accessible images from publicly available Doppler radar. Actual rainfall totals during sampled storm events will be monitored from the CTP and City's SCADA rain gauges.

Sequential Sampling Program – Once the sampler detected the appropriate flow velocity, water height, and/or conductivity to indicate stormwater runoff, a flow based sampling sequence is activated. Once the sampler is activated, the sampler is programmed to collect discrete sequential flow proportional composite samples. Samples taken are based on the flow proportional sampling criteria set (every 50,000 gallons, 200,000 gallons, or whatever is set by the user).

Each time the sampler samples, approximately 200 to 250 mls sample is taken. Four samples are composited into each discrete sample container. A complete sampling sequence will be 48 samples in the 12, one-liter (Figure 8-1). A minimum volume of 10 to 14 liters (up to 48 aliquots, depending on the QC that is being performed) is required to perform the selected analysis.

Figure 8-1. Sequential sampler base.

The frequency of the flow proportional sampling is of course dependent on the magnitude of the storm and the flow in the pipe. Flow proportional sampling criteria are at times adjusted based on the magnitude of the storm that was being predicted. At times, a small storm may not achieve the necessary volumes to trigger enough sampling to meet the minimum volume criteria to perform the necessary analysis. At other times, if the flow proportioning was set too low, and a large storm was encountered, the sampling containers may all have filled in a very short period of time sampling only a small portion (the beginning) of the storm.

8.2.1.1 Stormwater Compositing

Once back at the City's laboratory, the storm data is downloaded electronically from the samplers and transferred to a desktop computer for data analysis using ISCO FloLink, the manufacturer-supplied software. The data is reviewed to determine the flow hydrograph and where on that hydrograph samples are taken. The storm data is compared to the storm criteria to determine if the samples are representative of the storm. The S8 Program Manager or a designee determines whether the samples meet the sampling criteria, and which of the discrete samples will be composited for analysis. The following criteria will be used to determine the acceptability of storm flow water samples:

1. <u>Sufficient Sample for Analysis</u>. The samples are checked to determine if there were adequate sample aliquots and volume for analysis.
2. <u>Review Rainfall Data and Criteria</u>. The total rainfall and antecedent dry weather period are determined to see if the minimum precipitation criteria are met using data from the City rainfall gage located at the City's Central Wastewater Treatment Plant.
3. <u>Review Flow Hydrograph, Sample Collection (time and number), Corresponding Tide Chart, and Storm Criteria</u>. The S8 Program Manager determines which of the discrete samples will be composited by reviewing the flow hydrograph, the discrete sampling times relative to tidal stage and storm flow, and the conductivity (salinity) of the samples.

The storm hydrograph will be evaluated to determine the number of aliquots collected (i.e., minimum of 10 aliquots for compositing) and which of the discrete samples will be composited to best represent the storm criteria (i.e., minimum of 75 percent of the hydrograph volume for the event or up to 24 hours duration). The discrete samples will be screened for conductivity. Samples with < or = 2,000 uhmos/cm are considered not tidally influenced. The conductivity, time and number of discrete samples to be composited will be compared to the storm criteria to determine if the composite is representative of the storm runoff.

8.2.1.2 Baseflow Compositing

Only those containers that show no signs of tidal influence will be combined to make a baseflow sample. Once back at the City's laboratory, the flow data obtained from the samplers is downloaded electronically from the samplers and transferred to a desktop computer for data analysis using ISCO FloLink (the manufacturer-supplied software). The S8 Program Manager will determine whether the samples met the sampling criteria, and which of the discrete samples will be composited for analysis. The following criteria will be used to determine the acceptability of baseflow water samples:

1. <u>Sufficient Sample for Analysis</u>. The samples will be checked to determine if there were adequate sample aliquots and volume for analysis (i.e., minimum of 10 aliquots for compositing).

2. Reviewed Rainfall Data and Criteria. Upon return (or before hand) to the laboratory, the rain gauge at the Central Wastewater Treatment Plant will be checked to verify that precipitation for the sampling period did not exceed 0.02 inches.
3. Reviewed Flow Hydrograph, Sample Collection (time and number), and Corresponding Tide Chart. The S8 Program Manager will determine which of the discrete samples will be composited that represent the baseflow by reviewing the flow hydrograph, the discrete sampling times relative to tidal stage and baseflow, and the conductivity (salinity) of the samples.

The sampler level, velocity and flow data will be reviewed to determine if any significant variability occurred over the sampling period. The discrete samples will be screened for conductivity. Each sample jar will be tested for conductivity to confirm that no samples were taken that are tidally influenced. Any sample containers that shows tidal influence above the accepted criteria will be discarded. The accepted criteria for specific conductance is defined in the Foss 2001 SAP as < or = 2,000 umhos/cm for OF237B and OF235. Specific conductance in OF245 is elevated during tidal influence. The specific conductance criteria for OF245 is < or = 5,000 umhos/cm in the wet season and < or = 10,000 umhos/cm at OF245 in the dry season. The criteria may change if salinity conditions change from year to year.

8.2.2 *Manual Grab Samples*

During each storm event that a composite sample is collected, a discrete stormwater "grab" samples will be collected manually. Grab samples will be collected at each stormwater monitoring site during qualifying storm events as early in the storm event as possible. If it is not possible to collect a manual grab sample due to logistical or safety reasons, a grab sample will be collected at a separate qualifying event.

Because we expect some storm events to occur in the middle of the night, on weekends, or during holidays (and automatic samplers may begin sampling if enabled), having staff immediately available may be difficult. During these times, it is possible that grab samples may be taken during different storm events when no composite samples are targeted. If the grab sample is collected during storm runoff that meets all qualifying storm event criteria, except for the minimum amount of rainfall, the grab sample will be analyzed and considered a valid sample.

Attempts should be made to have fecal coliform bacteria and TPH analyzed in the same grab sample. However, if the 8-hour maximum holding time for fecal coliform bacteria cannot be met (for example, due to the laboratory being closed on a weekend or holiday), a grab sample could be taken either later in the storm event, or during a future storm event.

The grab sample will be collected by skimming the surface. Every attempt will be made to collect the sample by skimming the surface. However, during storm events velocities at OF237A and OF235 sample locations are extremely high making it physically difficult if not impossible to hold the sample container at the water surface.

Runoff conditions are very turbulent resulting in very well-mixed conditions throughout the water column. Since the water column is well-mixed, TPH samples are believed to be representative of site conditions whether the sample is collected by skimming the surface or collected within the water column during storm events.

8.2.3 *Sediment*

8.2.3.1 OF237B and OF235 Sediment Traps

In OF237B and OF235, sediment samples will be collected using sediment traps, which consist of a stainless steel bracket mounted inside the MS4 that holds a wide-mouth Teflon bottle (Figure 8-2). Traps are designed to passively collect suspended particulates present in stormwater that passes by the sampling site. Sediment traps were initially designed by Ecology (Wilson and Norton 1996) and have since been modified by Tacoma (Norton 1997). Tacoma's modifications enable the sample bottle to be installed in a vertical position in most field conditions (i.e., manholes, vaults, and pipes). Brackets are mounted onto the wall of the pipe, maintenance hole, or other structure using stainless steel screws.

Figure 8-2. Sediment trap mounting bracket.

Two traps will be installed at each monitoring location to ensure that an adequate volume of sample is collected for chemical analysis. Wherever possible, traps will be mounted near the bottom of the junction boxes, where possible, to maximize sample collection. The trap will be mounted so that the mouth of the sample bottle is just above the base flow level to sample only storm flows. In pipes and other locations, the trap will be installed at the lowest point in the pipe. Sampling locations will be selected to avoid small diameter pipes (e.g., less than 24-inch diameter) because a large storm event is generally needed in these systems to inundate the approximately 8-inch tall sample bottle. A typical installation is shown in Figure 8-3.

Figure 8-3. Typical sediment trap installation - large and medium pipe.

Traps will be deployed for approximately 12 months. During the first deployment, traps will be checked after about 3 months and after significant events to evaluate their condition (e.g., damage and sediment volume). Installations will be repaired if any damage does occur.

Trap samples will be retrieved following PSEP (1997) sample handling guidelines. Gloves will be worn at all times when collecting sediment samples. The sample bottles will be capped in place with a clean Teflon lid, removed from the bracket, stored in a cooler on ice, and transported directly to the analytical laboratory. Clean Teflon bottles will be immediately redeployed for the next 12-month sampling period. Descriptions of field observations (e.g., potential construction activities that could interfere with sample collection) and sample characteristics (e.g., sheen, odor, color, amount and type of particles being removed, size description) will be included in the field notes recorded during sample collection.

Teflon sample bottles (approximately $100 each) will be cleaned by the City's laboratory and re-used. The one-liter Teflon bottles with Teflon lids are cleaned to EPA QA/QC specifications Glassware Cleaning Following EPA Protocols (EPA 1990). After cleaning, the bottles will be capped for storage and transport to site.

Stormwater Sediment-Trap Sample Processing. Processing of stormwater sediment trap samples will be performed following the specific procedures developed for the Thea Foss Water Stormwater Monitoring Program. Processing of the samples is accomplished using stainless steel utensils. These utensils are decontaminated prior to use in accordance with the City's laboratory SOP.

Analysis of the stormwater sediment trap samples will be performed on the solids fraction of the collected sample. In order to separate the liquid fraction, stormwater sediment trap samples will be processed in accordance to the revised March 25, 2005 laboratory SOP, Foss Waterway Sediment Trap Sample Handling. The process used is:

1. The sample containers will be allowed to sit for 24 hours.
2. All of the overlying water is decanted, centrifuged, and saved for rinsing. The centrifuge is run for 5 minutes at top speed or until the decanted overlying water was visually clear.
3. The stormwater SPM in the field sample container is transferred to another container. These sediments, which are mostly sand, contain no free water and did not need to be centrifuged.
4. Any remaining sample in the field sample container is rinsed with the decant water and centrifuged to concentrate the sediment fraction and remove the water. The overlying water is then discarded from the tubes. The remaining solid portion is transferred to the appropriate containers for analysis and then submitted for analyses.
5. The decanted overlying water will not be discarded until visually clear with no solids removed during centrifugation.

No part of the sample, in particular the liquid fraction, is discarded without being centrifuged. All particles that can be removed are removed and retained with the solid fraction for analyses. The revised March 25, 2005 laboratory SOP, Foss Waterway Sediment Trap Sample Handling was provided to Ecology in March 2005 and was provided in Appendix K of the August 2001-2005 Stormwater Monitoring Report.

8.2.3.2 OF245 – Manhole 390Sump

Manhole 390, manhole sump, is located immediately upstream of OF 245. This sump functions similarly to a catch basin and sediment traps (Figure 8-4).

A representative stormwater sediment sample is collected from the sump using procedures developed during the Thea Foss Waterway Stormwater Monitoring Program. First, the depth of accumulated stormwater sediment will be measured and noted in the field notebook. The sediment will then be well mixed with the high-pressure truck water hose. After mixing with the high-pressure water, thirty aliquots will be collected at random locations, mixed in a stainless steel bowl and placed in the appropriate sample containers. This procedure of mixing and sampling results in a well-mixed composite sample.

After sampling is completed, the sump will be cleaned out to ensure that the stormwater sediment represents the discrete annual sampling period.

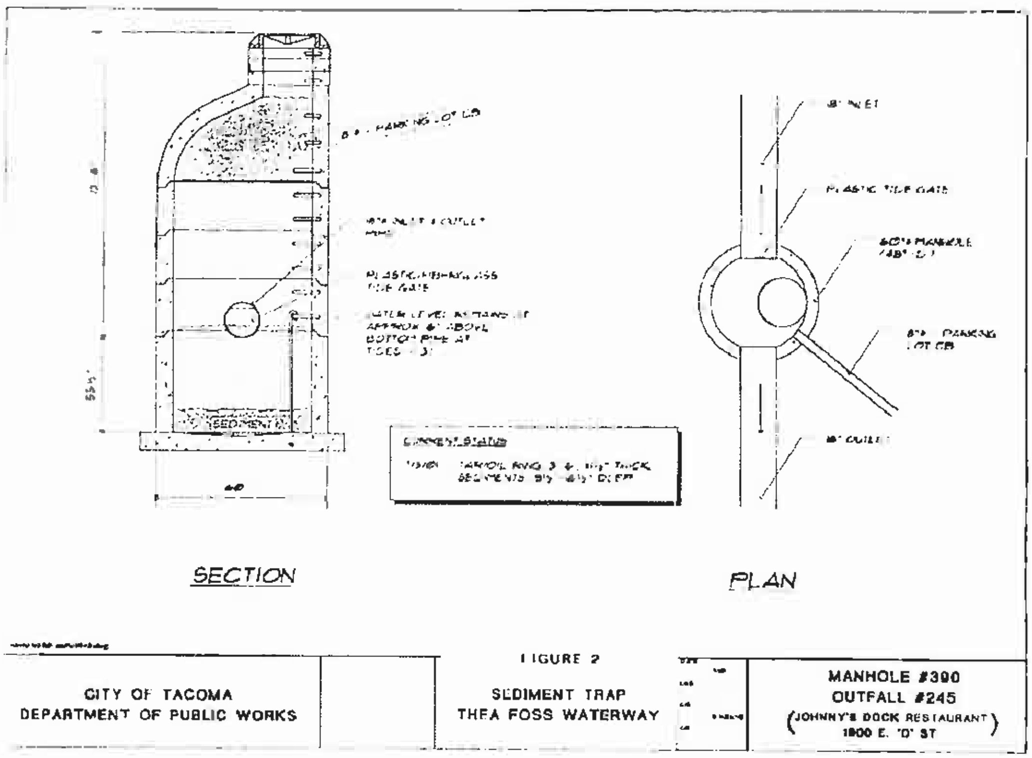


Figure 8-4. MH390 schematic.

8.2.4 *Toxicity Samples - Automatic Time-weighted Composite*

Automatic time-weighted composite samples using an ISCO 6700 series sampler to collect large volumes for toxicity and associated analytical chemistry. Clean hands protocols should be followed during sampler setup, sample collection and handling to avoid sample contamination. Samples should remain on ice during the collection period. The sampler purges, rinses with sample water, purges and then samples.

The objective is to collect a large volume composite sample that represents at least 75 percent of the storm event hydrograph for storm events lasting less than 24 hours and 75 percent of the first 24 hours of the storm hydrograph for storms lasting longer than 24 hours. The goal of composite sampling is to sample representative storm runoff. The 6700 sampler will be programmed to sample anytime storm drain conditions indicated that runoff was occurring and there was not tidal influence. The ISCO 6712 sampler with flow module, which is used to collect the flow-composite samples, will be used to initiate the ISCO 6700 sampler. Once the ISCO 6712 sampler detects the appropriate flow velocity, water height, and/or conductivity to indicate stormwater runoff, a signal will be sent to a parallel ISCO 6700 sampler to initiate the time based sampling program.

The enable is determined based on the velocity of the water in the pipe, height of the water in the pipe, and/or the conductivity of the water in the pipe. The time weighted large volume sample will be initiated and disabled and collected in conjunction with a flow weighted sampler. The activation protocols (enables) will be dictated by the site conditions, and were therefore site specific for each location. Site-specific sampler activation for the ISCO 6712 samplers are listed in Tables 7-12 and 7-13.

Antecedent conditions and storm predictions will be monitored via the Internet and review of rain gauge data, and a determination will be made as to whether to target an approaching storm for sampling. Once it is determined that conditions will be met and at least 5 days prior to the approaching storm, the Toxicity Lab will be contacted to determine if gamete (test organisms) will be available for the targeted event. If the Toxicity Lab confirms that gametes of sufficient quantity and quality will not be available for toxicity testing, the targeted storm event will not be sampled for toxicity testing.

If gametes of sufficient quantity and quality are available and conditions are met, field personnel will conduct site visits to deploy clean sample bottles in the automated samplers at each monitoring station, calibrate equipment as necessary, clear any obstructions from the sampler intakes, and check the operational status of the flow monitoring equipment. Field personnel will then fill the automatic samplers with ice and initiate the sampler program. Ice is estimated to keep the interior of the samplers cool for 48 hours; consequently, ice will not be added to the samplers more than 24 hours before a targeted storm event. The speed and intensity of incoming storm events will then be tracked using Internet-accessible images from publicly available Doppler radar. Actual rainfall totals during sampled storm events will be monitored from the CTP and City's SCADA rain gauges.

Once the ISCO 6700 sampler is activated, the sampler is programmed to collect 1000 milliliters (ml) aliquot samples for 50 events at 15 minute intervals for a total time of 12.5 hours.

For each sample aliquot, approximately a 950 to 1000 ml sample is taken. All sample aliquots are placed into one discrete sample container of sufficient volume to contain at least 50 L. A minimum volume of 45 to 50 L (up to 50 aliquots) is required to perform the selected Whole Effluent Toxicity (WET) analysis.

8.2.4.1 Stormwater Compositing

Once back at the City's laboratory, the storm data is downloaded electronically from the master ISCO sampler and transferred to a desktop computer for data analysis using ISCO FloLink, the manufacturer-supplied software. The data is reviewed to determine the flow hydrograph and where on that hydrograph samples are taken. The WET storm data is compared to the storm criteria to determine if the samples are representative of the storm. The field team leader determines whether the WET samples meet the sampling criteria. The following criteria will be used to determine the acceptability of WET storm water samples:

1. Sufficient Sample for Analysis. The samples are checked to determine if there were adequate sample aliquots and volume for analysis.
2. Review Rainfall Data and Criteria. The total rainfall and antecedent dry weather period are determined to see if the minimum precipitation criteria are met using data from the City rainfall gage located at the City's Central Wastewater Treatment Plant.
3. Review Flow Hydrograph, Sample Collection (time and number), Corresponding Tide Chart, and Storm Criteria. The field team leader determines if the sample is acceptable

by reviewing data (from the master ISCO sampler) of the flow hydrograph, the relative to tidal stage and the conductivity (salinity) of the parallel flow weighted samples.

The storm hydrograph will be evaluated to determine the number of aliquots collected (i.e., minimum of 45 aliquots for composited) (i.e., minimum of 75 percent of the hydrograph volume for the event or up to 24 hours duration).

9 Measurement Procedures

Please refer to S8 Program QAPP, Section 9 Measurement Procedures for Water and Sediment Quality Analysis. Toxicity testing procedures which are specific for S8D are described in the following paragraphs.

9.1 Toxicity Testing

This section describes the laboratory procedures needed to test the seasonal first-flush sample for toxicity. The laboratory will conduct water quality measurements on all samples and test solutions for toxicity testing as specified in the most recent version of Department of Ecology publication # WQ-R-95-80, Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria.

9.1.1 *Testing Procedures*

Testing procedures should follow the E-test (seven day), Environment Canada, Pacific Environmental Science Center, Environmental Toxicology Section, SOP ID: RBTELS1 1 .SOP, 1999. The test procedure may take advantage of the smaller volume modification described in: Canaria, E.C., Elphick, J.R. and Bailey, H.C. 1999. A simplified procedure for conducting small scale short-term embryo toxicity tests with salmonids is found in Environ. Toxicol. 14:301 -307. Toxicity tests must meet quality assurance criteria in the most recent versions of the Environment Canada manual EPS 1/RM/28 and the Department of Ecology Publication #WQR-95-80, Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria.

The 50 percent effective concentration (EC50) must be calculated by the trimmed Spearman-Karber procedure. Abbott's correction may be applied to the data before deriving this point estimate. A minimum of five (5) concentrations and a control must be used in the testing. Terminated organisms must be preserved for up to six months.

The test configuration for 44 liters shall have five concentrations and a control with four replicates at each concentration. An additional seven replicates of 100% sample shall be run in order to provide tissue for yolk/embryo analysis if needed. The test concentration series shall be determined using a 0.5 dilution factor.

If the total sample volume for toxicity analysis, excluding the volume required for associated chemical analysis, is less than 11.6 gallons (44 liters) but greater than 6.3 gallons (24 liters) then the volume that was collected will determine changes in the toxicity-testing configuration described above in accordance with the following:

- 10 gallons (38 liters) of sample – base the concentration series on a 0.3 dilution factor.
- 8.7 gallons (33 liters) of sample – base the concentration series on a 0.3 dilution factor and reduce the number of replicates to three.
- 7.9 gallons (30 liters) – reduce the number of extra replicates of 100 percent sample for yolk/embryo analysis from seven to three and the number of replicates in the test itself to three.
- 6.9 gallons (26 liters) – reduce the number of extra replicates of 100 percent sample for yolk/embryo analysis from seven to three and base the concentration series on a 0.3 dilution factor.
- 6.3 gallons (24 liters) – reduce the number of extra replicates of 100 percent sample for yolk/embryo analysis from seven to three, base the concentration series on a 0.3 dilution factor, and reduce the number of replicates in the test itself to three.

If the sample volume falls between the values listed above, then the test configuration must match the next lowest volume and the excess sample used for additional replicates of 100 percent sample to improve the detection limit for the egg analysis. If sample volume is less than 6.3 gallons (24 liters), toxicity sample analysis will not be conducted.

9.1.2 *Follow Up Actions*

If the EC50 from any valid and non-anomalous test is 100 percent stormwater or less, follow-up actions will be implemented. Follow-up actions include: (1) a chemical analysis comparison of associated chemical analyses results to identify a possible chemical contaminant of concern within sixty (60) days after final validation of the data and (2) following completion of the comparison, if a possible chemical contaminant of concern is not determined by library comparison and literature review, a Gas Chromatograph/Mass Spectrometer (GC/MS) analysis of the eggs.

9.1.2.1 Potential Chemical Contaminant of Concern Determination

The first follow-up step includes: (1) comparing the chemical analysis results for the same sample event to a library of toxicity test results compiled by the Department and identified for this purpose; and (2) using good faith efforts to determine if the presence of an analyzed contaminant is within a range reported in the literature that may adversely affect fish embryos and if so, to review the source literature. If a possible chemical contaminant(s) of concern is determined by the library comparison and literature review, a report will be prepared and submitted summarizing:

- The toxicity and chemical analysis results,
- the library comparison,
- a review of relevant sources of literature from the Department's library,
- the possible chemical contaminant(s) of concern, and
- an explanation of how the City's stormwater management actions are expected to reduce stormwater toxicity.

9.1.2.2 Additional egg chemical analysis

If a possible chemical contaminant of concern is not determined by library comparison and literature review, a Gas Chromatograph/Mass Spectrometer (GC/MS) analysis of the eggs from the highest test concentrations must be performed. The GC/MS need not be quantitative but only capable of identifying stormwater contaminants present in the eggs. A report will be prepared and submitted summarizing:

- The toxicity and chemical analysis results,
- the library comparison,
- a review of relevant source literature from the Department's library,
- the GC/MS results, and
- an explanation of how City's stormwater management actions are expected to reduce stormwater toxicity.

9.1.2.3 Reporting

The reporting schedule for follow-up actions is summarized below in Table 9-1. The report will be attached as an appendix to the following year's annual stormwater monitoring report.

Table 9-1. Toxicity follow-up reporting schedule.

Report	Submittal date to Ecology
Potential chemical contaminant of concern determination	Within one hundred twenty (120) days after final validation of the toxicity and chemistry data
Additional egg chemical analysis	Within one hundred fifty (150) days after final validation of the toxicity and chemical analysis (including additional GC/MS analysis described in Section 9.2.2.2) data.
Appendix to Annual Report	March 31 of year following submittal date of above reports to Ecology

10 Quality Control

Please refer to S8 Program QAPP, Section 10 Measurement Procedures.

11 Data Management & Documentation Procedures

Please refer to S8 Program QAPP, Section 11 Data Management & Documentation Procedures.

11.1 Laboratory Records

In addition to the laboratory records as identified in S8 Program QAPP, Section 11.1.1 Laboratory Records, will also include the Toxicity Data Package. The Toxicity Data Package will follow the most recent version of Department of Ecology Publication # WQ-R-95-80, Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria and will include in addition to the above:

- Test report,
- Bench sheets, and
- Reference toxicant results for test methods.

12 Audits and Reports

Please refer to S8 Program QAPP, Section 12 Audits and Reports.

13 Data Verification and Validation

Please refer to S8 Program QAPP, Section 13 Data Verification and Validation.

14 Data Quality (Usability) Assessment

This section describes the process for assessing data usability, specifically, whether data of the right type, quality, and quantity have been collected to meet project objectives. The proposed methods for qualitative and quantitative data analysis are also described. Please also refer to S8 Program QAPP, Section 14.1 Data Usability Assessment.

14.1 Data Quality Assessment Metrics

The data quality assessment process determines whether the sampling and analytical program has fulfilled the project objectives, including the DQOs established in Section 6.1, and whether the data can be used to support project management decisions with the desired level of confidence.

Data quality assessment is a professional judgment based on several lines of evidence:

- **Laboratory Data Validation Results**. This metric evaluates laboratory data quality, i.e., the extent to which MQOs for accuracy, precision, sensitivity, and bias have been met during laboratory analysis, as determined by the data validation process (see Section 13 of the S8 Program QAPP).

- **Field and Laboratory Completeness**. This metric evaluates data quantity, i.e., the extent to which the QAPP-specified number of valid field and laboratory measurements has been obtained and whether field and laboratory completeness goals have been achieved.
- **Sample Representativeness**. The degree to which the monitoring program provides a representative sample of the physical-chemical characteristics of stormwater in space and time will be evaluated. We will assess whether the data are suitably representative of the spatial characteristics of the drainage area (i.e. land use, gradient, ground cover, etc.), as well as the time-varying characteristics of stormwater within an individual storm event (i.e., adequate sampling of the runoff hydrograph and time of concentration) and between storm events (i.e., seasonal changes throughout the monitoring year, base flow versus storm flow), and the representativeness of the weather and hydrology during the monitored year(s) compared to an average or "normal" year.
- **Statistical Power**. The statistical variability of the monitoring data (specifically, the coefficient of variation) will be evaluated using the statistical power table (Table 6-1) to determine whether the assumptions used to develop the sampling design are valid, and whether the sample sizes obtained are sufficient to meet the desired levels of statistical confidence and power.

14.2 Data Analysis Methods

14.2.1 *Summary Statistics*

For each detected chemical at each outfall, the following summary statistics will be calculated for stormwater, base flow, and sediment trap data sets:

- Number of samples analyzed
- Number and percentage of samples with detected concentrations
- Arithmetic mean concentration
- Arithmetic standard deviation
- Coefficient of variation
- Minimum and maximum concentrations
- Median concentration (50^{th} percentile)

- 10th and 90th percentile concentrations

Summary statistics will be calculated each year for the current monitoring year as well as for the entire duration of the monitoring program. The outfalls have been monitored continuously using comparable field and analytical methods since August 2001 under Tacoma's previous NPDES permit.

In addition, the following hydrologic parameters will be tabulated for each sampled storm event:

- Rain depth (inches)
- Average storm intensity (inches/hour)
- Antecedent dry period (hours)
- Event-average and peak flow (cfs)
- Total runoff volume (acre-feet)

14.2.2 *Graphical Data Presentation*

Graphical data presentations will be prepared for key constituents of interest in Thea Foss Waterway, including the following:

- Total suspended solids (TSS)
- Copper, lead, and zinc
- Bis(2-ethylhexyl)phthalate (DEHP)
- Phenanthrene (a low-molecular weight PAH)
- Pyrene and Indeno(123-cd)pyrene (high-molecular weight PAHs)

Box-and-whisker plots will provide a graphical representation of spatial and temporal trends in stormwater and base flow quality. Box-and-whisker plots will be generated using *Data Analysis for Microsoft Excel* (Berk & Carey 2000) or a suitable substitute. These plots will display the following characteristics of the data distributions:

- Interquartile range, or IQR (data between the 25th and 75th percentile)
- Median and arithmetic mean
- Moderate outliers (more than 1.5 x IQR above the 75th percentile, or below the 25th percentile)
- Extreme outliers (more than 3 x IQR above the 75th percentile, or below the 25th percentile)

The following box-and-whisker plots will be prepared:

- Outfall-to-outfall comparison – stormwater (land use differences)
- Outfall-to-outfall comparison – base flow (land use differences)
- Stormwater versus base flow comparison
- Wet season versus dry season comparison (seasonal differences)
- Year-by-year comparisons within a given outfall (long-term trends)

In addition, time-series scatter plots of the key constituents in stormwater will be prepared with annotation to delineate the different monitoring years, and the wet and dry seasons within each monitoring year. Time-series plots, as well as box plots, will include comparable data collected under the previous permit period dating back to August 2001.

Evaluation of box plots and time-series graphs will initially be qualitative in nature. Possible trends will be preliminarily identified by visual inspection, to be confirmed with more quantitative statistical tests, as described below in Sections 14.2.6 and 14.2.7.

14.2.3 *Treatment of Non-Detected Values*

The analytical laboratory will be required to report estimated values for any detections between the Method Detection Limit (MDL) and the reporting limit (RL), with appropriate data qualifiers (e.g. J-flags). For general summary statistics, undetected values will be substituted at one-half the MDL.

For higher-level statistical analyses, other treatment methods are available for evaluating constituents with a high percentage of undetected values (i.e., >15 percent non-detects). Such constituents will likely include many of the organic constituents of interest in the Thea Foss Waterway (e.g., PAHs, phthalates). The primary methods for evaluating data sets with a high percentage of non-detects (i.e., "censored" data sets) include: (1) use of nonparametric statistical methods, and (2) extrapolation of data distributions into the undetected region through the use of probability plot regressions (see Ecology 1993).

14.2.4 *Identification of Outliers*

Outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected. It should be noted, however, that lognormal data distributions can tolerate relatively extreme high values, and nonparametric tests are relatively insensitive to the magnitude of the outlier concentration. Thus, it may be possible to select statistical tests that minimize the impacts from outliers.

Moderate outliers (deviations greater than 1.5 times the IQR) and extreme outliers (deviations greater than 3 times the IQR) will initially be identified in the box plots described in Section 14.2.2. Other types of outlier tests may be selected based on the recommended methods in Section 4.4 of the EPA document "Guidance for Data Quality Assessment" (EPA/600/R-96/084).

Outliers will not be removed from any data set unless there is supporting information to indicate the outlier was caused by an unusual and nonrepresentative event. Such events could include acts of nature (e.g. fire, landslide) or man-made events, such as extensive land disturbance from an unexpected construction activity. The impact the outlier has on the statistical processing of the data will be evaluated. The information will be discussed with Ecology before any decisions are made whether to include or exclude any outlier data points.

14.2.5 *Statistical Distribution Testing*

To verify the appropriateness of using parametric statistical tests, including ANOVA and various regression techniques, conformance of stormwater and storm sediment data with standard statistical distributions (e.g., normal or lognormal distributions) should be demonstrated. Statistical distribution testing will generally follow *Statistical Guidance for Ecology Site Managers* (Ecology 1992, 1993) using the *MTCAStat* program.

For uncensored data (mainly conventionals and some metals), numerical distribution tests may be used (Gilbert 1987). For censored data (some metals and most organic contaminants), probability plot regression methods will be used. Probability plots will be developed using either original data or log-transformed data to evaluate conformance with normal and lognormal distributions, respectively. Least-squares regression models will be fit to the detected values in the distribution, and projected into the undetected region. Conformance to normal/lognormal distributions will be demonstrated if the coefficient of determination for the probability plot regression model is greater than 0.9 (Ecology 1993).

Coeffficients of determination and lognormal test results for Tacoma's stormwater monitoring data from 2001 through 2007 are shown in Table 14-1. Forty-seven of the forty-nine data sets showed excellent conformance to lognormal distributions, with coefficients of determination greater than 0.90, and in no case did the coefficient drop below 0.83. These results indicate there is a high likelihood that Tacoma's stormwater monitoring data is lognormal in character, and that parametric statistical tests may be used.

Table 14-1. Lognormal Goodness-of-Fit Test results for Tacoma stormwater 2001-2007.

	230	235	237A	237B	243	245	254
TSS	LOGNORM 0.991	LOGNORM 0.978	LOGNORM 0.985	LOGNORM 0.979	LOGNORM 0.985	LOGNORM 0.983	LOGNORM 0.945
Lead	LOGNORM 0.981	LOGNORM 0.966	LOGNORM 0.988	LOGNORM 0.995	LOGNORM 0.965	LOGNORM 0.988	LOGNORM 0.986
Zinc	LOGNORM 0.935	LOGNORM 0.978	LOGNORM 0.970	LOGNORM 0.958	(LOGNORM) 0.831	LOGNORM 0.971	LOGNORM 0.990
Phenanthrene	LOGNORM 0.982	LOGNORM 0.932	LOGNORM 0.912	(LOGNORM) 0.894	LOGNORM 0.947	LOGNORM 0.916	LOGNORM 0.969
Pyrene	LOGNORM 0.957	LOGNORM 0.953	LOGNORM 0.949	LOGNORM 0.957	LOGNORM 0.961	LOGNORM 0.972	LOGNORM 0.961
Indenopyrene	LOGNORM 0.906	LOGNORM 0.923	LOGNORM 0.925	LOGNORM 0.918	LOGNORM 0.960	LOGNORM 0.901	LOGNORM 0.974
BEP	LOGNORM 0.920	LOGNORM 0.961	LOGNORM 0.919	LOGNORM 0.940	LOGNORM 0.961	LOGNORM 0.940	LOGNORM 0.940

Notes:
R^2 value provided below each distribution determination
LOGNORM = R^2 value greater than 0.9
(LOGNORM) = R^2 value greater than 0.8

14.2.6 *Testing for Spatial Trends*

Analysis of variance (ANOVA) will be performed to determine whether or not there are statistically significant differences in stormwater quality between the outfalls and the land uses they represent. The ANOVA test will help to determine whether stormwater quality is relatively uniform across drainages, or whether there is reason to believe that certain drainages are unique, i.e. characterized by unusually high or low concentrations. If lognormality of Tacoma stormwater and storm sediment data is confirmed, ANOVA tests will be conducted using log-transformed data, as described in Zar (1999). The test statistic is the F statistic with n-1 degrees of freedom

If the ANOVA test shows statistically significant differences in stormwater quality between drainages, follow-on tests will be performed to determine which specific drains are higher or lower than normal. These follow-on tests are called pair-comparison tests, or post-hoc tests. The Tukey Test will be used for post-hoc testing.

The Kruskal-Wallis Test is a nonparametric variant of ANOVA performed using ranks rather than concentrations. The Kruskal-Wallis Test statistic is approximated by the Chi-squared distribution with n-1 degrees of freedom (n = number of stormwater outfalls or drainages). Because it is a nonparametric test, it requires no assumptions about the underlying statistical distribution of the data.

The Kruskal-Wallis Test may be well suited for evaluating statistical differences in base flow concentrations because of the typically high percentage of non-detects in base flow data. The equivalent nonparametric post-hoc test is the Dunn Test (Zar 1999; Tacoma 2007).

If the test for statistical difference is between two populations, for example, a test of wet season versus dry season concentrations, it reduces to a simple T-test (Gilbert 1987).

14.2.7 *Testing for Time Trends*

The objective of time trend analysis is to identify particular constituents in particular drains that show evidence of improvement or degradation of stormwater quality over time. Improvements (i.e. decreasing concentrations) can be the result of source control actions in the drainage basins, whereas degrading conditions (i.e. increasing concentrations) may be the result of development or disturbance in the watershed, including the effects of population pressure such as increased urban density and traffic congestion.

The primary parametric method for time trend analysis is linear regression performed on either the original data or log-transformed data. The magnitude and statistical significance of the slope of the regression line will be calculated for constituents and outfalls for which time trends in stormwater quality are indicated based on visual inspection of the data. If significant seasonal effects are evident in the data, these can be controlled by incorporating a second variable in the regression analysis which is a seasonal index (for example, the integers "1" and "2" could be assigned to wet season and dry season samples, respectively). The months comprising the wet season (October through April) and the dry season (May through September) are defined in the NPDES permit.

Nonparametric methods may be preferable for censored data sets or data sets that do not conform to standard statistical distributions. An equivalent nonparametric method for time trend analysis is the Mann-Kendall Test (Helsel and Hirsch 2002). If evident, seasonality may be controlled using the Seasonal Kendall Test (Gilbert 1987).

14.2.8 *Estimation of Annual Mass Loads*

This section provides methods to calculate seasonal and annual contaminant mass loads for storm flow and base flow. Annual mass loads will be expressed as pounds per year, and pounds per acre per year.

The annual contaminant mass load (mass/time) is the product of contaminant concentration (mass/volume) times flow (volume/time). While certain types of BMPs can be implemented to reduce stormwater volume and flow, storm flow is fundamentally affected by random, year-to-year changes in weather and runoff hydrology in the drainage basins beyond the control of municipalities. As a result, contaminant concentrations will be used in time trend analysis, as opposed to contaminant loads, because the large component of random variability in contaminant loads is more likely to confound the interpretation of long-term changes in stormwater quality, including the effects of Tacoma's source control actions.

Tacoma's stormwater samples are collected as flow-weighted composite samples using automated samplers. As a result, the reported laboratory concentrations for the composite samples represent event mean concentrations (EMC). Similarly, the calculation of average annual and seasonal mass loads will be performed using flow-weighted averages.

The total annual load is the sum of base flow and storm flow loads. Outfalls 235 and 237B contain perennial base flow contributions. Because the chemical composition of base flow is different than storm flow (Tacoma 2008a), due to added contributions from groundwater, subsurface flow, seeps and springs, base flow and storm flow loads will be calculated separately.

The overall equation for calculating the total annual mass load [ML] for a particular chemical constituent is:

$$ML = (F_{bd} \times C_b) + (F_{bw} \times C_b) + (F_{sd} \times C_s) + (F_{sw} \times C_s) \quad \text{[Equation 14-1]}$$

Where [F_{bd}] is) the base flow in the dry season, [F_{bw}] is the base flow in the wet season, [C_b] is the average annual flow-weighted base flow concentration, [F_{sd}] is the storm flow in the dry season, [F_{sw}] is the storm flow in the wet season, and [C_s] is the average annual flow-weighted stormwater concentration.

Step 1a. Determine Base Flows and Volumes. Base flows will be determined from the record of continuous flow measurements in the drainages. Flows occurring in the municipal drainages after 72 hours with no measurable rainfall (i.e., less than 0.02 inches) will be defined as base flows, similar to the MS4 storm event criteria. Base flows in Outfalls 235 and 237B are continuous, and contribute to the total flow during a storm event. Integration of base flows over the wet season and dry season gives the seasonal base flow volumes. The sum of the wet season and dry season base flows gives the total annual base flow.

Step 1b. Determine Flow-Weighted Mean Base Flow Concentration. Chemical concentrations of sampled base flow events during the monitoring year will be tabulated. Then, a flow-weighted mean base flow concentration will be calculated. Initially, a flow-weighted mean concentration will be calculated for the entire monitoring year. However, if seasonal differences in base flow quality are evident, mean base flow concentrations may be calculated separately for the wet and dry seasons.

Step 1c. Estimate Base Flow Mass Load. The contaminant mass load associated with base flow is derived from the results of Steps 1A and 1B. The base flow mass load is estimated from the first two products in Equation 14-1.

Step 2a. Determine Storm Flows and Volumes. The total combined flow (i.e. sum of base flow and storm flow) will be determined from the record of continuous flow measurements in the municipal drainages. The total flow will be integrated over the time period of interest. Wet season and dry season base flows will be subtracted from their respective total flows to estimate seasonal storm flows. The sum of dry season and wet season storm flows gives the total annual storm flow.

Step 2b. Separate Storm Flow and Base Flow in Sampled Storm Events. In outfalls with base flow contributions, the sampled storm events represent a mixture of storm flow and base flow. The base flow contribution to the storm must be subtracted from the total flow to give the storm flow contribution. The storm flow and base flow components of the sampled storm event should be normalized to their fractional volumetric contributions, such that the fraction of storm flow [f_s] plus the fraction of base flow [f_b] are equal to one. These fractions are storm event-specific and are expected to change from one storm to the next.

Step 2c. Calculate Storm Flow EMC. The total stormwater EMC [EMC_{tot}], derived from laboratory analysis of a flow-weighted composite sample, is a mixture of storm flow and base flow components. As a result, the base flow must be "unmixed" from the EMC_{tot} using the principles of mass balance to calculate a EMC for the storm flow contribution alone [EMC_{sf}]. This calculation is performed using the volumetric fractions from Step 2B [f_s and f_b] and the mean base flow concentration from Step 1B [C_b]:

$EMC_{sf} = [EMC_{tot} – (C_b \times f_b)] / f_s$ [Equation 14-2]

Step 2d. Determine Flow-Weighted Mean Storm Flow Concentration. Total stormwater EMCs for sampled storm events during the monitoring year will be converted to storm flow EMCs as described in Step 2c. Then, a flow-weighted mean storm flow concentration will be calculated. Initially, a flow-weighted mean concentration will be calculated for the entire monitoring year. However, if seasonal differences in stormwater quality are evident, mean storm flow concentrations may be calculated separately for the wet and dry seasons.

Step 2e. Estimate Storm Flow Mass Load. The contaminant mass load associated with storm flow is estimated from the results of Steps 2a and 2d. The storm flow mass load is calculated from the last two products in Equation 14-1.

Step 3. Quantify Rainfall – Runoff Relationship. The rainfall-runoff relationship in each of the monitored drainages will be quantified from the continuous flow records coupled with Tacoma rainfall records. A number of discrete storm events of varying magnitude will be analyzed to determine the runoff volumes associated with incident rain depths. A regression model will be fit to this relationship so that runoff volumes may be predicted from rainfall records in future years when flow meters are not collecting continuous measurements over the entire monitoring year. Different relationships may need to be modeled for the wet and dry seasons if the hydrologic response is significantly different.

15 Data Analysis & Presentation

This section discusses the content of the Annual Stormwater Monitoring Report, which will cover data collected during the previous water year. Each Annual Stormwater Monitoring Report, which is an attachment to the Annual Report under the Phase I Permit, is required to include the following elements (Permit Section H.1 .a):

1) A summary including the location, land use, drainage area size, and hydrology for each site.
2) A comprehensive data and Quality Assurance/Quality Control (QA/QC) report for S8.D Stormwater Monitoring, with an explanation and discussion of the results from each monitoring site.
3) A data analysis summary for each site including graphical and statistical testing as presented in Sections 14.2.1 through 14.2.7.
4) The annual pollutant load based on water year for each monitoring site expressed in total pounds, and pounds/acre
5) The wet and dry season pollutant loads based on water year, expressed in total pounds, and pounds/acre

These requirements are discussed below in three sections that will likely provide the outline for the report; a site summary, a comprehensive data summary, and a QA/QC summary.

15.1 Site Summary

The "summary including the location, land use, drainage area size, and hydrology for each site" is a brief description of the more detailed information presented in this QAPP.
Additionally, the following information, if applicable, will be included in this section of the Annual Stormwater Monitoring Report:

- Describe any land use changes in the drainage basin that would potentially affect hydrology or pollutant loading.
- Indicate hydrologic information if a monitoring site is subject to base flow from groundwater or is tidally influenced. Describe backwater conditions or other site-specific conditions if they influence sampling

15.2 Comprehensive Data Summary

The comprehensive data summary will include at a minimum:

1. Stormwater sampling results

- A table or descriptive summary indicating whether the sampled storm events met the requirements listed in Section S8.D.2.a & b of the permit.
- A table or descriptive summary indicating the number of qualifying storm events sampled, additional storm events sampled that may not have met all storm event criteria, the total percentage of forecasted qualifying storms that occurred in each monitoring site, and the ratio of storm events sampled in the wet and dry season.
- For each storm event at each site, a summary or graph of the following:
  - Time versus precipitation,
  - Time versus flow rate, and
  - Time versus initiation of aliquot collection.
- Tables showing qualified analytical results from each sampling event.

- Tables showing summary statistics, distributional testing, and testing for spatial trends and time trends
- Graphical presentations including boxplots and time series graphs and annual, wet season, and dry season pollutant loads calculated for whole water for each of the monitored parameters.
- Tables showing annual, wet season, and dry season pollutant loads calculated for whole water for each of the monitored parameters.

2. **Toxicity testing results**
    - Documentation of any invalid or anomalous test results, good faith attempts to collect the required volume, and any unsuccessful second attempts.
    - Bench sheets for toxicity 7-day E-tests.
    - An analytical report for the chemistry analysis.
    - A toxicity data analytical report.
    - Reference toxicant results for test methods.
    - If required under Section 9.2.2, a "follow-up report" which will include:
    - A summary of the "library of toxicity test results" comparison findings,
    - A summary review of relevant source literature used from the library of toxicity test results,
    - The GC/MS data analytical results (if applicable),
    - An explanation of how the City of Tacoma Surface Water Management Program is expected to reduce stormwater toxicity, and
    - If the follow-up actions for toxicity detections are not complete in time for the Annual Report, the toxicity report will include a description of the status of these activities and an estimated date of completion. The full toxicity report will be submitted to Ecology when complete, and along with the following annual report.

3. **Sediment Sample Results**
    - Tables showing qualified sediment quality data.

4. **Program Changes**
    - A description of any changes made to the sampling program. Significant changes must be documented in a revised QAPP.
    - A list of parameters that are below detection limits after two years of data and will be dropped from the analysis. The QAPP will be updated with the revised list without approval from Ecology.
    - When appropriate, the determination that base flow monitoring should or should not be included in the study.

15.3 Quality Assurance/Quality Control Summary

The QA/QC summary will include at a minimum:

- A data validation memo for each sampling event that includes: (a) a narrative analysis of appropriate field quality control procedures data quality indicator results and of any associated issues and corrections made and (b) a narrative analysis of appropriate laboratory quality control procedures with measurement quality objectives discussed, any associated issues and corrections made.
- A summary Quality Assurance Report, which includes:
  - A narrative summarizing the data validation memos that apply to the entire reporting period.
  - An overall assessment of the usability and representativeness of the data.
  - A summary description of any planned changes or deviations from the approved QAPP to address problems encountered during QA/QC.

References

Berk & Carey. *Data Analysis with Microsoft® Excel Updated for Office 2000*. Kenneth N. Berk and Patrick Carey. Duxbury Thomson Learning, 2000.

Ecology 1992, Statistical Guidance for Ecology Site Managers, August 1992, Olympia, Washington State Department of Ecology Pub. No. 92-54

Ecology 1993, Supplement S-6 to Statistical Guidance for Ecology Site Managers, Analyzing Site or Background Data with Below-Detection Limit or Below-PQL Values (Censored Data Sets). Washington State Department of Ecology.

Ecology 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Publication No. 04-03-030 Revision of Publication No. 01-03-003. http://www.ecy.wa.gov/pubs/0403030.pdf. July 2004.

Ecology 2007. Phase I Municipal Stormwater Permit. National Pollutant Discharge Elimination System and State Waste Discharge. Discharge General Permit for Discharges from large and Medium Municipal Separate Storm Sewer Systems. State of Washington Department of Ecology. Issuance Date January 17, 2007.

Gilbert,1987. Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reihold Co., New York.

Helsel and Hirsch, 2002. Statistical Methods in Water Resources, United States Geological Survey, September 2002.

Norton, D. 1997. Stormwater sediment trap monitoring of discharges to Thea Foss Waterway. No. 97-322. Washington Department of Ecology, Olympia, WA 1997.

Tacoma 1997. Round 2 Data Evaluation Report, Thea Foss and Wheeler-Osgood Waterways, Appendix G. City of Tacoma and Hart Crowser, January 17, 1997.

Tacoma 1999. Round 3 Data Evaluation and Pre-Design Evaluation Report, Thea Foss and Wheeler-Osgood Waterways. Appendix W AKART Study-Stormwater Source Control Feasibility Study. City of Tacoma and Hart Crowser, September 30, 1999.

Tacoma 2000. Memo to Troy Naccarato, City of Tacoma from Cosmopolitan Engineering Group, RE: Time of Concentration for Foss Drains, May 23, 2000.

Tacoma 2001. Thea Foss and Wheeler-Osgood Waterways, Stormwater Monitoring, Sampling and Analysis Plan, City of Tacoma, September 2001.

Tacoma 2003. *Surface Water Management Manual,* City of Tacoma. 2003.

Tacoma 2007. Growth Strategy & Development Concept Element. City of Tacoma Comprehensive Plan Amended Ordinance #27664, December 2007.

Tacoma 2008. August 2001-2007 Report, Stormwater Monitoring. Thea Foss and Wheeler-Osgood Waterways. City of Tacoma. February 2008.

USEPA 1990. Specifications and Guidance for Obtaining Contaminant-Free Sample Containers. OSWER Directive #93240.0-05

Wilson, C. and D. Norton (1996). Stormwater sediment trap pilot study. No. 96-347. Washington Department of Ecology, Olympia, WA 1996.

Zar 1999. Biostatistical Analysis, 4th ed. Prentice Hall, Saddle River, New Jersey, pages 223-225.

List of Revisions

The current list of revisions for this QAPP follows.

Revision Number	Revision Date	Revised by	Revision Summary
S8D-001	08/11/2008	Dana de Leon, Chris Burke and Todd Thornburg	Initial Draft.
S8D-002	01/15/2009	Dana de Leon, Chris Burke and Todd Thornburg	Redline Draft.
S8D-003	08/16/2009	Dana de Leon and Chris Burke	Final